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NEW JERSEY STATE DEPARTMENT OF HEALTH
STONY BROOK-MILLSTONE SEWERAGE STUDY COMMITTEE

STONY BROOK-MILLSTONE WATERSHED
REGIONAL SEWERAGE
FEASIBILITY STUDY

SEELYE STEVENSON VALUE & KNECHT



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Mr. Jeremiah Farrington
Committee Chairman
Stony Brook-Millstone Sewerage Study Committee
Princeton, New Jersey

Dear Mr. Farrington:

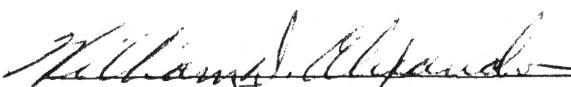
In accordance with our agreement with the Committee, dated September 16, 1965, we have completed our Study to determine the practical feasibility of establishing a regional system for the disposal of wastewater within the Stony Brook-Millstone Watershed. We are pleased to submit herewith our Report containing the results of the Study.

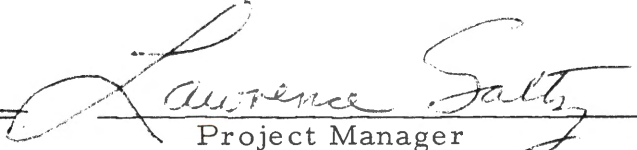
We wish to express our appreciation for the assistance extended to us during the course of our work by the members of the Committee, the New Jersey State Health Department, the Planning Boards of the Counties involved in the Study, and the various public and private officials who have all imparted pertinent information, data and advice. Their cooperation has been an invaluable aid in the preparation of this Report.


Respectfully submitted,

SEELYE STEVENSON VALUE & KNECHT, INC.

LS:ml
encl.


Partner


Project Manager


Principal Engineer

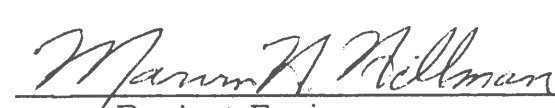

Project Engineer

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SUMMARY OF REPORT

General Information

An extensive investigation and study was conducted to determine the feasibility of establishing a regional system of wastewater disposal for the various municipalities, or portions thereof lying within the area generally delineated as the Stony Brook-Millstone Watershed. The Study has produced a practical plan for handling wastes contributed by the growing Watershed population over the next 50 years. Several workable alternative schemes have also been developed. The details and estimated costs of the various plans are fully described in the main body of the report and are briefly summarized herein.

It is neither possible nor necessary to cover in this summary every item of accumulated data. The information presented herein gives pertinent data as concisely as possible to provide an overall view of the investigation and the important results and conclusions drawn. The reader is referred to the main report for additional detailed information and supplementary substantiating data.

The study was conducted by the engineering organization of Seelye Stevenson Value and Knecht under an agreement with an informal group, representing local governmental units, known as the Stony Brook-Millstone Sewerage Study Committee. Funds for the study were made available by the New Jersey State Department of Health under a grant provided in accordance with the provisions of the Sanitary Sewerage Facilities Assistance Act of 1965.

Basic Studies

The engineering work performed consisted primarily of the following:

1. Studies of the problem of providing for the present and future collection, treatment and disposal of wastewater within the area on a regional basis, including the development of a feasible plan showing the location and arrangement of proposed facilities.
2. Development of a practical plan to retain wastewater within the Watershed and reclaim, or renovate, it for re-use.
3. Development of estimates of capital cost of construction and annual operating and maintenance costs for the proposed regional plan

along with development of a practical method of financing the system. Presently available State and Federal grants have been delineated, and annual costs to each of the individual municipalities within the Watershed have been estimated.

4. Establishment of methods by which the proposed plan might be implemented, including the creation of an operating organization and the associated legislative modifications required.

Supplementary Investigations

Supplementary surveys pertinent to the basic studies, extended into many related fields, and included:

1. A compilation of general information on topography, geology, meteorological and hydrological data, ground water resources and stream conditions.

2. A study of the physical, social and economic factors affecting development within the Watershed including planning and zoning objectives, land use and trends of residential, industrial, agricultural and recreational development.

3. A population study estimating growth five decades into the future.

4. An evaluation of existing wastewater collection and treatment facilities analyzing capacities, operational efficiency, character of wastes received, effect of effluent on the receiving streams, and potential for inclusion in a regional system.

Municipalities Within Watershed Limits

The Stony Brook-Millstone Watershed is shown on PLATE 2 and covers an area of approximately 285 square miles. The map indicates the various municipalities involved and illustrates the proportion of each municipal area which lies partially or wholly within the limits of the Watershed. TABLE 1 lists total areas of the various townships and boroughs and the approximate amount of area of each lying within the Watershed.

Watershed Land Use and Population Growth

The Stony Brook-Millstone Watershed area is presently experiencing the outward spread of development from the New York and Philadelphia-Trenton areas, and it is anticipated that, in future years, a rapid surge

NEW JERSEY STATE DEPARTMENT OF HEALTH
STONY BROOK-MILLSTONE SEWERAGE STUDY COMMITTEE

STONY BROOK-MILLSTONE WATERSHED
REGIONAL SEWERAGE FEASIBILITY STUDY
**GENERAL MAP SHOWING
LIMIT OF STUDY AREA**

SEELYE STEVENSON VALUE & KNECHT
CONSULTING ENGINEERS
PRINCETON, N.J. NEW YORK, N.Y.

LEGEND

- LIMIT OF STUDY AREA 
- COUNTY BOUNDARY 
- TOWNSHIP BOUNDARY 

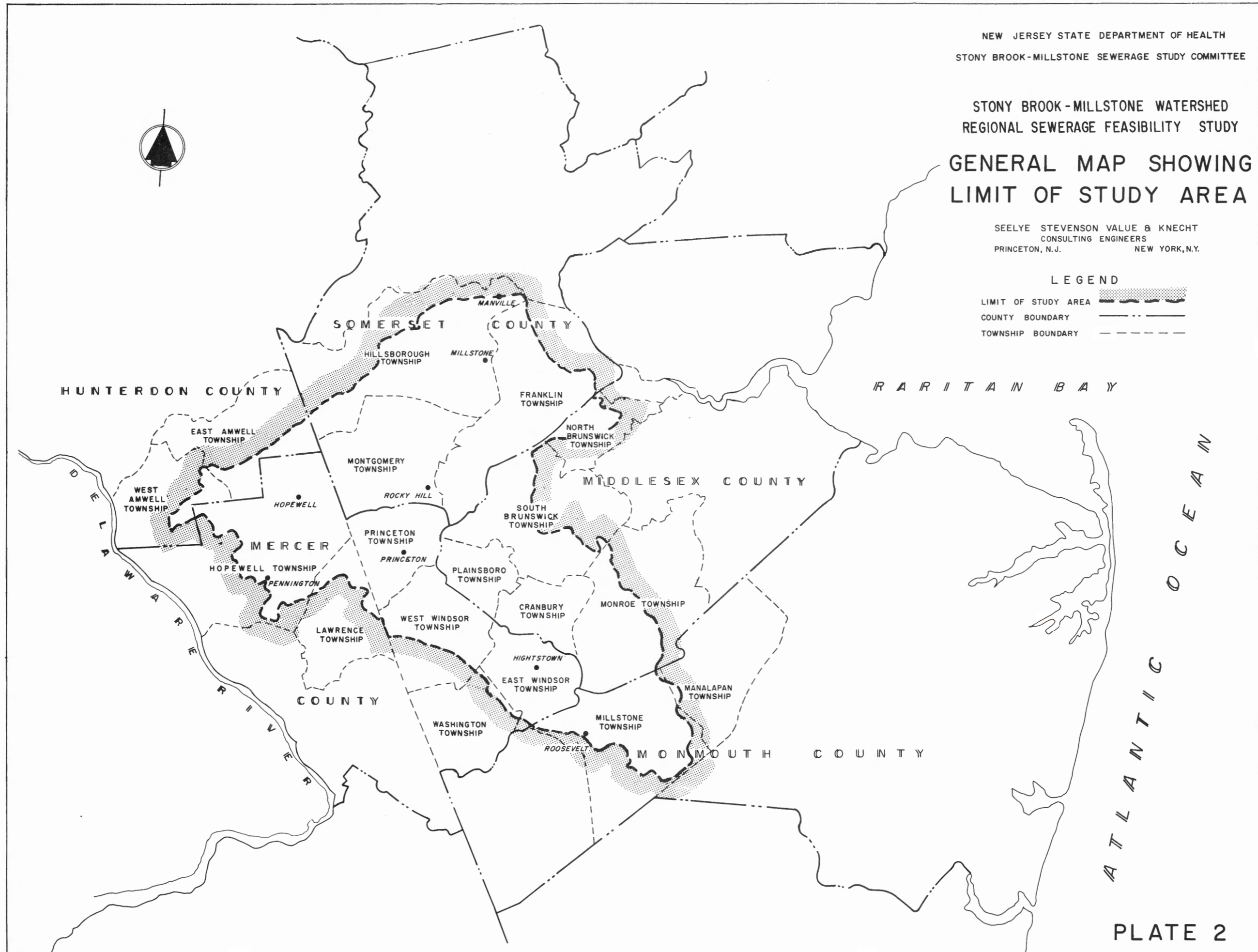


TABLE 1

MUNICIPALITY AREAS WITHIN THE
STONY BROOK - MILLSTONE WATERSHED

<u>Municipality</u>	<u>Total Area in Square Miles</u>	<u>Percent of Area Within Watershed</u>	<u>Approximate Area Within Watershed in Square Miles</u>
Hunterdon County			
East Amwell Township	27.8	29.0	8.1
West Amwell Township	21.9	11.5	2.5
Mercer County			
East Windsor Township	15.6	90.0	14.0
Hightstown Borough	1.2	100.0	1.2
Hopewell Township	56.5	59.0	33.3
Hopewell Borough	0.7	100.0	0.7
Pennington Borough	1.0	92.0	0.9
Lawrence Township	27.2	14.0	3.8
Princeton Township	14.9	100.0	14.9
Princeton Borough	1.8	100.0	1.8
Washington Township	22.7	5.0	1.1
West Windsor Township	31.8	55.0	17.5
Middlesex County			
Cranbury Township	13.1	100.0	13.1
Monroe Township	41.8	46.0	19.2
North Brunswick Township	11.9	27.0	3.2
Plainsboro Township	11.7	100.0	11.7
South Brunswick Township	41.4	50.0	20.1
Monmouth County			
Manalapan Township	32.1	1.6	0.6
Millstone Township	39.3	46.5	18.3
Roosevelt Borough	1.9	16.0	0.3
Somerset County			
Franklin Township	46.4	70.0	32.5
Hillsborough Township	54.7	58.0	31.7
Manville Borough	2.5	48.0	1.2
Millstone Borough	0.6	100.0	0.6
Montgomery Township	32.3	100.0	32.3
Rocky Hill Borough	0.6	100.0	0.6
Total Watershed Area in Square Miles			285.2

of new residential, research facility and industrial growth will spread over a major part of the vacant and rural portions of the Watershed.

At present, the dominant land use in the Watershed is agricultural. However, commercial, industrial and other urban land uses are rapidly replacing agricultural activities along the major highways.

To estimate the future population growth of the study area, the official estimates by the New Jersey Department of Conservation and Economic Development were accepted for projections of State and County populations through 1990. The official estimates by County Planning Boards for individual municipalities were generally accepted through 1985, or other year, depending on the County. The population projections for the State were then extended from 1990 to 2015, and county and municipal populations for whole municipalities were derived for 2015. The resulting population estimates were then discussed with the planning staffs of the five counties, and some final adjustments ensued due to their special knowledge of the local situation and trends.

The estimates of population by decades to the year 2015, for each municipality or part thereof, within the Watershed limits are shown in TABLE 5.

In the process of projecting future population growth, consideration was given to the effect that existing and planned transportation media would have on the population growth and distribution in a given municipality. Judgment was applied to determine the proportion of the estimated future population which would be located within the Stony Brook-Millstone Watershed.

Existing Wastewater Disposal Facilities

With few exceptions, most wastewater emanating from domestic or industrial sources in the Watershed is disposed of by local minor treatment facilities or individual residential subsurface systems. Major treatment facilities, disposing of larger waste quantities received from a collection system, are operated by the following municipalities or authorities:

Princeton Borough
Hightstown Borough
South Brunswick Municipal Utilities Authority

In addition, two major facilities are currently under construction, sponsored respectively by the East Windsor Municipal Utilities Authority

TABLE 5

POPULATION FORECAST FOR MUNICIPALITIES WITHIN THE STONY BROOK - MILLSTONE WATERSHED

Municipality	Census 1960	Estimated Population for the Year *					
		1970	1980	1990	2000	2010	2015
Hunterdon County							
East Amwell Township	1,210	2,300	2,825	3,650	4,800	5,900	6,400
West Amwell Township	420	1,000	1,300	1,900	2,800	3,700	4,100
Mercer County							
East Windsor Township	2,220	6,000	12,000	20,000	29,000	38,000	43,000
Hightstown Borough	4,317	5,500	6,400	7,300	8,200	9,200	9,700
Hopewell Township	5,557	9,800	15,000	20,800	26,650	33,300	36,500
Hopewell Borough	1,928	2,300	2,850	3,500	4,200	5,000	5,300
Pennington Borough	2,063	2,300	2,550	2,900	3,350	3,800	4,000
Lawrence Township	1,366	1,900	2,200	2,650	3,100	3,600	3,800
Princeton Township	10,400	11,100	11,800	12,400	13,100	13,800	14,150
Princeton Borough	11,950	11,940	11,930	11,920	11,910	11,900	11,900
Washington Township	43	60	80	90	95	98	100
West Windsor Township	3,200	8,000	14,000	23,000	35,000	46,000	52,500
Middlesex County							
Cranbury Township	2,001	5,000	9,100	14,000	19,500	25,000	27,800
Monroe Township	3,660	12,000	26,000	41,000	61,000	81,000	91,000
North Brunswick Township	2,175	3,000	4,500	6,000	7,500	9,000	9,500
Plainsboro Township	1,182	4,450	8,800	14,250	19,750	26,250	29,300
South Brunswick Township	5,190	11,000	19,000	29,200	41,000	52,700	58,700
Monmouth County							
Manalapan Township	160	500	840	1,180	1,540	1,970	2,100
Millstone Township	1,530	4,000	8,000	13,000	18,000	23,000	26,000
Roosevelt Borough	31	40	90	150	210	270	300
Somerset County							
Franklin Township	6,000	12,000	19,300	25,500	34,500	41,000	45,550
Hillsboro Township	6,400	13,000	23,500	36,000	50,500	65,000	72,100
Manville Borough	4,300	5,500	6,000	6,100	6,500	6,700	6,700
Millstone Borough	409	575	700	850	1,000	1,200	1,300
Montgomery Township	3,851	8,500	16,000	25,000	34,500	44,000	49,000
Rocky Hill Borough	528	850	950	1,100	1,300	1,500	1,600
Total Watershed Population	82,091	142,615	225,715	323,440	439,005	552,828	612,400

*Estimates include only that portion of political subdivisions within Stony Brook - Millstone Watershed.

and Foresgate Sanitation Company.

1. Minor Waste Disposal Facilities

There are some 47 minor treatment facilities in scattered locations throughout the Watershed. The majority of the installations are "package" aeration units. Some trickling filter plants exist and, for disposal of very low amounts of wastewater flow, Imhoff tanks followed by sand filters, are prevalent.

During the course of this study, inspections were made at almost all of the various minor plants in the area. The vast majority of the plants inspected were well maintained. However, a few plants were obviously community nuisances. Generally, these nuisances were caused by overloading, resulting in unsightly spills, odors and flooding.

The "package" treatment plant is a small, compact installation that, usually, is well designed to provide treatment for relatively small volumes of wastewater flow from residential or industrial facilities which cannot economically connect to central or regional collection systems. The package plant represents an interim stage of development in solving the immediate waste treatment needs of an area. To be effective, however, the plant must be properly operated. Failure of package plant treatment can usually be traced to lack of skilled operation.

The State Department of Health has recognized this defect and has exerted control by requiring that a qualified plant operator be employed. As a further safeguard, many of these minor disposal installations received approval for construction from the State Department of Health subject to the condition that the plants would be abandoned as soon as public sewerage facilities became available.

2. Individual Residential Sub-Surface Disposal Systems

Individual sub-surface disposal facilities are, usually, either a cesspool or septic tank installation. Neither one provides a really desirable form of wastewater disposal.

The cesspool is nothing more than an underground holding tank in which solid wastes, including greases and fats, are allowed to accumulate while the liquid waste seeps into the surrounding sub-surface area. The cesspool usually produces some degree of ground water pollution and unsatisfactory surface conditions. After a period of use, it has a tendency to clog and become watertight. Flow is then discharged to the

surface. Periodic cleaning out, at considerable expense, must be undertaken to obtain even a small degree of efficiency in waste disposal.

Septic tanks provide a more desirable form of wastewater disposal, but, at best, are inefficient units also requiring periodic cleaning and large seepage areas for satisfactory disposal of effluent. Similarly to cesspools, septic tanks also tend to pollute the underlying ground water supply to some extent.

In the areas of high ground water and inadequate sub-surface conditions, septic tank effluent carries to the local streams wastewater flows which contain an appreciable amount of suspended solids and dissolved organic material. Solid matter is deposited in quiescent portions of the stream and forms sludge banks. This settled matter undergoes further decomposition which may be evidenced by gas bubbles and, frequently, lumps of sludge on the surface and partial, or complete, oxygen depletion. The nutrient value of the effluent also stimulates the growth of algae.

Stream Classification in the Watershed

The New Jersey State Department of Health has assigned certain classifications to the waterways of the State and has established the standards of quality to be maintained therein. All streams within the Stony Brook-Millstone Watershed are designated as Class FW-2, defined as follows:

Fresh surface waters approved as sources of public potable water supply. These waters are to be suitable for public potable water supply after such treatment as shall be required by the State Department of Health. These waters shall be suitable also for all recreational purposes including fishing. . . .

The New Jersey State Department of Health maintains stream sampling stations for water pollution control purposes. The various stream samples obtained undergo sanitary analyses in the laboratory to determine those characteristics and constituents of the water which have a bearing upon its suitability as public supply.

Based on the results of sanitary analyses, it is quite evident that the streams within the Stony Brook-Millstone Watershed do not meet the standards of quality established. In lieu of containing a potable water supply, the stream channels are actually grossly polluted and convey

a weak, domestic wastewater.

The situation, at present, is not serious in the sense that the natural surface waters would recover quality, quite rapidly, once the sources of pollution were eliminated. This, of course, could be effected by the establishment of a regional wastewater collection and disposal system. The real problem lies in allowing conditions to remain static, with the inherent danger of ultimately polluting the underlying ground water resources.

The Need for Additional Collection and Disposal Facilities

Unsanitary conditions in certain municipalities within the Watershed have reached a level at which the State Department of Health has found it necessary to issue formal orders to the offending municipality to abate pollution. Pollution or nuisance abatement orders presently require the unsewered Boroughs of Hopewell, Pennington and Rocky Hill to provide adequate disposal facilities within a reasonable time.

Though formal orders have not been issued to date, it has been recognized, for quite some time, that serious sanitary problems exist in the various unsewered areas of other municipalities, as follows:

Hopewell Township
Plainsboro Township
Montgomery Township
Cranbury Township
West Windsor Township
Hillsborough Township
Franklin Township
Millstone Borough

Proposed Regional System for Wastewater Disposal

Several possible plans have been considered to develop a feasible regional system of facilities for the present and future collection, treatment and disposal of wastewater for the Watershed.

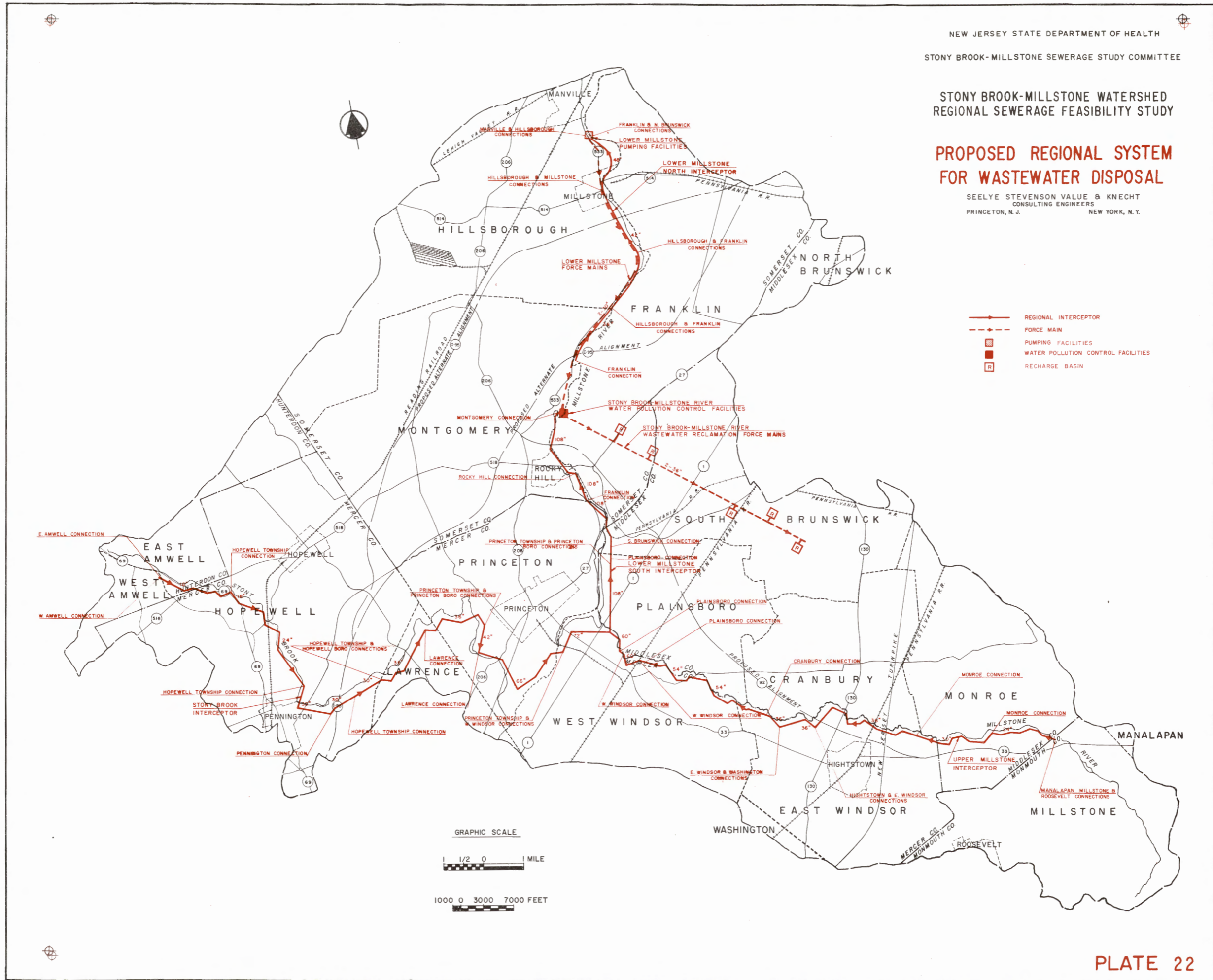
The recommended regional system for wastewater disposal is shown on PLATE 22, and basically consists of the following facilities:

1. The Wastewater Collection Facilities
2. The Water Pollution Control Facilities
3. The Wastewater Reclamation Facilities

STONY BROOK-MILLSTONE WATERSHED
REGIONAL SEWERAGE FEASIBILITY STUDY

**PROPOSED REGIONAL SYSTEM
FOR WASTEWATER DISPOSAL**

SEELYE STEVENSON VALUE & KNECHT
CONSULTING ENGINEERS
PRINCETON, N.J. NEW YORK, N.Y.



The proposed regional wastewater collection facilities would receive flow from local community waste collection facilities and convey the wastewater to the water pollution control plant for processing and final disposal. Each municipality, or part thereof, as indicated, has one or more individual points of connection to the regional collection system.

The proposed interceptors follow the natural water courses, or drainage valleys, of the Watershed and would convey flow by gravity insofar as possible. The Stony Brook and Upper Millstone Interceptors would connect to the Lower Millstone South Interceptor which would convey the wastewater north to the Water Pollution Control Plant to be located on a site near the confluence of Beden Brook and the Millstone River. Wastewater, originating from local collection facilities downstream of the plant, would be conveyed by the Lower Millstone North Interceptor to Lower Millstone Pumping Station, situated in the vicinity of Manville Borough. The pumping facilities would deliver the flow back to the treatment plant.

The proposed site for the water pollution control facilities should be neatly landscaped and could be coordinated with the proposed State Millstone Valley Park along the Millstone River and Delaware and Raritan Canal. The architectural appearance of the facility should not detract from the area.

Under normal conditions of river flow, the plant could discharge treated effluent to the Millstone River for final dispersion. However, during periods of drought, the low flow prevailing in the river would limit the permissible quantity and quality of plant final effluent which could be discharged without creating a nuisance.

For the dual purpose of providing a means of effluent disposition during drought and to recover the valuable water content, it is proposed to provide facilities to renovate wastewater for re-use within the Watershed. The specific re-use, considered at this time, is ground water recharge. Other re-use, such as irrigation, is possible.

Pumping facilities and force mains would be provided to convey processed plant effluent to recharge facilities located within the Watershed. The recharge facilities would be placed at points where the geologic substrata appears optimum for recharging the underlying ground water aquifers. Pilot studies would be conducted, during the early stages of operation, to determine optimum methods of renovation and alternate re-use for reclaimed water.

Basis of Design for Regional System

The regional system has been developed in accordance with certain criteria established under the study. TABLE 14 has been prepared to summarize the pertinent design criteria both for the ultimate project and, also, for the facilities to be constructed in the initial phase.

All facilities for the ultimate regional system have been developed for a design period of 50 years.

Shorter design periods have been used for initial phase facilities for water pollution control and wastewater reclamation. This will be discussed subsequently.

Scheduled Potential Contributing Population

To facilitate development of the regional system in sensible stages, a schedule has been prepared showing estimated potential contributing population in various future years. This schedule is produced in TABLE 15.

The estimated future municipal populations within the Watershed have been divided into two categories as follows:

1. Potential immediate contributors
2. Potential future contributors

Immediate contributors include municipalities in which:

- (a) Local wastewater collection and disposal facilities exist, but are inadequate and require augmentation.
- (b) A serious sanitary problem exists, which must be eliminated by creation of disposal facilities.

Future contributors include those municipalities which, in the future, would participate in the regional wastewater disposal system, but for which immediate participation may, at the present time, not be essential, practical, or economical for the following reasons:

- (a) The municipality is now of a rural nature with low population density and immediate sanitary needs can be fulfilled with simple local facilities without causing serious problems.

TABLE 14

SUMMARY OF PERTINENT DESIGN CRITERIA FOR ULTIMATE REGIONAL SYSTEM AND FOR INITIAL CONSTRUCTION PHASE

<u>Pertinent Design Criteria</u>	<u>Ultimate Project</u>	<u>Initial Construction</u>
Wastewater Collection Facilities:		
Design Period (Years)	50	50
Design Year	2015	2015
Design Population for:		
(a) Interceptor Pipe Size	612,400	612,400
(b) Interceptor Extent	612,400	317,325
Average Daily Flow (gpcd)	100	100
Peak Flow Rate (gpcd)	400	400
Design Capacity (MGD)	60	60
Water Pollution Control Facilities:		
Design Period (Years)	50	20
Design Year	2015	1990
Design Population	612,400	173,470
Average Daily Domestic Waste		
Flow (gpcd)	100	100
Industrial Waste Flow (gpcd)	5	5
Total Design Flow (gpcd)	105	105
Design Capacity (MGD)	60	20
Wastewater Reclamation Facilities:		
Design Period (Years)	50	3
Design Year	2015	1973
Design Population	612,400	38,000
Total Design Flow (gpcd)	105	105
Design Capacity (MGD)	60	4

TABLE 15

ESTIMATED SCHEDULE FOR
POTENTIAL CONTRIBUTING POPULATION
TO THE
REGIONAL SYSTEM FOR WASTEWATER DISPOSAL

<u>MUNICIPALITY</u>	<u>ESTIMATED POPULATION</u>					
	<u>1970</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>	<u>2010</u>	<u>2015</u>
<u>Potential Immediate Contributors</u>						
Mercer County						
Hopewell Township	9800	15000	20800	26650	33300	36500
Hopewell Borough	2300	2850	3500	4200	5000	5300
Pennington Borough	2300	2550	2900	3350	3800	4000
Lawrence Township	1900	2200	2650	3100	3600	3800
Princeton Township	11100	11800	12400	13100	13800	14150
Princeton Borough	11940	11930	11920	11910	11900	11900
West Windsor Township	8000	14000	23000	35000	46000	52500
Middlesex County						
Cranbury Township	5000	9100	14000	19500	25000	27800
Plainsboro Township	4450	8800	14250	19750	26250	29300
South Brunswick Township	11000	19000	29200	41000	52700	58700
Somerset County						
Franklin Township (50%)	6000	9650	12750	17250	20500	22775
Montgomery Township	8500	16000	25000	34500	44000	49000
Rocky Hill Borough	850	950	1100	1300	1500	1600
Total Immediate Contributors	83140	123830	173470	230610	287350	317325
<u>Potential Future Contributors</u>						
Hunterdon County						
East Amwell Township	2300	2825	3650	4800	5900	6400
West Amwell Township	1000	1300	1900	2800	3700	4100
Mercer County						
East Windsor Township	6000	12000	20000	29000	38000	43000
Hightstown Borough	5500	6400	7300	8200	9200	9700
Washington Township	60	80	90	95	98	100
Middlesex County						
Monroe Township	12000	26000	41000	61000	81000	91000
North Brunswick Township	3000	4500	6000	7500	9000	9500
Monmouth County						
Manalapan Township	500	840	1180	1540	1910	2100
Millstone Township	4000	8000	13000	18000	23000	26000
Roosevelt Borough	40	90	150	210	270	300
Somerset County						
Franklin Township (50%)	6000	9650	12750	17250	20500	22775
Hillsborough Township	13000	23500	36000	50500	65000	72100
Manville Borough	5500	6000	6100	6500	6700	6700
Millstone Borough	575	700	850	1000	1200	1300
Total Future Contributors	59475	101885	149970	208395	265478	295075
Total Potential Contributors	142615	225715	323440	439005	552828	612400

(b) Due to proximity, it may be temporarily expedient for the municipality to connect to some existing municipal waste disposal facility.

(c) The municipality presently has its own disposal facilities which still have a period of useful life.

Design Population

The estimated ultimate total Watershed population for the year 2015 is 612,400. This population includes all potential contributors, and has been used in the design of all facilities for the ultimate regional disposal system.

In the initial construction phase, the wastewater collection facilities will be sized to handle the peak flow estimated for 2015. However, the length of the interceptors will be limited to that extent necessary to provide connections for the local waste collection facilities of immediate contributors.

Initial water pollution control facilities will be designed to handle flow from the potential immediate contributors in the year 1990. Eventually, future plant expansion will provide additional capacity to handle the total population expected in 2015.

The first phase of construction for the wastewater reclamation facilities will provide sufficient capacity to handle flow from an expected population slightly less than one-half the total potential immediate contributors in the year 1970. Experimental studies are necessary in connection with the proper development of these facilities, and the initial units constructed will be utilized basically for this purpose.

Estimated Project Costs

TABLE 18 presents a summary of estimated total capital cost for the ultimate regional system, consisting of the wastewater collection facilities, the water pollution control facilities and the wastewater reclamation facilities.

The project costs are based on estimated 1970 construction prices which have been determined by projecting present prices in accordance with the rising trend of the Engineering News-Record Cost Index.

TABLE 18

SUMMARY OF ULTIMATE TOTAL PROJECT COST
FOR
REGIONAL SYSTEM FOR WASTEWATER DISPOSAL

<u>Facilities</u>	<u>Construction</u>	+ <u>Land</u>	= <u>Total</u>
Wastewater Collection	\$33,084,475	\$840,525	\$33,925,000
Water Pollution Control:			
- Initial Construction	10,554,000	360,000	10,914,000
- Future Expansion	8,136,000	0	8,136,000
Wastewater Reclamation	<u>23,950,000</u>	<u>900,000</u>	<u>24,850,000</u>
 TOTAL ULTIMATE COST	 \$75,724,475	 \$2,100,525	 \$77,825,000

STONY BROOK-MILLSTONE WATERSHED
REGIONAL SEWERAGE FEASIBILITY STUDY

**RECOMMENDED
INITIAL CONSTRUCTION**

SEELYE STEVENSON VALUE & KNECHT
CONSULTING ENGINEERS
PRINCETON, N. J. NEW YORK, N. Y.



Project costs include construction cost, cost of real estate and easements, and an allowance of 20% to cover legal, engineering, financing, administrative and other expense.

Initial Facilities to be Constructed

The initial construction of facilities must include a portion of the wastewater collection facilities, and water pollution control facilities capable of handling a flow of 20 MGD to serve the potential immediate contributors. In addition, in order to begin the recharge studies and pilot program, recharge basins adequate for 4 MGD will be constructed.

The recommended initial construction program for the regional facilities is shown on PLATE 31.

Capital Costs for Initial Facilities Constructed

The detailed capital cost for the initial facilities is summarized in TABLE 22. The total cost, adjusted to 1970 estimated prices, amounts to \$34,877,000. For an estimated immediate contributory population of 83,140, previously shown in TABLE 15, the cost per person is approximately \$420. This is a reasonable capital expenditure per capita for the service to be obtained.

The initial facilities include interceptors sized for the ultimate contributing population. The immediate contributors, therefore, are actually paying a slightly higher capital cost for these oversized interceptors than would be necessary if the proposed system were to be designed with capacity limited to that necessary to handle only waste delivered by the immediate contributors. The total capital cost differential involved amounts to about \$1,640,000, or 10 percent of the initial wastewater collection facilities cost. The extra cost can be recovered by increased rate charges to future participants.

The additional cost is well worth paying now to permit economical future system expansion. If interceptor size were limited initially, future expansion costs might run over \$20,000,000.

Estimated Annual Costs

The approximate annual costs, which would be incurred by an operating organization, for the ultimate regional system facilities are shown in TABLE 23. The table also indicates the approximate annual rate charges to system participants per million gallons of waste treated.

TABLE 22

DETAILED COST SUMMARY FOR INITIAL CONSTRUCTION
OF REGIONAL SYSTEM FACILITIES

Facilities	1970 Construction Cost*	Land & R. O. W.	Total Project Cost
Water Pollution Control	\$10,554,000	\$360,000	\$10,914,000
Wastewater Collection:			
Stony Brook Interceptor	5,832,000		
Upper Millstone Interceptor	3,590,000		
Lower Millstone So. Interceptor	8,031,000		
Collection Sub-Total	\$17,453,000	\$354,000	\$17,807,000
Wastewater Reclamation:			
Force Main	\$ 4,442,500		
Basins 15 Acres	1,057,500		
Pumping Station	450,000		
Reclamation Sub-Total	\$ 5,950,000	\$206,000	\$ 6,156,000
TOTAL CONSTRUCTION COST (1970 ENR 1175)			\$34,877,000

* Includes 20% Development Expense

TABLE 23

ESTIMATED ANNUAL RATES TO BE CHARGED TO PARTICIPATING MUNICIPALITIES FOR ULTIMATE REGIONAL DISPOSAL FACILITIES

Year	Project	Cumulative Project Cost	Est. Average Daily Flow MGD	Total Annual Flow MG/Yr.	Operation and Maintenance Cost	Debt Service	Reserve Fund	Total Annual Cost	Rate Per MG		
1970	\$34,877,000	\$34,877,000	8.0	2,920	\$ 325,000	\$2,141,000	\$214,100	\$2,680,100	\$918		
1971			8.3	3,030	335,000	2,141,000	214,100	2,690,100	888		
1972			8.7	3,180	340,000	2,141,000	214,100	2,695,100	847		
1973			9.0	3,280	345,000	2,282,000	228,200	2,855,200	870		
1974	23,000,000	37,177,000	9.3	3,390	355,000	2,282,000	228,200	2,865,200	845		
1975			9.6	3,500	365,000	2,282,000	228,200	2,875,200	821		
1976			10.0	3,650	375,000	2,282,000	228,200	2,885,200	790		
1977			10.5	3,830	385,000	2,282,000	223,200	2,895,200	755		
1978			11.0	4,020	400,000	2,282,000	228,200	2,910,200	724		
1979			11.5	4,200	415,000	2,282,000	228,200	2,925,200	696		
1980			12.0	4,380	425,000	2,282,000	228,200	2,935,200	670		
1981			12.8	4,670	450,000	2,282,000	228,200	2,960,200	634		
1982			40,648,000	77,825,000	13.7	5,000	470,000	2,282,000	228,200	2,980,200	596
1983					14.8	5,400	480,000	2,282,000	228,200	2,990,200	554
1984	15.8	5,770			500,000	2,282,000	228,200	3,010,200	522		
1985	17.0	6,200			525,000	4,778,000	477,800	5,780,800	932		
1986	18.5	6,750			550,000	4,778,000	477,800	5,805,800	860		
1987	19.6	7,150			573,000	4,778,000	477,800	5,828,800	815		
1988	21.0	7,650			595,000	4,778,000	477,800	5,850,800	764		
1989	22.4	8,170			620,000	4,778,000	477,800	5,875,800	719		
1990	24.0	8,760			640,000	4,778,000	477,800	5,895,800	673		
1991	25.3	9,230			660,000	4,778,000	477,800	5,915,800	641		
1992	26.7	9,750	685,000	4,778,000	477,800	5,940,800	609				
1993	28.3	10,330	715,000	4,778,000	477,800	5,970,800	578				
1994	29.5	10,750	740,000	4,778,000	477,800	5,995,800	558				
1995	31.0	11,310	765,000	4,778,000	477,800	6,020,800	533				
1996	32.3	11,700	790,000	4,778,000	477,800	6,045,800	516				
1997	33.7	12,300	810,000	4,778,000	477,800	6,065,800	493				
1998	35.4	12,920	830,000	4,778,000	477,800	6,085,800	471				
1999	36.8	13,400	860,000	4,778,000	477,800	6,115,800	456				
2000	38.0	13,300	885,000	2,637,000	264,000	3,785,700	285				
2001	39.7	14,500	910,000	2,637,000	264,000	3,810,700	263				
2002	41.0	14,960	930,000	2,637,000	264,000	3,830,700	256				
2003	42.6	15,530	960,000	2,496,000	250,000	3,705,600	238				
2004	44.0	16,050	990,000	2,496,000	250,000	3,735,600	233				
2005	45.3	16,540	1,012,000	2,496,000	250,000	3,757,600	227				
2006	47.0	17,150	1,035,000	2,496,000	250,000	3,780,600	221				
2007	48.5	17,700	1,060,000	2,496,000	250,000	3,805,600	215				
2008	50.0	18,250	1,085,000	2,496,000	250,000	3,830,600	210				
2009	51.2	18,700	1,115,000	2,496,000	250,000	3,860,600	206				
2010	53.0	19,340	1,135,000	2,496,000	250,000	3,880,600	201				
2011	54.0	19,700	1,160,000	2,496,000	250,000	3,905,600	198				
2012	55.5	20,300	1,185,000	2,496,000	250,000	3,930,600	194				
2013	57.0	20,800	1,210,000	2,496,000	250,000	3,955,600	190				
2014	58.5	21,400	1,232,000	2,496,000	250,000	3,977,600	186				

To develop this tabulation, the following simplifying assumptions have been made:

1. Construction would be completed and financing would begin in 1970. Initial facilities would include a 20 MGD water pollution control plant, reclamation facilities for 4 MGD and a portion of the wastewater collection facilities. The initial construction capital cost for these facilities is estimated at \$34,877,000, as previously shown in TABLE 22.

2. A project capital cost of \$2,300,000 would be spent about 1973 to increase recharge basin capacity to 20 MGD.

3. A \$40,648,000 expansion to the water pollution control and wastewater reclamation facilities would be provided in 1985 to furnish additional system capacity to 60 MGD.

4. All construction would be financed by the issuance of 30-year revenue bonds at 4-1/2% interest rate. Debt service is assumed to be constant over each 30-year bond term.

5. A reserve fund would be established with an annual contribution amounting to 10% of the debt service to provide additional interest coverage on bonds and to cover some portion of depreciation on facilities.

The annual costs shown in TABLE 23 would be apportioned to each participating municipality in proportion to the actual metered flow contributions received from each. The annual amounts paid, by each municipal participant, to the operating organization would, in turn, be recovered by charges to the benefited users within each municipality.

It has been assumed, in determining the annual costs and rate charges listed in TABLE 23, that the operating organization would have no outside source of revenue other than charges to participating municipalities. However, certain interest income will accrue on bank account funds, and other sources are possible. These outside revenue sources will not produce a substantial reduction in annual costs, but some small decrease will result.

To be conservative in presenting costs, it has also been assumed that none of the capital cost would be defrayed by current State or Federal Aid programs. There is, however, every indication that the

proposed regional system would receive such assistance in the form of Grants-in-Aid as may be available from both the Federal Government and New Jersey State. Since no definite commitment can exist at this time, these grants are not included in the estimate of construction costs. Any amount received, of course, would be a benefit and the annual charges to system participants would be reduced accordingly.

Elimination of Wastewater Reclamation Costs to Provide Equitable Basis for Cost Comparison by Municipal Immediate Contributors

The cost data presented in this section is furnished primarily for the benefit of the proposed immediate municipal contributors to the regional disposal system. The information given herein permits the municipality to compare the annual costs for participation in the regional system against the annual costs of constructing and operating individual municipal wastewater treatment facilities. Costs for individual municipal facilities either have been, or can be, obtained as a result of independent engineering studies conducted by the municipalities involved.

Engineering reports, presently in existence for several of the municipalities, develop plans and costs for municipal wastewater treatment facilities in which the treatment process is limited to that degree of waste removal known as secondary treatment. This is a lower degree of treatment than that proposed to be provided by facilities developed in this Report. The proposed regional facilities would remove sufficient impurities to permit reclamation of the water for re-use. There is, of course, some additional cost associated with wastewater reclamation above the cost which might prevail if facility construction were limited to that extent necessary to provide only secondary treatment.

To permit equitable cost comparison by the proposed municipal participants, TABLE 25 has been prepared. This table indicates the estimated system annual costs and charge rate per million gallons treated for a regional system in which wastewater reclamation facilities, and all costs attributable thereto, have been eliminated.

Assumptions used in establishing the tabulation are essentially the same as those previously listed for TABLE 23 under the section Estimated Annual Costs. However, the initial and future capital expenditures are lower due to elimination of facility cost for wastewater reclamation. In turn, annual costs for debt service, reserve fund, operation and maintenance are reduced accordingly.

TABLE 25

ESTIMATED ANNUAL RATES TO BE CHARGED TO PARTICIPATING MUNICIPALITIES
FOR ULTIMATE REGIONAL DISPOSAL FACILITIES WITHOUT WASTEWATER RECLAMATION FACILITIES

Year	Project Cost	Cumulative Project Cost	Est. Average Daily Flow MGD	Total Annual Flow MGD Yr.	Operation and Maintenance Cost	Debt Service	Reserve Fund	Total Annual Cost	Rate Per MGD
1970	\$28,721,000	\$28,721,000	8.0		\$ 250,000	\$1,763,000	\$176,300	\$2,189,300	5750
1971			8.3		260,000	1,763,000	176,300	2,199,300	726
1972			8.7	3,100	265,000	1,763,000	176,300	2,204,300	645
1973			9.0	3,200	270,000	1,763,000	176,300	2,209,300	676
1974			9.3	3,300	280,000	1,763,000	176,300	2,219,300	655
1975			9.6	3,500	290,000	1,763,000	176,300	2,229,300	638
1976			10.0	3,650	300,000	1,763,000	176,300	2,239,300	615
1977			10.5	3,830	310,000	1,763,000	176,300	2,249,300	585
1978			11.0	4,020	325,000	1,763,000	176,300	2,264,300	562
1979			11.5	4,200	335,000	1,763,000	176,300	2,274,300	541
1980			12.0	4,380	350,000	1,763,000	176,300	2,289,300	524
1981			12.8	4,670	360,000	1,763,000	176,300	2,299,300	493
1982			13.7	5,000	380,000	1,763,000	176,300	2,319,300	465
1983			14.8	5,400	392,000	1,763,000	176,300	2,331,300	432
1984			15.8	5,770	410,000	1,763,000	176,300	2,349,300	407
1985	24,254,000	52,975,000	17.0	6,200	435,000	3,252,000	325,200	4,012,200	647
1986			18.5	6,750	450,000	3,252,000	325,200	4,027,200	597
1987			19.6	7,150	470,000	3,252,000	325,200	4,047,200	566
1988			21.0	7,670	500,000	3,252,000	325,200	4,077,200	531
1989			22.4	8,170	520,000	3,252,000	325,200	4,097,200	501
1990			24.0	8,760	540,000	3,252,000	325,200	4,117,200	470
1991			25.3	9,230	560,000	3,252,000	325,200	4,137,200	448
1992			26.7	9,750	585,000	3,252,000	325,200	4,162,200	427
1993			28.3	10,330	610,000	3,252,000	325,200	4,187,200	405
1994			29.5	10,750	640,000	3,252,000	325,200	4,217,200	372
1995			31.0	11,310	660,000	3,252,000	325,200	4,237,200	374
1996			32.3	11,700	680,000	3,252,000	325,200	4,257,200	364
1997			33.7	12,300	700,000	3,252,000	325,200	4,277,200	348
1998			35.4	12,920	730,000	3,252,000	325,200	4,307,200	334
1999			36.7	13,400	750,000	3,252,000	325,200	4,327,200	323
2000			38.0	13,300	780,000	1,489,000	148,900	2,417,900	182
2001			39.7	14,500	800,000	1,489,000	148,900	2,437,900	168
2002			41.0	14,960	820,000	1,489,000	148,900	2,457,900	164
2003			42.6	15,530	850,000	1,489,000	148,900	2,487,900	160
2004			44.0	16,050	880,000	1,489,000	148,900	2,517,900	157
2005			45.3	16,540	900,000	1,489,000	148,900	2,537,900	153
2006			47.0	17,150	925,000	1,489,000	148,900	2,562,900	149
2007			48.5	17,700	950,000	1,489,000	148,900	2,587,900	146
2008			50.0	18,250	975,000	1,489,000	148,900	2,612,900	143
2009			51.2	18,700	1,000,000	1,489,000	148,900	2,637,900	141
2010			53.0	19,340	1,022,000	1,489,000	148,900	2,659,900	137
2011			54.0	19,700	1,050,000	1,489,000	148,900	2,687,900	136
2012			55.5	20,300	1,075,000	1,489,000	148,900	2,712,900	133
2013			57.0	20,800	1,100,000	1,489,000	148,900	2,737,900	131
2014			58.5	21,400	1,125,000	1,489,000	148,900	2,762,900	129

Comparison of Estimated Charges with Other System Charges

Certain areas of the State of New Jersey presently treat wastewater on a regional system basis. System facilities, treatment process, degree of treatment provided, and amount of waste flow handled vary considerably in each area, and no direct comparison with the proposed system for the Stony Brook-Millstone Watershed is possible. However, to indicate that the rate charges derived in TABLE 25 do bear a reasonable relationship to presently existing rate charges experienced by participants in other regional systems, the following tabulation is offered:

<u>Existing Regional System</u>	<u>Year Reported</u>	<u>Average Daily Flow MGD</u>	<u>Total Annual Flow MGD</u>	<u>Total Annual Charge to Participating Municipalities</u>	<u>Approx. Rate Per MG</u>
Ewing-Lawrence Sew. Auth.	1964	5.6	2,040	\$1,001,924	\$492
Bergen County Sewer Auth.	1965	33.4	12,180	2,358,657	193
Middlesex Sewerage Auth.	1964	47.5	17,350	2,910,236	168
Passaic Valley Sewerage Com.	1965	182.2	66,515	3,513,300	53

General Criteria for Proposed Administrative Organization for Regional System

Pertinent administrative and legal arrangements must be selected in order to effect the physical plan of development of the regional system for wastewater disposal. A number of alternatives are available, and an intelligent choice among them can be made only after agreement on certain criteria. Some of these criteria are established by the nature of the problem, and others are optional matters of policy. The various criteria may be summarized as follows:

1. The administrative organization should be able to represent the interests of 26 different municipalities, in whole or in part.
2. It should be adaptable to use over an area including parts of five different counties, Hunterdon, Somerset, Middlesex, Monmouth and Mercer, without encompassing all of any one county.
3. It must have the legal, administrative and financial capability of providing for wastewater collection and disposal facilities upon a regional basis, in accordance with the physical plan.

4. It should be provided with adequate powers to finance the acquisition of the required physical improvements, preferably without recourse to the general credit of the counties and municipalities involved, but in any event, without impairing their borrowing power for other purposes under existing statutory debt limits.
5. It should be adaptable to the various present needs and estimated future rates of growth among the constituent municipalities.
6. It should provide for a single executive with full operating responsibility and authority, accountable to a single policy-making body.
7. To the fullest extent feasible, the administrative organization should be accountable for policy decisions to the duly elected representatives of the people affected.

Recommended Administrative Organization, Financing and New Legislation

None of the alternatives, offered by existing law, provide the exact means by which an appropriate organization can be established to administer the proposed regional system for waste disposal. The most appropriate alternative appears to be a sewerage authority. However, the enactment of legislation by the State Legislature is necessary to amend the present sewerage authorities law to permit the creation of a county sewerage authority on a multi-county basis.

Under the Sewerage Authorities Law of 1946, the governing body of any of the counties can create a sewerage authority for the county. Under the same statute, the governing bodies of any two or more of the municipalities involved in the study can create a single sewerage authority, provided "the areas of. . . (the municipalities) together comprise an integral body of territory." It is significant, however, that a county sewerage authority is limited by the statute to a single county.

The statute delegates full power to the sewerage authority to construct, maintain and finance the required physical facilities for the regional disposal facilities.

The principal feature of the Sewerage Authorities Law is its provision for financing the capital and operating costs of the system from user charges. The authority is authorized by statute to issue bonds

payable solely out of revenues of the authority, and specifically provides that any such bonds shall not constitute or create a debt or liability of the county or of any municipality. In order to provide for the payment of principal and interest on such bonds and for the operation and maintenance of the system, the sewerage authorities are authorized by the statute to "charge and collect rents, rates, fees or other charges for direct or indirect connection with, or the use of services of, the sewerage system." The statute also provides that such service charges "shall as nearly as the sewerage authority shall deem practicable and equitable be uniform throughout the district for the same type, class and amount of use or service of the sewerage system." (N. J. S. A. 40:14A-8)

This method of financing the system with user charges has a number of important advantages. It does not depend upon the general credit of the county or municipality, and thus does not use any of the legally limited borrowing power of these units. It automatically apportions the cost of service to the municipalities, and to the parts of each municipality, in direct proportion to the service benefit received. It also is readily adaptable to the presently uneven growth of need among the different municipalities.

There are also various disadvantages to the sewerage authority type of organization. At the outset, its members are only indirectly responsible to the people, since they are appointed by the respective elected governing bodies, rather than being directly elected. The method of financing, however useful, also could result in a somewhat higher interest cost than that for bonds issued on the full faith and credit of the municipalities or county and backed by the full taxing power of these political subdivisions.

It would be quite feasible to seek improved legislation to reduce some of the disadvantages inherent in the sewerage authority type of organization, especially if there were a consensus of agreement, among the interested parties, on the legal improvements to be sought. The examination of the law already discussed, suggests two possible changes of a basic nature:

1. Provision for an elected regional board, and
2. Provision for a self-liquidating system of financing, primarily dependent upon user charges, but with the added credit base of power to resort to taxation, if it should ever be necessary.

These alternatives are not available under existing law, but could be

provided, for example, through amendment of the sewerage authority law which was outlined previously.

INTRODUCTION

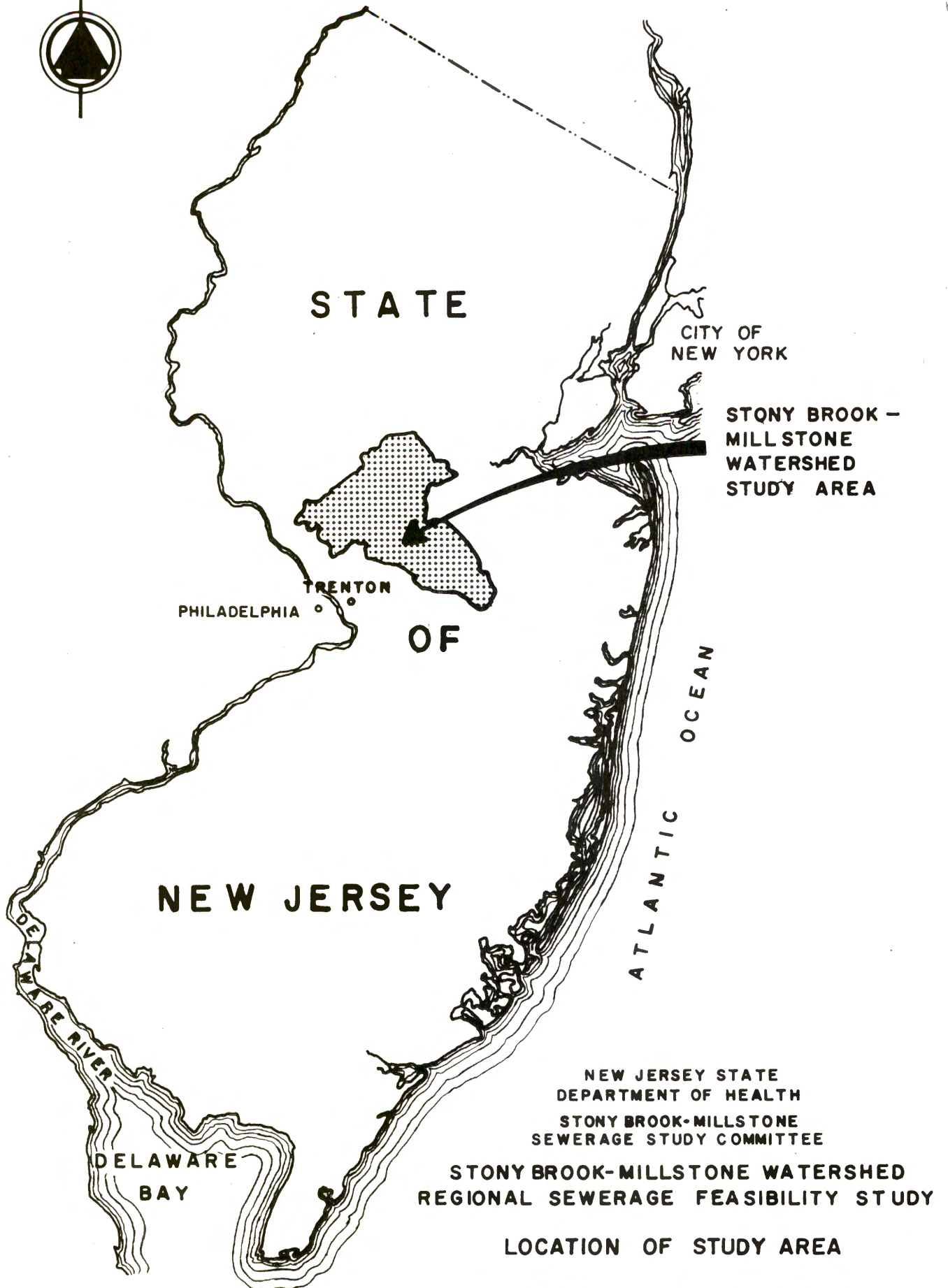
Purpose of Study

In accordance with the terms of an agreement between the Stony Brook-Millstone Sewerage Study Committee and the engineering organization of Seelye Stevenson Value and Knecht, a study has been made, and is reported upon herewith, to determine the practical feasibility of establishing a regional system for wastewater disposal for the area in central New Jersey, defined as the watershed which drains to Stony Brook and the Millstone River. The location of the study area is shown on PLATE 1. The report also considers the important aspect of water conservation within the watershed area, specifically with regard to the possibility of reclaiming effluent for re-use.

Scope of Work

The scope of work performed by this organization in accordance with the agreement includes the following:

1. A study of the physical, social and economic factors affecting development within the area including planning and zoning objectives, land use and trends of residential, industrial, agricultural and recreational development .
2. A population study projecting growth five decades into the future, or to saturation limits.
3. A compilation of general information on topography, meteorological and hydrological data, subsurface conditions and pertinent stream data.
4. An evaluation of existing wastewater collection and treatment facilities analyzing capacities, operational efficiency, character of wastes received, effect of effluent on the receiving streams, and potential for inclusion in a regional system.
5. Studies of the problem of providing for the present and future collection, treatment and disposal of wastewater within the area on a regional basis, including the aspect of water conservation. These studies include a schematic plan showing the location of proposed intercepting sewers, force mains, pumping stations and treatment facilities.



SEELYE STEVENSON VALUE & KNECHT
CONSULTING ENGINEERS
PRINCETON, N.J. NEW YORK, N.Y.

6. Estimates of capital cost of construction and annual operating and maintenance costs for the proposed regional plan along with development of a feasible method of financing the system. Presently available State and Federal grants have been determined, and an estimated net cost to each of the individual municipalities within the watershed has been established.

7. Methods by which the proposed plan might be implemented, including the establishment of an operating organization and the associated legislative modifications required.

N. J. State Grant and the Sewerage Study Committee

Funds for the necessary engineering services were made available under a grant provided by the State of New Jersey to the Stony Brook-Millstone Sewerage Study Committee. The grant was made under the Provisions of Section 4 of the State Public Sanitary Sewerage Facilities Assistance Act of 1965. This Act declares that the public policy of the State of New Jersey is to encourage and support the promotion, planning, development and construction of adequate public sanitary sewerage facilities including wastewater collection, transmission, treatment and disposal works on a stream valley, regional or multi-unit basis. A further objective of the State Department of Health, in the administration of its duties under this Act, is the promotion of projects which protect public health and conserve the waters of the State, with special emphasis upon the concept of their re-use for appropriate purposes.

The grants are administered by the Commissioner of Health, who is also empowered to establish the rules and regulations under which such grants will be made. In the regulations established by the Commissioner, the following statement is made, "Feasibility studies may include conventional sanitary engineering studies or elementary exploratory studies by formal or informal groups representing local governmental units." The Stony Brook-Millstone Sewerage Study Committee is an informal group representing 26 municipal governmental units and parts of five counties.

Past History Prior to This Study

For many years, the problem of stream pollution and the necessity to conserve water in the Stony Brook-Millstone Watershed had been recognized both by the residents and by the State Department of Health. One group of interested citizens, the Stony Brook-Millstone Watershed Association, had, for a long time, been instrumental in organizing meetings and discussions aimed at providing some regional approach to the solution of the growing problems.

Although there had always been fairly consistent agreement between the participants at such meetings, there seemed to be no practical way to take positive action toward producing a substantial solution to the problem. The fundamental difficulty was the inability to obtain fund contributions from such a large group of municipalities, many of whom questioned the need for detailed studies in their particular area. By 1965, the mounting problems of stream pollution, together with the responsibility of safeguarding public health within the area, particularly in some of the older communities, had reached a point where decisive action had to be taken. The State Health Department had issued formal orders to a number of communities within the Watershed to abate stream pollution and other health hazards by providing proper disposal facilities. Other communities, with existing plants, found that necessary improvements to expand facilities, entailing considerable expenditures, would have to be undertaken within a very short time.

The passage of the Sanitary Sewerage Facilities Assistance Act of 1965 provided the funds and the incentive to initiate the necessary engineering study to determine the feasibility of establishing a regional system for wastewater disposal. At the invitation of Commissioner Roscoe P. Kandle and Mr. Robert Shaw, Assistant Director of the Division of Environmental Health, of the State Health Department, meetings were held at the State Health Department Office in Trenton to determine the interest in applying for a State Grant-in-Aid under the legislation. There was enough positive interest, particularly on the part of the large communities, which had been suffering from major pollution problems, to establish an informal committee and elect officers. This action was taken almost concurrently with the passage of the legislation. An application for aid was immediately filed with the New Jersey State Department of Health, and approval of the grant was obtained in October, 1965.

REGIONAL SEWERAGE STUDY AREA

General Description

The regional sewerage study area comprises approximately 285 square miles of the central heart land of New Jersey, and is based on a physically delineated drainage basin rather than an entity determined by political boundaries. The area is the natural drainage basin, or watershed, of the Millstone River and Stony Brook. The stream valley provides the normal course to which wastewater contributions within the area would normally flow by gravity. The main interceptor sewers of a regional sewerage system would ordinarily be located in the valley to intercept flow from local gravity collection systems and convey it to treatment facilities for disposition.

On PLATE 2, the limit of the study area is shown. This map indicates the various municipalities involved in the study and illustrates the proportion of each municipal area which lies partially or wholly within the Watershed. TABLE 1 lists total area of the various townships and boroughs and the approximate amount of area of each lying within the Watershed.

The Stony Brook-Millstone Watershed can be sub-divided into three smaller tributary drainage areas. The sub-watersheds are respectively designated as follows:

1. Lower Millstone Sub-Watershed
2. Stony Brook Sub-Watershed
3. Upper Millstone Sub-Watershed

PLATE 3 indicates the general limits of each of the three sub-watersheds, and TABLE 2 tabulates the political subdivisions represented within their bounds.

Climate

The climate of the study area reflects average conditions in the State of New Jersey and is characterized by a relatively moderate range of temperatures, by mild winters, and by usually dependable rainfall. At present, however, a general drought condition has prevailed in the area for the past three years.

STONY BROOK-MILLSTONE WATERSHED
REGIONAL SEWERAGE FEASIBILITY STUDY

GENERAL MAP SHOWING
LIMIT OF STUDY AREA

SEELYE STEVENSON VALUE & KNECHT
CONSULTING ENGINEERS
PRINCETON, N.J. NEW YORK, N.Y.

LEGEND

- LIMIT OF STUDY AREA 
- COUNTY BOUNDARY 
- TOWNSHIP BOUNDARY 

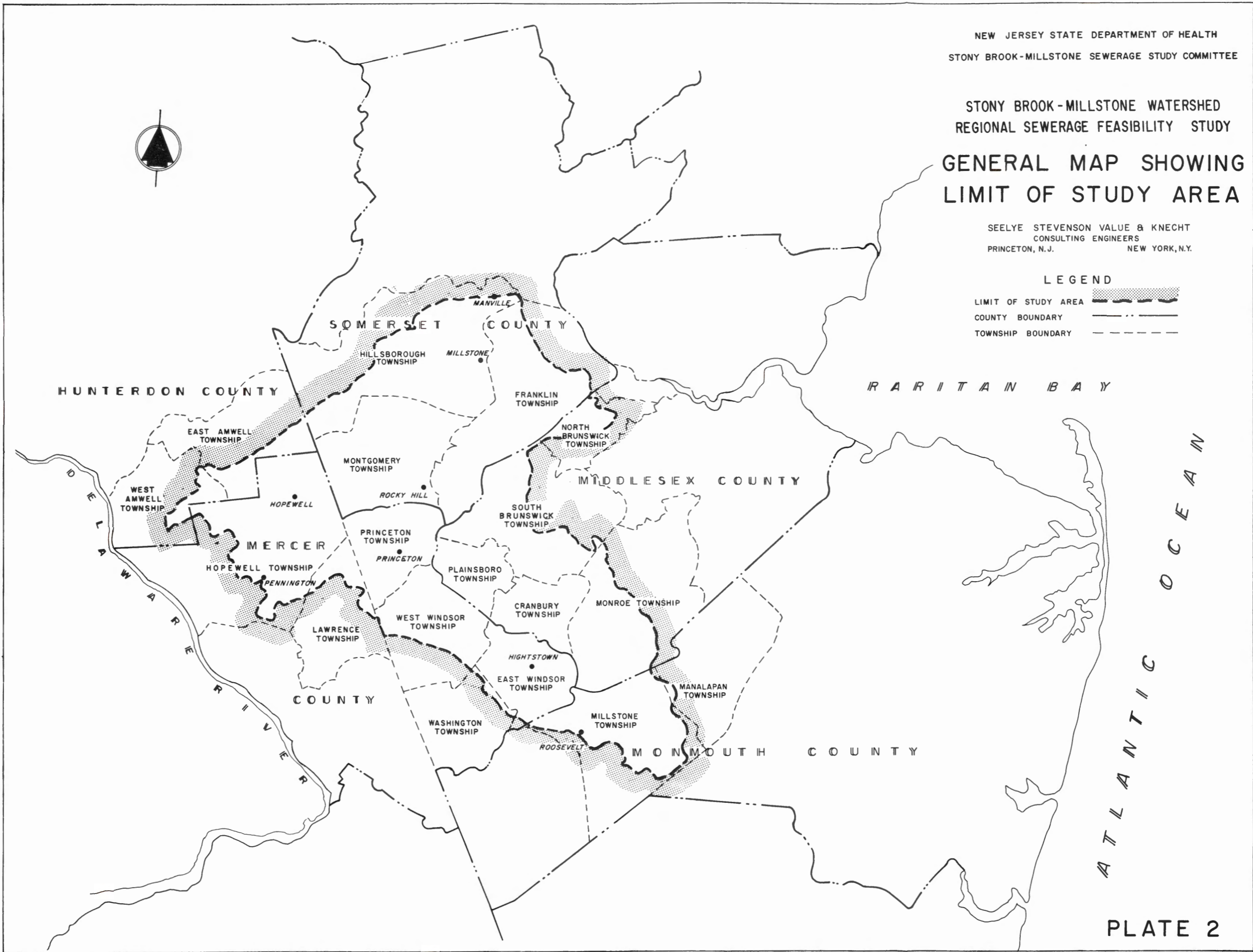


TABLE 1
MUNICIPALITY AREAS WITHIN THE
STONY BROOK - MILLSTONE WATERSHED

<u>Municipality</u>	<u>Total Area in Square Miles</u>	<u>Percent of Area Within Watershed</u>	<u>Approximate Area Within Watershed in Square Miles</u>
Hunterdon County			
East Amwell Township	27.8	29.0	8.1
West Amwell Township	21.9	11.5	2.5
Mercer County			
East Windsor Township	15.6	90.0	14.0
Hightstown Borough	1.2	100.0	1.2
Hopewell Township	56.5	59.0	33.3
Hopewell Borough	0.7	100.0	0.7
Pennington Borough	1.0	92.0	0.9
Lawrence Township	27.2	14.0	3.8
Princeton Township	14.9	100.0	14.9
Princeton Borough	1.8	100.0	1.8
Washington Township	22.7	5.0	1.1
West Windsor Township	31.8	55.0	17.5
Middlesex County			
Cranbury Township	13.1	100.0	13.1
Monroe Township	41.8	46.0	19.2
North Brunswick Township	11.9	27.0	3.2
Plainsboro Township	11.7	100.0	11.7
South Brunswick Township	41.4	50.0	20.1
Monmouth County			
Manalapan Township	32.1	1.6	0.6
Millstone Township	39.3	46.5	18.3
Roosevelt Borough	1.9	16.0	0.3
Somerset County			
Franklin Township	46.4	70.0	32.5
Hillsborough Township	54.7	58.0	31.7
Manville Borough	2.5	48.0	1.2
Millstone Borough	0.6	100.0	0.6
Montgomery Township	32.3	100.0	32.3
Rocky Hill Borough	0.6	100.0	<u>0.6</u>

Total Watershed Area in
Square Miles

285.2

STONY BROOK-MILLSTONE WATERSHED
REGIONAL SEWERAGE FEASIBILITY STUDY

GENERAL MAP OF WATERSHED

SEELYE STEVENSON VALUE & KNECHT
CONSULTING ENGINEERS
PRINCETON, N. J. NEW YORK, N. Y.



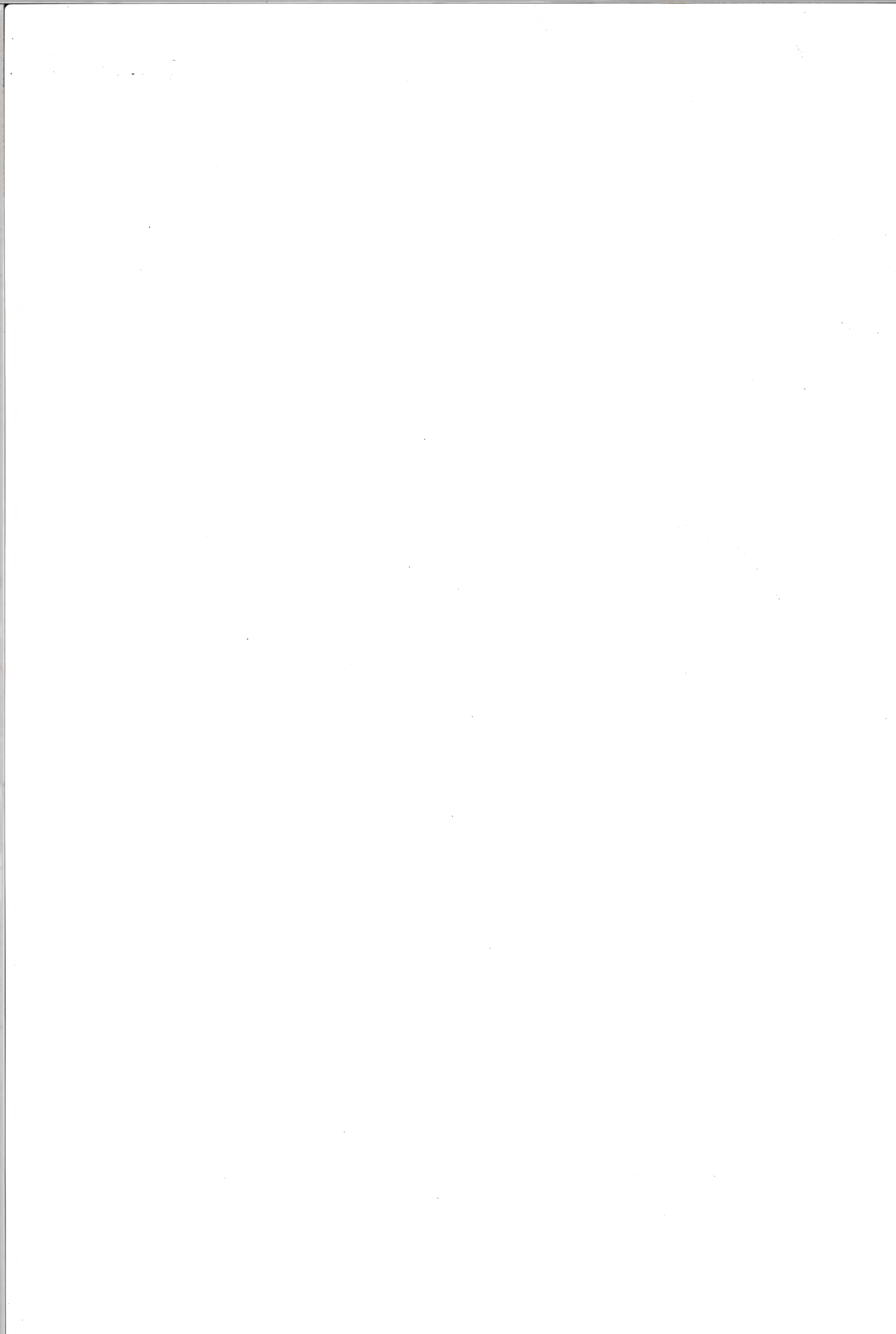


TABLE 2
COUNTIES AND MUNICIPALITIES
REPRESENTED IN THE
STONY BROOK - MILLSTONE SUB-WATERSHEDS

Lower Millstone Watershed

Hunterdon County
 East Amwell Township

Mercer County
 Hopewell Borough
 Hopewell Township
 Princeton Borough
 Princeton Township

Middlesex County
 North Brunswick Township
 Plainsboro Township
 South Brunswick Township

Somerset County
 Franklin Township
 Hillsborough Township
 Manville Borough
 Millstone Borough
 Montgomery Township
 Rocky Hill Borough

Stony Brook Watershed

Hunterdon County
 East Amwell Township
 West Amwell Township

Mercer County
 Hopewell Township
 Lawrence Township
 Pennington Borough
 Princeton Borough
 Princeton Township

Upper Millstone Watershed

Mercer County
 East Windsor Township
 Hightstown Borough
 Washington Township
 West Windsor Township

Middlesex County
 Cranbury Township
 Monroe Township
 Plainsboro Township
 South Brunswick Township

Monmouth County
 Manalapan Township
 Millstone Township
 Roosevelt Borough

Prevailing winds are from the northwest during the period from November through April. South winds prevail from May through August, while in September and October winds are generally from the north. They are usually of moderate strength.

The Appalachian Mountains, Atlantic Ocean and the Great Lakes all have a moderating influence on the climate of the Watershed. Average monthly and annual temperatures recorded by the U. S. Weather Bureau Stations, in or near the study area, are shown in TABLE 3. Average monthly and annual rainfall records of these stations are shown in TABLE 4 and indicate that rainfall is rather evenly distributed throughout the area.

The annual precipitation as recorded at the headquarters of the Stony Brook-Millstone Watersheds Association is shown on PLATE 4. This record visibly reveals the present drought conditions.

Transportation

The Watershed lies astride the main transportation routes connecting the New York and Philadelphia-Trenton metropolitan regions. The main lines of the Pennsylvania and Reading Railroads, U. S. Routes 1 and 130, State Route 27 and the New Jersey Turnpike traverse the area roughly on a north-south line. In the future, Interstate Route 95, the Maine to Florida expressway, will also pass through the area. Final alignment of this major artery is now in process of resolution.

In the past, these transportation corridors have acted as lines of flow for residential development extending into the area principally from the New York and, secondarily, from the Philadelphia-Trenton urban regions. New suburban residential development has followed Route 27 which carries a frequently-operated bus service providing express connections to Manhattan. This route is also convenient for rail commuters who drive to stations in the New Brunswick area.

Industrial development has flowed principally along the lines of Route 1 and the New Jersey Turnpike. Emphasis has been mainly on the establishment of many research centers due, in some part, to the close proximity of such notable institutions as Princeton and Rutgers Universities.

Utilities

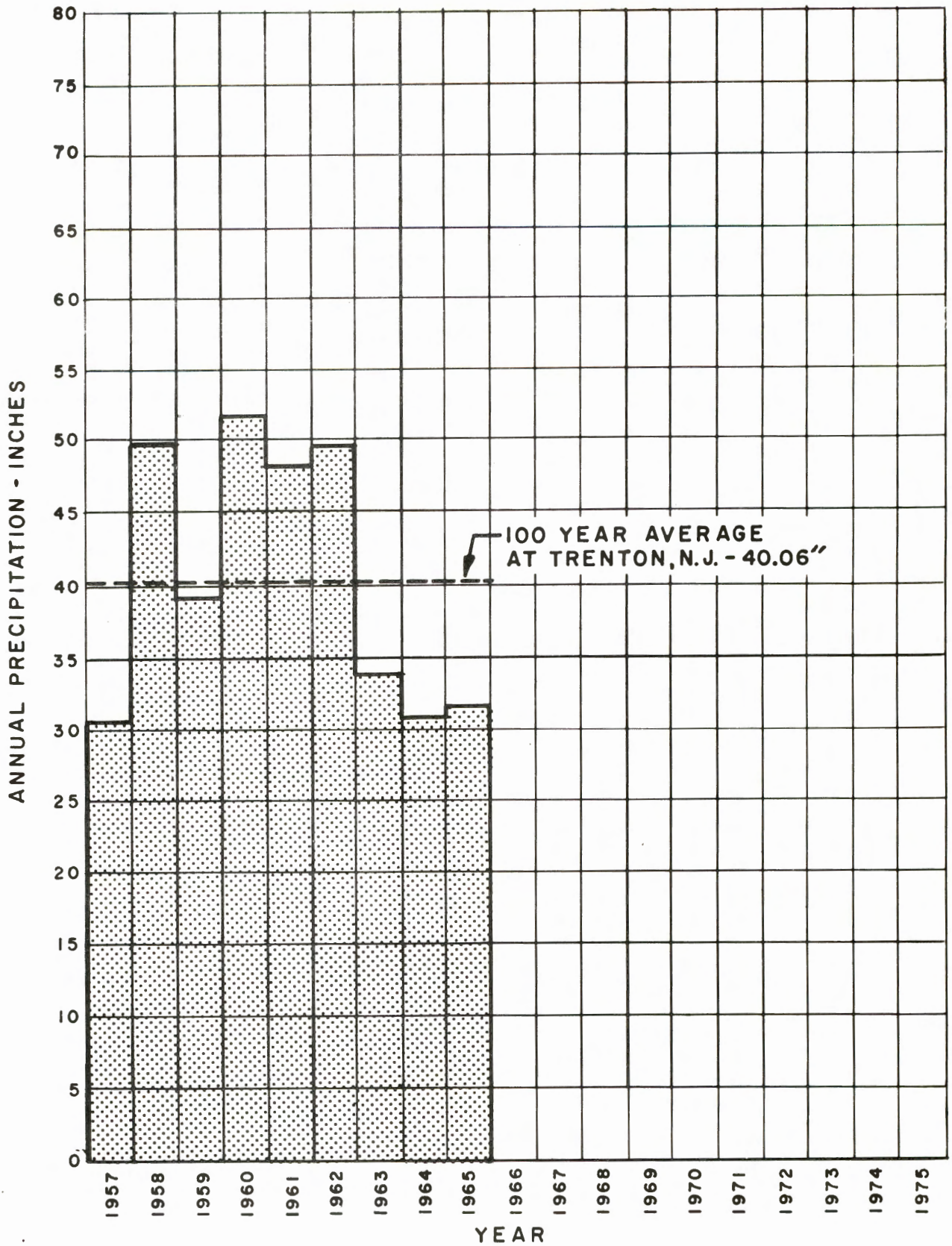
The location and capacities of public utilities is a major influence upon the patterns of development within the Watershed area. Sites which are served by public water, sewers, gas and electricity are

TABLE 3
 AVERAGE MONTHLY AND ANNUAL
 TEMPERATURE IN DEGREES FAHRENHEIT

<u>Month</u>	<u>Hightstown</u>	<u>New Brunswick</u>	<u>Flemington</u>	<u>Trenton</u>
January	32.4	32.3	31.5	33.1
February	32.9	32.8	32.3	33.4
March	40.2	40.2	40.1	40.7
April	50.9	51.1	51.2	51.7
May	61.4	61.6	61.8	58.5
June	69.9	70.1	70.6	71.0
July	74.8	75.0	75.4	75.4
August	72.9	73.2	73.4	73.9
September	66.2	66.5	66.6	67.1
October	55.9	56.1	55.8	56.8
November	45.2	45.3	44.3	45.8
December	<u>34.3</u>	<u>34.2</u>	<u>33.3</u>	<u>35.2</u>
Annual Average	53.1	53.2	53.0	53.9
No. of Years of Record through 1963	67	106	66	91

TABLE 4
 AVERAGE MONTHLY AND ANNUAL
 PRECIPITATION IN INCHES

<u>Month</u>	<u>Hightstown</u>	<u>New Brunswick</u>	<u>Flemington</u>	<u>Trenton</u>
January	3.22	3.34	3.32	3.10
February	2.73	2.77	2.78	2.59
March	3.82	3.75	3.99	3.84
April	3.38	3.48	3.80	3.21
May	3.72	3.75	4.01	3.62
June	3.83	3.63	3.80	3.60
July	4.46	4.53	4.52	4.18
August	4.52	4.70	5.02	4.77
September	3.99	4.06	3.59	3.50
October	3.32	3.16	3.32	2.84
November	3.39	3.64	3.74	3.16
December	<u>3.03</u>	<u>3.17</u>	<u>3.42</u>	<u>2.87</u>
Annual Average	43.41	43.98	45.31	41.28
No. of Years of Record through 1963	70	109	77	91



ANNUAL PRECIPITATION
AS RECORDED AT HEADQUARTERS OF
STONY BROOK-MILLSTONE
WATERSHEDS ASSOCIATION

in greater demand than those in areas where the expense of providing such facilities must be shared in part by the prospective developer.

The Watershed is amply supplied with electric power. The two main sources are the facilities of the Public Service Electric and Gas Company and Jersey Central Power and Light Company, with the former supplying more than half the area. New Jersey Power and Light Company also furnishes power to a small portion of the Watershed within Hunterdon County.

Several utility companies are presently franchised to deliver natural gas within the Watershed. However, not all of the area receives service at this time. Major service areas include the southwest part of Middlesex County, the contiguous northeast part of Mercer County and the area around Manville in Somerset County. The supplier is Public Service Electric and Gas Company. Gas is also available to limited areas around the Boroughs of Hopewell and Pennington served by City Gas Company.

Existing water supply and sewerage systems are intimately allied with the objectives of this study. They are, therefore, included and discussed fully, in separate succeeding sections of the report.

EXPECTED POPULATION GROWTH

Population Forecasting

Population forecasting is a speculative undertaking at best. To be truly useful, any forecast must be updated constantly to take into account unforeseen changes resulting from major political, social and economic events. However, a comprehensive population forecast predicated on past, current and known immediate-future trends provides a reasonably sound foundation on which long range planning to meet future public needs can be based.

Watershed Growth and Land Use

The Stony Brook-Millstone Watershed area is presently experiencing the outward spread of development from the New York and Philadelphia-Trenton areas, and it is anticipated that, in future years, a rapid surge of new residential, research facility and industrial growth will spread over a major part of the vacant and rural portions of the Watershed.

At present, the dominant land use in the Watershed is for agricultural purposes. However, commercial, industrial and other urban land uses are replacing agricultural activities along the major highways at a rapid pace.

A cluster of industrial research facilities surrounds the area of Princeton, and more are in process of development in the vicinity. Research facilities are there because Princeton is the home of both Princeton University, with its highly-regarded graduate school, and the unique Institute for Advanced Study to which gifted scientists and philosophers have come from all parts of the world to concentrate in mathematics, astrophysics, history and philosophy. The Institute is an international center for intellectuals.

Princeton University is deeply occupied with research, particularly at the huge Forrestal Research Center near Route 1, where atomic energy is under study at the multi-million dollar electron accelerator installation.

Industry has understandably responded eagerly to these intellectual magnets. RCA's David Sarnoff Research Center is in Princeton and nearby, American Cyanamid has opened what it calls "the largest and most modern industrial research farm in the world." A few miles away in Plainsboro, ten privately-owned companies pursue cooperative research on peace-time use of atomic energy.

The State of New Jersey, in general, has continued to show a more active growth rate than any of the New England or other Middle Atlantic States. A recent U. S. Bureau of Census report indicated that the State's population may have been notably increased by the arrival of families aware of the opportunities for skilled factory workers, research scientists and executive administrators, and who appreciate the excellent facilities for recreation, education and suburban living near metropolitan centers.

Method of Estimating Population Growth

To estimate the population growth of the study area, the official estimates by the New Jersey Department of Conservation and Economic Development were accepted for projections of State and County populations through 1990. The official estimates by County Planning Boards for individual municipalities were generally accepted through 1985, or other year, depending on the County. The population projections for the State were then extended from 1990 to 2015, and county and municipal populations for whole municipalities were derived for 2015.

In this process, consideration was given to the effect that existing and planned transportation media would have on the population growth and distribution in a given municipality. Judgment was applied to determine the proportion of the estimated future population which would be located within the Stony Brook-Millstone Watershed. The preliminary 2015 population estimates were compared with the existing zoned capacity for each whole or part municipality, based on lot size requirements in the residential districts. In the cases where the estimate exceeded the zoned capacity, the excess was distributed into adjoining municipalities with surplus capacity. This occurred in thirteen of the twenty-six municipalities. The resulting population estimates were then discussed with the planning staffs of the five counties, and some final adjustments ensued due to their special knowledge of the local situation and trends.

Possible Zoning Changes

Population growth of the magnitude estimated in this study will bring pressure to bear on the existing zoning regulations of the various municipalities. This situation has already been noted by the Middlesex County Planning Board. In their 1964 report, reviewing municipal population predictions for 1985, the Board foresaw that local zoning requirements are likely to be relaxed, noting that this has taken place in New Jersey municipalities nearer to New York City, where strong population and economic pressures have already come to bear.

In redistributing population based on present zoned capacity, the effect of possible zoning relaxation was considered, particularly in the Upper Millstone sub-watershed, which includes Route 1 and the New Jersey Turnpike. However, it cannot be expected that wholesale relaxation of zoning will generally occur in the Watershed. Those municipalities where comprehensive planning and zoning are established as beneficial functions of orderly community development will evolve generally in accord with the established zoning regulations.

Estimated Future Population

The results of the study of population trends in each community are presented as population curves on PLATES 5 thru 14.

The estimates of population by decades to the year, 2015, for each municipality, or part thereof, within the Watershed limits are shown in TABLE 5. In TABLE 6, the final estimated populations in the year 2015 are further distributed to the three sub-watersheds in the study area.

As shown by TABLE 6, the following are the total estimated populations for each of the three sub-watersheds in 2015:

<u>Sub-Watershed</u>	<u>2015 Population</u>
Stony Brook	55,300
Upper Millstone	312,000
Lower Millstone	<u>245,100</u>
Stony Brook-Millstone Watershed Total	612,400

For the Stony Brook and Upper Millstone, it is interesting to compare the above figures with those presented in a 1957 study by the Rutgers Planning Service:

<u>Sub-Watershed</u>	<u>1955 Population</u>	<u>Saturation Capacity in Accordance with 1957 Zoning</u>
Stony Brook	16,600	145,100
Upper Millstone	15,100	407,200

TABLE 5

POPULATION FORECAST FOR MUNICIPALITIES WITHIN THE STONY BROOK - MILLSTONE WATERSHED

Municipality	Census 1960	Estimated Population for the Year *					
		1970	1980	1990	2000	2010	2015
Hunterdon County							
East Amwell Township	1,210	2,300	2,825	3,650	4,800	5,900	6,400
West Amwell Township	420	1,000	1,300	1,900	2,800	3,700	4,100
Mercer County							
East Windsor Township	2,220	6,000	12,000	20,000	29,000	38,000	43,000
Hightstown Borough	4,317	5,500	6,400	7,300	8,200	9,200	9,700
Hopewell Township	5,557	9,800	15,000	20,800	26,650	33,300	36,500
Hopewell Borough	1,928	2,300	2,850	3,500	4,200	5,000	5,300
Pennington Borough	2,063	2,300	2,550	2,900	3,350	3,800	4,000
Lawrence Township	1,366	1,900	2,200	2,650	3,100	3,600	3,800
Princeton Township	10,400	11,100	11,800	12,400	13,100	13,800	14,150
Princeton Borough	11,950	11,940	11,930	11,920	11,910	11,900	11,900
Washington Township	43	60	80	90	95	98	100
West Windsor Township	3,200	8,000	14,000	23,000	35,000	46,000	52,500
Middlesex County							
Cranbury Township	2,001	5,000	9,100	14,000	19,500	25,000	27,800
Monroe Township	3,660	12,000	26,000	41,000	61,000	81,000	91,000
North Brunswick Township	2,175	3,000	4,500	6,000	7,500	9,000	9,500
Plainsboro Township	1,182	4,450	8,800	14,250	19,750	26,250	29,300
South Brunswick Township	5,190	11,000	19,000	29,200	41,000	52,700	58,700
Monmouth County							
Manalapan Township	160	500	840	1,180	1,540	1,910	2,100
Millstone Township	1,530	4,000	8,000	13,000	18,000	23,000	26,000
Roosevelt Borough	31	40	90	150	210	270	300
Somerset County							
Franklin Township	6,000	12,000	19,300	25,500	34,500	41,000	45,550
Hillsboro Township	6,400	13,000	23,500	36,000	50,500	65,000	72,100
Manville Borough	4,300	5,500	6,000	6,100	6,500	6,700	6,700
Millstone Borough	409	575	700	850	1,000	1,200	1,300
Montgomery Township	3,851	8,500	16,000	25,000	34,500	44,000	49,000
Rocky Hill Borough	528	850	950	1,100	1,300	1,500	1,600
Total Watershed Population	82,091	142,615	225,715	323,440	439,005	552,828	612,400

*Estimates include only that portion of political subdivisions within Stony Brook - Millstone Watershed.

TABLE 6

ESTIMATED POPULATION IN THE STONY BROOK, UPPER AND LOWER
MILLSTONE SUB-WATERSHEDS IN THE YEAR 2015

<u>Stony Brook Sub-Watershed</u>	<u>Percent of Population in Sub-Watershed</u>	<u>Population in Sub-Watershed 2015</u>
East Amwell Township (Hunterdon) (d)	50	5,300
West Amwell Township (Hunterdon)	25	4,100
Hopewell Township (Mercer) (e)	56	22,300
Pennington Borough (Mercer)	100	4,000
Lawrence Township (Mercer)	10	3,800
Princeton Township (Mercer) (a)	70	8,650
Princeton Borough (Mercer) (b)	60	<u>7,150</u>
Total for Stony Brook Sub-Watershed		55,300
<u>Upper Millstone Sub-Watershed</u>		
East Windsor (Mercer)	97	43,000
Hightstown Borough (Mercer)	100	9,700
Washington Township (Mercer)	2	100
West Windsor Township (Mercer)	80	52,500
Cranbury Township (Middlesex)	100	27,800
Monroe Township (Middlesex)	63	91,000
Plainsboro Township (Middlesex) (c)	87	26,800
South Brunswick Township (Middlesex) (f)	35	32,700
Manalapan Township (Monmouth)	4	2,100
Millstone Township (Monmouth)	60	26,000
Roosevelt Borough (Monmouth)	4	<u>300</u>
Total for Upper Millstone Sub-Watershed		312,000
<u>Lower Millstone Sub-Watershed</u>		
East Amwell Township (Hunterdon) (d)	11	1,100
Hopewell Township (Mercer) (e)	15	14,200
Hopewell Borough (Mercer)	100	5,300
Princeton Township (Mercer) (a)	30	5,500
Princeton Borough (Mercer) (b)	40	4,750
North Brunswick Township (Middlesex)	20	9,500
Plainsboro Township (Middlesex) (c)	13	2,500
South Brunswick (Middlesex) (f)	15	26,000
Franklin Township (Somerset)	30	45,550
Hillsborough Township (Somerset)	85	72,100
Manville Borough (Somerset)	40	6,700
Millstone Borough (Somerset)	100	1,300
Montgomery Township (Somerset)	100	49,000
Rocky Hill Borough (Somerset)	100	<u>1,600</u>
Total for Lower Millstone Sub-Watershed		245,100
Total for Stony Brook-Millstone Watershed		612,400

NOTES:

- (a), (b), (c) Municipality partly in one sub-watershed, remainder in another sub-watershed.
- (d), (e), (f) Municipality partly in one sub-watershed, partly in another sub-watershed, remainder outside the Stony Brook-Millstone Watershed limits.

Distribution of Future Population

The distribution of future population within the Watershed has been analyzed to determine the necessity of providing sewerage facilities in various localities. The qualifying criteria is the density of resident population expressed in persons per gross acre of land. Three levels of residential development are identified as follows:

<u>Residential Development</u>	<u>Density of Resident Population in Number of People per Gross Acre</u>
Rural	6 or less
Suburban	More than 6 but less than 12
Urban	12 or more

The expected distribution of these three levels of population density is shown on PLATE 15. Generally, distribution was established by examination of the available information on zoning, land use projections, and the estimated population growth. The results were then reviewed with the staff planners, or planning directors, of the five counties in the Watershed area with respect to the comprehensive planning considerations developed in their offices. In this process, consideration was given to the projected development of industrial, as well as residential, use along such major arterial highways as the New Jersey Turnpike, Route 1 and proposed Interstate 95 and Route 92.

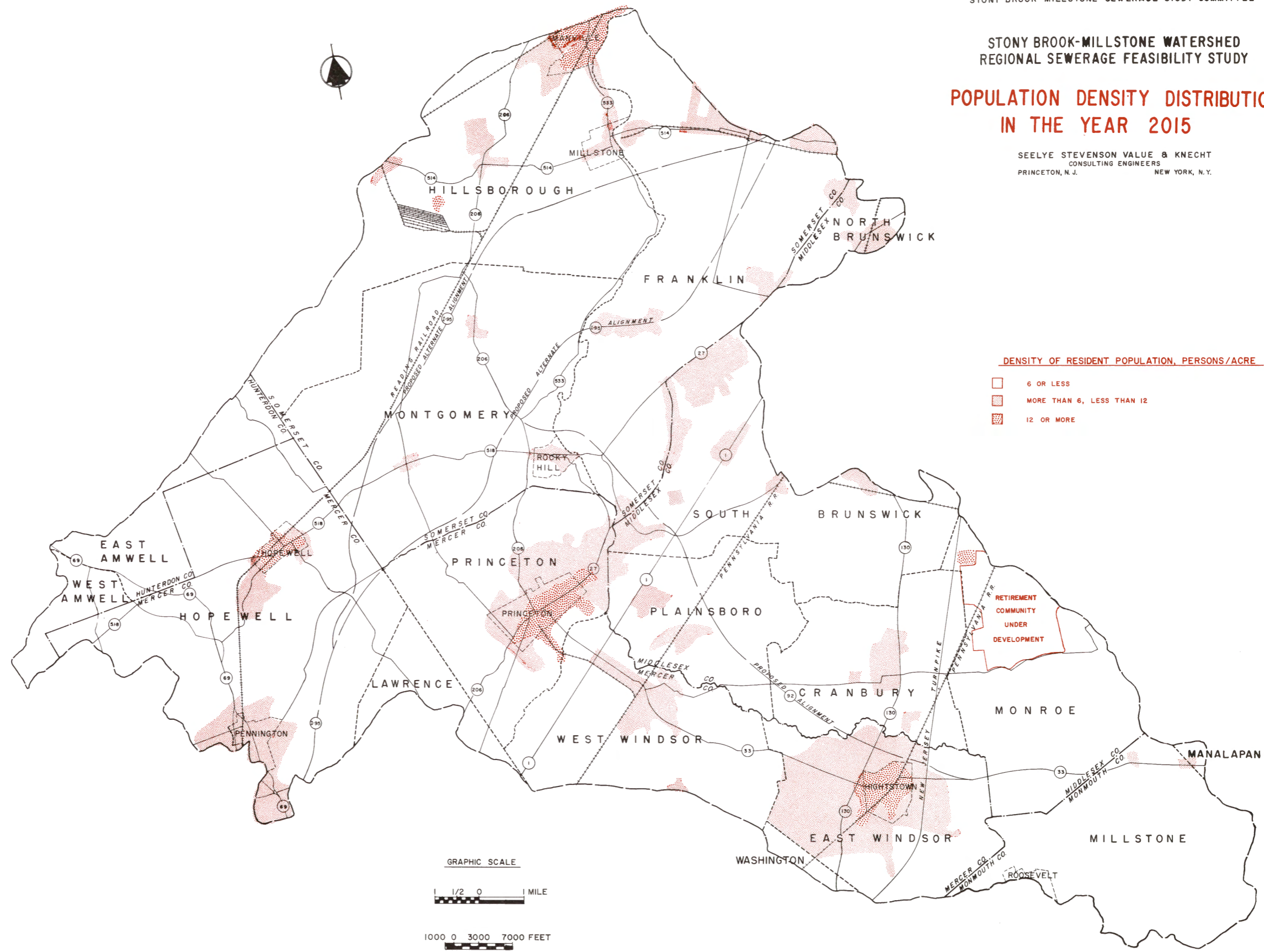
The distribution of population densities shown indicates that, even in 2015, a large part of the Watershed will still be in the Rural classification. This reflects the prevalence of one-half acre or larger residential lot sizes required by existing zoning ordinances. It is also true that much of the land in this classification is in rough terrain, such as that found in the Sourland Mountain area, and is not readily useable for heavier density development. Another factor affecting development of these areas is the proposed county and state open space projects, such as the Six Mile Run Reservoir and Millstone Valley Park.

PLATE 15 indicates that Urban development is expected to be highly concentrated in the centers of present day principal communities. In projecting this pattern, the study was concerned with locating relatively large areas of this residential density. Therefore, the location of minor centers of dense occupancy, such as a new garden apartment

STONY BROOK-MILLSTONE WATERSHED
REGIONAL SEWERAGE FEASIBILITY STUDY

**POPULATION DENSITY DISTRIBUTION
IN THE YEAR 2015**

SEELYE STEVENSON VALUE & KNECHT
CONSULTING ENGINEERS
PRINCETON, N. J. NEW YORK, N. Y.



development of limited area, is not prominently emphasized on the map. As a result of relaxation of the zoning regulations, projects of this smaller order have occurred in a number of places. These projects will generally tend to magnify the number of persons per gross acre within the development level. If widespread relaxation of zoning takes place, these projects will multiply and their existence would, of course, have greater significance in the planning of wastewater disposal facilities.

As might be expected, the Suburban development level is shown as expanding in the areas around existing community centers and, frequently, along principal roads or highways connecting such centers. This classification is of particular importance in considering the need for sewerage facilities, since there is little question that service will be essential to permit development of significant proportions. Leisure World in the Township of Monroe is a case in point. The developers of this project are providing a complete collection and disposal system. However, it is not only the exceedingly large development that requires such service. Smaller sub-divisions of average size are required to have "package treatment plants," if public sewerage is not available.

TOPOGRAPHY AND GEOLOGY

Topography

An imaginary line, known as the Fall Line, running roughly in a northeast-southwest direction between Perth Amboy and Trenton, divides the Stony Brook-Millstone Watershed into two major physiographic provinces, the Piedmont Plain to the northwest and the Inner Coastal Plain to the southeast.

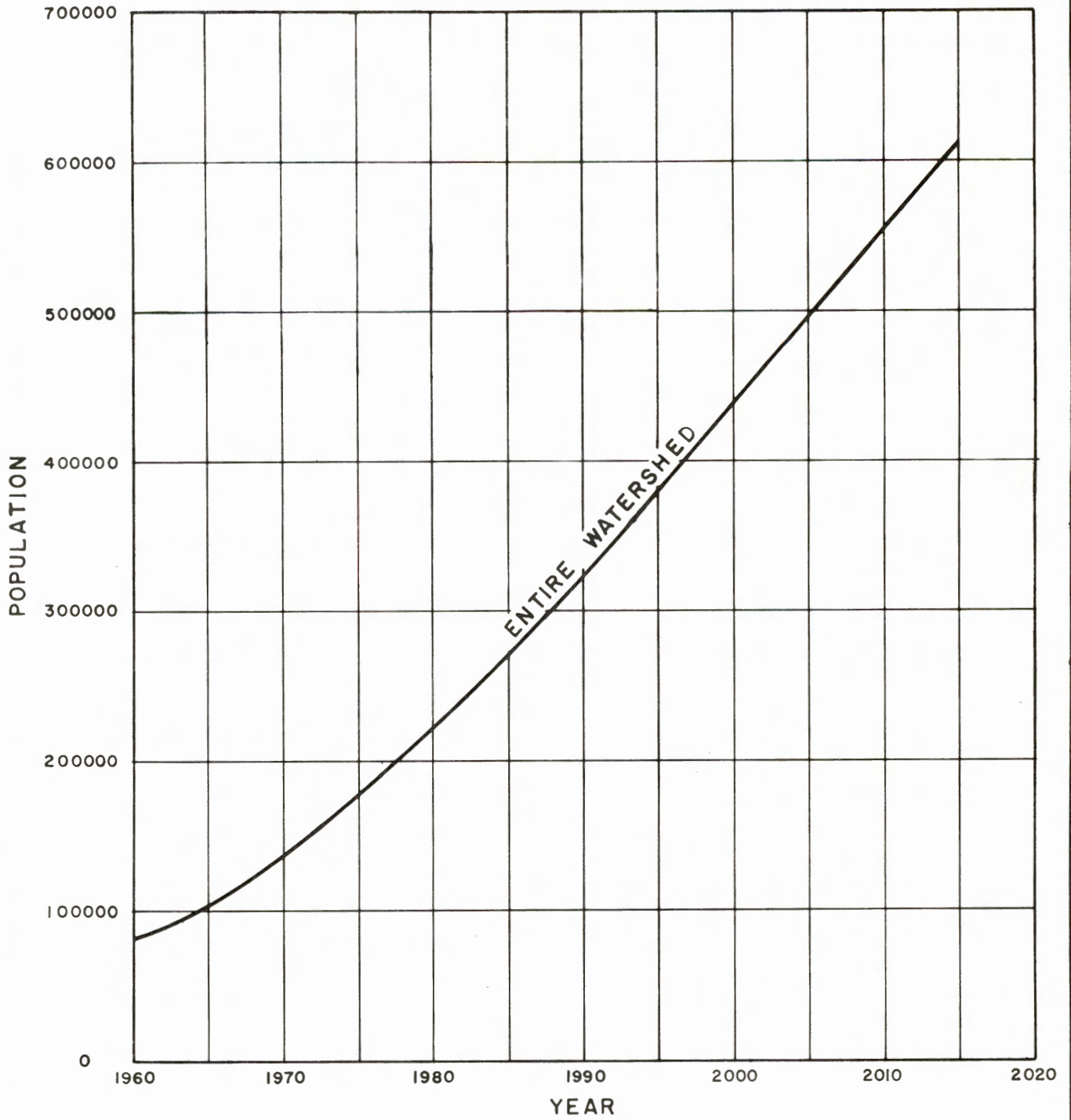
The Stony Brook and Lower Millstone sub-watersheds lie on the eastern boundary of the Piedmont Plain, which appears as an undulating plain sloping eastward to sea level. The topography is marked by rounded hills separated by broad valleys. Much of the area is cleared for farmland or urban development with excessive surface drainage and erosion resulting. Maximum elevation at the head of Stony Brook is approximately 550 feet above mean sea level. Elevation diminishes down stream at Carnegie Lake to about 50 feet.

The Upper Millstone sub-watershed lies along the western margin of the Inner Coastal Plain. The topography is generally flat or slightly rolling with steep slopes existing only in the upper reaches of the Millstone River in Millstone Township. Elevations are low and streams meander slowly throughout the area. Poor drainage, due to the combination of low stream gradients and underlying impermeable clays, produces a significant extent of wet and swampy areas, especially along Devils Brook. These areas are covered by a poor scrub forest. The central portion of the sub-watershed contains soils of extremely high quality and is intensively farmed.

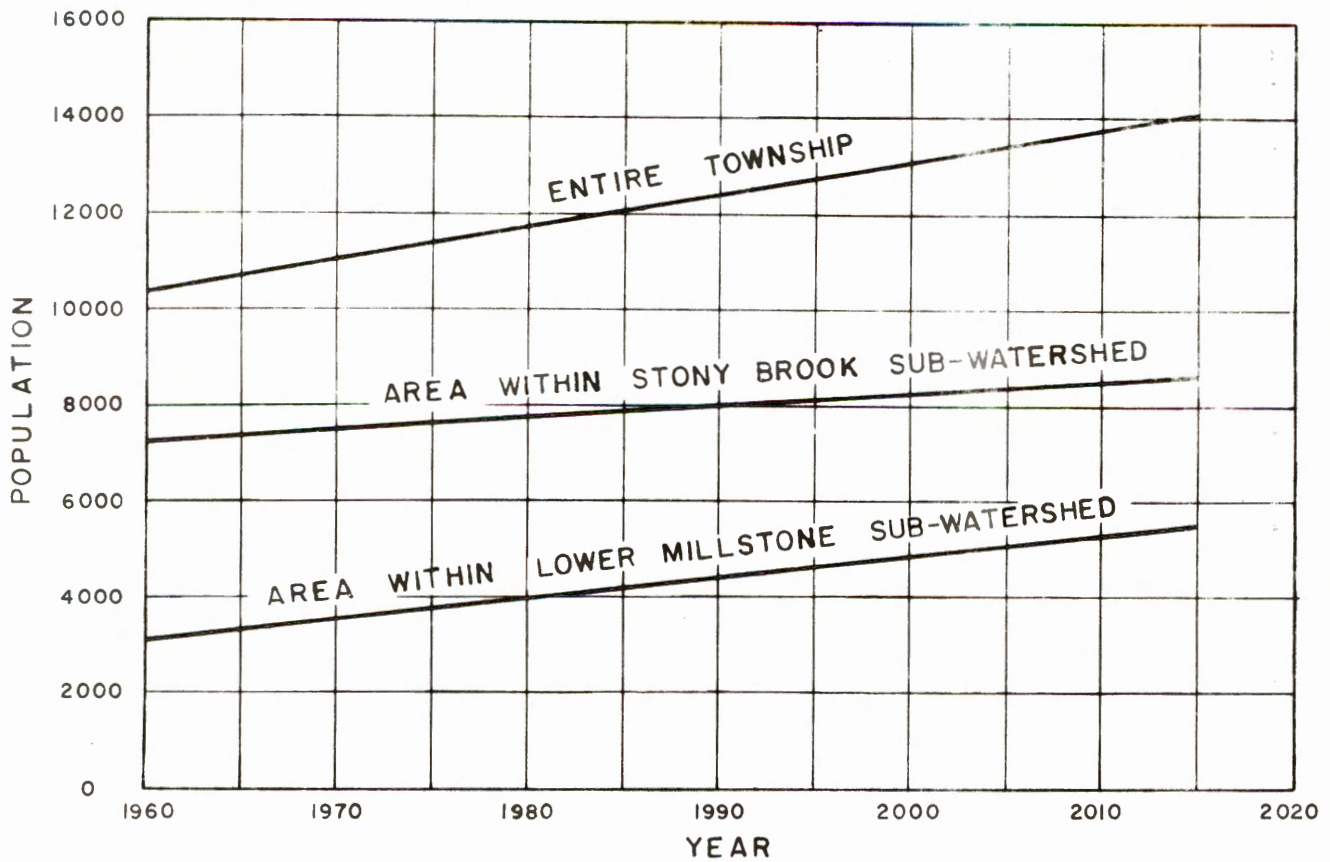
Geology

The geologic outcrops, or areas where the subsurface formations are exposed, are shown for the Watershed on PLATE 16. A corresponding generalized geologic cross-section of these formations is illustrated by PLATE 17.

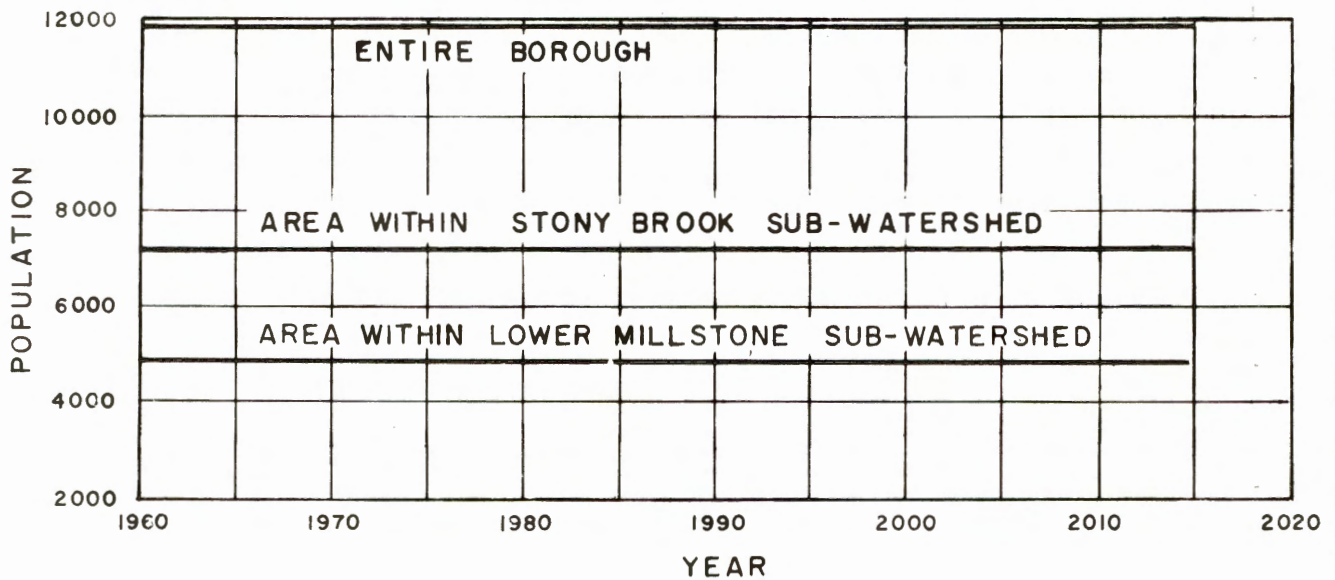
The streams in the Stony Brook and Lower Millstone sub-watersheds rise in and flow through areas underlain by crystalline rocks of Precambrian and Paleozoic age and by Triassic shale, sandstone, argillite, and diabase. In general, these rock formations have been tilted down about 30 degrees toward the northwest and broken into big blocks 10 to 15 miles wide. The result is that the various rock formations occur as bands. Two Lockatong argillite belts extend in a



STONY BROOK-MILLSTONE WATERSHED
REGIONAL SEWERAGE FEASIBILITY STUDY
POPULATION FORECAST
FOR
THE STONY BROOK-MILLSTONE WATERSHED

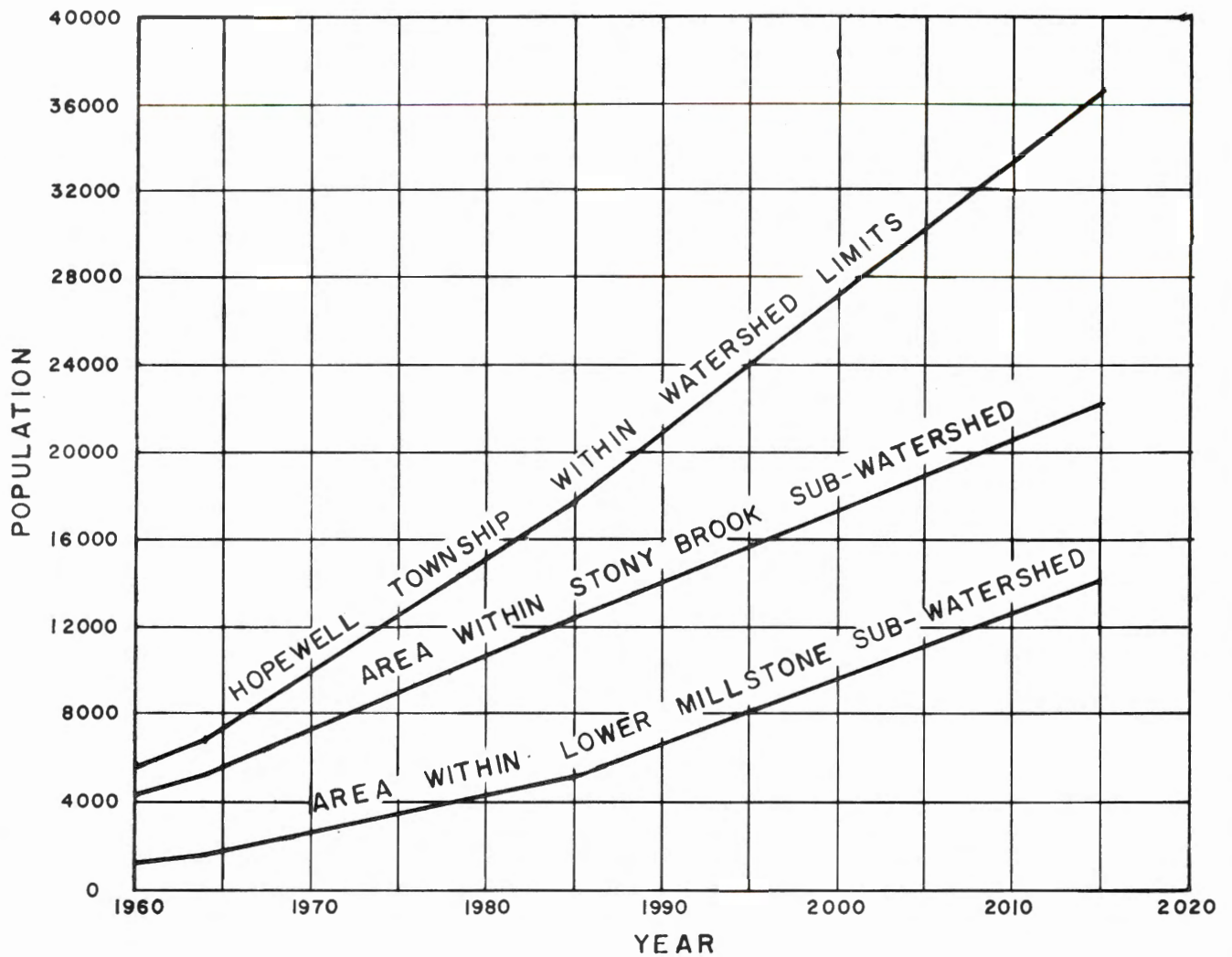


PRINCETON TOWNSHIP

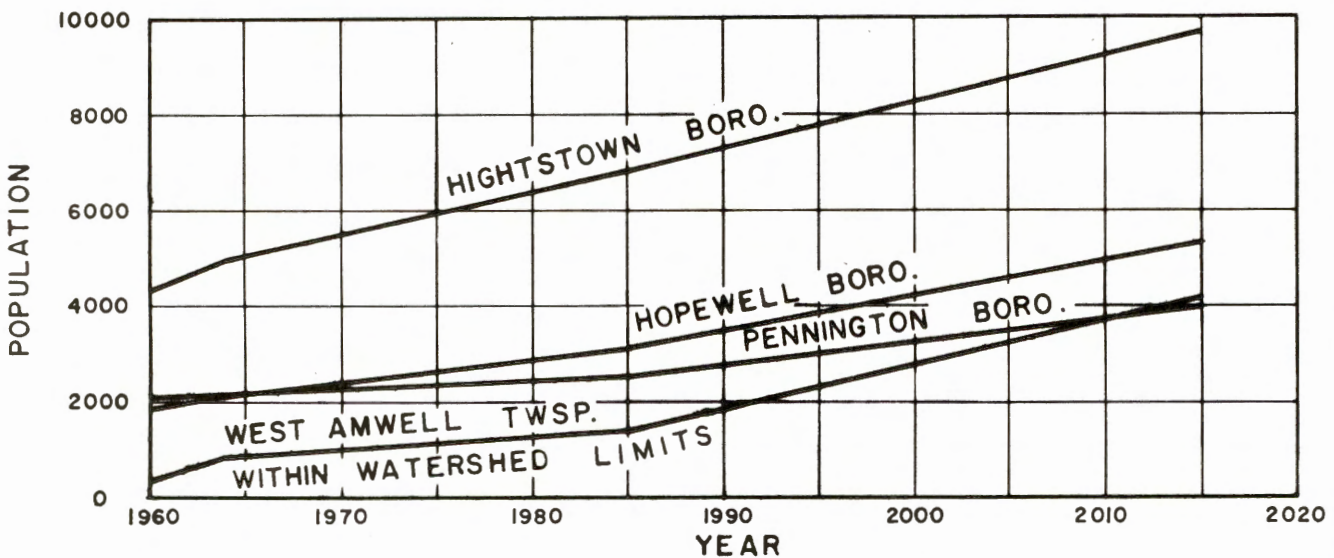
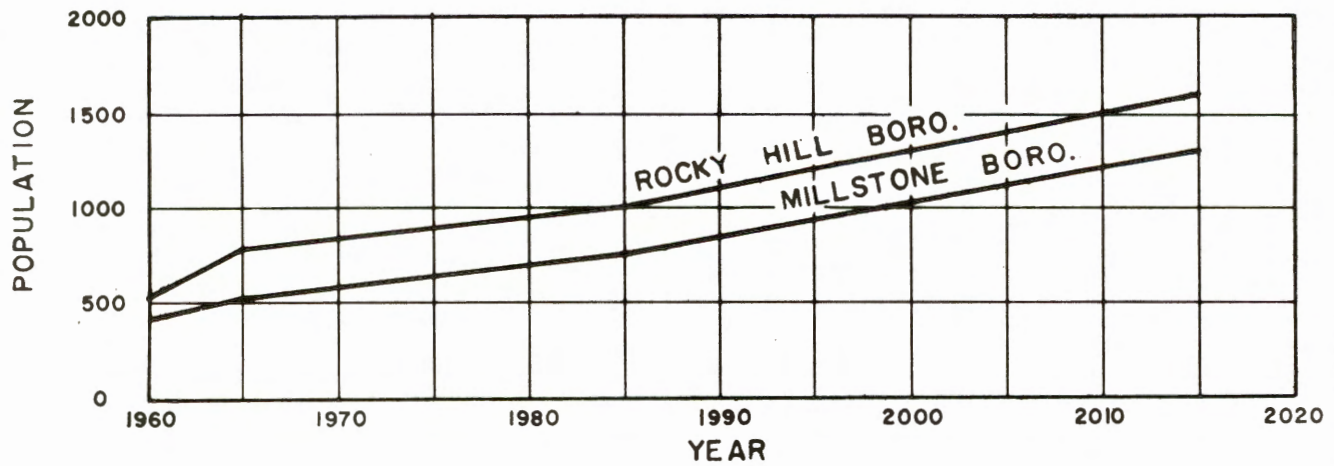
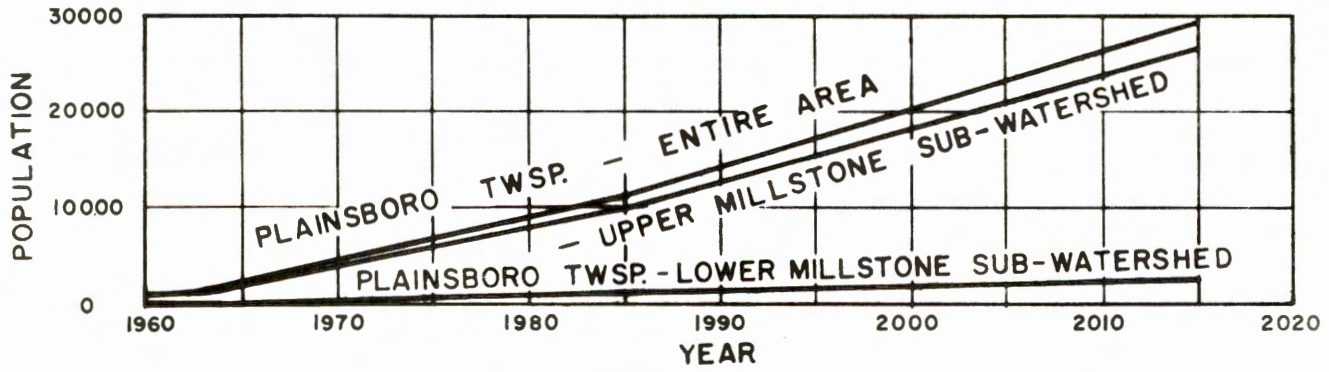


PRINCETON BOROUGH

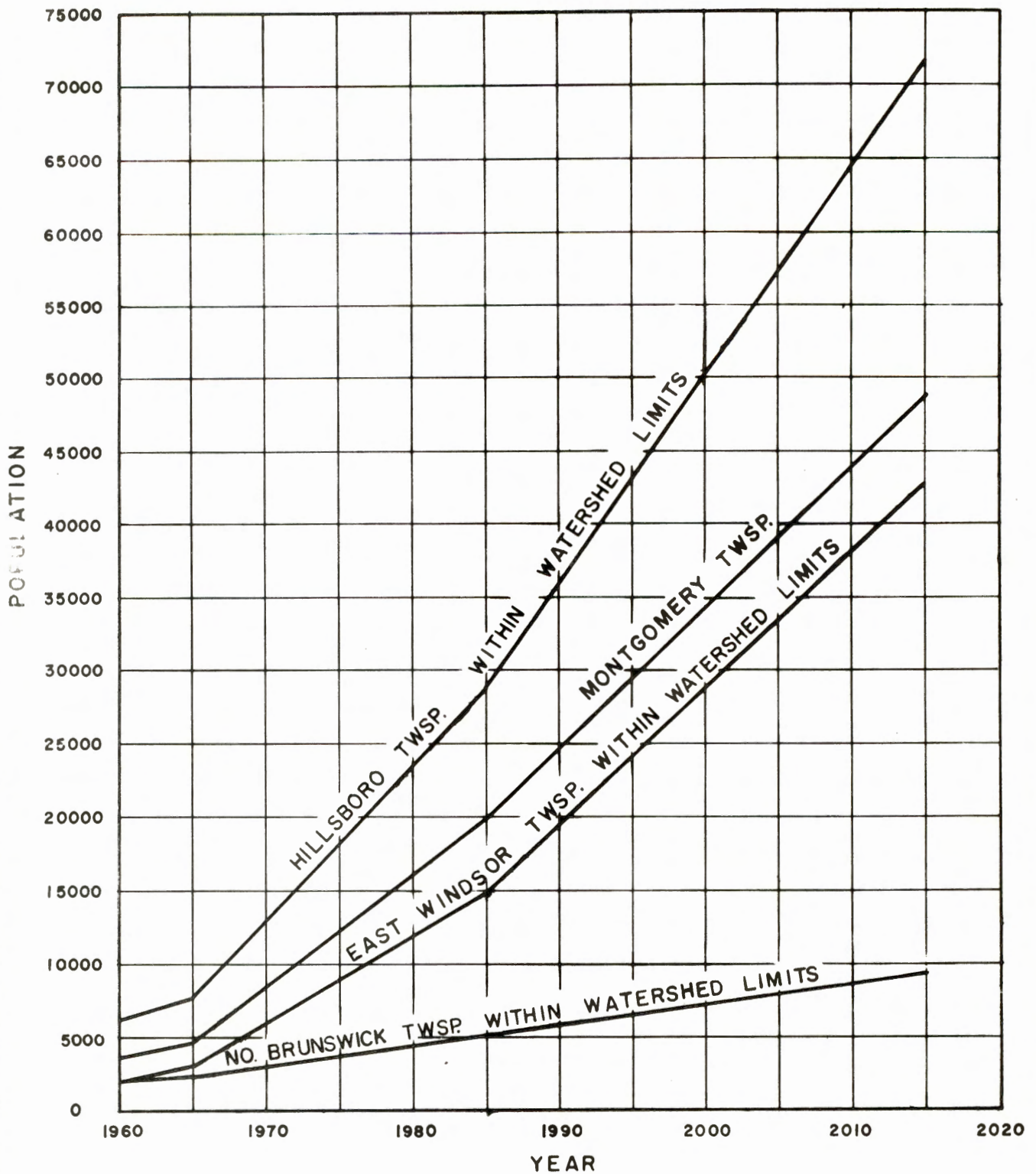
STONY BROOK-MILLSTONE WATERSHED
 REGIONAL SEWERAGE FEASIBILITY STUDY
 POPULATION FORECASTS
 FOR
 PRINCETON TOWNSHIP AND BOROUGH



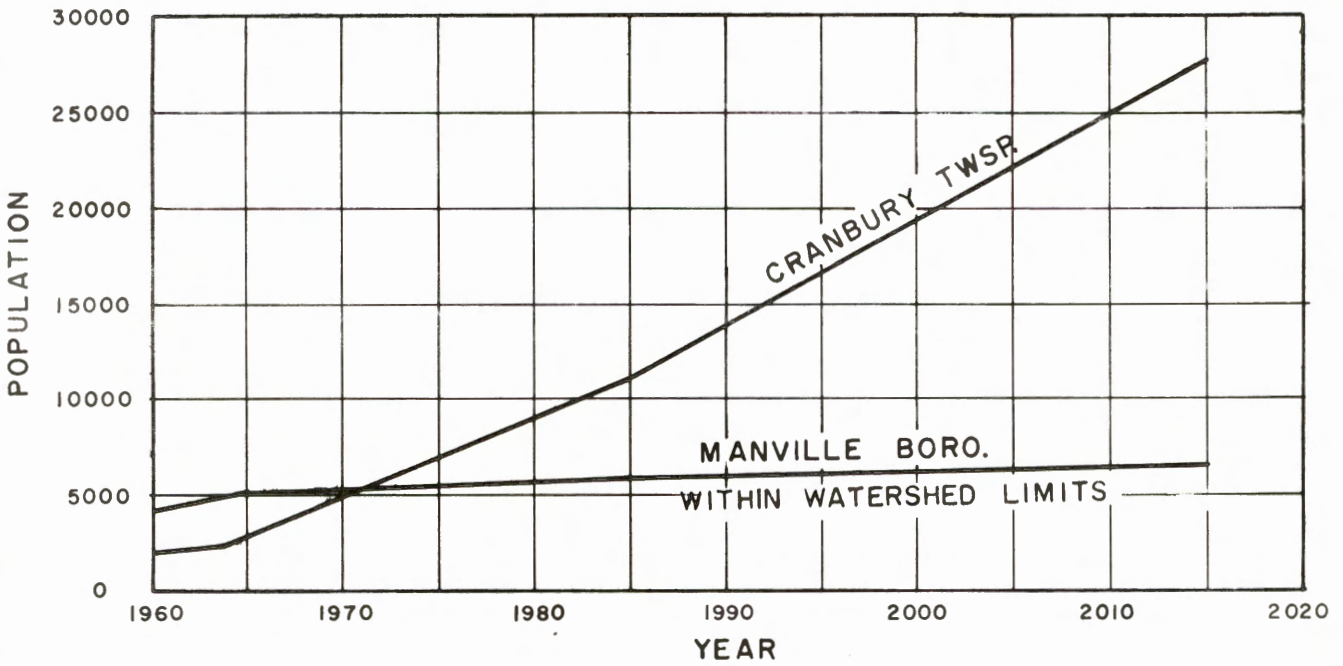
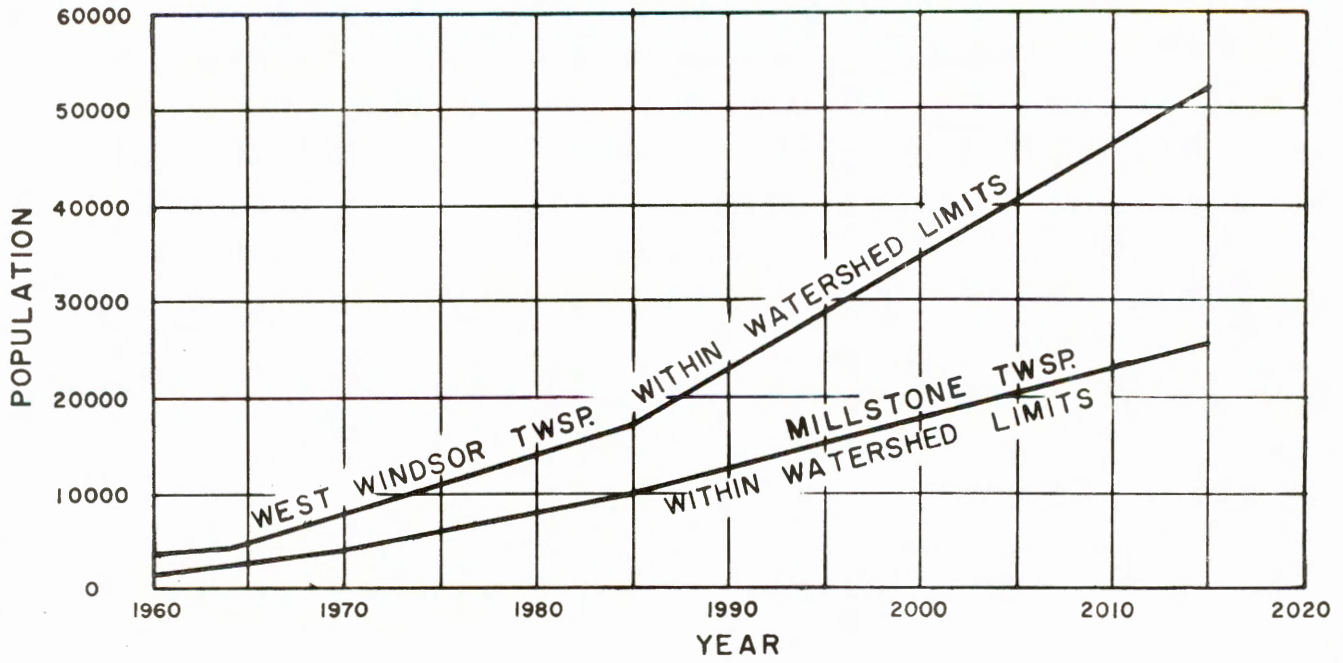
STONY BROOK-MILLSTONE WATERSHED
 REGIONAL SEWERAGE FEASIBILITY STUDY
 POPULATION FORECAST
 FOR
 HOPEWELL TOWNSHIP



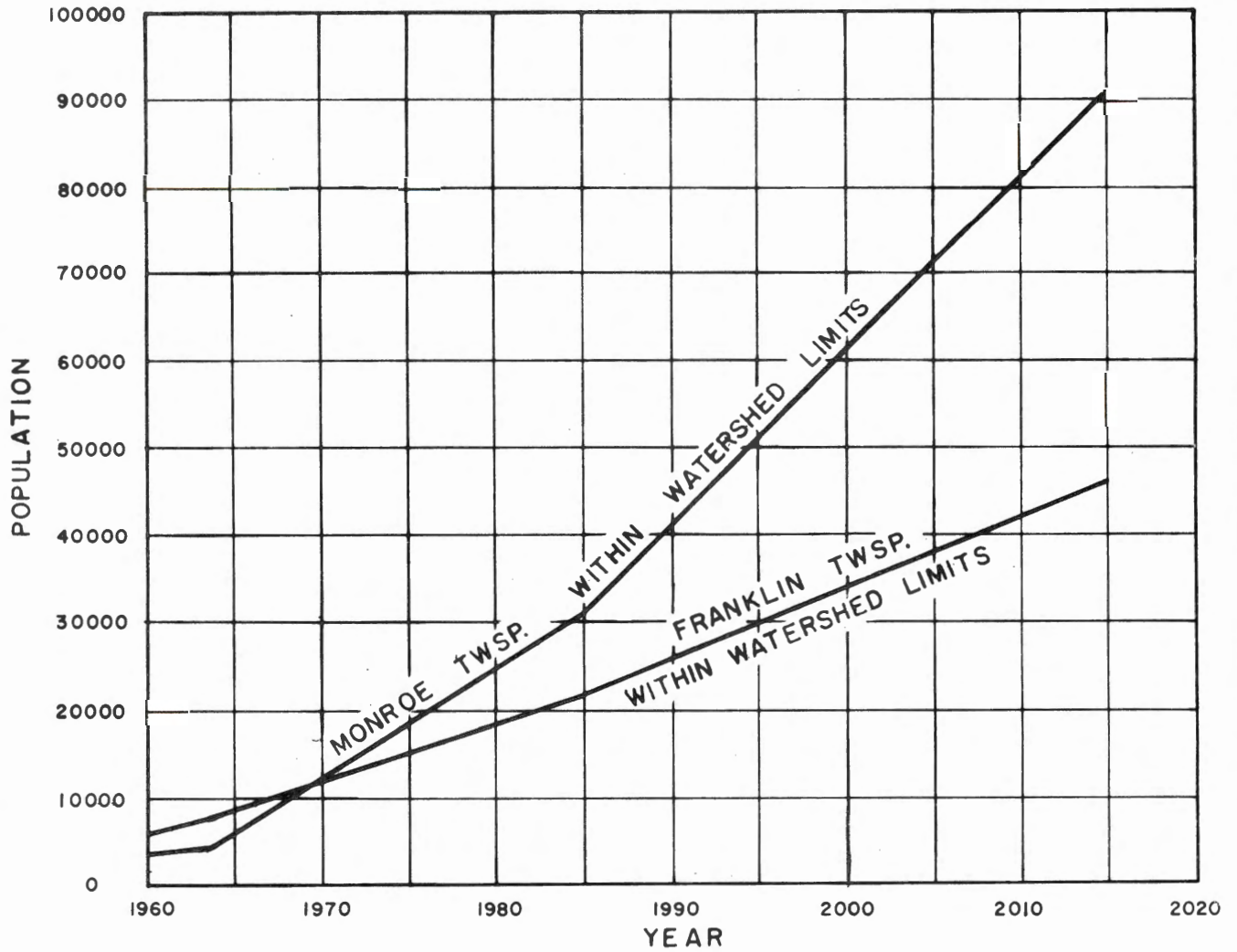
STONY BROOK-MILLSTONE WATERSHED
 REGIONAL SEWERAGE FEASIBILITY STUDY
 POPULATION FORECASTS
 FOR
 PLAINSBORO AND WEST AMWELL TOWNSHIPS
 ROCKY HILL, MILLSTONE, HIGHTSTOWN, HOPEWELL
 AND PENNINGTON BOROUGHS



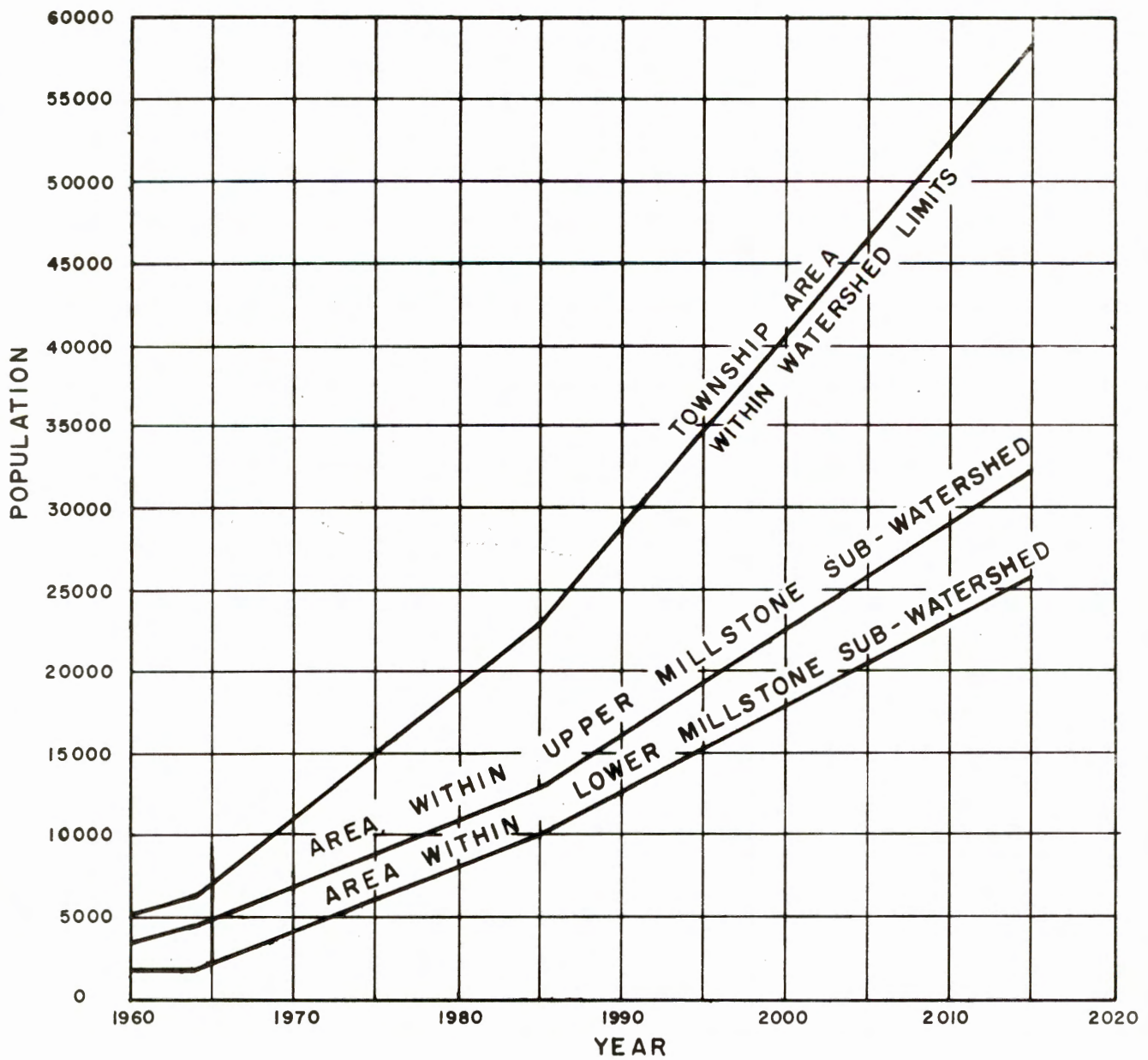
STONY BROOK-MILLSTONE WATERSHED
 REGIONAL SEWERAGE FEASIBILITY STUDY
 POPULATION FORECASTS
 FOR
 HILLSBORO, MONTGOMERY, EAST WINDSOR
 AND NORTH BRUNSWICK TOWNSHIPS



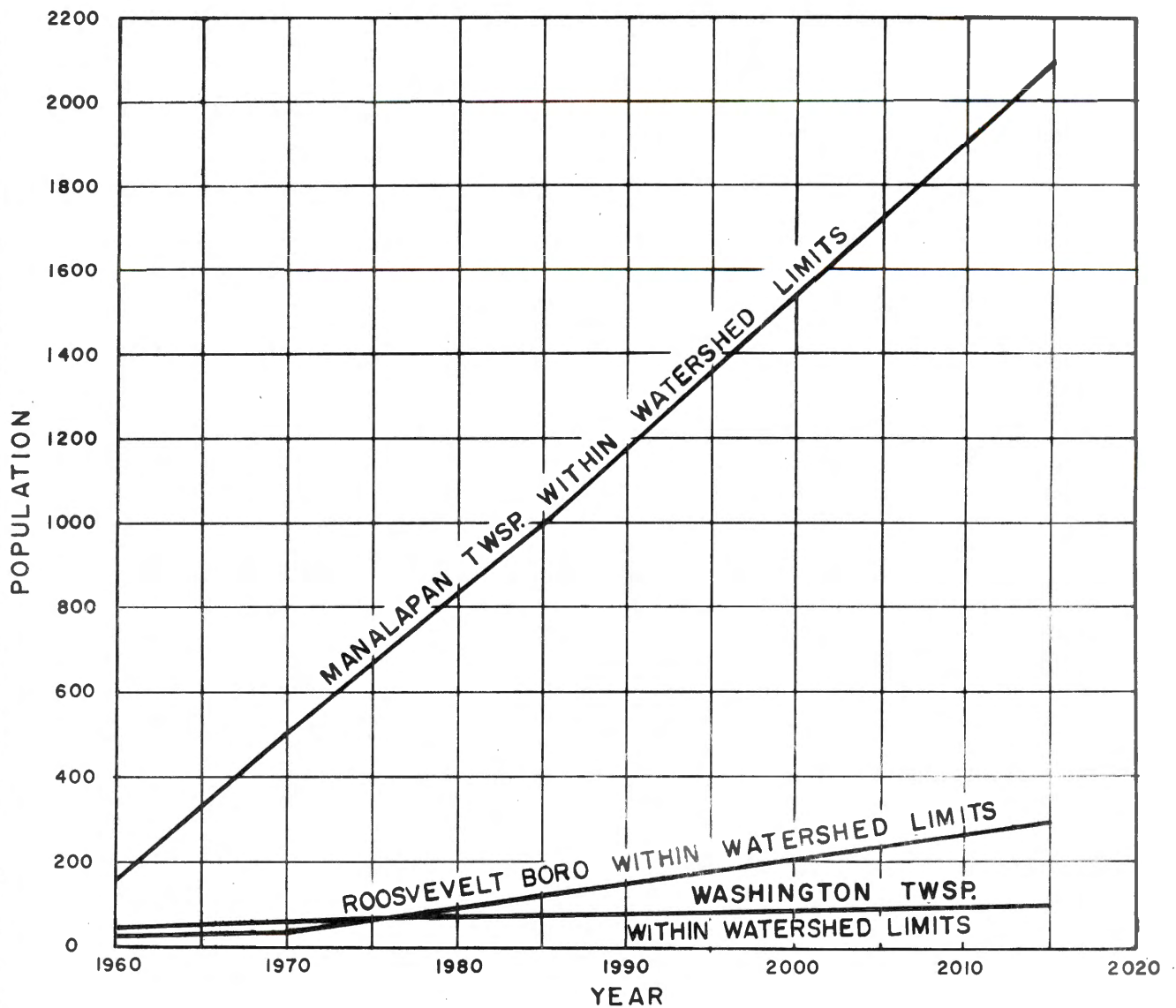
STONY BROOK-MILLSTONE WATERSHED
 REGIONAL SEWERAGE FEASIBILITY STUDY
 POPULATION FORECASTS
 FOR
 WEST WINDSOR, MILLSTONE AND CRANBURY TOWNSHIPS
 AND MANVILLE BOROUGH



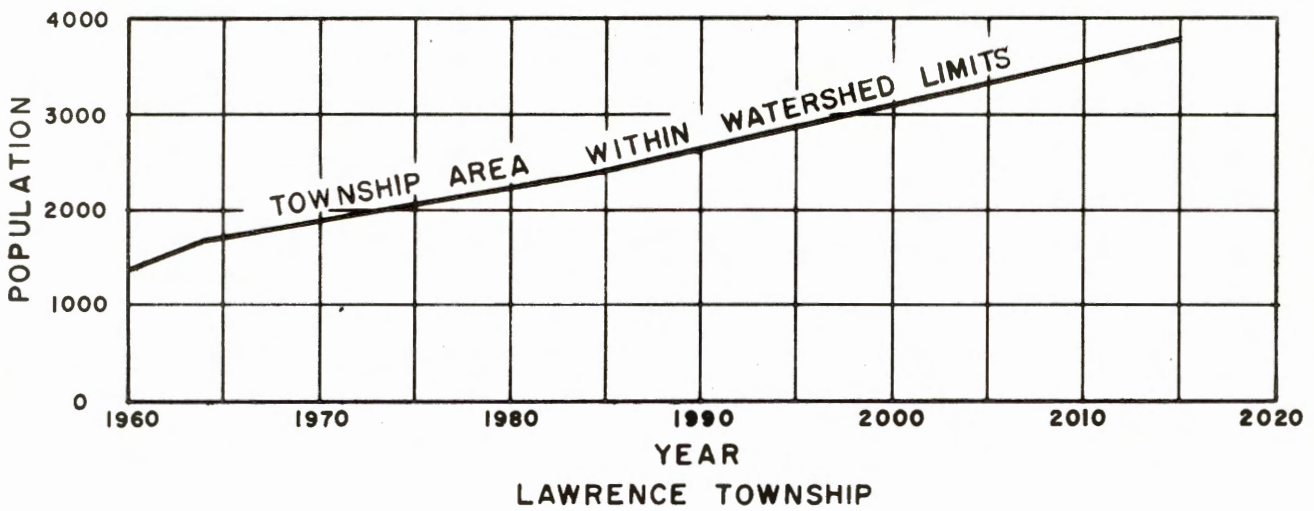
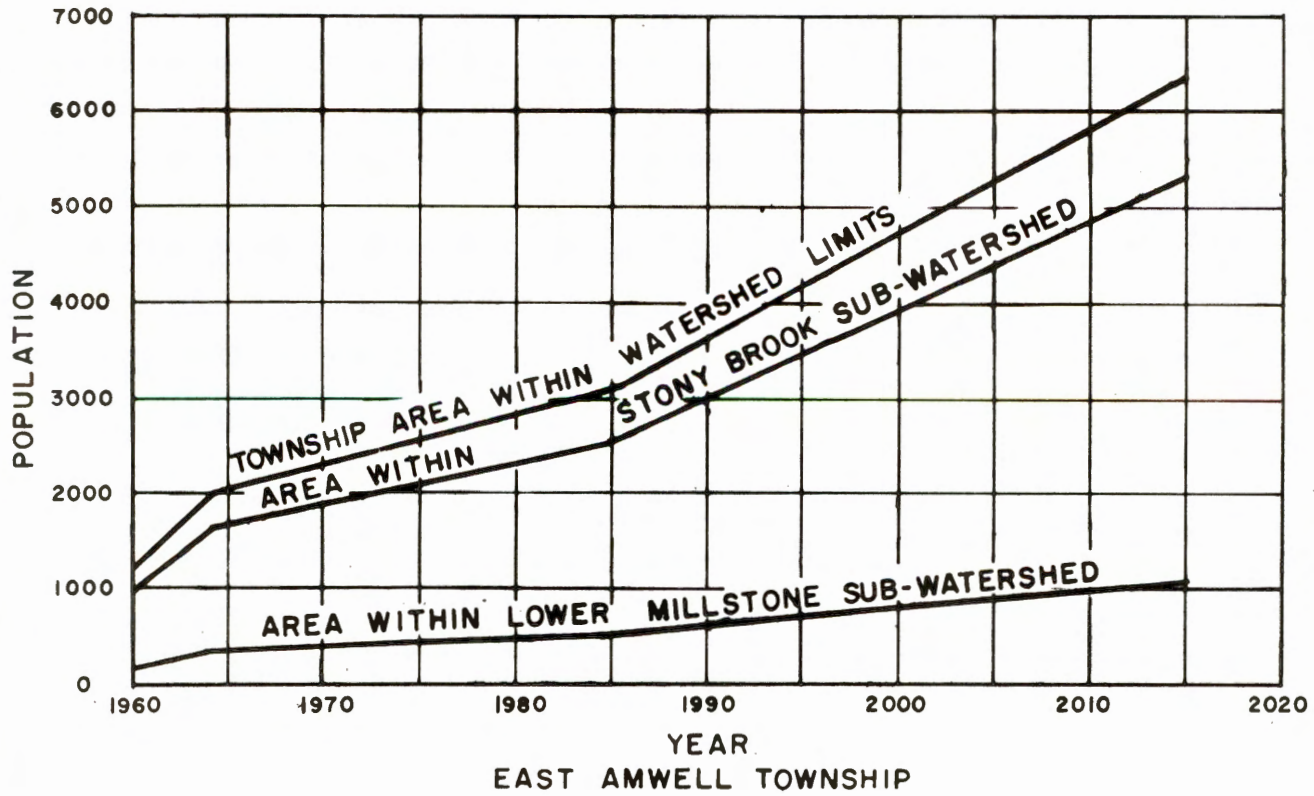
STONY BROOK-MILLSTONE WATERSHED
 REGIONAL SEWERAGE FEASIBILITY STUDY
 POPULATION FORECAST
 FOR
 MONROE AND FRANKLIN TOWNSHIPS



STONY BROOK-MILLSTONE WATERSHED
 REGIONAL SEWERAGE FEASIBILITY STUDY
 POPULATION FORECAST
 FOR
 SOUTH BRUNSWICK TOWNSHIP



STONY BROOK-MILLSTONE WATERSHED
 REGIONAL SEWERAGE FEASIBILITY STUDY
 POPULATION FORECASTS
 FOR
 MANALAPAN AND WASHINGTON TOWNSHIPS
 AND ROOSEVELT BOROUGH



STONY BROOK-MILLSTONE WATERSHED
 REGIONAL SEWERAGE FEASIBILITY STUDY
 POPULATION FORECASTS
 FOR
 EAST AMWELL AND LAWRENCE TOWNSHIPS

northeast-southwest direction across the sub-watersheds. The Lockatong formations are slightly metamorphosed shale. Being rather resistant and dense, these formations are generally transitional in elevation between the diabase and shale. The internal drainage system is generally poor.

The other principal formations are the Brunswick shale and Stockton sandstone. Both are more porous than the diabase and argillite, and the internal drainage systems of these areas are fair. The better agricultural lands of the Stony Brook and Lower Millstone are found in the shale and sandstone areas.

The geology of the Upper Millstone sub-watershed consists of a series of unconsolidated, or poorly consolidated, gravels, sands and clays of Cretaceous age. Laid down by an ancient sea, these formations tilt slightly to the southeast. Where the formations outcrop at the surface, belts trending northeast-southwest are formed. The sandy formations are highly permeable to the passage of water.

WATER RESOURCES

Ground Water Supply

Virtually all, except a very small amount, of the potable water in the Stony Brook-Millstone Watershed is derived by withdrawal from local wells. The principal aquifers, or sources of ground water, occur in the sand and gravel layers of the Raritan and Magothy Formations, the Stockton Formation, and, to a lesser degree, the Brunswick Shale. In general, moderate to large supplies of ground water can be developed from these aquifers. All the other geologic formations in the Watershed, except the Merchantville Formation, the Woodbury Clay and the Marshalltown Formation yield at least small supplies of ground water and can be considered minor aquifers.

Ground water occurs in the Watershed under water-table, semi-artesian, and artesian conditions. Water-table conditions are most prevalent in the outcrop areas of the Stockton and Brunswick Formations. Local artesian conditions exist at depth in the outcrop areas of the Stockton, Raritan and Magothy, and Englishtown Formations; and widespread artesian conditions are present in the Raritan and Magothy Formations southeast of their outcrop area where they are overlain by the confining clay of the Merchantville Formation.

The aquifers are recharged almost entirely by local precipitation on their outcrop areas. It has been estimated that a little more than one million gallons of water per day per square mile of intake area is available for recharge from precipitation after the losses due to the evapo-transpiration process have occurred. Evapo-transpiration losses include the amount evaporated to the atmosphere from the soil and open bodies of water, and the amount lost by transpiration, or moisture demand, by the natural vegetation and crops. The remainder either flows off as surface runoff, or gradually percolates through the soil to recharge the ground water supply.

The actual amount of recharge to the aquifers is probably somewhat less than the estimated 1 million gallons per day per square mile, however, because of inadequate storage space in the underground formations. In the consolidated rocks of the Piedmont Plain, underlying the Stony Brook and Lower Millstone sub-watersheds, fractures and solution cavities provide almost the only means for storage and travel of water. These openings constitute a very small part of the total volume of the consolidated rocks, and their capacity to store and transmit water, therefore, is very low.

Very different conditions exist in the unconsolidated sands and gravels of the Inner Coastal Plain, underlying the Upper Millstone sub-watershed. Ground water occurs in the interstitial openings among the individual grains of the unconsolidated deposits. Sand and gravel deposits have relatively high porosity and permeability, and their capacity to store and transmit water is therefore much greater than that of the consolidated rocks.

Movement of water in the aquifers is generally controlled by the natural hydraulic gradients. The rate of movement is very slow, a few inches to a few feet per day. In the aquifers of the Stony Brook and Lower Millstone sub-watersheds, ground water moves from high level intake areas on hills to low-level discharge areas in nearby stream valleys. Ground water is generally discharged from these aquifers near their intake areas so that the distance water travels through these formations is not very great.

The natural pattern of movement in the Upper Millstone sub-watershed aquifers also is from high-level intake areas to low-level discharge areas. However, besides being discharged to streams in the outcrop areas, water also moves downdip through these aquifers in response to broad regional hydraulic gradients. It is then discharged by wells, by interformational leakage, and by seepage across subaqueous outcrops of the aquifers many miles from the intake area.

Ground Water Yields

The water resources of the Stony Brook and Lower Millstone sub-watersheds are considerably less than those of the Upper Millstone sub-watershed. Yields in the diabase and argillite areas are extremely low. The Stock sandstones and Brunswick shales offer moderate yields, and several municipal water companies in the region tap these formations with satisfactory results.

The Upper Millstone geology is such that there are vast underground water supplies. The Raritan Formations contain the best aquifers, and are the basic sources of large supplies of ground water for public-supply, industrial, irrigation, and domestic wells. Surface water enters this aquifer at its outcrop and flows slowly downdip towards the Atlantic Ocean. Cities east of the outcrop drill through upper formations to reach the Raritan sand. Hightstown taps the Raritan sand at a depth of 200 feet, Asbury Park at a depth of 1000 feet. Other formations outcropping to the east of the Raritan sand, such as the Englishtown, Kirkwood, Mt. Laurel and Wenonah sands offer excellent yields.

Ground water yields, estimated by the State Geology Department in the outcrop areas are shown in TABLE 7.

TABLE 8 is a preliminary estimate of the ground water potential of the Watershed based on utilizing yields shown in TABLE 7 and approximate measurements of the exposed areas of the geologic formations. The yields of the three sub-watersheds in millions of gallons per day are estimated to be as follows:

Stony Brook	12.5 M. G. D.
Upper Millstone	47.7 M. G. D.
Lower Millstone	53.7 M. G. D.

If an average combined domestic and industrial per capita consumption of 250 gallons per day is assumed, future water demand may exceed the estimated ground water yield prior to the year 2000, and demand will have to be satisfied from supplemental sources.

Water Quality

Ground water contains mineral matter dissolved mainly from the soil and rock through which it has percolated. For this reason, the quality of the water may differ considerably from one aquifer to another and also from place to place within the same aquifer.

Standards of quality also vary considerably, according to the use that is to be made of the water; water that is suitable for one use may be unsuitable for another. For example, water for public supply must be free from objectionable tastes and odors and must meet sanitary specifications, but water for an industrial use might be required to have a certain temperature or be free from a particular constituent, such as iron.

Many properties and chemical constituents contribute to the quality of water. The major properties are temperature, odor and taste, pH or hydrogen ion concentration, color, turbidity, specific conductance, and hardness. The chemical constituents most likely to occur in objectionable concentrations in ground water are silica, calcium, magnesium, iron, manganese, sodium, potassium, chloride, fluoride, nitrate, bicarbonate, sulfate, and dissolved carbon dioxide.

Most of the ground water in the Watershed is of excellent quality for domestic, industrial, and agricultural use. The quality varies somewhat in different locations, and it is sometimes necessary to remove

TABLE 7

GROUND WATER YIELDS FOR GEOLOGIC FORMATIONS
AS ESTIMATED BY
N. J. STATE GEOLOGY DEPARTMENT

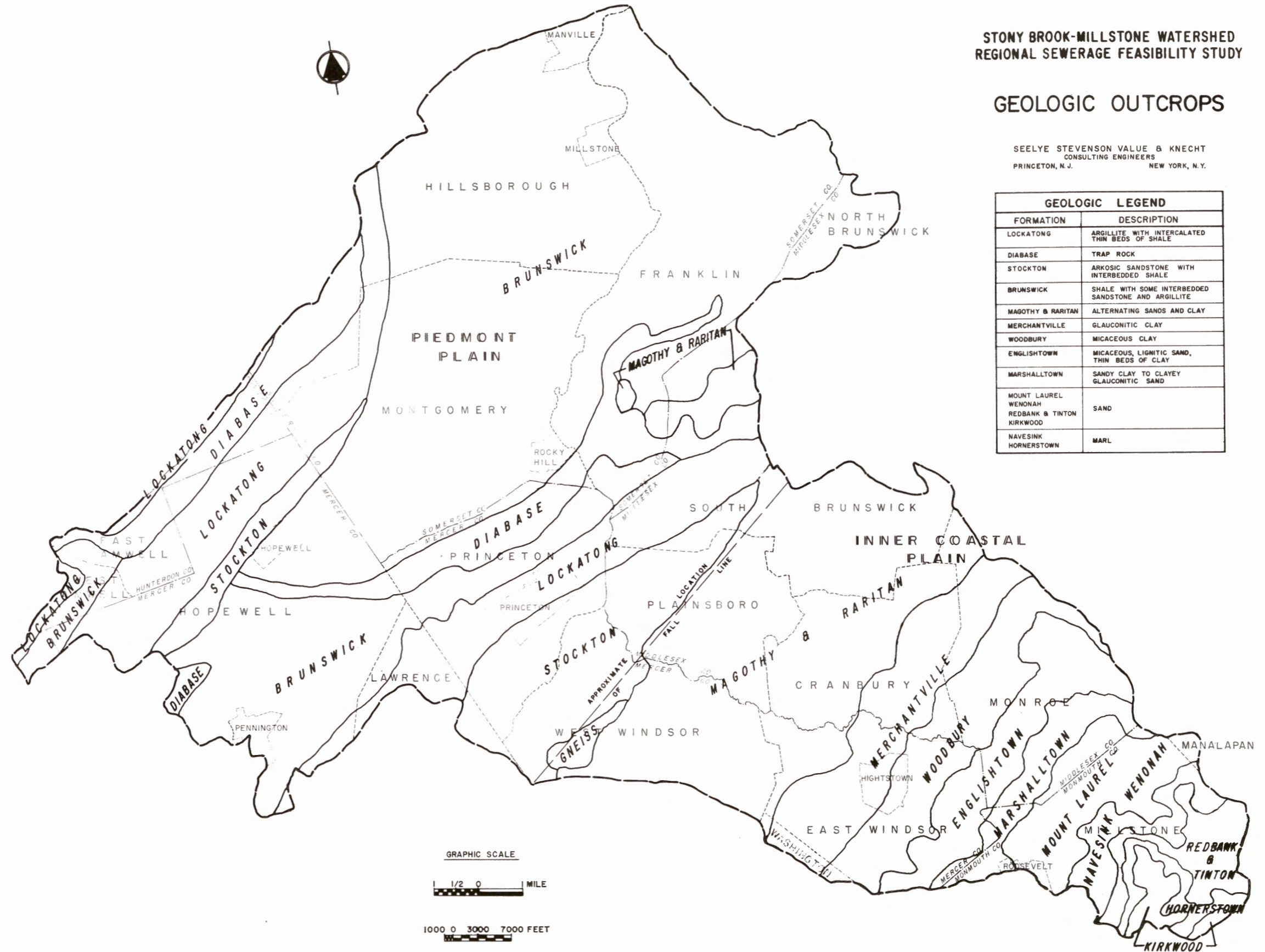
<u>Geologic Formation</u>	<u>Yield in</u>	
	<u>Gallons per Day per Acre</u>	<u>M. G. D. per Square Mile</u>
Raritan sand	1,600	1.0
Kirkwood sand	1,600	1.0
Englishtown sand	800	0.5
Mt. Laurel & Wenonah sands	800	0.5
Brunswick shale	800	0.5
Stockton sandstone	600	0.4
Merchantville clay	300	0.2
Woodbury clay	300	0.2
Marshalltown clay	300	0.2
Navesink marl	300	0.2
Red Bank & Tinton sand	300	0.2
Hornerstown marl	300	0.2
Magothy clay	150	0.1
Byram gneiss	negligible	negligible
Diabase (trap rock)	negligible	negligible

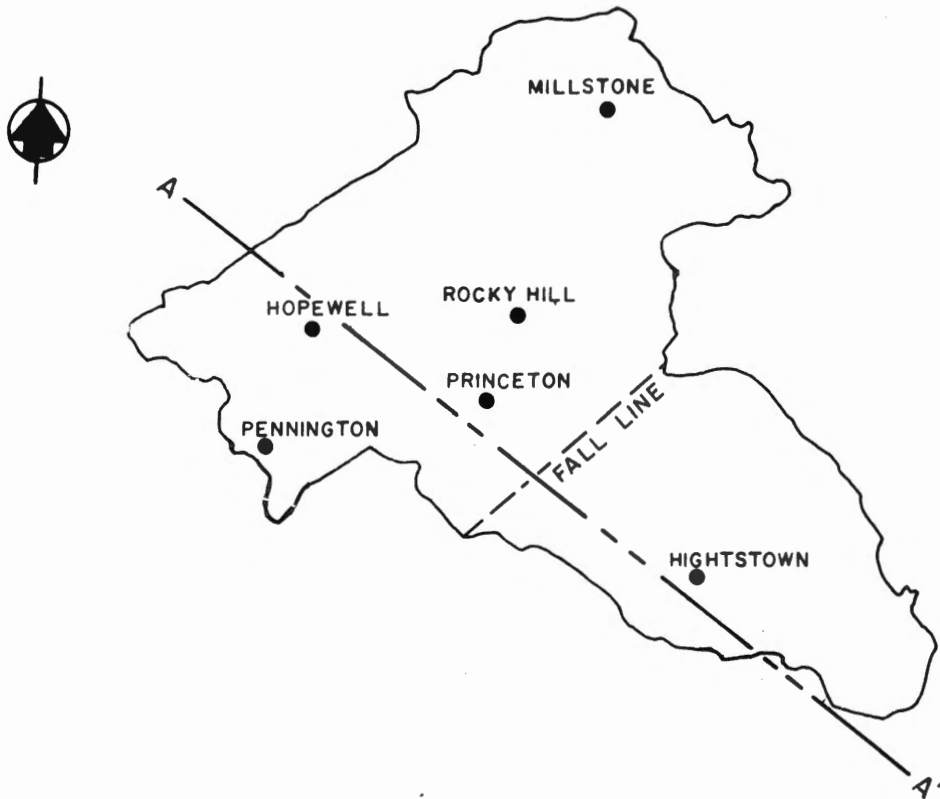
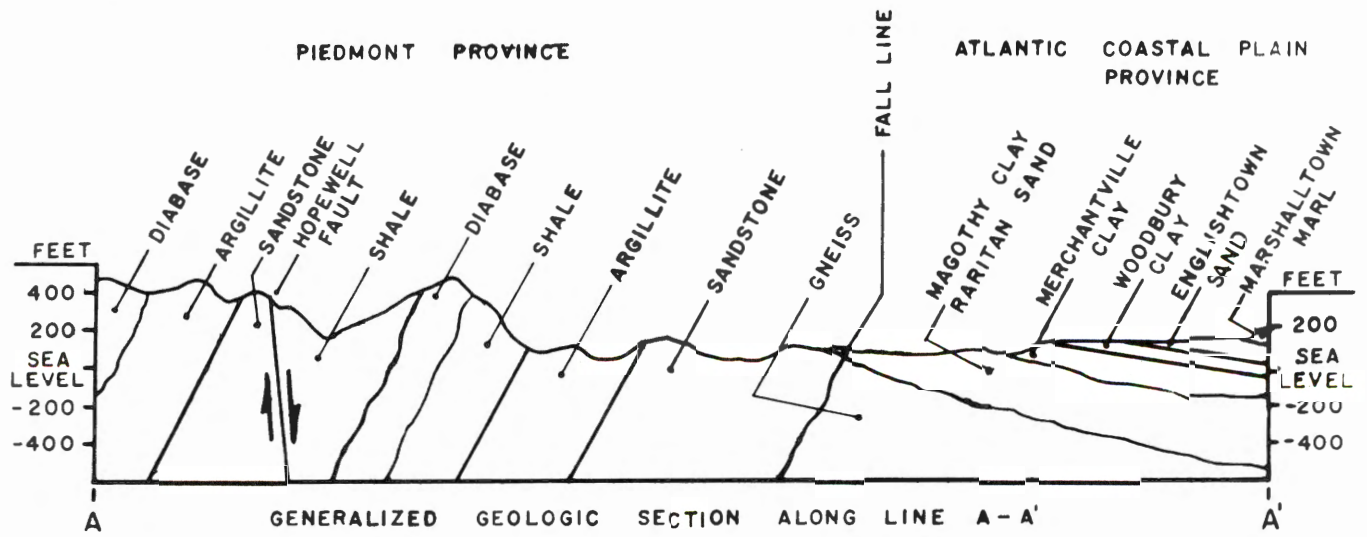
STONY BROOK-MILLSTONE WATERSHED
 REGIONAL SEWERAGE FEASIBILITY STUDY

GEOLOGIC OUTCROPS

SEELYE STEVENSON VALUE & KNECHT
 CONSULTING ENGINEERS
 PRINCETON, N. J. NEW YORK, N. Y.

GEOLOGIC LEGEND	
FORMATION	DESCRIPTION
LOCKATONG	ARGILLITE WITH INTERCALATED THIN BEDS OF SHALE
DIABASE	TRAP ROCK
STOCKTON	ARKOSIC SANDSTONE WITH INTERBEDDED SHALE
BRUNSWICK	SHALE WITH SOME INTERBEDDED SANDSTONE AND ARGILLITE
MAGOTHY & RARITAN	ALTERNATING SANDS AND CLAY
MERCHANTVILLE	GLAUCONITIC CLAY
WOODBURY	MICACEOUS CLAY
ENGLISHTOWN	MICACEOUS, LIGNITIC SAND, THIN BEDS OF CLAY
MARSHALLTOWN	SANDY CLAY TO CLAYEY GLAUCONITIC SAND
MOUNT LAUREL WENONAH REDBANK & TINTON KIRKWOOD	SAND
NAVESINK HORNERSTOWN	MARL





NEW JERSEY STATE
 DEPARTMENT OF HEALTH
 STONY BROOK-MILLSTONE
 SEWERAGE STUDY COMMITTEE

STONY BROOK-MILLSTONE WATERSHED
 REGIONAL SEWERAGE FEASIBILITY STUDY

GENERALIZED GEOLOGICAL CROSS SECTION

SEELYE STEVENSON VALUE & KNECHT
 CONSULTING ENGINEERS
 PRINCETON, N. J. NEW YORK, N. Y.

TABLE 8

ESTIMATED GROUND WATER POTENTIAL
 BASED ON OUTCROP AREAS
 OF GEOLOGIC FORMATIONS

<u>Geologic Formation</u>	<u>Outcrop Area in Sq. Mi.</u>	<u>Estimated Ground Water Yield Per Sq. Mile of Outcrop Area MGD/Sq. Mi.</u>	<u>Estimated Yield in MGD</u>
Stony Brook Sub-watershed:			
Brunswick shale	18.6	0.5	9.3
Lokatong argillite	13.7	nil	---
Diabase (trap rock)	8.8	negligible	---
Stockton sandstone	<u>7.9</u>	0.4	<u>3.2</u>
Total	49.0		12.5
Upper Millstone Sub-watershed:			
Raritan sand	23.5	1.0	23.5
Magothy clay	17.2	0.1	1.7
Merchantville clay	11.8	0.2	2.4
Woodbury clay	10.7	0.2	2.1
Stockton sandstone	9.6	0.4	3.8
Englishtown sand	8.6	0.5	4.3
Mt. Laurel & Wenonah sand	8.6	0.5	4.3
Marshalltown clay	4.3	0.2	0.8
Red Bank & Tinton sand	4.3	0.2	0.8
Kirkwood sand	3.2	1.0	3.2
Hornerstown marl	2.1	0.2	0.4
Navesink marl	2.1	0.2	0.4
Gneiss	<u>1.0</u>	negligible	<u>---</u>
Total	107.0		47.7
Lower Millstone Sub-watershed:			
Brunswick shale	101.0	0.5	50.5
Lokatong argillite	14.0	nil	---
Diabase (trap rock)	10.0	negligible	---
Stockton sandstone	1.3	0.4	0.5
Raritan sand	<u>2.7</u>	1.0	<u>2.7</u>
Total	129.0		53.7

objectionable quantities of iron, to adjust the pH, or to soften the water prior to use.

Ground water from the Raritan Formation of the Upper Millstone sub-watershed generally is soft and low in dissolved solids. However, its pH is low, and the water is corrosive locally. In the Stony Brook and Lower Millstone sub-watershed, the water has a higher dissolved-solids content, its hardness is greater, and the pH ranges from 5.9 to 7.9.

Principal Water Uses and Sources

At the present time, all of the water, used for any purpose in the Watershed, originates from a local source within the Watershed. None of the major water utility companies, delivering water obtained from surface supply, serves any area in the Watershed. Thus, the Watershed is dependent upon its own resources to satisfy its water needs.

Several local water companies supply water for domestic consumption, in addition to that obtained from individually-owned wells in the Watershed. An inventory of the major water supply facilities in each municipality is given in TABLE A-1 located in the APPENDIX.

Each of the water companies tap local ground water resources in the region. The major sources are the Brunswick, Stockton and Raritan Formations. The Princeton Water Company also draws supplementary water from the Delaware and Raritan Canal. Before being distributed to consumers generally, the water is stored in standpipes, elevated tanks, or small enclosed reservoirs, in which a two or three day supply may be maintained.

Large diameter wells operated by private industries also withdraw a considerable volume of ground water. The amount withdrawn for industrial and commercial enterprises may exceed municipal consumption. However, no reports on volume used privately are available.

Nearly all of the water for farm and livestock use comes from shallow wells and small streams. Many of these experience a severe draw-down, and even go dry, during prolonged droughts. During these periods, a serious water shortage exists for livestock and domestic use.

The development of portable sprinkler systems, in recent years, has resulted in a rapid increase in crop irrigation, both for protection of crops during dry periods and for increased yield. Most of the water used for irrigation purposes is withdrawn from surface water supplies,

the remainder from deep wells. Small on-stream dams have been constructed in the Upper Millstone sub-watershed area to store water for irrigation purposes, and frequently, farmers have constructed small ponds on their properties which are fed by ground water.

Irrigation is usually carried on during the relatively dry weather periods of the spring and summer. During this time, high daily temperatures cause most of the water distributed for irrigation to be lost to the atmosphere by evaporation. Transpiration also takes its toll. Very little water, therefore, is returned to the streams or ground water storage.

The Need for Conservation

A readily available ground water supply is an extremely valuable natural resource. It is generally considered more advantageous than a surface water supply, basically, for the following reasons:

1. Ground water is usually more dependable during drought periods.
2. Major expenditure for long transmission pipelines is unnecessary.
3. The water temperature is usually constant.
4. Required treatment is usually minimal.

These factors make ground water advantageous for industrial users, and, in many cases, for residential users as well.

It is difficult to evaluate the potential ground water supply available at any selected locality in the Watershed because of the lack of detailed geologic and hydrologic data. Estimates have been made of the amounts of ground water available in the various formations, but continued collection of basic data is necessary before any true picture of the extent of these resources can emerge.

Since rate of recharge can only be estimated, it is possible that, at this time, too much water is being withdrawn in certain areas. Increased amounts withdrawn in any one area can lower yield at a withdrawal point many miles away. The manifestation of this effect is not readily detectable. However, it can be expected that, with normal growth of population, industrial expansion, and increase in irrigation causing corresponding increase in daily withdrawals, yields are currently being affected in this manner.

To meet the future water supply needs of a growing area, it is quite essential that the existing ground and surface water resources of the Watershed be protected and development controlled in a manner that will conserve and insure their maximum utilization. The need for conservation of these natural resources has, of course, been foreseen for quite some time. Some of the positive steps which have been taken in this direction include:

1. The State Division of Water Policy and Supply presently controls the amounts of water that can be legally withdrawn from an aquifer by determining and authorizing diversion rights.

2. A proposal has been developed to establish a 5 billion gallon water supply reservoir on Six Mile Run in Franklin Township. The use of the reservoir to supplement the Delaware and Raritan Canal would provide a most important source of additional water supply capacity.

3. Under the Stony Brook Watershed Work Plan, a program has been continuously conducted to construct a number of small impoundment reservoirs on various tributaries of Stony Brook. The reservoirs have the multiple purpose of providing recreation facilities, reducing erosion downstream by controlling floods, and preventing downstream deposition of sediment by acting as desilting basins. The improvement in water management also increases ground water recharge and has a favorable effect on the yield of wells.

A further stride forward in effective conservation efforts is the current interest in the concept of wastewater reclamation. If it is generally acknowledged that water is a valuable natural resource, then it normally follows that wastewater is similarly of value.

Wastewater reclamation is a prime consideration of this study and is discussed fully in a separate succeeding section of this report.

EXISTING WASTEWATER COLLECTION AND DISPOSAL FACILITIES

Existing Wastewater Collection Systems

Each area in the Watershed presently provided with an existing wastewater collection system is shown on PLATE 18. The municipalities, served in total or part, include the following:

Princeton Borough

Princeton Township

Manville Borough

Hillsboro Township

South Brunswick Township

Hightstown Borough

East Windsor Township

Feasibility studies and/or preliminary reports have been prepared, or are in preparation, for some of the remaining unsewered areas within the Stony Brook-Millstone Watershed.

Deficiencies of Existing Wastewater Collection Systems

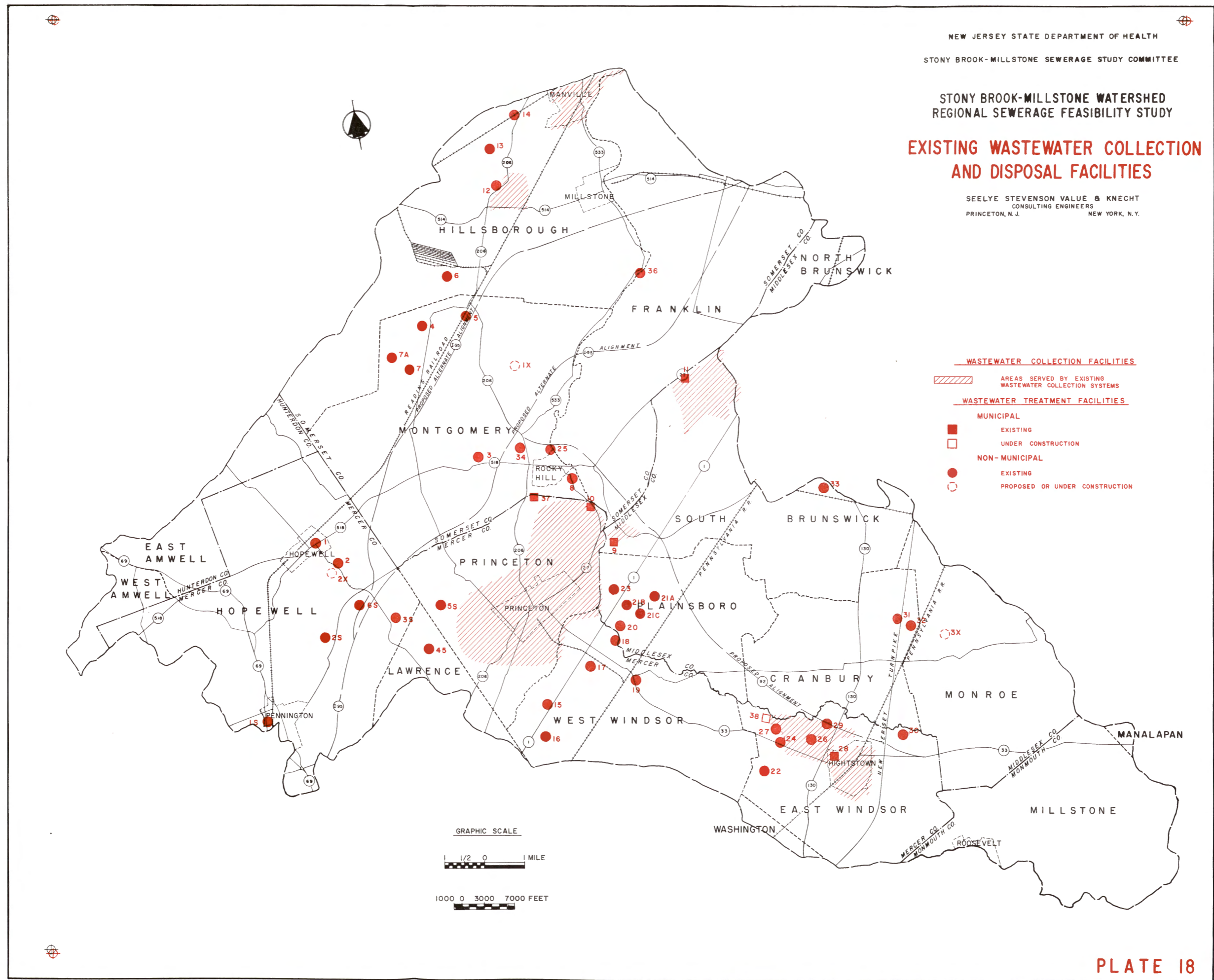
Most of the existing collection systems are adequately performing their intended function with no serious defects noted. Reported functional disturbance is limited to that which would normally be experienced in daily operation and which would be handled by normal maintenance.

Certain municipal systems, however, are afflicted with the problem of excessive infiltration of ground water or storm water. It is recognized that sewers are seldom laid with water tight joints and that a certain amount of ground water will normally enter the system. Good engineering design practice usually allows for this inflow in sizing the system. However, illegal drainage connections, poorly constructed or maintained pipe joints, broken or leaky manhole walls and other factors of similar nature will permit, especially during wet weather, the entrance of excessive water. This rapidly overloads the conduit, usually exceeds its carrying capacity and causes backed-up waste to

STONY BROOK-MILLSTONE WATERSHED
 REGIONAL SEWERAGE FEASIBILITY STUDY

**EXISTING WASTEWATER COLLECTION
 AND DISPOSAL FACILITIES**

SEELYE STEVENSON VALUE & KNECHT
 CONSULTING ENGINEERS
 PRINCETON, N. J. NEW YORK, N. Y.



overflow the tops of manholes. The nuisance created is decidedly unpleasant, and the condition is a potential health hazard.

1. Princeton Trunk Sewer

The Princeton trunk sewer is the main interceptor collecting flow from the local system in Princeton Borough for conveyance to the Princeton disposal facilities. Soon after it was constructed in 1932, the actual flow in the trunk sewer, during wet weather, exceeded its hydraulic capacity and wastewater in excess of capacity flowed out of manholes or backed up into basements. Investigations revealed that stormwater from illegal connections and a high rate of groundwater infiltration contributed substantially to the overload. To relieve this condition, overflows were established at various points along the trunk sewer to permit the by-passing of excess flow to the Millstone River. The by-passing of the waste flow, however, furnishes only temporary relief and is not a satisfactory solution to the overall problem.

The Princeton Sewer Operating Committee is aware of the inadequacies of the existing trunk sewer, and various solutions for expanding and modifying the trunk sewer have been under consideration. With the realization that the trunk sewer is potentially a part of a regional collection system, the Committee has expressed its willingness to cooperate with neighboring municipalities in the establishment of facilities for joint use.

2. Hightstown Borough Collection System

The collection system in Hightstown also experiences a high infiltration rate. Wet weather flows are reported to exceed normal dry weather flow by more than 100 per cent.

3. Kendall Park Collection System

For the collection system of Kendall Park, a community located in South Brunswick Township, the following average daily flows in gallons per capita per day have been reported:

During the dry weather period from June to November: 77

During the wet weather period from December to May: 101

Annual Daily Average Flow: 90

The flow figures indicate that an infiltration problem exists during wet weather. However, a flow rate of 101 g. c. d. , including infiltration, is not unreasonable.

Existing Wastewater Disposal Facilities

With few exceptions, most wastewater, emanating from domestic or industrial sources in the Watershed, is disposed of by local minor treatment facilities or individual residential subsurface systems. Major treatment facilities, disposing of larger waste quantities received from a collection system, are operated by the following municipalities or authorities:

Princeton Borough
Hightstown Borough
South Brunswick Municipal Utilities Authority

In addition, major facilities are currently under construction by the East Windsor Municipal Utilities Authority and Foresgate Sanitation Company. Facilities constructed by the latter will dispose of waste emanating from the retirement community, known as "Leisure World", currently under development in the Township of Monroe.

A detailed survey of existing waste disposal facilities in the Watershed has been conducted, and the location of each principal facility serving a municipality, development, institution or industrial establishment is shown on PLATE 18. Pertinent information with regard to plant units, design capacity, approximate present average daily flow, and type of waste treated and degree of treatment is summarized for each facility in TABLE 9.

Major Waste Disposal Facilities

1. Princeton Borough Municipal Plant

The Princeton waste treatment facility serves the sewered population of the Borough of Princeton and Princeton Township and the urban campus of Princeton University. There are over 5200 sewer connections and the collection system serves a residential and commercial population of approximately 22,000. The plant is designed to treat an average sewage flow of 2.8 MGD from a contributing population of 28,000 people.

At the request of the Princeton Operating Committee, the State Department of Health conducted a comprehensive study of the municipal plant on February 25, 1964. The study included a sampling program

TABLE 9

DESCRIPTION OF EXISTING WASTE DISPOSAL FACILITIES

<u>Key No.</u>	<u>Disposal Facility</u>	<u>Plant Capacity (MGD)</u>	<u>Average Daily Flow (MGD)</u>	<u>Type of Waste Treated</u>	<u>Degree of Treatment</u>	<u>Plant Units</u>	<u>Receiving Waters</u>
1S	Hopewell Township Board of Education H.S.	0.024	0.004	D	S	Septic tanks, sand filters and chlorination.	Lewis Brook, tributary to Stony Brook, Millstone River.
2S	Socony-Mobil Oil Co. Research	0.015	0.003	D & I	T	Mechanical aeration, settling, sand filtration, neutralization, chlorination.	Honey Brook to Stony Brook & Millstone River.
3S	Western Electric Co.	0.04	0.05	D & I	T	Extended aeration, sand filters, chlorination, sludge drying beds.	Tributary to Millstone River.
4S	Educational Testing Service	0.04		D	S	Extended aeration, sludge digestion tank, chlorination.	Stony Brook, Millstone River.
5S	Princeton University, Pretty Brook Subdivision	0.02	0.02	D	S	Aeration, settling, digestion, chlorination.	Stony Brook.
6S	Princeton Farms	0.06	---	D	S	Clarigester, trickling filter, chlorination. Sludge removed by private scavenger.	Honey Brook to Millstone River.
1.	Rockwell Manufacturing Co.	0.009	0.004	D	S	Extended aeration, chlorination, sludge holding tank.	Beden's Brook to Millstone River.
2.	St. Michael's Children's Home	0.1	0.008	D	S	Settling (Imhoff) tanks, sand filters, sludge drying beds.	Beden's Brook tributary to Millstone River.
3.	N. J. State Dept. of Agencies, N. J. Neuro-Psychiatric Institute	0.33	0.190	D	S	Standard rate trickling filters, settling, chlorination, digestion, sludge drying beds.	Beden's Brook tributary to Millstone River.
4.	Carrier Clinic	0.012	0.035	D	S	Contact aeration, chlorination, digestion, sludge drying beds.	Cruser's Brook tributary to Millstone River.
5.	Consumer Farmer Milk Cooperative, Inc.	0.0225	0.007	I	S	Holding tanks, highrate trickling filter, settling tank, chlorination, sludge holding pit.	Cruser's Brook tributary to Millstone River.

(Continued on following page)

TABLE 9 (Continued)

Key No.	Disposal Facility	Plant Capacity (MGD)	Average Daily Flow (MGD)	Type of Waste Treated	Degree of Treatment	Plant Units	Receiving Waters
6.	U.S. Government Supply Depot	0.075	0.001	D	S	Primary settling, sand filtration, chlorination, sludge drying beds.	Tributary to Cruser's Brook & Millstone River.
7.	Minnesota Mining & Manufacturing, Lower Plant	0.0062	---	D	S	Imhoff tanks, sand filters, chlorination.	Cruser's Brook, tributary to Millstone River.
7A.	Minnesota Mining & Manufacturing, Upper Plant	0.0058	---	D	S	Imhoff tanks, sand filters, chlorination.	Cruser's Brook, tributary to Millstone River.
8.	Hercules Powder Co.	0.009	0.012	D	S	Extended aeration, chlorination, sludge holding tank.	Millstone River.
9.	South Brunswick Municipal Utilities Authority (Kingston)	0.50	0.15	D	S	Aeration, aerobic digestion, chlorination, sludge filtration.	Heathcote Brook, tributary to Millstone River.
10.	Princeton Borough, Municipal	2.8	3.5+	D	S	Primary settling tanks, standard rate trickling filters, final settling, chlorination, digestion, sludge beds.	Millstone River.
11.	South Brunswick Municipal Utilities Authority (Kendall Park)	0.06	0.06+	D	S	Contact aeration (multi-surface oxidation), chlorination, digestion, sludge drying.	Ten Mile Run, tributary to Millstone River.
12.	Hillsboro Sewerage Co. (Amwell Estates)	0.08	---	D	S	Contact aeration, chlorination, digestion, sludge drying beds.	Royce Brook, tributary to Millstone River.
13.	Valley Road Sewerage Co.	0.0492	0.018	D	S	Aeration, settling, sludge storage, chlorination.	North Brook, Royce Brook, Millstone River.
14.	U.S. Government (U.S. Veterans Administration Supply Depot)	0.045	0.04	D	S	Primary settling, sand filtration, sludge drying beds.	Tributary to Royce Brook & Millstone River.
15.	Princeton Recreation Center Inc. (Discharges into Delaware & Raritan Canal)	0.12	0.04	D	S	Modified activated sludge, aerobic sludge digestion, chlorination.	Delaware - Raritan Canal.

(Continued on following page)

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TABLE 9 (Continued)

<u>Key No.</u>	<u>Disposal Facility</u>	<u>Plant Capacity (MGD)</u>	<u>Average Daily Flow (MGD)</u>	<u>Type of Waste Treated</u>	<u>Degree of Treatment</u>	<u>Plant Units</u>	<u>Receiving Waters</u>
16.	American Cyanamid Co. Agriculture Research Center	0.03	0.045	D	S	Extended aeration, sludge holding tank, chlorination.	Tributary to Assunpink Brook, Delaware River.
17.	American Cyanamid Co., Princeton Division	0.006	---	D	S	Septic tank, sandfilters, chlorination.	Haddon Brook & Millstone River.
18.	Radio Corp. of America, David Sarnoff Research	0.042	0.03	D	S	Clarigester, high rate trickling filter, final settling, chlorination, sludge drying beds.	Millstone River.
19.	Electro-Mechanical Research Corp.	0.010	---	D	S	Extended aeration, settling, sludge holding tank, chlorination.	Lower Bear Brook, Millstone River
20.	Food Machinery & Chemical Corp.	0.05	0.074	I	-	Neutralization, storage and mixing tank.	Millstone River.
		0.015	0.003	D	S	Aeration, settling, aerobic digestion, chlorination.	Millstone River.
21A.	Princeton University (Forrestal Research Center, Plasma Physics Lab)	0.035	0.015	D	S	Imhoff tank, sand filtration, chlorination, sludge drying beds.	Bees Brook, Devils Brook, tributary to Millstone River.
21B.	Princeton University (Forrestal Research Center)	0.02	0.025	D	S	Imhoff tank, sand filters, chlorination, sludge drying bed.	Tributary to Millstone River.
21C.	Princeton University (Forrestal Research Center Accelerator)	0.01	0.0025	D	S	Oxigest with chlorination.	Millstone River.
*22.	Southern Gulf Utilities, N. J. Div., Inc.	0.040	---	D	S	Extended aeration, settling tank, sludge digestion and recirculation, chlorination.	Big Bear Brook, tributary to Millstone River.
23.	The Motor Lodge, Princeton, Inc. (Holiday Inn)	0.0364	0.02	D	S	Aeration, settling, sludge holding, chlorination.	Millstone River.

(Continued on following page)

TABLE 9 (Continued)

Key No.	Disposal Facility	Plant Capacity (MGD)	Average Daily Flow (MGD)	Type of Waste Treated	Degree of Treatment	Plant Units	Receiving Waters
*24.	R. C. A. Astro-Electronics Division	0.064	0.04	D	S	Extended aeration, chlorination, sludge holding tank.	Millstone River.
25.	Ingersoll-Rand	0.003	U/C	D	S	Aeration, settling, chlorination, sludge holding tank.	Millstone River.
		0.0015	U/C	I	-	Neutralization.	
*26.	McGraw-Hill Publishing Co.	0.042	0.023	D	S	Extended aeration, chlorination, sludge holding tank.	Tributary to Millstone River.
*27.	Creative Playthings, Inc.	0.001	0.0008	D	T	Extended aeration, sand filters, sludge holding tank, chlorination.	Millstone River.
28.	Hightstown, Municipal	1.5	0.4	D	S	Primary settling, standard rate trickling filters, final settling, chlorination, digestion, sludge drying beds.	Rocky Brook, tributary to Millstone River
*29.	Shady Rest Trailer Camp	0.015	0.007	D	S	Extended aeration, chlorination, sludge holding tank.	Ditch to Rocky Brook, Millstone River.
30.	National Lead Co.	0.015	0.074	D	T	Extended aeration, sand filters, chlorination, sludge holding tank.	Millstone River
31.	N. J. Turnpike Authority	0.3	0.080	D	S	Clarigester, trickling filter, chlorination, sludge drying beds.	Cedar Brook thence Cranbury Brook, tributary to Millstone River.
32.	Carter Products, Inc.	0.02	0.022	D	T	Extended aeration, sand filters, chlorination, sludge holding tank.	Cranbury Brook, tributary to Millstone River.
**33.	International Business Machines Corp. (2)	0.0110	0.005	D	S	Septic tank, sand filters, chlorination.	Devils Brook to Millstone River.
		0.00576	0.004	I	-	Neutralization, storage, mixing tank.	Trucked to barge.
34.	Board of Education (Montgomery Township)	0.0153	nil	D	T	Extended aeration, sand filters, chlorination.	Back Brook to Millstone River.

(Concluded on following page)

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TABLE 9 (Concluded)

Key No.	Disposal Facility	Plant Capacity (MGD)	Average Daily Flow (MGD)	Type of Waste Treated	Degree of Treatment	Plant Units	Receiving Waters
35.	The Bedens Brook Club	0.01	---	D	T	Extended aeration, sand filters, chlorination.	Bedens Brook.
36.	Valley Road Sewage Co.	0.08	---	D	S	Extended aeration, chlorination.	Millstone River.
37.	Princeton Township	Low Flow	nil	D	P	Septic tank.	Van Horn Brook.
38.	East Windsor Municipal Utilities Authority	0.50	U/C	D	S	Extended aeration, chlorination, sludge drying beds.	Millstone River.
1X.	Montgomery Ltd. (Proposed)	0.20		D	S		
2X.	Borough of Hopewell (Steps being taken to rescind)	0.24		D	S		
3X.	Forsgate Sanitation Co., Inc. (Construction Contract awarded)	3.0		D	T	Aerated grit chamber, contact aeration, settling tanks, rapid sand filters, chlorination, sludge digestion and dewatering.	Storage ponds for recharge.

D = Domestic
 I = Industrial
 P = Primary
 S = Secondary
 T = Tertiary
 U/C = Under Construction

* To be connected with East Windsor Municipal Utilities Authority S. T. P. when system is completed.

** To be connected with South Brunswick Municipal Utilities Authority early part of 1966.

conducted over a nine-hour daytime period and embraced the influent raw sewage, primary settling tank effluent, trickling filter effluent and the final settling tank effluent.

In the APPENDIX, TABLE A-2 gives the analyses of the samples and TABLE A-3 lists the computed treatment efficiencies in terms of per cent removals of pollutants.

The State Health Department study summarized findings as follows:

"It is finally concluded that the Princeton Sewage Treatment Plant now receives average flows very close to its designed capacity. Maximum day-time flows and organic loadings are considerably in excess of the average and place temporary overloads on the facilities. The plant is not capable of handling the additional future loads which will result from continued population growth of the greater Princeton area. Because of this growth and the increasing need for public sewerage, the Princeton area is faced with regional planning problems whose resolution will entail increased sewage treatment capacity over that which is now provided. "

To permit handling the future increased quantity of wastewater flow from the Borough of Princeton, Princeton University and that area of the Township of Princeton presently contributing to the municipal disposal facility, the consulting engineers for the Princeton plant have recommended modifications and alterations to the plant to increase the nominal treatment capacity from 2.8 to 3.5 MGD. They have estimated the cost of these improvements at \$872,000.

2. Hightstown Borough Municipal Plant

The Hightstown Plant recently increased treatment capacity from 0.6 MGD to 1.5 MGD and corrected certain deficiencies in the existing plant.

An inspection of the plant did not reveal any apparent plant problems or difficulties. It was noted, however, that periodic use of a deodorant is necessary, and that the plant is in close proximity to adjacent residences.

3. South Brunswick Municipal Utilities Authority Plants

A. Kendall Park Plant

Kendall Park is a fairly heavily populated, residential subdivision which has developed in recent years in the northern portion of

South Brunswick Township. The area is served by a treatment facility which discharges its effluent to Ten Mile Run. Stream samples taken downstream indicate that the receiving stream is highly polluted.

The plant has sufficient capacity to handle the wastewater flow from the present contributing population of 6000. However, wet weather flows cause considerable overload and, in general, persistent odors from the plant have created a public nuisance. The plant is presently scheduled to be abandoned. Wastewater will be pumped to the Authority's Kingston Plant for treatment.

B. Kingston Plant

This plant has a treatment capacity of 0.5 MGD, and serves a population of approximately 1,700. Present average daily flow is about 0.15 MGD. The plant monthly operating reports indicate that the plant effluent has a relative stability of 90%. No other operating data has been reported.

With the pending abandonment of the Kendall Park plant, the Kingston Plant must now consider additions and improvements to handle the combined Kendall Park-Kingston flows. The present combined flow would be about 0.75 MGD, which would exceed the plant's capacity by 50%.

The Kingston Plant was constructed in 1964 in the Kingston section of South Brunswick Township. It was originally designed to serve an anticipated population of 5,000, expected prior to 1970. This is an unusually short design period for a major treatment facility. At the time, negotiations were said to be underway with Princeton sewerage officials for the purpose of possibly establishing future joint disposal facilities. The State Department of Health, therefore, approved the permit for the plant's construction with the special provision that "the approval of a design basis of less than 10 years and not in conformity with routine procedure under the Rules and Regulations of the Department is given in consideration of the probability that a regional solution to sewage treatment and disposal problems in South Brunswick Township, Princeton Borough, Princeton Township and Rocky Hill areas will be reached."

Minor Waste Disposal Facilities

There are some 47 minor treatment facilities dispersed throughout the Watershed. The majority of the installations are "package" aeration units. Some trickling filter plants exist, and, for disposal of very low amounts of waste flow, Imhoff tanks followed by sand filters, are prevalent.

During the course of this study, inspections were made at almost all of the various minor plants in the area. The vast majority of the plants inspected were well maintained. However, a few plants were obviously community nuisances. Generally, these nuisances were caused by overloading, resulting in unsightly spills, odors and flooding.

In addition to inspecting the treatment plants in the Watershed, the Monthly Operating Reports, prepared by the plant operators for submission to the State Department of Health, were reviewed. A great variance was found in the amount of laboratory test information furnished by the operators. For example, in reviewing the monthly reports received from 28 minor disposal plants, a breakdown of the data furnished is as follows:

<u>DATA REPORTED</u>	<u>NUMBER OF PLANTS REPORTING</u>
Daily Amount of Chlorine Fed	28 (All Plants)
Suspended Solids in Raw & Effluent	6
Biochemical Oxygen Demand in Raw & Effluent	3
pH of Effluent	5
Dissolved Oxygen in Effluent	2
Relative stability of Effluent	6

Due to the apparent lack of reported laboratory test data on removals of suspended solids and biochemical oxygen demand, it is virtually impossible to comment on the sanitary efficiencies of these plants. The biochemical oxygen demand determination, or B. O. D. test, is of prime importance in sanitary analysis to measure the effectiveness of the plant treatment process.

The relative stability of the plant effluent is an approximate expression of the amount of oxygen available in the water in terms of the total amount of oxygen required for complete stability. The test for relative stability is useful in making a quick estimate of the condition of a plant effluent, but it does not supplant the B. O. D. test in value. In general, a plant effluent with a relative stability greater than 90% may be discharged into a stream without danger of substantially reducing the oxygen content of the stream. Of the six package plants reporting on relative stability, only one reported a stability of less than 90%.

The "package" treatment plant is a small, compact installation that, usually, is well designed to provide treatment for relatively small volumes of wastewater flow from residential or industrial facilities which cannot economically connect to central, or regional collection systems. The package plant represents an interim stage of development in solving the immediate waste treatment needs of an area. To be effective, however, the plant must be properly operated. Failure of the package plant treatment concept can be traced, more often than not, to lack of skilled operation.

The State Department of Health, long ago, recognized this defect and has exerted control by requiring that a qualified plant operator be employed. As a further safeguard, many of these minor disposal installations received approval for construction from the State Department of Health subject to the condition that the plants would be abandoned as soon as public sewerage facilities became available.

Individual Residential Sub-Surface Disposal Systems

Individual sub-surface disposal facilities are, usually, either a cesspool or septic tank installation. Neither one provides a really desirable form of wastewater disposal.

The cesspool is nothing more than an underground holding tank in which solid wastes, including greases and fats, are allowed to accumulate while the liquid waste seeps into the surrounding sub-surface area. The cesspool usually produces some degree of ground water pollution and unsatisfactory surface conditions. After a period of use, it has a tendency to clog and become watertight. Flow is then discharged to the surface. Periodic cleaning out, at considerable expense, must be undertaken to obtain even a small degree of efficiency in waste disposal.

Septic tanks provide a more desirable form of wastewater disposal, but, at best, are inefficient units also requiring periodic cleaning and large seepage areas for satisfactory disposal of effluent. Similarly to cesspools, septic tanks also tend to pollute the ground water supply to some extent.

In all instances of inefficient, or ineffective treatment, partly treated sewage from a human source may reach the ground water, the source of the area's water supply, or it may reach the surface of the ground and the possibility of disease transmission presents itself. The hazard of this condition is the possibility of transmitting water borne diseases, such as typhoid, cholera, dysentery or other organisms of intestinal origin. Sewage bacteria may also be air-borne. Where insanitary

conditions exist, a rapid spread of disease may follow the occurrence of one or more cases.

In the areas of high ground water and inadequate sub-surface conditions, septic tank effluent carries to the local streams sewage flows which contain an appreciable amount of suspended solids and dissolved organic material. Solid matter is deposited in quiescent portions of the stream and forms sludge banks. This settled matter undergoes further decomposition which may be evidenced by gas bubbles and, frequently, lumps of sludge on the surface and partial, or complete, oxygen depletion. The nutrient value of the effluent also stimulates the growth of algae.

There is some evidence, particularly in the Stony Brook and Lower Millstone Sub-Watersheds, that individual sanitary disposal systems are not operating satisfactorily, even in the case of new systems in use for a short time. Due to the vast number of these units in existence, however, it is practically impossible to determine the operating efficiency of these systems. This fact, alone, is sufficient reason to recommend abandonment of these disposal facilities.

There is a lack of factual data to indicate the extent of the pollution of wells from individual disposal systems. In Montgomery Township, a recent investigation of existing wells, especially those located near septic systems, indicated some degree of pollution in up to 25% of the drilled wells and in a greater percentage of the dug wells.

Industrial Waste Disposal Facilities

Industrial development in the Watershed is relatively limited. Most of the present industries are of the nature of research and educational facilities from which the quantity of industrial waste produced is low. Industries equipped with facilities for disposal of process wastes are listed in TABLE 9. TABLE 10 describes the general treatment process employed by each disposal facility.

The Need for Additional Collection and Disposal Facilities

Unsanitary conditions in certain municipalities within the Watershed have reached a level at which the State Department of Health has found it necessary to issue formal orders to the offending municipality to abate pollution. Pollution or nuisance abatement orders, in existence at this time, require the presently unsewered Boroughs of Hopewell, Pennington and Rocky Hill to provide adequate disposal facilities within a reasonable time.

TABLE 10

INDUSTRIAL WASTES AND DISPOSAL PROCESSES

<u>Key No.</u>	<u>Industry</u>	<u>Disposal Method</u>
25.	Socony Mobil Research	Acid wastes are neutralized. Petroleum, phenols and toxic wastes are separated from treated wastewater and removed by private scavenger.
35.	Western Electric Company	Wastes are chemically treated to remove all deleterious substances including cyanides, cyanates, trivalent and hexavalent chromium compounds.
5.	Consumer Farmer Milk Corporation	Dairy waste solids are removed by sedimentation and liquid waste is biologically treated prior to discharge. Sludge is removed by private scavenger.
20.	Food Machinery & Chemical Corp.	Acid wastes are neutralized.
25.	Ingersoll-Rand (under construction)	Acid wastes are to be neutralized. Oils, phenols and toxic wastes are to be separated and removed by private scavenger.
33.	International Business Machines Corp.	Wastes are pretreated prior to discharge to the corporate domestic waste disposal facilities.

Though formal orders have not been issued to date, it has been recognized, for quite some time, that serious sanitary problems also exist in the various unsewered areas of other municipalities as follows:

Hopewell Township

Plainsboro Township

Montgomery Township

Cranbury Township

West Windsor Township

Hillsborough Township

Franklin Township

Millstone Borough

STREAM SAMPLING SURVEY

Stream Classification in the Watershed

The New Jersey State Department of Health has assigned certain classifications to the waterways of the State and has established the standards of quality to be maintained in waters so classified. All streams within the Stony Brook-Millstone Watershed are classified as Class FW-2 which is defined as follows:

"Fresh surface waters approved as sources of public potable water supply. These waters are to be suitable for public potable water supply after such treatment as shall be required by the State Department of Health. These waters shall be suitable also for all recreational purposes including fishing . . ."

The complete text of the definition and the required criteria to maintain the classification has been extracted from the State Regulations and appears in the APPENDIX.

Stream Sampling Stations

The New Jersey State Department of Health maintains stream sampling stations for water pollution control purposes. The location of each sampling station within the Stony Brook-Millstone Watershed is shown on PLATE 19 and listed in TABLE 11.

Stream Samples and Laboratory Analyses

Stream samples were collected at intervals of 3 to 4 months, over a five-year period beginning late in 1960 and extending through the end of 1965.

The various stream samples obtained have undergone sanitary analyses in the laboratories of the State Department of Health to determine those characteristics and constituents of the water which might have a bearing upon its suitability as a public supply. The following physical, chemical and bacteriological determinations were made upon all samples taken:

1. Color
2. Turbidity
3. Odor
4. Temperature
5. Suspended Solids

STONY BROOK-MILLSTONE WATERSHED
REGIONAL SEWERAGE FEASIBILITY STUDY

**LOCATION OF STREAM
SAMPLING STATIONS**

SEELYE STEVENSON VALUE & KNECHT
CONSULTING ENGINEERS
PRINCETON, N. J. NEW YORK, N. Y.

▲ STREAM SAMPLING STATION

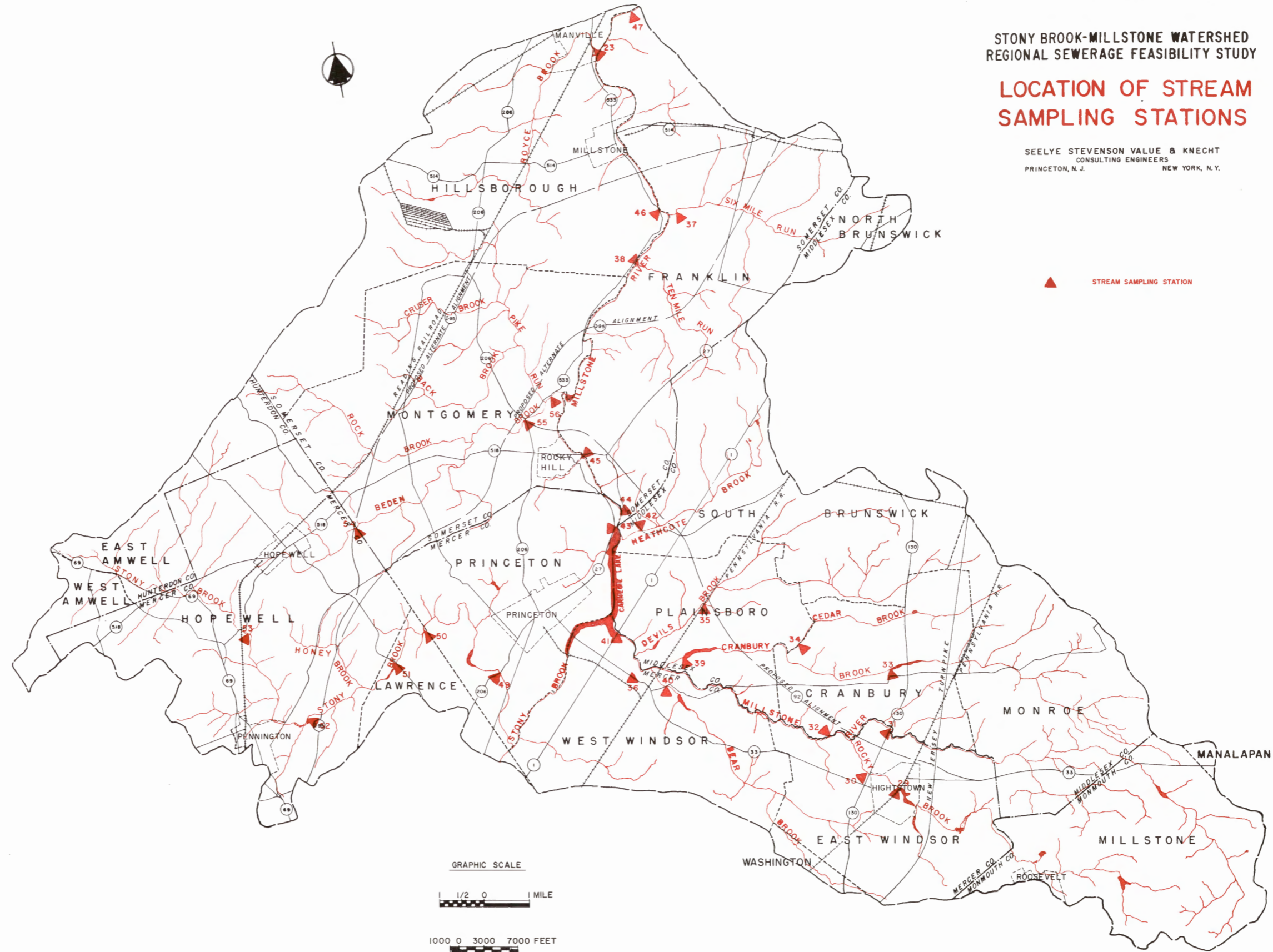


TABLE 11

STREAM SAMPLING STATIONS
STONY BROOK-MILLSTONE WATERSHED

<u>Station No.</u>	<u>Stream</u>	<u>Station Location</u>
23	Royce Brook	In Manville, at north end of guard rail on curve of Route 533; 0.3 mile south of railroad underpass.
29	Rocky Brook	At outlet of Peddie Lake, Hightstown.
30	Rocky Brook	At Hightstown-Route 130 bridge.
31	Millstone River	At Hightstown-Route 130 bridge.
32	Millstone River	At Cranbury-Edinburg Road, 0.8 mile N. E. of Locust Corner.
33	Cranbury Brook	At Brainard Dam, Main Street, Cranbury.
34	Cedar Brook	South side of bridge on Cranbury-Plainsboro Road.
35	Devil's Brook	At bridge on dirt road which runs north from Plainsboro, immediately west of Plainsboro railroad underpass. Sample from upstream side (stock watering facility on downstream side).
36	Little Bear Brook	At Route 539 bridge, between Penn's Neck and Princeton Junction.
37	Six Mile Run	At wooden guard rail, on Canal Road 0.2 mile south of Blackwells Mills.
38	Ten Mile Run	At Iron Bridge on Canal Road approximately 1.8 miles south of Blackwells Mills.
39	Cranbury Brook	At Plainsboro Lake Dam, Plainsboro-Grovers Mills Road.

TABLE 11 (continued)

<u>Station No.</u>	<u>Stream</u>	<u>Station Location</u>
40	Bear Brook	At Grovers Mills-Princeton Junction Road
41	Millstone River	At Route 1 bridge, east of Penn's Neck.
42	Heathcote Brook	Kingston - At bridge on road to St. Joseph College, adjacent to Princeton Nurseries.
43	Millstone River	Near Kingston-Carnegie Lake outlet.
44	Millstone River	Kingston-Rocky Hill Road. Downstream from Route 27 bridge, but upstream of Princeton Disposal Plant outfall.
45	Millstone River	At Route 518, Rocky Hill.
46	Millstone River	At cement bridge near Blackwells Mills gaging station.
47	Millstone River	Above confluence with Raritan River and Elizabethtown Water Company Intake.
49	Stony Brook	At U. S. G. S. gaging station at Route 206 bridge, west of Princeton.
50	Stony Brook	At Province Line Road.
51	Stony Brook	At Carter Road.
52	Stony Brook	At Reeds Mill Dam (on dirt road connecting Pennington-Mt. Rose Road with Federal City Road, just east of Pennington).
53	Stony Brook	At Glenmore Bridge near entrance to Hopewell Valley Golf Club on Spur 518.
54	Bedens Brook	At Province Line. 0.6 mile south of Stoutsburg on Province Line Road.
55	Bedens Brook	At junction Routes 533 and 206.
56	Bedens Brook	At Route 533, 1 mile east of Junction 533 and 206.

6. Free Ammonia Nitrogen
7. Hydrogen-ion Concentration, or pH
8. Alkyl Benzene Sulfonate, or A. B. S.
9. Biochemical Oxygen Demand, or B. O. D.
10. Dissolved Oxygen, or D. O.
11. Coliform Index

A compilation of the stream sample sanitary analyses is included in the APPENDIX.

Interpretation of Analytical Results

1. Color

Color in water has little sanitary significance except possibly to indicate its source. Dissolved organic material from decaying vegetation and certain inorganic matter cause color in water. Occasionally, excessive blooms of algae, or the growth of aquatic microorganisms, may also impart color. While color itself is not usually objectionable from the standpoint of health, its presence is aesthetically objectionable.

The standards of the U. S. Public Health Service limit the permissible amount of color in an acceptable water to 20 and preferably less than 10 parts per million (ppm). The sanitary analyses indicate that color amounts invariably exceed these limits to a substantial degree, and treatment would be required to produce acceptance.

2. Turbidity

Turbidity is the presence of substances in water which interfere with its clarity. It is, usually, a measure of the amount of the suspended and colloidal matter, such as fine sand or clay, in the water. Its presence is not particularly detrimental to potability, however, it is indicative of surface run-off, suggesting the possible existence of pollution resulting from the washing of fertilizer and other substances from the ground surface.

Turbidity greater than 0.5 ppm is noticeable. The U. S. Public Health Service standards limit the permissible turbidity to 10 ppm and suggest, in general, that it should not exceed 5 ppm. Sanitary analyses reveal a great fluctuation in turbidity of the streams with amounts varying from zero to, in some cases, many times the accepted limits. It can be concluded that the variation in turbidity is the result of surface run-off and the attendant existence of polluting substances must be suspected.

3. Odor

Odors may result from any one, or a combination, of such conditions as the presence of micro-organisms, dissolved gases, mineral substances, phenols and other tarry or oily wastes. No factor is so intangible in its real effect upon quality of water. From the public relations standpoint, it is most important, since nothing will produce more prompt criticism than the presence of odor. As a measure of safety of supply, its importance is minor.

As indicated by the sanitary analyses, odor does not appear to be a serious problem in the streams. However, in more than 30% of the samples tested, it was noted that an odor was readily detectable and might cause the water to be regarded with disfavor.

4. Temperature

The most desirable range of temperatures for a public water supply is between 40 and 50 degrees Fahrenheit (4.4 and 10 degrees Centigrade). Temperatures above 80 degrees F (27 degrees C) are undesirable, and, above 90 degrees F (32 degrees C), the water is unfit for a public supply.

To support organic life and prevent the possible development of a septic condition in a stream, the presence of a quantity of dissolved oxygen is necessary. The solubility of oxygen in water is dependent on temperature. At 90 degrees F, water can carry some 40% less oxygen in solution than it can at 40 degrees F.

An extended period of hot weather can, of course, raise stream temperature, but only to a slight extent. High temperature industrial discharge is the usual source of extreme temperature rise experienced in a stream. The sanitary analyses reveal at least one case of this nature in the Watershed. Temperatures recorded at Station 47 range from 91 to 172 degrees F (33 to 78 degrees C). This is an extreme departure from accepted stream standards, in direct contravention of the requirement limiting thermal discharge to a level which is not detrimental to aquatic biota.

5. Suspended Solids

The total solids in the water may be classified as dissolved, colloidal, suspended and settleable. The line of separation between these classes cannot be sharply drawn. Suspended solids, or that portion removable by filtration, is further divided into volatile and fixed portions. It is generally assumed that the volatile portion represents

organic matter, which may putrefy, while the fixed portion is of little significance.

A typical sanitary chemical analysis of a weak domestic sewage will show a suspended solids content of about 100 parts per million, or more, with the volatile portion amounting to about 70%. The volatile percentage is not indicated for the suspended solids analyses performed on the Watershed stream samples. However, the suspended solids content recorded, for most of the stream samples, exceeds that which might be obtained by analysis of a weak domestic sewage.

6. Free Ammonia Nitrogen

Nitrogen may be reported in a sanitary water analysis in several different forms, of which one is the quantity of free ammonia. The presence of free ammonia is generally considered evidence of pollution unless the quantity is extremely small. A determination yielding 0.05 ppm or more must be regarded with suspicion. Sanitary analyses of Watershed samples consistently produce reported concentrations far in excess of this limit.

7. Hydrogen-ion Concentration, or pH

The pH determination indicates, generally, whether a water supply tends toward an alkaline or acid condition. The pH of natural waters lies between 7.0 and 8.0 to 8.5. Higher values indicate abnormal alkalinity and lower values, abnormal acidity. If these conditions exist in a stream, we can usually suspect the presence of an industrial waste.

A few instances of slightly acidic conditions are reported for the stream samples. However, in general, the pH determinations do not show radical departure from the acceptable range of values.

8. Alkyl Benzene Sulphonate, or A. B. S.

The determination for ABS indicates the presence of a synthetic organic chemical used as a principal ingredient of modern household detergents. Any concentration of this substance occurring in a water supply can have appeared only as a result of seepage from local domestic wastewater sub-surface disposal systems. By association, we must suspect the presence of other pollutants. The substance by itself is a nuisance, since it causes foaming, and is detrimental due to the fact that it will kill the fish life necessary to a water supply.

Only the samples analyzed from 7 stream sampling stations of the total of 28 within the Watershed, showed a "negligible" concentration of ABS. All other stations yielded samples in which decided concentrations were measurable. There is some doubt that even "negligible" amounts present are acceptable, since ABS, which does not readily decompose, can reach and pollute the underlying ground water resources.

9. Biochemical Oxygen Demand, or B. O. D.

The biological metabolism of any organic life in natural surface waters will consume oxygen dissolved in the water. The amount of oxygen consumed is known as the biochemical oxygen demand, or B. O. D. It is a measure of the amount of organic life and food in the water. The test is seldom used in the determination of the quality of a water supply, because high contamination is necessary to produce a significant amount of B. O. D.

In ordinary circumstances, we would expect a water supply of only fair quality to have a B. O. D. of 1.5 ppm maximum. A good quality supply should have a B. O. D. of less than 0.1 ppm. Sanitary analyses of stream samples yield B. O. D. values which range from a minimum of 1 to over 11 ppm, with the great majority higher than 2 ppm. At Station 47, a sample taken in 1960 yielded the extraordinary B. O. D. of 2800 ppm. In general, the B. O. D. values are not much better than those which might be expected in analyzing the effluent from a waste treatment facility just prior to final disposal by dilution in the receiving waters.

10. Dissolved Oxygen, or D. O.

Dissolved oxygen represents the amount of oxygen actually dissolved in the water. Oxygen may be added to water by dilution received from tributaries, through aeration over rocks and falls, by the action of the wind, by quiescent absorption from the atmosphere, or by the action of microscopic organisms. Its presence in natural waters is essential to the maintenance of fish life and to the prevention of putrefactive conditions.

Natural surface waters of a satisfactory quality should be saturated with dissolved oxygen, that is, the water should contain 100 per cent of the amount of oxygen that it is capable of dissolving depending on its temperature. A lower oxygen content indicates the presence of organic matter in the process of oxidation.

TABLE 12 has been prepared to indicate the actual dissolved oxygen content in terms of the percentage of content at saturation for the latest stream samples for which data has been furnished. Except for the first two stations listed, the per cent of saturation content is below the acceptable level for a good quality water supply, and, in only 7 out of 27 samples is the D. O. above 90% of saturation, the minimum requirement for a fair quality supply.

11. Coliform Index

Coliform organisms are normally present only in the intestinal tracts of humans and animals, and their presence in water is direct evidence of pollution by domestic waste. Since pathogenic bacteria are not readily identified in polluted waters, it has become standard practice to use the count of coliform organisms as an index of the safety of water for use in drinking or bathing. The concentration of coliform organisms, expressed as the most probable number (M. P. N.) of coliforms per 100 milliliters, is known as the coliform index.

Numerous state and other agencies have established bacterial-quality standards for waters used as sources of potable water. These standards have proved effective in protecting public health, in the sense that significant disregard of standards has resulted in numerous outbreaks of enteric disease, while reasonably consistent conformance with standards has led to the absence of disease.

A widely-used standard for potable water, promulgated by the U. S. Public Health Service, establishes a monthly average coliform index of 5,000 for water acceptable for treatment by filtration and post-chlorination. The sanitary analyses of stream samples yield coliform indices for a great number of individual samples which are in excess of this limit. It is conceivable, however, that, if daily samples were taken and analyzed, the resulting average monthly coliform indices might fall within the acceptable limit. We cannot, therefore, either condemn or approve the streams within the Watershed as a source of potable water on the bases of currently available coliform density analyses. However, the prevalence of high coliform counts does furnish evidence of pollution, and, in all likelihood, more comprehensive sampling would probably lead to condemnation rather than acceptance of the streams as a source of potable water supply.

At present, there is a wide diversity of opinion regarding the proper coliform standards for public waters used for recreational purposes. The possibility that infection might result from water sports, boating or fishing when exposed to natural waters high in coliform organisms has been the concern of various public health agencies for many years.

TABLE 12

COMPARISON OF ACTUAL DISSOLVED OXYGEN CONTENT
WITH CONTENT AT SATURATION FOR LATEST
STREAM SAMPLES TAKEN IN 1965

Sampling Station No.	Date Collected	Temperature in Degrees Centigrade	Dissolved Oxygen in ppm		D.O. in Percent of Saturation
			Saturation	Actual	
23	7-7-65	23	8.68	8.6	99.0
29	11-4-65	13	10.60	12.1	114.0
30	"	11	11.08	7.1	64.2
31	"	12	10.83	9.4	86.8
32	"	12	10.83	7.3	67.3
33	10-27-65	9	11.59	11.0	95.1
34	"	8	11.87	8.1	68.2
35	"	7	12.17	4.0	32.9
36	10-22-65	8	11.87	7.0	59.0
37	10-27-65	7	12.17	8.6	70.8
38	3-23-65	5	12.80	12.4	96.8
39	10-28-65	12	10.83	10.6	97.8
40	"	9	11.59	9.0	77.7
41	"	10	11.33	7.6	67.0
42	"	7	12.17	6.5	53.5
43	"	10	11.33	8.9	78.5
44	"	9	11.59	6.0	51.8
45	"	10	11.33	4.2	37.1
46	"	10	11.33	5.0	44.2
49	10-18-65	9	11.59	8.9	76.8
50	"	8	11.87	10.2	86.0
51	"	11	11.08	10.4	93.8
52	10-28-65	11	11.08	10.0	90.3
53	10-18-65	10	11.33	8.0	70.7
54	"	11	11.08	8.4	75.8
55	"	8	11.87	8.4	70.8
56	"	9	11.59	8.4	72.4

Nevertheless, no certain evidence has been forthcoming on which to base a coliform standard for recreational waters.

Some bacteriological standards of quality have been established and are presently utilized in connection with waters used for bathing purposes. These standards have a range from a minimum coliform index of 100 up to 2400 or higher. The variation can be accounted for by the lack of epidemiological evidence to demonstrate the extent to which intestinal diseases are transmitted to bathers in polluted waters. The State Department of Health performs regular sanitary surveys of bathing areas and, in regard to recreational waters, employs a coliform index of 2400 as an administrative guide in determining sanitary quality. Values in excess of this standard classify the waters in question as unfit for bathing purposes. On the basis of this standard, the streams in the Watershed cannot meet the qualifications.

General Significance of Analytical Results

Based on the results of sanitary analyses, it is quite evident that the streams within the Stony Brook-Millstone Watershed do not meet the standards of quality established for Class FW-2 by the State Department of Health. In lieu of containing a potable water supply, the open stream channels actually furnish conveyance for a weak, domestic wastewater.

The situation, at present, is not serious in the sense that the natural surface waters would recover quality, quite rapidly, once the sources of pollution were eliminated. This, of course, could be effected by the establishment of a regional wastewater collection and disposal system. The real problem lies in allowing conditions to remain static, with the inherent danger of ultimately polluting the underlying ground water resources.

It is patently more difficult to pollute ground water than surface water. But once polluted, the ground water may remain contaminated for 50 or even 100 years. The period and rate of the natural recovery process are indeterminate.

WATERSHED HYDROLOGY

Major Streams

The principal stream of the Watershed is the Millstone River with Stony Brook joining it at Princeton. Many other smaller streams enter Stony Brook and Millstone River at various points along their courses.

In the upper reaches of the Millstone River, sandy formations, mill ponds, small lakes and swampy areas act as natural reservoirs storing excessive runoff during flood periods, and releasing stored runoff when stream flow is low. These natural reservoirs, together with a relatively flat streambed, maintain reasonably steady and reliable flows in the main stream.

By contrast, the Stony Brook watershed is characterized by impermeable geologic formations and steep stream channels (500 feet fall between headwaters and Lake Carnegie). Flood waters are not retained as in the Upper Millstone, and the stream flow fluctuates significantly between flood flows and dry weather conditions.

Flooding

Flooding is important to the selection of a site for any major wastewater disposal facilities along Stony Brook and the Millstone River. The flood incidence and extent of inundation must be considered, and their possible effects on the facility must be assessed.

Floods do occur in the Watershed, but areas of inundation are usually limited to flood plains along the Millstone River and Stony Brook. The frequency of occurrence is irregular and can be illustrated by the pattern recorded at the U. S. Geological Survey gaging station on the Millstone River at Blackwell's Mills.

Flooding, which starts at elevation 33 (feet about mean sea level), has occurred 21 times in the 32-year record, or one flood in 1-1/2 years. Actually, no floods occurred in 17, or about 1/2, of the years and none occurred during the 4-year period 1929 to 1932. Some years have produced two floods and, in 1955, there were three.

Few dwellings exist in the lower elevations of the flood plain subject to river overflows. Inundation areas are generally wood and pasturelands, and damages are usually limited to agricultural activities and transportation facilities.

Stream Gaging Stations

The following U. S. Geological Survey stream gaging locations are located within the Watershed:

<u>Location of Gaging Station</u>	<u>Upstream Drainage Area in Square Miles</u>	<u>Period of Recorded Measurements</u>
Millstone River at Plainsboro	65.8	May, 1964 to date and scattered observations 1962-4
Millstone River near Kingston	171.0	1934 to 1948
Millstone River at Blackwells Mills	258.0	June 1903 to Dec. 1904 gage heights only; August 1921 to date
Baldwin Creek at Baldwin Lake near Pennington	2.52	October 1962 to date
Stony Brook at Princeton	44.5	October 1953 to date

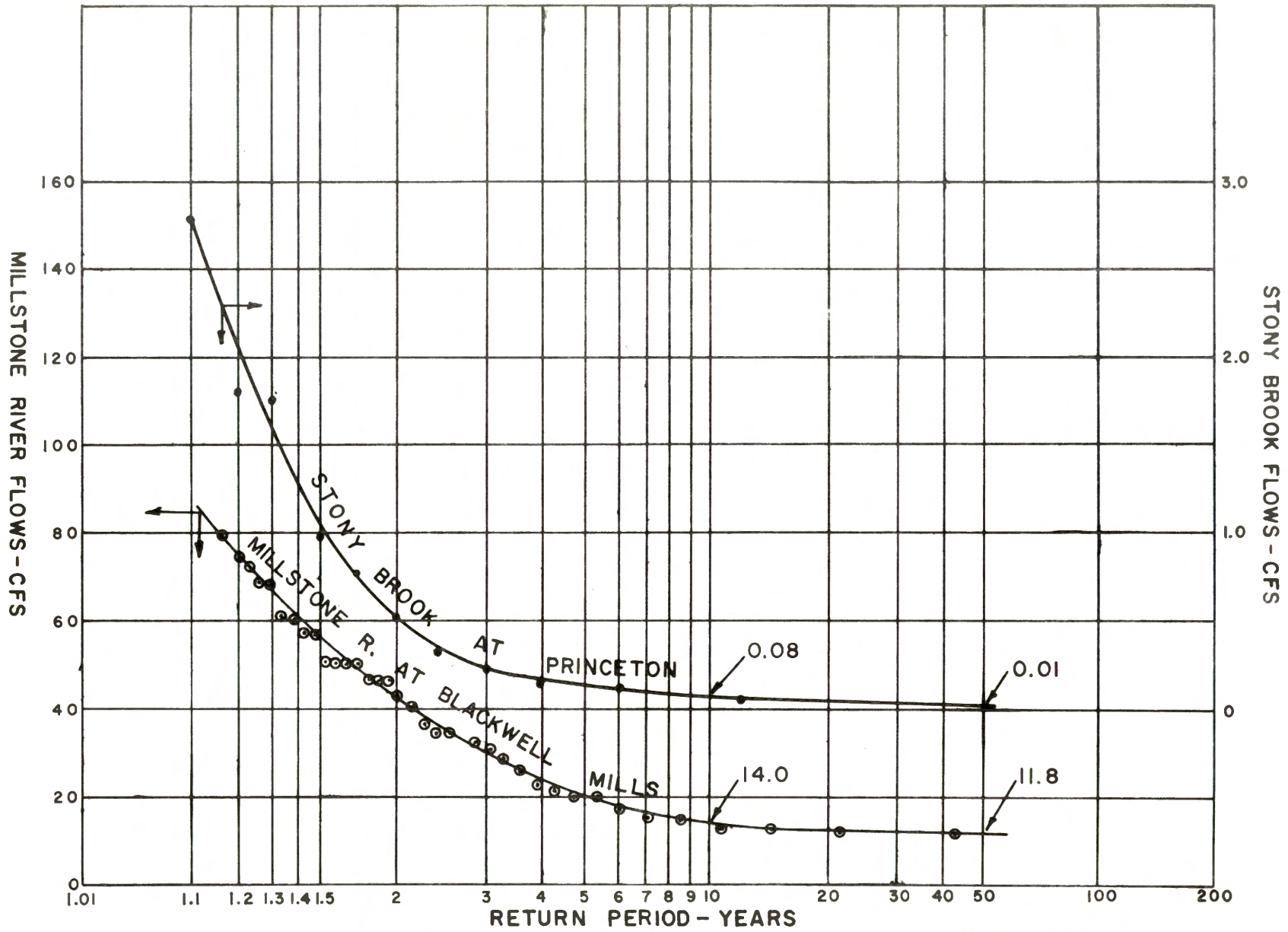
In addition, there are 21 locations where special stream flow measurements were made during low flow periods of recent years.

Determination of Minimum Flows

The aim of all wastewater treatment processes is not to purify the wastewater completely, but to produce an effluent of such quality that it can be discharged to a receiving stream without causing a nuisance. Sufficient stream flow must exist at all times to enable the stream to complete its part in the treatment process by providing ample dilution to quickly dissipate the few remaining impurities.

Normally, the stream flow criterion, used to determine the probable maximum quantity of treated effluent which can be assimilated, or dispersed, is the low flow for any consecutive 7-day period occurring in one out of ten (10) years.

The records of the stream gaging stations were analyzed for drought flows. Computed 7-day minimum flows with return periods between 2 and 50 years for Stony Brook at Princeton and for the Millstone River at Blackwells Mills are shown on PLATE 20. Ten-year frequency flows determined from PLATE 20 are as follows:



7 DAY MINIMUM FLOW - 2 TO 50 YEAR FREQUENCIES

STONY BROOK AT PRINCETON

MILLSTONE RIVER AT BLACKWELL MILLS

10-Year, 7-Day Minimum Flow

	<u>Cubic Feet Per Second</u>	<u>Million Gallons Per Day</u>
Stony Brook at Princeton	0.08	0.05
Millstone River at Blackwells Mills	14.0	9.0

Based upon coincident measurements at U. S. Geological Survey gaging stations and the special low flow measurement stations, 10-year, 7-day minimum flows have been determined for all reaches of the Millstone River within the Watershed. These flows are shown on PLATE 21 and listed in TABLE 13.

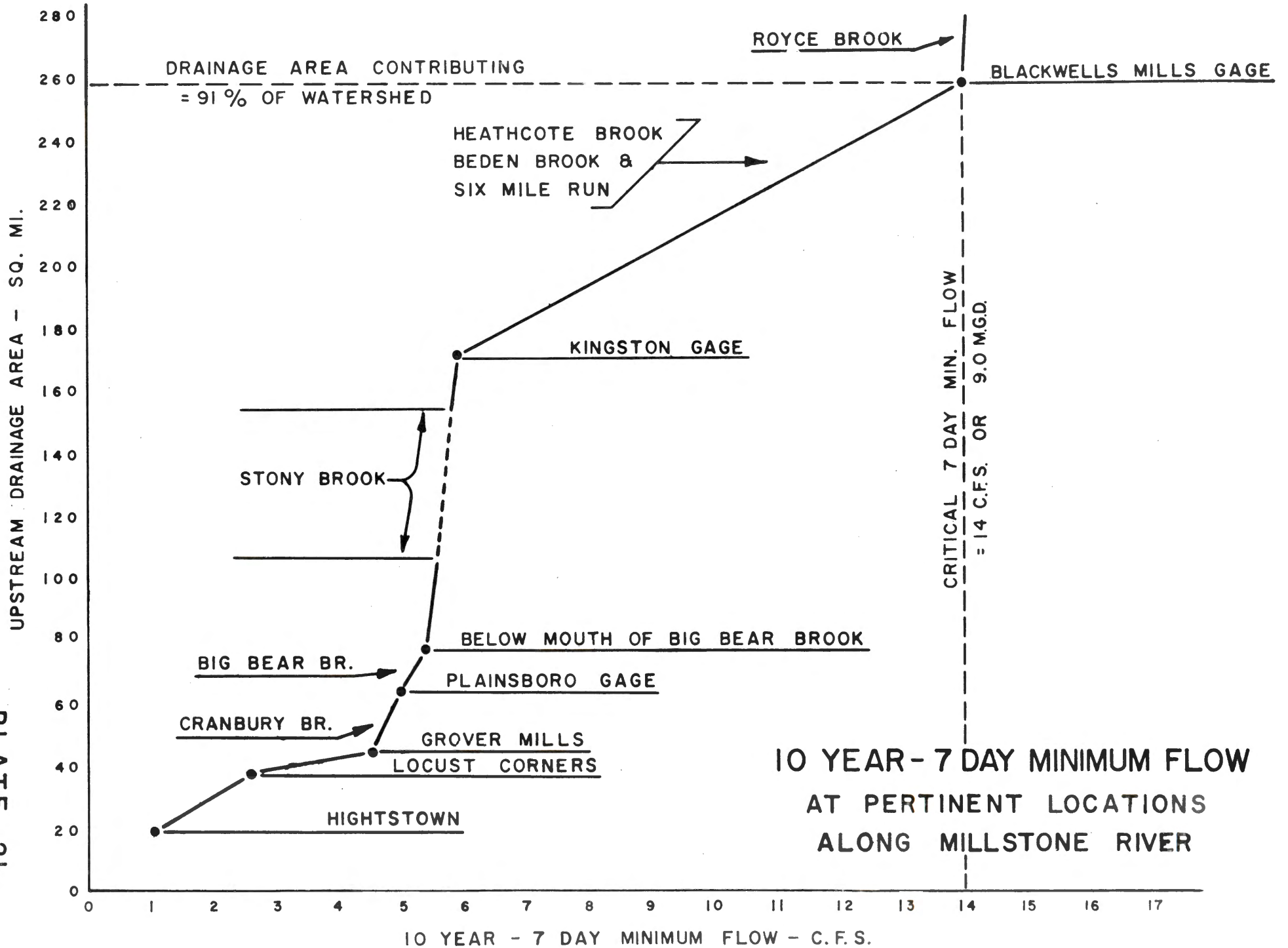
Critical Minimum Stream Flow

From examination of the results, graphically presented on PLATE 21, it is apparent that a critical minimum flow of about 9.0 MGD occurs in the Millstone River at Blackwells Mills. At this point, drainage is contributed from over 91% of the area of the Watershed. Downstream of Blackwells Mills, no appreciable increment in 7-day minimum flow is obtained by run-off contribution from the remainder of the drainage area. Accordingly, in connection with an assimilation study for a regional waste disposal facility to be located along the lower Millstone River, the 7-day minimum flow of 9.0 MGD, in conjunction with other pertinent factors, would be utilized to establish the permissible maximum quantity of plant discharge during drought periods.

TABLE 13

10-YEAR, 7-DAY MINIMUM FLOWS
 AT PERTINENT LOCATIONS
 ALONG THE MILLSTONE RIVER

<u>Location</u>	<u>Upstream Drainage Area in Square Miles</u>	<u>Minimum Flows</u>	
		<u>C. F. S.</u>	<u>M. G. D.</u>
Millstone River at Hightstown	19.7	1.1	0.7
Millstone River at Locust Corners	37.4	2.6	1.7
Millstone River near Grovers Mills	42.6	4.6	3.0
Millstone River at Plainsboro (Gage)	65.8	5.0	3.2
Millstone River below Big Bear Brook	78.2	5.4	3.5
Millstone River near Kingston (Gage)	171.0	5.9	3.8
Millstone River at Blackwells Mills (Gage)	258.0	14.0	9.0



10 YEAR-7 DAY MINIMUM FLOW
AT PERTINENT LOCATIONS
ALONG MILLSTONE RIVER

PROPOSED REGIONAL SYSTEM FOR WASTEWATER DISPOSAL

General

Several possible plans have been considered to develop a feasible regional system of facilities for the present and future collection, treatment and disposal of wastewater for the Watershed.

The recommended regional system for wastewater disposal is shown on PLATE 22. The possible alternative plans, which have been studied, are discussed in a separate section which is included in the APPENDIX.

In the proposed system, it is intended that the water pollution control facilities be located along the Millstone River upstream of Blackwells Mills. The previous discussion on stream flow characteristics noted that the critical minimum 7-day flow is approximately 9 MGD along this reach of the Millstone River. This minimum flow limits the permissible quantity and quality of plant final effluent which can be discharged, without creating a nuisance, during periods of drought flow in the river.

If the dissolved oxygen content of the stream is assumed to be 9.0 ppm (the solubility of oxygen in fresh water at 68°F.), and the plant effluent B. O. D. load is 26.5 ppm after secondary treatment (90% reduction of B. O. D.), the river, during drought conditions, could not assimilate average daily plant flows in excess of 3.0 MGD. A third stage of treatment to produce a plant effluent approaching drinking water standards would be necessary. The low drought flow in the river would then be able to dissipate the final effluent in a satisfactory manner.

As an alternative to discharging of final effluent to the receiving stream, it is proposed to pump the final effluent to reclamation facilities wherein the wastewater would be renovated for re-use within the Watershed. The specific re-use, considered in this report, is ground water recharge. Other re-use, such as irrigation, is possible, and it is intended that reclamation studies would be conducted to determine the optimum re-use.

In the APPENDIX of the report, as a part of this study, a review of the literature covering experimental research conducted and practical experience in connection with tertiary treatment and reclamation of wastewater is included.

Proposed Regional System

The proposed regional system basically consists of the following facilities:

1. The Wastewater Collection Facilities
2. The Water Pollution Control Facilities
3. The Wastewater Reclamation Facilities

These facilities are fully described, on an individual basis, in subsequent, separate sections of the report.

Basis of Design for Regional System

The regional system has been developed in accordance with certain criteria established under the study. These criteria basically consist of the following:

1. The design period of years for which the facility will have a useful life without requiring major modifications or additions.
2. The total population which is expected to develop during the period of useful life.
3. The wastewater flow which will be contributed by this population and which the facilities must dispose.

TABLE 14 has been prepared to summarize the pertinent design criteria both for the ultimate project to be developed and also for the facilities to be constructed in the initial phase.

Design Period of Useful Life

The Rules and Regulations of the New Jersey State Department of Health presently provide for the following design periods for waste handling facilities:

1. For Collection Facilities - The design period for the estimated flow shall be at least twenty-five (25) years with longer periods recommended for major projects.
2. For Treatment Facilities - Facilities shall be designed for population and waste flow anticipated not less than ten (10) years after the completion of construction. A longer design period should be used where future economies are indicated.

TABLE 14

SUMMARY OF PERTINENT DESIGN CRITERIA FOR ULTIMATE REGIONAL SYSTEM AND FOR INITIAL CONSTRUCTION PHASE

<u>Pertinent Design Criteria</u>	<u>Ultimate Project</u>	<u>Initial Construction</u>
Wastewater Collection Facilities:		
Design Period (Years)	50	50
Design Year	2015	2015
Design Population for:		
(a) Interceptor Pipe Size	612,400	612,400
(b) Interceptor Extent	612,400	317,325
Average Daily Flow (gpcd)	100	100
Peak Flow Rate (gpcd)	400	400
Design Capacity (MGD)	60	60
Water Pollution Control Facilities:		
Design Period (Years)	50	20
Design Year	2015	1990
Design Population	612,400	173,470
Average Daily Domestic Waste		
Flow (gpcd)	100	100
Industrial Waste Flow (gpcd)	5	5
Total Design Flow (gpcd)	105	105
Design Capacity (MGD)	60	20
Wastewater Reclamation Facilities:		
Design Period (Years)	50	3
Design Year	2015	1973
Design Population	612,400	38,000
Total Design Flow (gpcd)	105	105
Design Capacity (MGD)	60	4

All facilities for the ultimate regional system have been developed for a design period of 50 years.

Shorter design periods, for system facilities to be constructed in the initial phase, have been used in the case of the facilities for water pollution control and wastewater reclamation. This will be discussed in subsequent paragraphs.

Scheduled Potential Contributing Population

To facilitate development of the regional system in a sensible, staged program of construction, a schedule has been formulated in which the estimated potential population which might be contributing to the system in various future years is shown. This schedule is produced in TABLE 15.

The estimated future municipal populations within the Watershed have been divided into two categories as follows:

1. Potential immediate contributors
2. Potential future contributors

Immediate contributors include those municipalities in which:

1. Local wastewater collection and disposal facilities exist, but are inadequate and require augmentation.
2. A serious sanitary problem exists, which must be eliminated by creation of disposal facilities.

Future contributors include those municipalities which could participate in the regional wastewater disposal system, but for which immediate participation may not be essential, practical, or economical for the following reasons:

1. The municipality is of a rural nature with low population density, and sanitary needs can be fulfilled locally with simple facilities for a long time into the future without causing serious problems.
2. Due to proximity, it may be more convenient, or expedient, for the municipality to connect to some other regional disposal system.
3. The municipality presently has its own disposal facilities which can provide adequate service for some period of future time.

TABLE 15

ESTIMATED SCHEDULE FOR
POTENTIAL CONTRIBUTING POPULATION
TO THE
REGIONAL SYSTEM FOR WASTEWATER DISPOSAL

<u>MUNICIPALITY</u>	<u>ESTIMATED POPULATION</u>					
	<u>1970</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>	<u>2010</u>	<u>2015</u>
<u>Potential Immediate Contributors</u>						
Mercer County						
Hopewell Township	9800	15000	20800	26650	33300	36500
Hopewell Borough	2300	2850	3500	4200	5000	5300
Pennington Borough	2300	2550	2900	3350	3800	4000
Lawrence Township	1900	2200	2650	3100	3600	3800
Princeton Township	11100	11800	12400	13100	13800	14150
Princeton Borough	11940	11930	11920	11910	11900	11900
West Windsor Township	8000	14000	23000	35000	46000	52500
Middlesex County						
Cranbury Township	5000	9100	14000	19500	25000	27800
Plainsboro Township	4450	8800	14250	19750	26250	29300
South Brunswick Township	11000	19000	29200	41000	52700	58700
Somerset County						
Franklin Township (50%)	6000	9650	12750	17250	20500	22775
Montgomery Township	8500	16000	25000	34500	44000	49000
Rocky Hill Borough	850	950	1100	1300	1500	1600
Total Immediate Contributors	83140	123830	173470	230610	287350	317325
<u>Potential Future Contributors</u>						
Hunterdon County						
East Amwell Township	2300	2825	3650	4800	5900	6400
West Amwell Township	1000	1300	1900	2800	3700	4100
Mercer County						
East Windsor Township	6000	12000	20000	29000	38000	43000
Hightstown Borough	5500	6400	7300	8200	9200	9700
Washington Township	60	80	90	95	98	100
Middlesex County						
Monroe Township	12000	26000	41000	61000	81000	91000
North Brunswick Township	3000	4500	6000	7500	9000	9500
Monmouth County						
Manalapan Township	500	840	1180	1540	1910	2100
Millstone Township	4000	8000	13000	18000	23000	26000
Roosevelt Borough	40	90	150	210	270	300
Somerset County						
Franklin Township (50%)	6000	9650	12750	17250	20500	22775
Hillsborough Township	13000	23500	36000	50500	65000	72100
Manville Borough	5500	6000	6100	6500	6700	6700
Millstone Borough	575	700	850	1000	1200	1300
Total Future Contributors	59475	101885	149970	208395	265478	295075
Total Potential Contributors	142615	225715	323440	439005	552828	612400

Design Population

The estimated ultimate total Watershed population for the year 2015 is 612,400. This population includes all potential contributors, and has been used in the design of all facilities for the ultimate regional disposal system.

In the initial construction phase, the wastewater collection facilities will be built with pipe line interceptors fully sized to handle the peak flow which would eventually be contributed by the estimated ultimate population in 2015. However, the length of the constructed interceptors will be limited to that extent necessary to provide connections for the local waste collection facilities of only the total potential immediate contributors in the year 2015.

Initial water pollution control facilities will be designed to handle flow from a population of 173,470, the total of the potential immediate contributors in the year 1990. Eventually, future plant expansion will provide additional capacity to handle the total population expected in 2015.

The first phase of construction for the wastewater reclamation facilities will provide sufficient capacity to handle flow from an expected population slightly less than one-half the total potential immediate contributors in the year 1970. Experimental studies are necessary in connection with the proper development of these facilities, and the initial units constructed will be utilized basically for this purpose.

Domestic Waste Flow

The average daily per capita domestic waste flow used for preliminary design of all facilities of the regional system is 100 gallons per day. This figure is assumed to include normal expected infiltration of approximately 25 gallons per capita per day (gpcd).

In designing the units of the wastewater collection facilities, sizing of pipe lines and pumps is dependent on the peak rate of flow expected to occur at certain periods of the day. The State Department of Health normally requires that all sanitary conduits, including plant outfalls, shall be designed to carry a peak flow of at least four (4) times the estimated average daily flow, when the conduit is flowing full. To conform to this requirement, the design peak flow rate would be 400 gpcd. This is a relatively high factor on which to base sizing of a major interceptor system. However, by utilizing this peak rate, a decided factor of safety will exist in the capacity of the wastewater collection facilities to account for actual future populations in excess

of that estimated, excessive infiltration of ground water, unavoidable surface water contributions and industrial waste flow in excess of the allowance.

Industrial Waste Flow

Very little industrial flow, or trade waste, exists in the area now, and there is some tendency on the part of residents to discourage development of this type of industry. Nevertheless, the fact must be recognized that, in the future, normal growth of industry must produce some increase in the trade waste, which must be handled properly to avoid discharge to, and attendant pollution of, the streams.

At the present time, in other locations, industrial waste flows are being processed in a satisfactory manner at existing major water pollution control facilities. There is, therefore, no reason to exclude these wastes from facilities proposed for the Watershed. It is essential, however, that each existing and future trade waste proposed to be delivered to the regional system, be reviewed to determine that waste quality will not be injurious to system structures. If necessary, pre-treatment, by the contributor to produce a waste acceptable to the regional system, would be required.

To account for future quantity of industrial waste flow, an allowance equal to 5% of the average daily per capita domestic contribution will be added in the course of developing the design flow for the treatment facilities. It is assumed that this additional quantity of flow will consist solely of plant process and sanitary wastes. There is no intent to accept cooling water used for air conditioning or industrial processes.

Wastewater Characteristics

The characteristics of the present wastewater flows in the Watershed are primarily those of a medium to weak strength domestic waste.

The daily per capita loadings on the units of the water pollution control facilities will be based on average per capita contributions of 0.17 pounds per day of B. O. D. and 0.20 pounds per day of suspended solids, plus allowances for the increasing trend toward the use of home garbage grinders. Full use of garbage grinders in a community increases the suspended solids up to 100% with an average of about 60%, and increases the B. O. D. up to 65% with an average of 30%. The effect on the volume of sewage is negligible.

For design purposes, the following wastewater strengths will be used:

	Average Contribution Per Capita <u>(lbs. /day)</u>	x	Garbage Grinder <u>Allowance</u>	=	Per Capita Design Loading <u>(lbs. /day)</u>
Biochemical Oxygen Demand (B. O. D.)	0.17	x	1.3	=	0.22
Suspended Solids	0.20	x	1.6	=	0.32

For an average per capita flow contribution of 100 gallons per day, the water pollution control plant loadings are as follows:

B. O. D. 265 ppm

Suspended Solids 385 ppm

PROPOSED WASTEWATER COLLECTION FACILITIES

General

The proposed regional wastewater collection facilities will receive flow from local community waste collection facilities and convey the wastewater to the water pollution control for processing and final disposal.

The proposed wastewater collection facilities, as developed, are shown on PLATE 23. Each municipality, or part thereof, as indicated, has one or more individual points of connection to the regional collection system.

Proposed Wastewater Collection Facilities

The collection system consists basically of the following facilities:

- Stony Brook Interceptor
- Upper Millstone Interceptor
- Lower Millstone South Interceptor
- Lower Millstone North Interceptor
- Lower Millstone Pumping Station
- Lower Millstone Force Mains

The proposed interceptors follow the natural water courses, or drainage valleys, of the Watershed and convey flow by gravity insofar as possible. The Stony Brook and Upper Millstone Interceptors connect to the Lower Millstone South Interceptor which conveys the wastewater north to the Water Pollution Control Plant located approximately at the confluence of Beden Brook and the Millstone River. Wastewater, originating from local collection facilities downstream of the plant, is conveyed by the Lower Millstone North Interceptor to Lower Millstone Pumping Station, which is situated in the vicinity of Manville Borough. The pumping facilities deliver the flow back to the treatment plant.

The various components of the wastewater collection facilities individually serve the municipal areas indicated in TABLE 16.

STONY BROOK-MILLSTONE WATERSHED
REGIONAL SEWERAGE FEASIBILITY STUDY

**PROPOSED WASTEWATER
COLLECTION FACILITIES**

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CONSULTING ENGINEERS
PRINCETON, N.J. NEW YORK, N.Y.

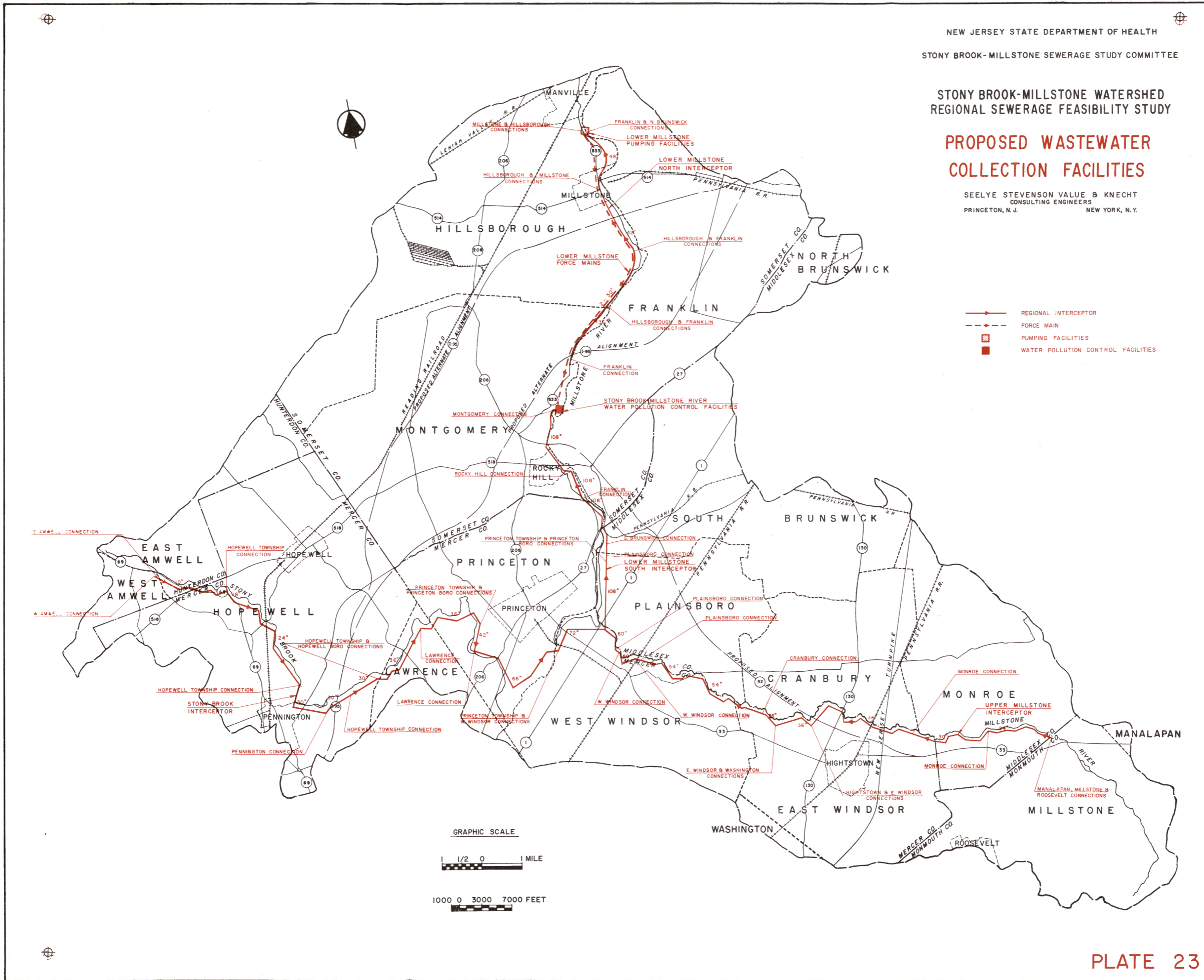


TABLE 16

MUNICIPALITIES SERVED BY PROPOSED WASTEWATER COLLECTION FACILITIES

<u>Stony Brook Interceptor</u>	<u>Upper Millstone Interceptor</u>	<u>Lower Millstone South Interceptor</u>	<u>Lower Millstone North Interceptor, Pumping Station and Force Mains</u>
Hunterdon County	Mercer County	Mercer County	Middlesex County
- East Amwell Township	- East Windsor Township	- Princeton Township	- No. Brunswick Township
- West Amwell Township	- Hightstown Borough	- Princeton Borough	Somerset County
Mercer County	- Washington Township	Middlesex County	- Franklin Township
- Hopewell Township	- West Windsor Township	- Plainsboro Township	- Hillsborough Township
- Lawrence Township		- So. Brunswick Township	- Manville Borough
- Pennington Borough	Middlesex County		- Millstone Borough
- Princeton Borough	- Cranbury Township	Somerset County	
- Princeton Township	- Monroe Township	- Franklin Township	
	- Plainsboro Township	- Montgomery Township	
	Monmouth County	- Rocky Hill Borough	
	- Manalapan Township		
	- Millstone Township		
	- Roosevelt Borough		

Design Criteria for Interceptors

Certain minimum design criteria were established for the interceptors of the wastewater collection facilities as follows:

1. Minimum interceptor pipe diameter - 10"
2. Minimum depth of interceptor - 8 feet
3. Pipe Velocities - Interceptors are designed to provide mean velocities, when flowing full or half full, of not less than 2.0 feet per second, based on Kutter's or Manning's formula using an "n" value of 0.13. Maximum velocities are limited to 10 feet per second.
4. Slopes - The design minimum pipe slopes are as follows:

<u>Pipe Diameter in inches</u>	<u>Minimum Slope in feet per 100 feet</u>
10	0.29
12	0.22
14	0.17
15	0.16
16	0.14
18	0.12
20	0.10
21	0.095
24	0.080
27	0.067
30	0.058
33	0.049
36	0.046
42	0.035
48	0.029
54	0.026
60	0.023
66 and greater	0.020

5. Manholes - Manholes will be provided at the ends of each line, at intersections and at all changes in grade, size and alignment. Distances between manholes will not exceed 500 feet for sizes 24 inches or less. For larger sewers, maximum manhole spacing is 1000 feet.

Details of Interceptor Construction

Interceptors will be constructed, as applicable, of asbestos cement, reinforced concrete or extra strength vitrified clay pipe. The material selected will be adapted to local conditions, such as character of any industrial waste flow, soil characteristics, exceptionally heavy external loadings, abrasion and similar problems. All joints will be rubber gasketed to insure tightness and minimize infiltration.

Manholes will be constructed of precast concrete barrels, brick, segmented concrete block or poured concrete. To secure watertight manholes, the outside of the structure will be plastered with cement mortar and/or a bituminous waterproof coating. In extremely wet areas, where the possibility of flooding exists, manhole covers will be rubber gasketed and bolted watertight to exclude surface water. The minimum diameter of manholes will be 42 inches.

In order to secure a reasonably watertight system, infiltration tests will be performed throughout the period of construction. In wet areas, this may be determined by weir readings in the interceptor system. Infiltration shall not exceed a rate of 100 gallons per inch of diameter per day per mile of pipe. Where no ground water exists for infiltration tests, internal hydrostatic pressure tests will be made to determine possible leaks. Maximum permissible exfiltration rate shall be 100 gallons per inch of diameter per day per mile of pipe, under a minimum differential head of 4 feet.

Pumping Station and Force Mains

Comparative cost estimates indicate that it is more economical to construct and operate a pumping facility at the lower end of the Watershed to deliver collected flow south to the Water Pollution Control Plant at Beden Brook for processing rather than to construct and operate an additional water pollution control plant in the vicinity of Manville Borough. The cost estimates for the latter alternative are included in the APPENDIX.

The structure of Lower Millstone pumping station will be developed to house facilities for the year 2015. Initial facilities installed will provide pumping capacity designed to handle flow expected in the year 1990. Space will be provided for future pumps, and emergency standby power facilities will be included.

The pumping station will be of the dry well type, with wet and dry wells completely separated. Adequate light, ventilation and a supply of fresh water will be provided. The station will be designed in

accordance with the requirements of the Rules and Regulations of the New Jersey State Department of Health.

The Lower Millstone Force Mains will be designed to maintain a self-cleansing, minimum velocity of 2-feet per second. To satisfy this condition, it will be necessary to provide one 30-inch force main for the initial average flow and a similar parallel force main for future flows.

The force mains will be provided with automatic air relief valves at high points to prevent air locking, and valved cross connections and suitable drains to permit flexibility in operation and maintenance.

Pipe Sizes and Lengths

Future populations have been projected under previous sections, and estimated flows were determined for the contributors within each drainage zone. In accordance with the design criteria, preliminary pipe sizes were established, and are indicated on PLATE 23.

TABLE 17 summarizes pipe sizes and lengths for the regional interceptors. The total length of the gravity interceptors is approximately 43.8 miles and the parallel force main is approximately 8.5 miles.

TABLE 17

LENGTHS OF PIPE FOR VARIOUS SIZE INTERCEPTORS
AND FORCE MAINS FOR WASTEWATER COLLECTION FACILITIES

Interceptor	Interceptor Lengths in 1,000 Feet (Gravity Lines)												Total Length (Miles)
	10"	18"	24"	30"	36"	42"	48"	54"	60"	66"	72"	108"	
Stony Brook	6.6	4.0	17.4	15.4	22.0	9.0				10.4	7.6		17.5
Upper Millstone			9.0	7.0	23.0			20.0	9.0				12.9
Lower Millstone So.												32.0	6.1
Lower Millstone No.					18.5	10.0	10.0						7.3
TOTALS	6.6	4.0	26.4	22.4	63.5	19.0	10.0	20.0	9.0	10.4	7.6	32.0	43.8

Lower Millstone Force Main -- 45,000 feet (8.5 miles) of two parallel force mains each 30" diameter in size.

PROPOSED WATER POLLUTION CONTROL FACILITIES

Location of Facilities

The proposed water pollution control facilities will be located on a suitable site at the confluence of Beden Brook and the Millstone River. This site provides the most economical design for the regional system for the following reasons:

1. The site is close to areas suitable for ground water recharge.
2. Since a plant located downstream of Beden Brook would have to pump treated effluent back to the proposed recharge basins, the pumping station and force main capacity can be reduced by intercepting a large portion of the flow at the Beden Brook site.
3. The site eliminates the need to continue a very large diameter interceptor along the Millstone River downstream of Beden Brook.

The proposed site would be neatly landscaped and could be coordinated with the proposed State Millstone Valley Park along the Millstone River and Delaware and Raritan Canal. The architectural appearance of the facility would not detract from the area.

Type of Treatment Process to be Employed

The New Jersey State Department of Health has established criteria for treatment of wastewater prior to discharge to receiving waters. The text of the regulations delineating the criteria are included in the APPENDIX of the report.

To furnish the high degree of treatment required by the criteria, the type of treatment proposed is that known as the activated sludge process, a widely used aerobic biochemical treatment process. The basic principle employed is that of intimately mixing the degradable organic waste with the biological matter that absorbs the waste. If sufficient concentration of bacteria exists in the mixture, the waste disappears in a short period of time, utilized as food by the biota and converted to carbon dioxide, water, and energy. The conversion process basically requires time, initial biota, some nutrients and free oxygen.

With regard to the recharge of plant effluent, pilot studies, or investigations, must be conducted to establish satisfactory methods of final treatment to assure that the recharged water will be of adequate quality.

Treatment Units

The design of the treatment units will comply with the requirements of the New Jersey State Department of Health.

Units for treatment of wastewater will include:

- Coarse Screens and Grinders
- Primary Pumping Facilities
- Grit Chambers
- Primary Settling Tanks
- Aeration Tanks
- Final Settling Tanks
- Chlorination Equipment and Chlorine Contact Tanks
- Secondary Pumping Facilities

Solid wastes, retained by the plant, will be concentrated, digested to reduce the weight and volume of solids, and disposed by suitable method.

A flow chart of the plant process is shown on PLATE 24.

Plant Capacity

Initial plant capacity will be for an average daily flow of 20 MGD. Future expansion will be planned to raise capacity ultimately to handle a flow of 60 MGD.

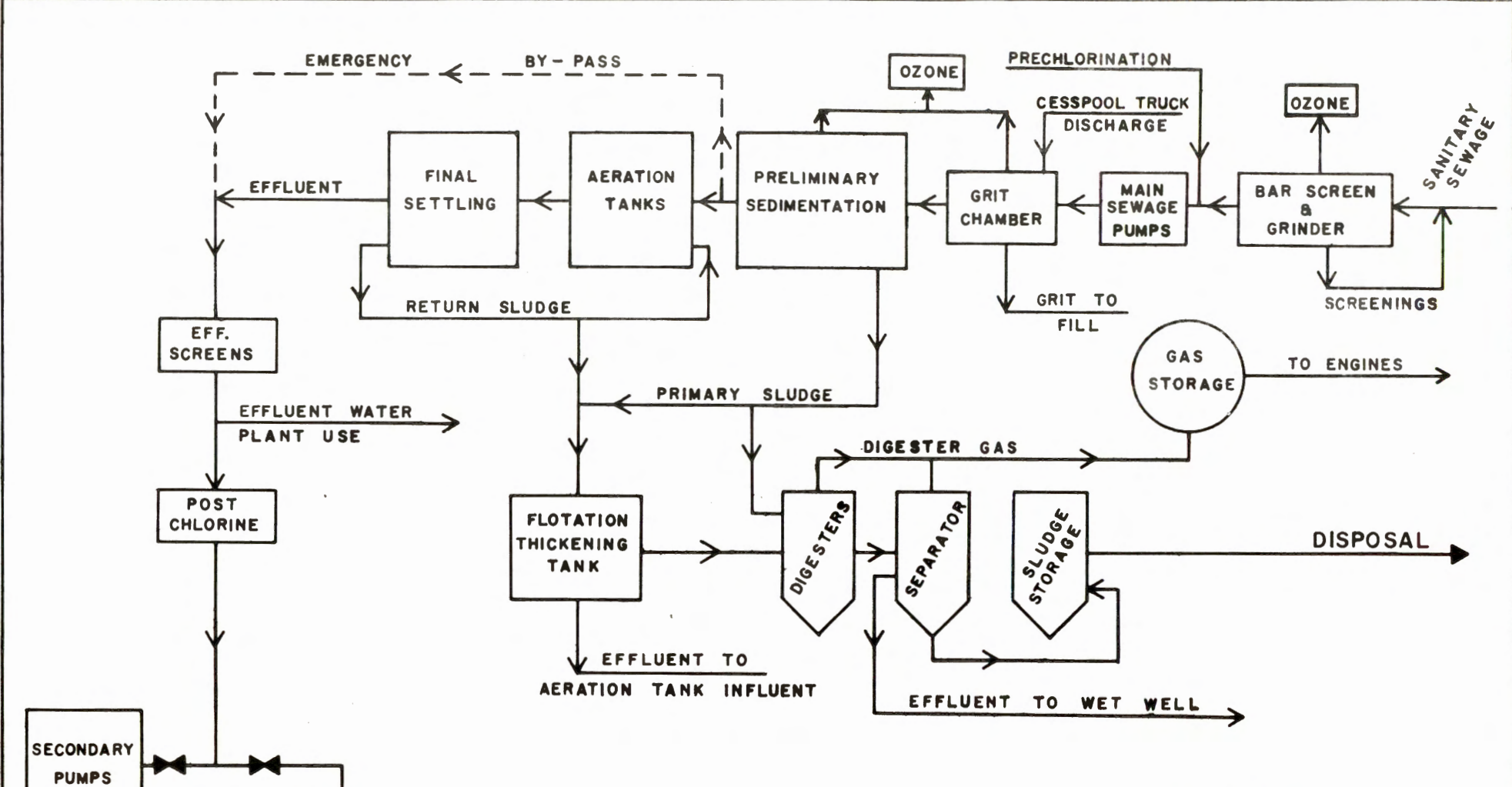
Coarse Screens and Grinders

Screens will be installed in duplicate. One screen will serve as standby. Screenings suitable for return to the flow will be shredded and ground; the balance will be trucked to a suitable site for disposal.

Primary Pumping Facilities

Following coarse screening, the wastewater will flow to the suction well of the pumping station. Multiple pumping units will deliver flow to the grit removal facilities.

The initial pumps will be capable of handling flows in excess of the expected peak flow, and will be designed to fit actual flow conditions. With any one pump out of service, the remaining pumps will have adequate capacity to handle maximum flows.



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 DEPARTMENT OF HEALTH
 STONY BROOK-MILLSTONE
 SEWERAGE STUDY COMMITTEE

STONY BROOK-MILLSTONE WATERSHED
 REGIONAL SEWERAGE FEASIBILITY STUDY
 WATER POLLUTION CONTROL FACILITIES

FLOW CHART OF PROCESS

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PLATE 24

In the future, additional pumping units will be installed in the space provided, to raise capacity as necessary to handle the expected increased flow.

Two force mains will connect with the grit chambers. At the initial low flows, one force main will provide for adequate, self-cleansing flow velocities.

Aerated Grit Chambers

Two aerated grit chambers will be provided initially with provision for a future chamber. Any two chambers will be adequate for the future maximum rate of flow.

The design will be adequate to keep organic matter in suspension and permit grit and similar inorganic matter to settle. The retained material will be removed by conveyors for direct truck loading for use as fill.

Primary Settling Tanks

The primary settling tanks will have a surface settling rate not exceeding 600 gallons per square foot per day for the design flow. The average depth will be 8 feet. Mechanical means will be provided for collecting sludge and scum.

Pumps for raw primary sludge will be located in an adjacent gallery, and these will deliver sludge either to thickening facilities or to digestion tanks.

Aeration Tanks

The proposed treatment plant will use the "step aeration" method of the activated sludge process. Return sludge will be introduced at the influent end of tanks and primary effluent at intervals along the tank axis. The first portion of the tank will be utilized for waste aeration.

Multiple, 15-foot deep tanks, capable of independent operation will be provided. The dimensions and proportions of the units shall be such as to maintain effective utilization of air and avert unaerated sections.

The need for special foam reduction equipment is not anticipated because, at the time of plant construction, detergents should be of the low sudsing, biodegradable type.

Final Settling Tanks

Multiple units, 10 to 11 feet deep, will afford a detention of 1.8 hours with an overflow rate of 1000 gallons per square foot per day at design flow.

Each tank will be equipped with longitudinal and transverse collectors. Facilities to automatically control sludge depth in the tanks will be installed. Secondary sludge, because of its high water content will be delivered to the thickening facilities for concentration prior to digestion.

Chlorination Equipment and Chlorine Contact Tanks

Chlorination equipment, consisting of devices for handling gas cylinders and for metering and feeding adequate amounts of chlorine to both the influent raw waste and the processed effluent as necessary, will be provided. Standby equipment will be furnished, and space will be provided for future additions. Chlorine residual measuring equipment will be installed to adjust chlorine feed rates and produce an automatic system insofar as possible.

A baffled chlorine contact tank will be constructed in which to chlorinate final effluent for disinfection purposes. The tank will provide 30 minutes detention at a flow of 20 MGD. Future construction will provide additional capacity for the ultimate average design flow of 60 MGD.

Secondary Pumping Facilities

Secondary pumping facilities will be provided as required for plant operation, and for distributing treated effluent to the wastewater reclamation facilities.

Sludge Digestion and Disposal

Before further treatment and disposal, sludge will be digested to reduce the weight and volume of solids for more economical subsequent disposal.

Digestion tanks will be heated and provided with mixing devices. A centrally located control building will house transfer pumps, boilers, heat exchangers, gas meters and gas safety equipment. The gas produced by the digestion process will be utilized as a source of power and heat.

The digested sludge will be disposed of by dewatering by means of vacuum filtration or centrifugation and used for land fill or soil conditioning, or, as an alternative, may be heat dried and destroyed by

multiple hearth incineration. Consideration will also be given to employment of the fluid solids or wet oxidation processes for final sludge disposal.

Odor Control

Good public relations are extremely important to any public works project. One of the most common complaints related to treatment plant location is odor. This condition can be controlled by good house-keeping and modern design practices. Common practice provides for enclosure of odor-producing units in the treatment process, with positive conditioning of the contained atmosphere before exhaustion to the outside. Ozonation is one accepted method of conditioning.

Power

It is feasible to generate all power for plant operation using dual-fueled engines, sludge gas and commercial gas (or fuel oil). Electric power can also be used, if rates are favorable, and standby power is available at the source.

Sludge gas for plant use will be stored in a storage sphere. Excess gas, if any, will be destroyed in waste gas burners.

Administration Building

This building will serve as the control center of the plant, monitoring all major plant operations. The building, located at the plant entrance, will provide office space for supervisory personnel and a laboratory.

Maintenance Building

A garage and repair shop for minor maintenance of vehicular equipment will be provided. A small machine shop, furnished with suitable machine tools for maintenance of plant equipment, and storage space for spare parts and other accessories will be provided in this facility.

PROPOSED WASTEWATER RECLAMATION FACILITIES

General

There are two basic reasons to justify the proposed construction of facilities to reclaim, or renovate, wastewater for re-use:

1. To conserve water resources in the Watershed.
2. To provide a satisfactory means by which processed plant effluent can be disposed during drought periods when relatively low flows will exist in the Millstone River. The low amount of residual waste in the highly treated plant effluent might easily overwhelm the limited dispersal capability of a low river flow.

It is proposed, therefore, to provide facilities by which processed effluent can be conveyed to certain areas within the Watershed for renovation and disposition, initially, by recharging the underlying ground water aquifers. Pilot studies will be conducted, during early stages of plant operation, to determine optimum methods of renovation and alternate disposal for reclaimed water.

Wastewater Reclamation Facilities

The proposed reclamation facilities are shown on PLATE 25 and include the following:

1. Pumping facilities to be located at the water pollution control plant. The pumps will have variable capacities so that varying quantities of treated waste effluent can be pumped to the recharge areas. The rate of pumping and initial installed capacity will be determined from pilot recharge studies.
2. Two 36-inch force mains from the water pollution control plant, running south-easterly across the Millstone River to proposed recharge basins located in Franklin Township and South Brunswick Township. It is anticipated that recharge basins in Franklin will recharge aquifers in the Lower Millstone and Stony Brook Sub-Watersheds. The recharge basins in South Brunswick will recharge the Upper Millstone Sub-Watershed aquifers.
3. Recharge areas have been tentatively selected from geologic and topographic maps. The most desirable site should be acquired based on soil tests and geologic investigations. Additional pilot studies and

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REGIONAL SEWERAGE FEASIBILITY STUDY

PROPOSED RECHARGE FACILITIES

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monitoring programs will determine the basis of design for the recharge basins. For this study, required basin area has been based on a rate of 0.5 cfs per wetted acre. (7.5 gal. per square foot per day.) Additional land area will be required for landscaping and to act as a buffer zone.

To recharge an average plant effluent flow of 20 MGD, the required basin area is approximately 67 acres. The ultimate area required for 60 MGD is approximately 200 acres.

Pilot Recharge Studies

The initial low flows to the water pollution control plant would be the basis for pilot recharge studies utilizing prototype facilities. These studies would determine:

1. The feasibility of reclaiming waste water at reasonable cost and the practical aspects of recharge.
2. The requirement for tertiary treatment.
3. Hydrological effects on ground waters in the recharge areas.
4. Effects on stream flow.
5. Effect on ground water quality in the area.
6. Effect on the water bearing strata.
7. Cost of installation, operation, and maintenance of recharge basins.
8. The most economical and efficient type of basin and method of operation. Several types of basins or methods of operation may be employed as follows:
 - (a) Dosing siphon to each bed.
 - (b) Direct flow to center of each bed.
 - (c) Flow to one basin - overflow to recharge basin.
 - (d) Continuous operation.
 - (e) Intermittent operation.
 - (f) Clean and harrow after each use.
 - (g) Clean and harrow seasonally.
 - (h) Clean and harrow based on permeability rate.
 - (i) Maintain constant water head.
 - (j) Facilities for backwash.

- (k) Different types of filter material.
- (l) Underdrains.
- (m) Controls.

Based on the data obtained from the pilot recharge studies, plans for extension of the recharge system shall be formulated.

Monitoring and Research Program

A most important part of the initial pilot study and future recharge basin management will be a monitoring and research program. The program might include:

1. Observation wells.
2. Sample collection facilities.
3. Testing procedures to determine effect on ground water.
4. Subsurface exploration.
5. Water quality tests at adjacent wells.
6. Injection well tests.
7. Tests for improving percolation rates.
8. Metering and automation of basins.
9. Development of various secondary and tertiary polishing treatment processes to be used in conjunction with injection wells or possibly basins.
10. Research and other methods of recharge.

Physical Requirements for Recharging

Factors affecting the success of the proposed recharge facilities include the following:

1. Geology
2. Recharge rate
3. Quality of recharged wastewater

Geology

The recharge facility must be suitable from the standpoint of storage capacity and transmissibility of aquifers. Referring to previously presented PLATES 16 and 17, excellent areas for recharge are represented by the Magothy and Raritan outcrops and the Stockton Sandstone outcrop.

To the southeast of the geologic fall line, the unconsolidated coastal plain formations are overlain by a fairly thick lensatic mantle of sands, gravels and clays. Because of the coarseness of the sand and gravel, the overlying mantle acts as a sponge and most of the precipitation soaks in and percolates down to the water table, recharging the underlying formations.

Northwest of the fall line and southeast of Carnegie Lake, the Stockton Sandstone is also overlain by a mantle which acts like a sponge to recharge the sandstone.

Northwest of Carnegie Lake and the Delaware and Raritan Canal, the Stockton Sandstone is covered by topsoil and subsoil and may have some potential for the location of recharge basins.

Recharge Rate

Recharging rates must be maintained at adequate levels in the recharge areas, consistent with the permeability of the sub-strata.

Wastewater Quality

Recharged wastewater must have a suitable temperature and be chemically compatible with the existing ground water. The mineral salt content of reclaimed wastewater must be evaluated not only from the standpoint of immediate effects, but also future effects, as the salts may accumulate in the aquifer.

Ground water in the Coastal Plain section of the Watershed is generally low in dissolved solids (less than 100 mg/l). In the Piedmont section of the Watershed, the water has a higher dissolved solids content.

The mineral increment in a water passing through a municipal system from source to point of disposal usually ranges from 100 to 300 mg/l of total dissolved solids, when industry is not a significant factor. Should the recharged wastewater increase the mineral content of the ground water above the presently recommended 500 mg/l limit set by the U. S. Public Health Service for domestic water supplies, future

waste treatment processes will require inclusion of techniques capable of removing these dissolved materials.

Where industrial wastes are not significant, conventional treatment methods have been used for the removal of organics from wastewater to the degree necessary for direct recharge of ground waters.

Methods of Recharge

Current wastewater reclamation projects make use of the following methods to recharge renovated water into the underlying aquifers:

1. Injection wells.
2. Spreading or Recharge Basins.

Injection Wells

Existing reports indicate that the use of injection wells is limited by:

1. Relatively small capacity.
2. High cost of method in comparison to surface spreading systems.
3. High incidence of clogging.

Recharge Basins

At the present time, it appears that spreading basins are the most economical means of recharge. Operating experiences for this method indicate successful results with proper basin management.

Location of Recharge Basins

As previously noted, excellent recharge areas are located in the vicinity of the geologic fall line in the Stockton Sandstone and Magothy and Raritan outcrops. Two possibilities exist in connection with development of facilities at the selected site or sites:

1. Centralized basins.
2. Basins distributed across the area.

Centralized Recharge

Advantages of locating all basins in one area are:

1. Simpler operation and maintenance.
2. Lower construction costs.

Disadvantages:

1. Sufficient area may not be available in one area.
2. High hydraulic loading in a concentrated area.
3. Only one area benefitting by the effects of recharge.
4. The selected area may not prove to be the best area for recharge.

Distributed Recharge Basins

The advantages of several recharge sites are as follows:

1. By observation tests, the most suitable area can be selected for further development.

2. Lower hydraulic loading per area.
3. Smaller area per basin.
4. Flexibility of operation.

5. It is anticipated that recharge basins northeast of the geologic fall line will recharge ground waters in the Lower Millstone and Stony Brook Sub-Watersheds. Recharge basins southeast of the fall line will recharge aquifers in the Upper Millstone Sub-Watershed.

Disadvantages of the distributed basins:

1. Higher capital costs.
2. Higher operation and maintenance.

Considering all the factors, it is proposed that recharge basins be distributed.

ESTIMATE OF CAPITAL COSTS
FOR
ULTIMATE REGIONAL SYSTEM

Project Costs

TABLES 18, 19, 20 and 21 respectively present a summary of ultimate total capital costs for the entire regional system and the various parts, consisting of the wastewater collection facilities, the water pollution control facilities and the wastewater reclamation facilities.

Trend of Rising Construction Costs

Since 1940, construction costs have been rising approximately 5% per year. PLATE 26 is a graph indicating the Engineering News-Record Construction Cost Index from 1913 to 1966 and its projection to 1970, the year in which construction is expected to start and the year in which the financial obligations on the bond issue will begin. The 1970 projection was used to increase estimated project costs.

Basis for Estimating Construction Costs

1. Water Pollution Control Facilities - PLATE 27 indicates, graphically, the basic costs of secondary treatment plants used for estimating facilities in the Stony Brook-Millstone Watershed. The chart was prepared from cost data compiled by this organization, the U. S. Public Health Service and other sources. To these costs, pertinent cost features such as site work and pumping facilities were added. A preliminary detailed estimate of cost was prepared, based on a preliminary design. Price quotations were obtained for the major items of manufactured equipment and include costs of installation.

The water pollution control plant estimate includes the total cost of a 20 MGD secondary treatment plant. Units not readily expanded would be designed for the ultimate tributary flow of 60 MGD. The total construction cost includes pumping facilities, site work, foundation work, structures, equipment, landscaping, grading and a garage and maintenance building.

2. Interceptors - Construction cost estimates were based on preliminary designs which were made utilizing existing topographic maps. No exploratory borings were taken to determine sub-surface conditions.

TABLE 18

SUMMARY OF ULTIMATE TOTAL PROJECT COST
FOR
REGIONAL SYSTEM FOR WASTEWATER DISPOSAL

<u>Facilities</u>	<u>Construction</u>	+	<u>Land</u>	=	<u>Total</u>
Wastewater Collection	\$33,084,475		\$840,525		\$33,925,000
Water Pollution Control:					
- Initial Construction	10,554,000		360,000		10,914,000
- Future Expansion	8,136,000		0		8,136,000
Wastewater Reclamation	<u>23,950,000</u>		<u>900,000</u>		<u>24,850,000</u>
TOTAL ULTIMATE COST	\$75,724,475		\$2,100,525		\$77,825,000

TABLE 19
SUMMARY OF ULTIMATE TOTAL COST
FOR
WASTEWATER COLLECTION FACILITIES

Facilities	Cost
Stony Brook Interceptor	\$ 5,437,000
Upper Millstone Interceptor	4,475,000
Lower Millstone South Interceptor	5,696,000
Lower Millstone North Interceptor	2,456,000
Sub-Total	\$18,064,000
Lower Millstone Pumping Station	\$ 360,000
Lower Millstone Force Mains	5,040,000
Construction Cost	\$23,464,000
+ 20% Development Cost, say	4,693,000
Total Construction Cost (1966-ENR=1000)	\$28,157,000
Total Construction Cost Adjusted to 1970 Costs (ENR-1175)	
$\frac{1175}{1000} \times \$28,157,000 =$	\$33,084,475
Land Acquisition and Easements	840,525
TOTAL ULTIMATE COST	\$33,925,000

TABLE 20
SUMMARY OF ULTIMATE COST
FOR
WATER POLLUTION CONTROL FACILITIES

<u>Units</u>	
Primary Pumping Station	\$ 400,000
Aerated Grit Chambers	70,000
Primary Settling Tanks	400,000
Aeration Tanks	800,000
Secondary Settling Tanks	500,000
Contact Tank - Chlorine Building	170,000
Secondary Pumping	300,000
Digestion Tanks	580,000
Gas Holder	75,000
Sludge Thickening Installation	150,000
Administration Building	200,000
Blower and Generator Building	800,000
Sludge Oxidation Plant	900,000
Ash Thickening Tank	40,000
Garage and Maintenance Building	<u>100,000</u>
Sub-Total	\$5,485,000
 <u>Special Trades</u>	
Electrical	\$1,000,000
Heating and Ventilating	200,000
Plumbing	100,000
Miscellaneous Piping and Valves	<u>200,000</u>
Sub-Total	\$1,500,000

TABLE 20 (Continued)

SUMMARY OF ULTIMATE COST
FOR
WATER POLLUTION CONTROL FACILITIES

<u>Site Work</u>		
Site Preparation		\$ 100,000
Special Foundation Allowance		100,000
Walks and Roads		100,000
Landscaping		60,000
Fencing		40,000
Contingencies		<u>100,000</u>
	Sub-Total	\$ 500,000
Construction Cost		7,485,000
+ 20% Development Expense		<u>1,497,000</u>
Total Construction Cost (1966 ENR = 1000)		\$8,982,000
Total Construction Cost Adjusted to 1970 Costs (ENR-1175)		
$\frac{1175}{1000}$	X \$8,982,000 =	\$10,553,850
	say	10,554,000
Land Acquisition - 80 Acres @ \$4,500/acre		<u>360,000</u>
TOTAL COST OF FACILITIES FOR INITIAL CONSTRUCTION		\$10,914,000
Additional Cost for Plant Expansion to Ultimate Capacity		<u>8,136,000</u>
TOTAL ULTIMATE COST		\$19,050,000

TABLE 21

SUMMARY OF ULTIMATE TOTAL COST
FOR
WASTEWATER RECLAMATION FACILITIES

Recharge Basins		
200 acres @ \$50,000/acre =		\$10,000,000
Force Main to Recharge Facilities		
45,000 l.f. of 2-36" dia. @ \$140/l.f. =		6,300,000
Initial Pumping Facility		
20 MGD @ \$16,000/MGD =		320,000
Future Pumping Facilities for 60 MGD		<u>365,000</u>
	Sub-Total	\$16,985,000
+ 20% Development Expense		<u>3,397,000</u>
	Total Construction Cost (1966 ENR = 1000)	\$20,382,000
Total Construction Cost Adjusted to 1970 ENR = 1175		
	$\frac{1175}{1000} \times \$20,382,000$, say	\$23,950,000
Land Acquisitions and Easements		<u>900,000</u>
TOTAL ULTIMATE COST		\$24,850,000

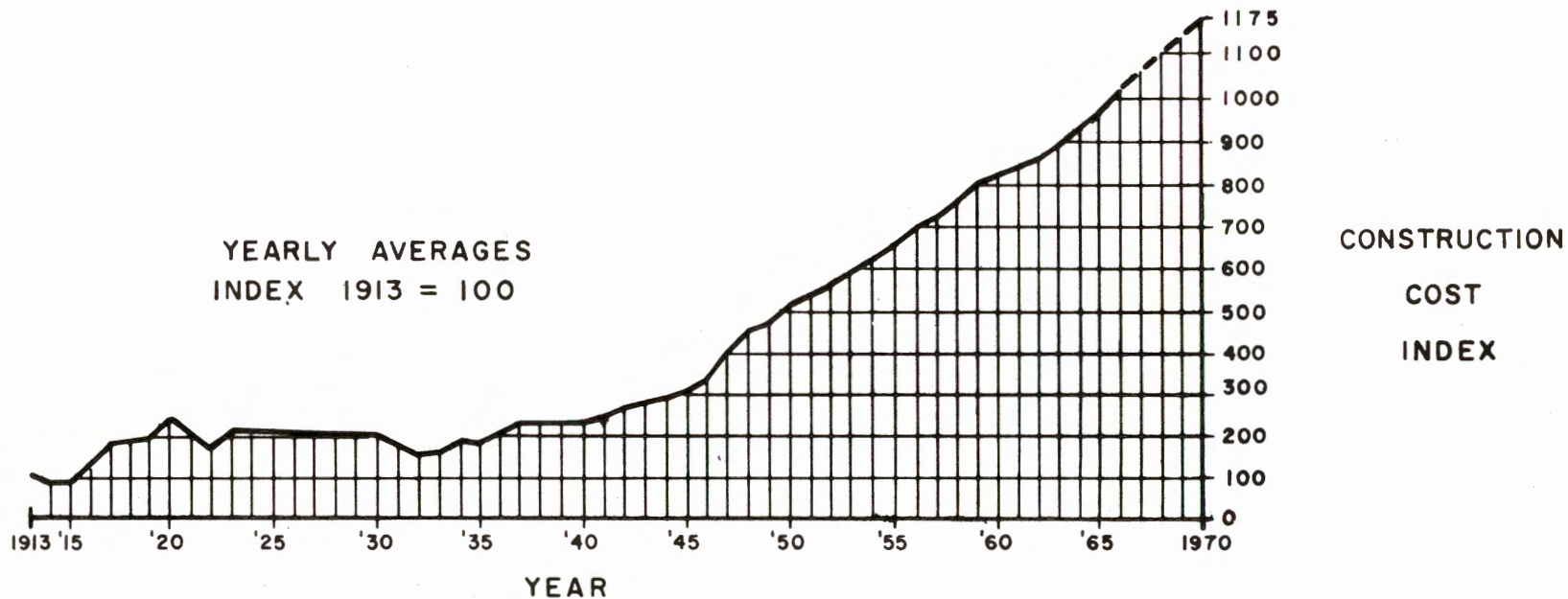


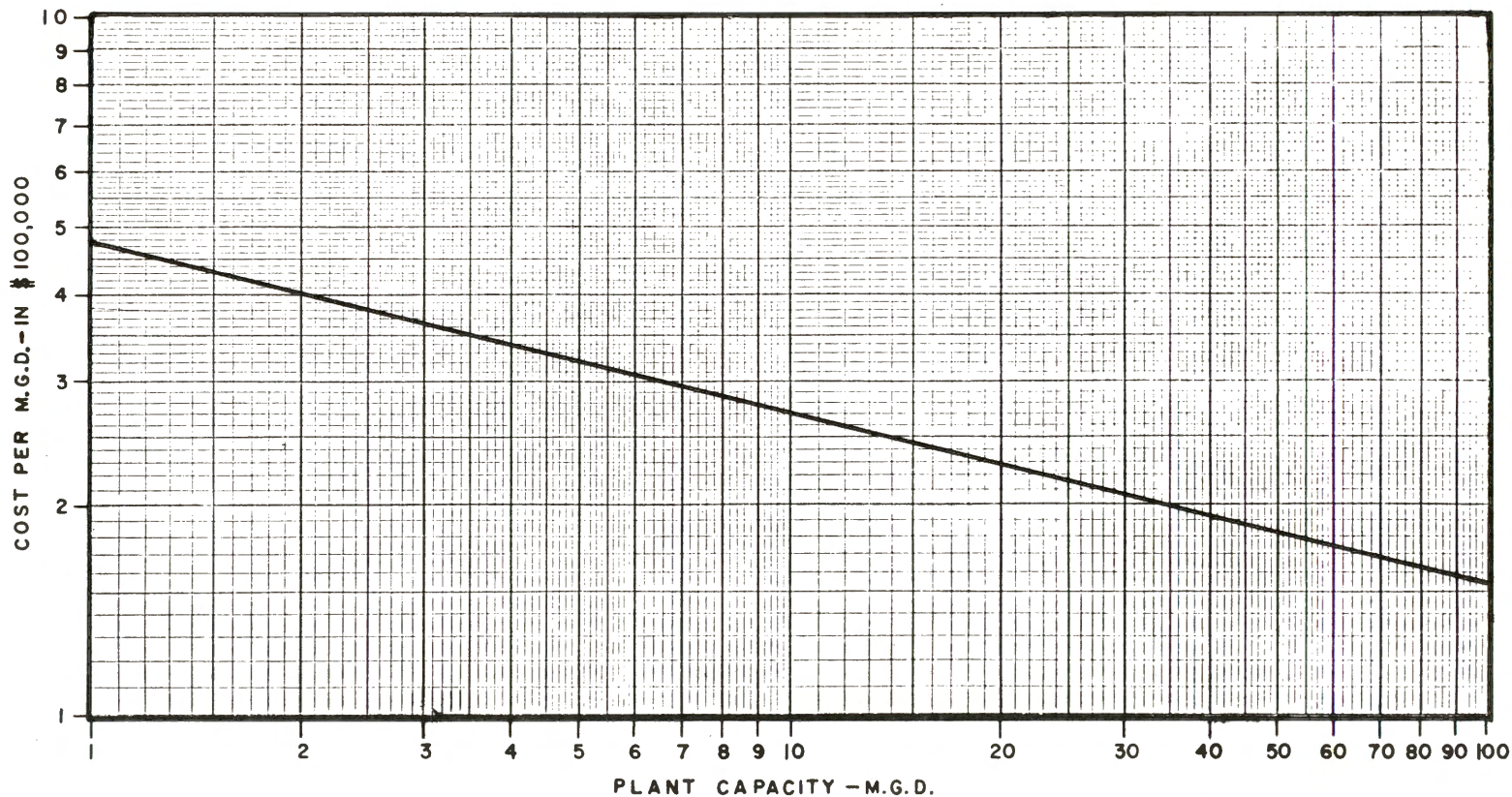
PLATE 26

NEW JERSEY STATE
DEPARTMENT OF HEALTH
STONY BROOK-MILLSTONE
SEWERAGE STUDY COMMITTEE

STONY BROOK-MILLSTONE WATERSHED
REGIONAL SEWERAGE FEASIBILITY STUDY
ENGINEERING NEWS-RECORD INDEX
OF COST TRENDS 1913-1970

SEELYE STEVENSON VALUE & KNECHT
CONSULTING ENGINEERS
PRINCETON, N. J. NEW YORK, N. Y.

PRIMARY AND SECONDARY TREATMENT



NEW JERSEY STATE
 DEPARTMENT OF HEALTH
 STONY BROOK-MILLSTONE
 SEWERAGE STUDY COMMITTEE

STONY BROOK-MILLSTONE WATERSHED
 REGIONAL SEWERAGE FEASIBILITY STUDY
 CONSTRUCTION COSTS
 WATER POLLUTION CONTROL FACILITIES

SEELYE STEVENSON VALUE & KNECHT
 CONSULTING ENGINEERS
 PRINCETON, N. J. NEW YORK, N. Y.

COSTS ARE BASED ON ESTIMATED
 1966 CONDITIONS, E. N. R. INDEX = 1000
 FOR PRIMARY AND SECONDARY
 TREATMENT FACILITIES

PLATE 27

Costs for interceptors are based on current costs compiled for similar work and are presented graphically on PLATE 28. The costs include trenching, installation, manholes, backfilling, sheeting, pavement cutting and replacement, an allowance for rock excavations, and miscellaneous work.

3. Pumping Stations and Force Mains - The cost of pumping stations and force mains were estimated from a compilation of construction costs for similar facilities presented graphically on PLATES 29 and 30 respectively.

4. Recharge Basins - The cost of recharge basins were based on estimates prepared by this office, and were compared with similar work such as sand filter beds and storm water recharge basins. The costs include excavation, piping, fencing, ramps, development, landscaping and other appurtenant work.

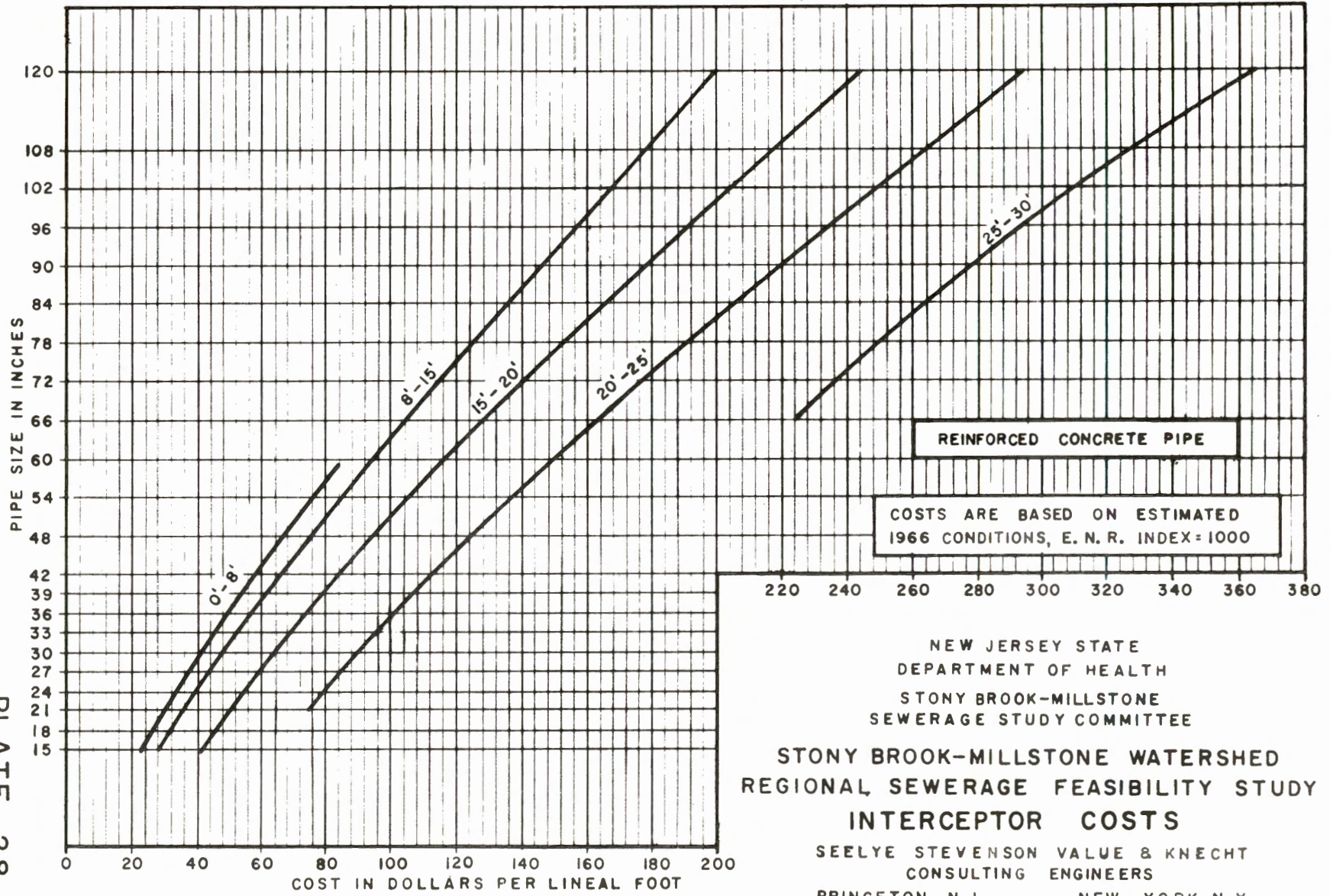
5. Development Expense - An allowance of 20% has been included for legal, engineering, cost of financing, administrative and other pertinent expenses.

Cost of Real Estate and Easements

The total project cost estimated includes the cost of land acquisition for treatment plants and pumping stations and the estimated cost of right of way easements for the interceptors and force mains. The unit costs used for these items are as follows:

Land acquisition per acre = \$4,500.00

Easements per linear foot = \$ 3.00



NEW JERSEY STATE
DEPARTMENT OF HEALTH
STONY BROOK-MILLSTONE
SEWERAGE STUDY COMMITTEE

STONY BROOK-MILLSTONE WATERSHED
REGIONAL SEWERAGE FEASIBILITY STUDY
INTERCEPTOR COSTS

SEELYE STEVENSON VALUE & KNECHT
CONSULTING ENGINEERS
PRINCETON, N.J. NEW YORK, N.Y.

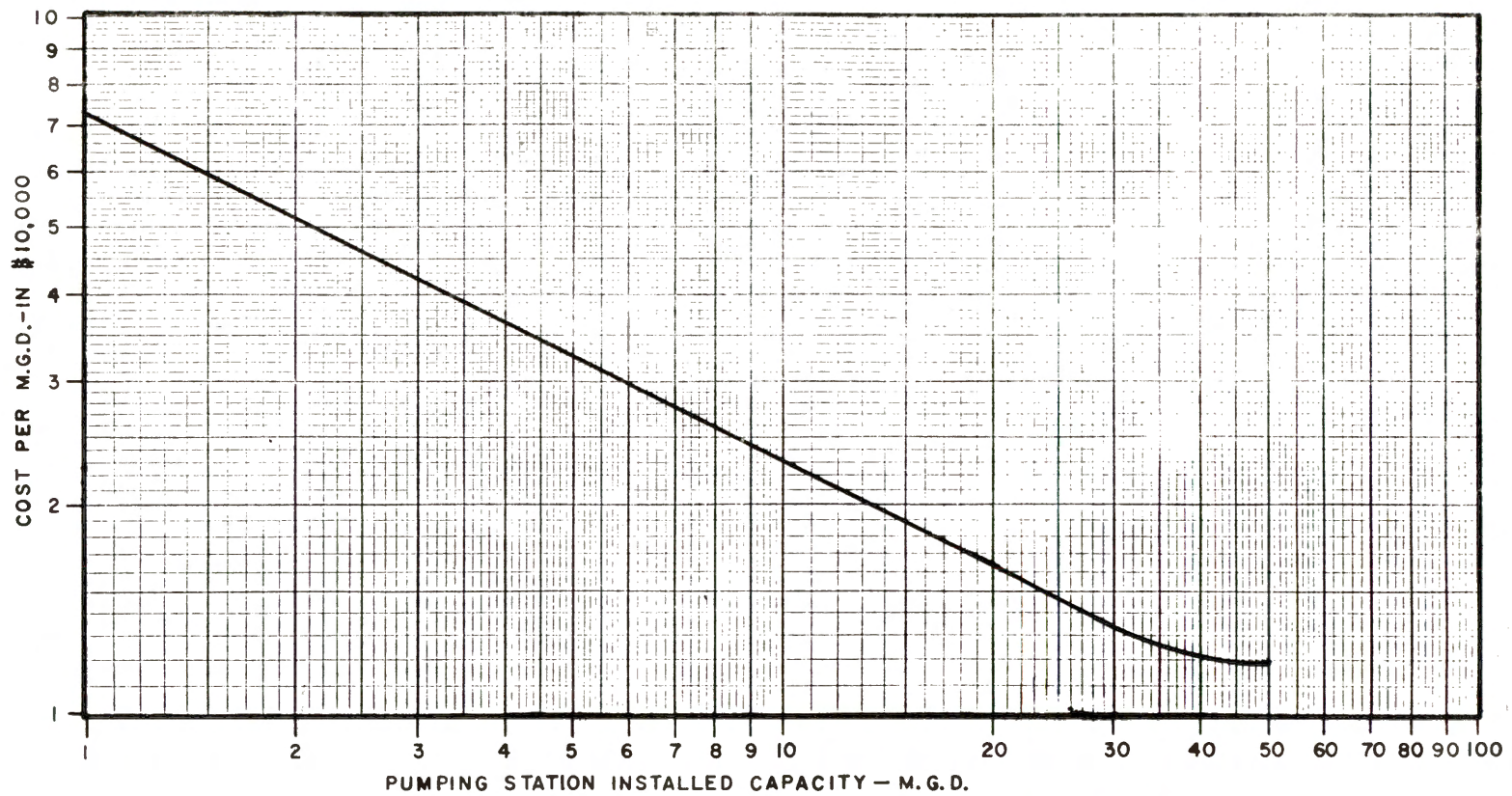


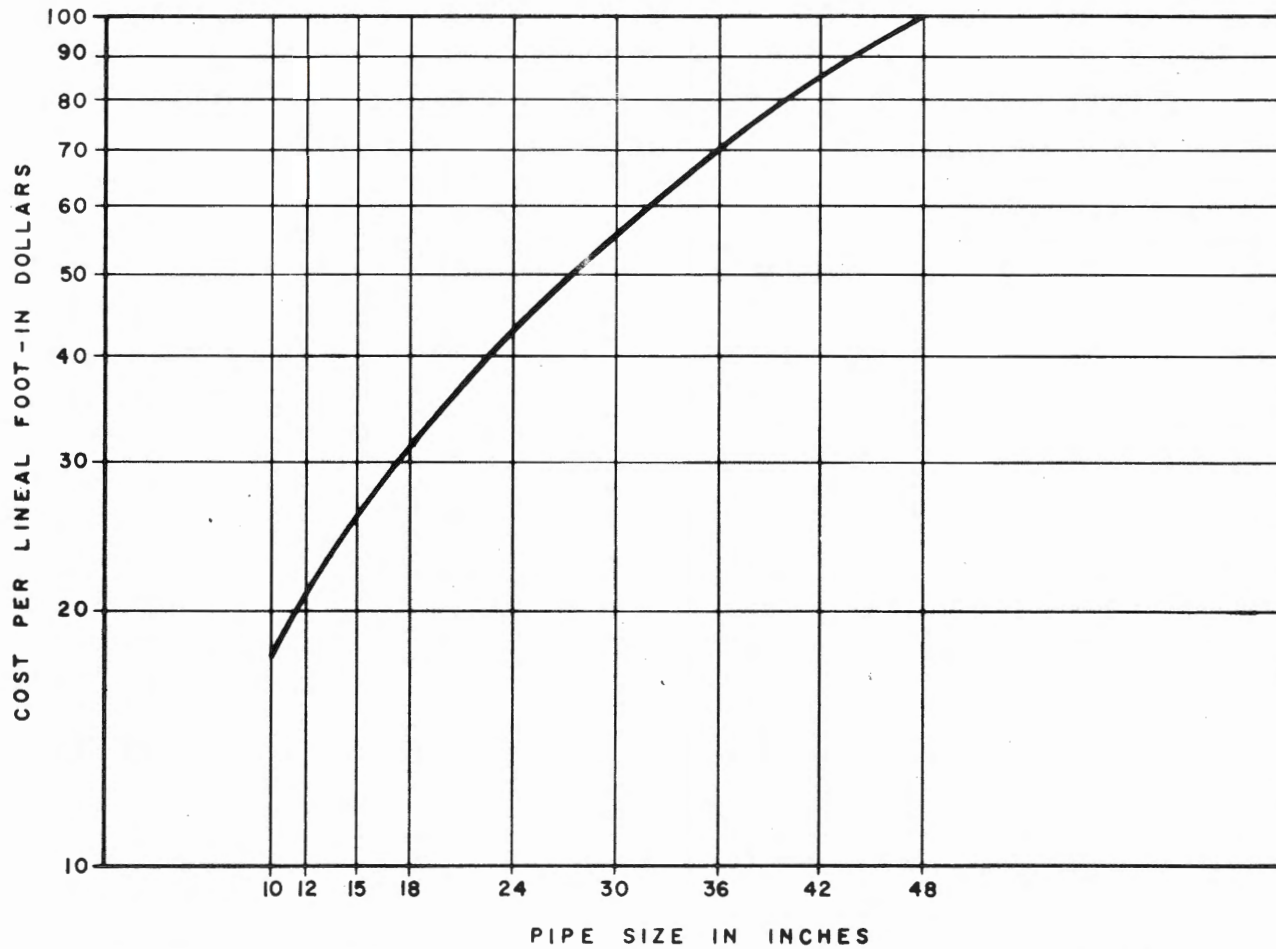
PLATE 29

COSTS ARE BASED ON ESTIMATED
1966 CONDITIONS, E. N. R. INDEX = 1000

NEW JERSEY STATE
DEPARTMENT OF HEALTH
STONY BROOK-MILLSTONE
SEWERAGE STUDY COMMITTEE

STONY BROOK-MILLSTONE WATERSHED
REGIONAL SEWERAGE FEASIBILITY STUDY
CONSTRUCTION COSTS
WASTEWATER PUMPING STATIONS

SEELYE STEVENSON VALUE & KNECHT
CONSULTING ENGINEERS
PRINCETON, N. J. NEW YORK, N. Y.



COSTS ARE BASED ON ESTIMATED
1966 CONDITIONS, E.N.R. INDEX = 1000

NEW JERSEY STATE
DEPARTMENT OF HEALTH
STONY BROOK-MILLSTONE
SEWERAGE STUDY COMMITTEE

STONY BROOK-MILLSTONE WATERSHED
REGIONAL SEWERAGE FEASIBILITY STUDY
FORCE MAIN COSTS

SEELYE STEVENSON VALUE & KNECHT
CONSULTING ENGINEERS
PRINCETON, N. J. NEW YORK, N. Y.

PLATE 30

ESTIMATE OF CAPITAL COSTS
FOR
INITIAL FACILITIES CONSTRUCTED

Initial Facilities to be Constructed

In order that the proposed regional system be completely functional, the initial construction of facilities must include a portion of the wastewater collection facilities, and water pollution control facilities capable of handling a flow of 20 MGD to serve the potential immediate contributors. In addition, in order to begin the recharge studies and pilot program, recharge basins adequate for 4 MGD will be constructed.

Construction Period

The estimated length of time for design and construction of initial facilities is four years. The remaining interceptors and recharge facilities will be constructed in future years as required.

The recommended initial construction program for the regional facilities is shown on PLATE 31.

Capital Costs for Initial Facilities Constructed

The detailed capital cost for the initial construction of the regional facilities is summarized in TABLE 22. The total initial capital cost, adjusted to 1970 estimated prices, amounts to about \$34,877,000. For an estimated immediate contributory population of 83,140, previously shown in TABLE 15, the cost per person is approximately \$420. This is a relatively reasonable capital expenditure per capita for the service to be obtained.

Additional Cost for Oversize Interceptors

The initial facilities to be constructed to serve the immediate contributors include interceptors sized for the ultimate contributing population. The immediate contributors, therefore, are actually paying a slightly higher capital cost for these oversized interceptors than would be necessary if the proposed system were to be designed with capacity limited to that necessary to handle only waste delivered by the immediate contributors. The total capital cost differential involved amounts to about 10 per cent of the initial wastewater collection facilities cost and is well worth paying in the primary construction phase to permit economical future system expansion to accommodate future participants. This subject is more fully discussed in the section of the APPENDIX entitled Limited Regional System for Wastewater Disposal.

STONY BROOK-MILLSTONE WATERSHED
 REGIONAL SEWERAGE FEASIBILITY STUDY

**RECOMMENDED
 INITIAL CONSTRUCTION**

SEELYE STEVENSON VALUE & KNECHT
 CONSULTING ENGINEERS
 PRINCETON, N.J. NEW YORK, N.Y.





-  REGIONAL INTERCEPTOR
-  FORCE MAIN
-  WATER POLLUTION CONTROL FACILITIES
-  RECHARGE BASIN



TABLE 22

DETAILED COST SUMMARY FOR INITIAL CONSTRUCTION
OF REGIONAL SYSTEM FACILITIES

<u>Facilities</u>	<u>1970 Construction Cost*</u>	<u>Land & R. O. W.</u>	<u>Total Project Cost</u>
Water Pollution Control	\$10,554,000	\$360,000	\$10,914,000
Wastewater Collection:			
Stony Brook Interceptor	5,832,000		
Upper Millstone Interceptor	3,590,000		
Lower Millstone So. Interceptor	<u>8,031,000</u>		
Collection Sub-Total	\$17,453,000	\$354,000	\$17,807,000
Wastewater Reclamation:			
Force Main	\$ 4,442,500		
Basins 15 Acres	1,057,500		
Pumping Station	<u>450,000</u>		
Reclamation Sub-Total	\$ 5,950,000	\$206,000	\$ 6,156,000
TOTAL CONSTRUCTION COST (1970 ENR 1175)			<u>\$34,877,000</u>

* Includes 20% Development Expense

ESTIMATE OF ANNUAL COSTS
FOR
REGIONAL SYSTEM FACILITIES

Method of Developing Annual Costs

The approximate annual costs, which would be incurred by an operating organization, for the ultimate regional system facilities are shown in TABLE 23. The table also indicates the approximate annual rate charges to system participants per million gallons of waste treated.

To develop this tabulation, the following simplifying assumptions have been made:

1. Construction would be completed and financing would begin in 1970. Initial facilities would include a 20 MGD water pollution control plant, reclamation facilities for 4 MGD and a portion of the wastewater collection facilities. The initial construction capital cost for these facilities is estimated at \$34,877,000, as previously shown in TABLE 22.
2. A project capital cost of \$2,300,000 would be spent about 1973 to increase recharge basin capacity to 20 MGD.
3. A \$40,648,000 expansion to the water pollution control and wastewater reclamation facilities would be provided in 1985 to furnish additional system capacity to 60 MGD.
4. All construction would be financed by the issuance of 30-year revenue bonds at 4-1/2% interest rate. Debt service is assumed to be constant over each 30-year bond term.
5. A reserve fund would be established with an annual contribution amounting to 10% of the debt service to provide additional interest coverage on bonds and to cover some portion of depreciation on facilities.

The annual costs shown in TABLE 23 would be apportioned to each participating municipality in proportion to the actual metered flow contributions received from each. The annual amounts paid, by each municipal participant, to the operating organization, would in turn, be recovered by charges to the benefited users within each municipality.

It has been assumed, in determining the annual costs and rate charges listed in TABLE 23, that the operating organization would have no

TABLE 23

ESTIMATED ANNUAL RATES TO BE CHARGED TO PARTICIPATING
MUNICIPALITIES FOR ULTIMATE REGIONAL DISPOSAL FACILITIES

Year	Project	Cumulative Project Cost	Est. Average Daily Flow MGD	Total Annual Flow MG/Yr.	Operation and Maintenance Cost	Debt Service	Reserve Fund	Total Annual Cost	Rate Per MG
1970	\$34,877,000	\$34,877,000	8.0	2,920	\$ 325,000	\$2,141,000	\$214,100	\$2,680,100	\$918
1971			8.3	3,030	335,000	2,141,000	214,100	2,690,100	888
1972			8.7	3,180	340,000	2,141,000	214,100	2,695,100	847
1973			23,000,000	37,177,000	9.0	3,280	345,000	2,282,000	228,200
1974			9.3	3,390	355,000	2,282,000	228,200	2,865,200	845
1975			9.6	3,500	365,000	2,282,000	228,200	2,875,200	821
1976			10.0	3,650	375,000	2,282,000	228,200	2,885,200	790
1977			10.5	3,830	385,000	2,282,000	223,200	2,895,200	755
1978			11.0	4,020	400,000	2,282,000	228,200	2,910,200	724
1979			11.5	4,200	415,000	2,282,000	228,200	2,925,200	696
1980			12.0	4,380	425,000	2,282,000	228,200	2,935,200	670
1981			12.8	4,670	450,000	2,282,000	228,200	2,960,200	634
1982			13.7	5,000	470,000	2,282,000	228,200	2,980,200	596
1983			14.8	5,400	480,000	2,282,000	228,200	2,990,200	554
1984			15.8	5,770	500,000	2,282,000	228,200	3,010,200	522
1985	40,648,000	77,825,000	17.0	6,200	525,000	4,778,000	477,800	5,780,800	932
1986			18.5	6,750	550,000	4,778,000	477,800	5,805,800	860
1987			19.6	7,150	573,000	4,778,000	477,800	5,828,800	815
1988			21.0	7,650	595,000	4,778,000	477,800	5,850,800	764
1989			22.4	8,170	620,000	4,778,000	477,800	5,875,800	719
1990			24.0	8,760	640,000	4,778,000	477,800	5,895,800	673
1991			25.3	9,230	660,000	4,778,000	477,800	5,915,800	641
1992			26.7	9,750	685,000	4,778,000	477,800	5,940,800	609
1993			28.3	10,330	715,000	4,778,000	477,800	5,970,800	578
1994			29.5	10,750	740,000	4,778,000	477,800	5,995,800	558
1995			31.0	11,310	765,000	4,778,000	477,800	6,020,800	533
1996			32.3	11,700	790,000	4,778,000	477,800	6,045,800	516
1997			33.7	12,300	810,000	4,778,000	477,800	6,065,800	493
1998			35.4	12,920	830,000	4,778,000	477,800	6,085,800	471
1999			36.8	13,400	860,000	4,778,000	477,800	6,115,800	456
2000			38.0	13,300	885,000	2,637,000	264,000	3,785,700	285
2001			39.7	14,500	910,000	2,637,000	264,000	3,810,700	263
2002			41.0	14,960	930,000	2,637,000	264,000	3,830,700	256
2003			42.6	15,530	960,000	2,496,000	250,000	3,705,600	238
2004			44.0	16,050	990,000	2,496,000	250,000	3,735,600	233
2005			45.3	16,540	1,012,000	2,496,000	250,000	3,757,600	227
2006			47.0	17,150	1,035,000	2,496,000	250,000	3,780,600	221
2007			48.5	17,700	1,060,000	2,496,000	250,000	3,805,600	215
2008			50.0	18,250	1,085,000	2,496,000	250,000	3,830,600	210
2009			51.2	18,700	1,115,000	2,496,000	250,000	3,860,600	206
2010			53.0	19,340	1,135,000	2,496,000	250,000	3,880,600	201
2011			54.0	19,700	1,160,000	2,496,000	250,000	3,905,600	198
2012			55.5	20,300	1,185,000	2,496,000	250,000	3,930,600	194
2013			57.0	20,800	1,210,000	2,496,000	250,000	3,955,600	190
2014			58.5	21,400	1,232,000	2,496,000	250,000	3,977,600	186

outside source of revenue other than charges to participating municipalities. However, certain interest income will accrue on bank account funds, and other sources are possible. These outside revenue sources will not produce a substantial reduction in annual costs, but some small decrease will result.

To be conservative in presenting costs, it has also been assumed that none of the capital cost would be defrayed by current State or Federal aid programs. There is, however, every indication that the proposed regional system would receive such assistance in the form of Grants-in-Aid as may be available from both the Federal Government and New Jersey State. Since no definite commitment can exist at this time, these grants are not included in the estimate of construction costs. Any amount received, of course, would be a benefit, and the annual charges to system participants would be reduced accordingly.

Annual Operation and Maintenance Cost

TABLE 24 indicates the estimated annual costs incurred for operation and maintenance of system facilities and includes those costs for:

- Salaries of Operating Personnel
- Equipment Maintenance
- Utilities
- Fuel
- Laboratory Supplies
- Chemicals
- Materials
- Special Tools
- Repairs

Costs for wastewater collection system operation and maintenance have been estimated at \$500 per mile of pipe.

Water pollution control plant costs have been taken from PLATE 32 which is a chart illustrating typical operation and maintenance costs for secondary treatment plants of the type proposed.

Operation and maintenance costs for wastewater reclamation facilities have been estimated by comparison to costs reported for existing facilities elsewhere.

TABLE 24

ESTIMATED ANNUAL COSTS OF OPERATION AND MAINTENANCE FOR
REGIONAL SYSTEM FACILITIES

<u>Year</u>	<u>Flow in MGD</u>	<u>Estimated Annual Operation and Maintenance Costs For</u>				<u>Total</u>
		<u>Wastewater Collection</u>	<u>Water Pollution Control</u>	<u>Recharge Facilities</u>	<u>Administration</u>	
1970	8	\$15,000	\$125,000	\$ 75,000	\$110,000	\$ 325,000
1980	12	15,000	175,000	80,000	155,000	425,000
1990	24	15,000	325,000	100,000	250,000	640,000
2000	38	30,000	475,000	105,000	300,000	885,000
2010	53	30,000	672,000	108,000	370,000	1,130,000
2015	60	30,000	770,000	110,000	390,000	1,260,000

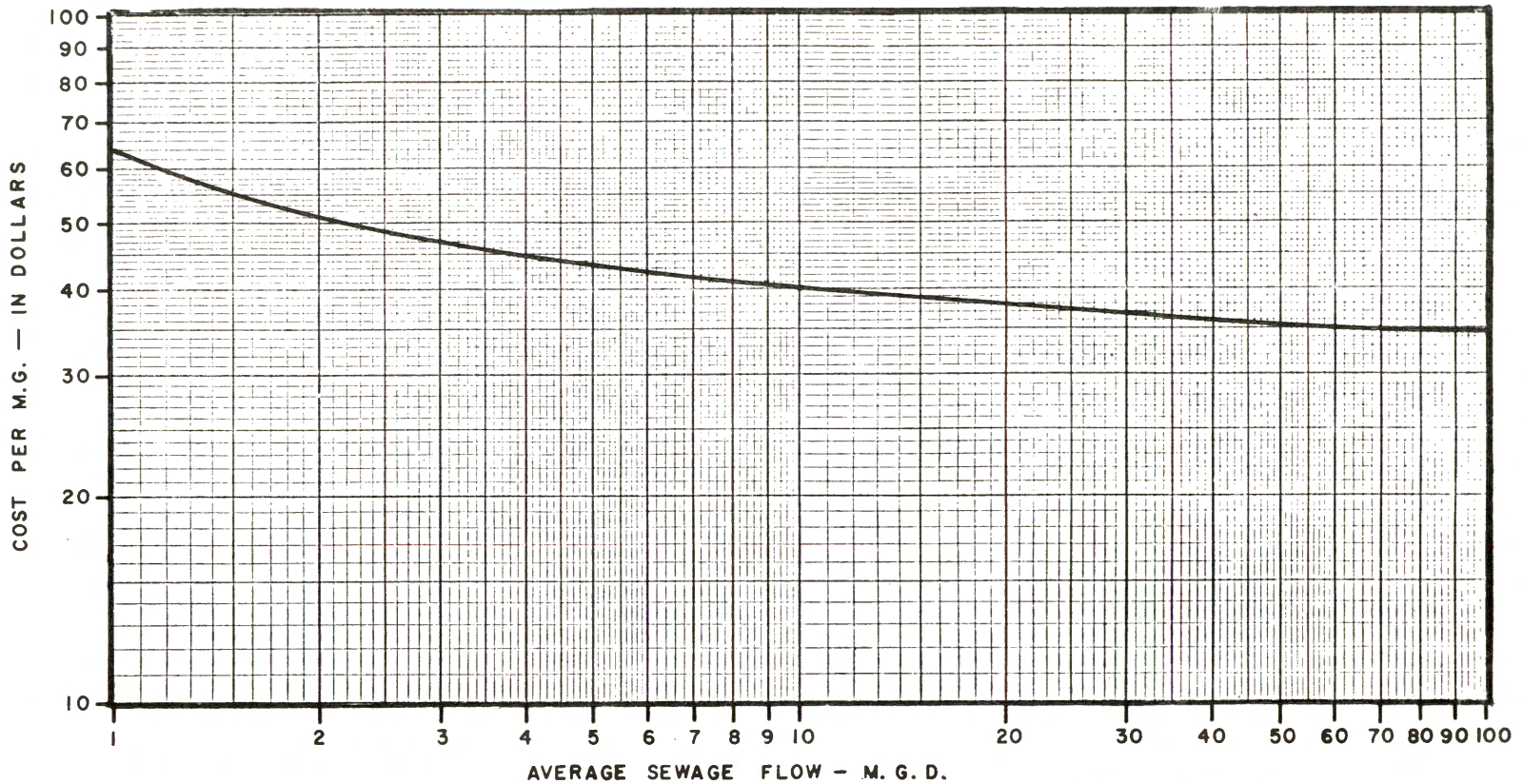


PLATE 32

COSTS ARE BASED
ON ESTIMATED
1966 CONDITIONS
FOR PRIMARY AND SECONDARY
TREATMENT FACILITIES

NEW JERSEY STATE
DEPARTMENT OF HEALTH
STONY BROOK-MILLSTONE
SEWERAGE STUDY COMMITTEE

STONY BROOK-MILLSTONE WATERSHED
REGIONAL SEWERAGE FEASIBILITY STUDY

OPERATION AND MAINTENANCE COSTS
WATER POLLUTION CONTROL FACILITIES

SEELYE STEVENSON VALUE & KNECHT
CONSULTING ENGINEERS
PRINCETON, N. J. NEW YORK, N. Y.

COMPARATIVE ANNUAL COSTS

Purpose of Cost Data Presented

The cost data presented in this section of the report is furnished primarily for the benefit of the proposed immediate municipal contributors to the regional disposal system. The information given herein permits the municipality to compare the annual costs for participation in the regional system against the annual costs of constructing and operating individual municipal wastewater treatment facilities. Costs for individual municipal facilities either have been, or can be, obtained as a result of independent engineering studies conducted by the municipalities involved.

Elimination of Wastewater Reclamation Costs to Provide Equitable Basis for Cost Comparison

Engineering reports, presently in existence for several of the municipalities, develop plans and costs for municipal wastewater treatment facilities in which the treatment process is limited to that degree of waste removal known as secondary treatment. This is a lower degree of treatment than that proposed to be provided by facilities developed in this report. The proposed regional facilities would remove sufficient impurities to permit reclamation of the water for re-use. There is, of course, some additional cost associated with wastewater reclamation above the cost which might prevail if facility construction were limited to that extent necessary to provide secondary treatment.

To permit equitable cost comparison by the proposed municipal participants, TABLE 25 has been prepared. This table indicates the estimated system annual costs and charge rate per million gallons treated for a regional system in which wastewater reclamation facilities, and all costs attributable thereto, have been eliminated.

Assumptions used in establishing the tabulation are essentially the same as those previously listed for TABLE 23 in the section dealing with ANNUAL COSTS FOR REGIONAL SYSTEM FACILITIES. However, the initial and future capital expenditures are lower due to elimination of facility cost for wastewater reclamation. In turn, annual costs for debt service, reserve fund, operation and maintenance are reduced accordingly.

Comparison of Estimated Charges with Other System Charges

Certain areas of the State of New Jersey presently treat wastewater on a regional system basis. System facilities, treatment process, degree of treatment provided, and amount of waste flow handled vary considerably in each area, and no direct comparison with the proposed system for the Stony Brook-Millstone Watershed is possible. However, to indicate that the rate charges derived in TABLE 25 do bear a reasonable relationship to presently existing rate charges experienced by participants in other regional systems, the following tabulation is offered:

<u>Existing Regional Systems</u>	<u>Year Reported</u>	<u>Average Daily Flow MGD</u>	<u>Total Annual Flow MG</u>	<u>Total Annual Charge to Participating Municipalities</u>	<u>Approx. Rate Per MG</u>
Ewing-Lawrence Sew. Auth.	1964	5.6	2,040	\$1,001,924	\$492
Bergen County Sewer Auth.	1965	33.4	12,180	2,358,657	193
Middlesex Sewerage Auth.	1964	47.5	17,350	2,910,236	168
Passaic Valley Sewerage Com.	1965	182.2	66,515	3,513,300	53

TABLE 25

ESTIMATED ANNUAL RATES TO BE CHARGED TO PARTICIPATING MUNICIPALITIES
FOR ULTIMATE REGIONAL DISPOSAL FACILITIES WITHOUT WASTEWATER RECLAMATION FACILITIES

Year	Project Cost	Cumulative Project Cost	Est. Average Daily Flow MGD	Total Annual Flow MG/Yr.	Operation and Maintenance Cost	Debt Service	Reserve Fund	Total Annual Cost	Rate Per MG
1970	\$28,721,000	\$28,721,000	8.0	2,920	\$ 250,000	\$1,763,000	\$176,300	\$2,189,300	\$750
1971			8.3	3,030	260,000	1,763,000	176,300	2,199,300	726
1972			8.7	3,180	265,000	1,763,000	176,300	2,204,300	695
1973			9.0	3,280	270,000	1,763,000	176,300	2,209,300	676
1974			9.3	3,390	280,000	1,763,000	176,300	2,219,300	655
1975			9.6	3,500	290,000	1,763,000	176,300	2,229,300	638
1976			10.0	3,650	300,000	1,763,000	176,300	2,239,300	615
1977			10.5	3,830	310,000	1,763,000	176,300	2,249,300	585
1978			11.0	4,020	325,000	1,763,000	176,300	2,264,300	562
1979			11.5	4,200	335,000	1,763,000	176,300	2,274,300	541
1980			12.0	4,380	350,000	1,763,000	176,300	2,289,300	524
1981			12.8	4,670	360,000	1,763,000	176,300	2,299,300	503
1982			13.7	5,000	380,000	1,763,000	176,300	2,319,300	465
1983			14.8	5,400	392,000	1,763,000	176,300	2,331,300	432
1984			15.8	5,770	410,000	1,763,000	176,300	2,349,300	407
1985	24,254,000	52,975,000	17.0	6,200	435,000	3,252,000	325,200	4,012,200	647
1986			18.5	6,750	450,000	3,252,000	325,200	4,027,200	597
1987			19.6	7,150	470,000	3,252,000	325,200	4,047,200	566
1988			21.0	7,670	500,000	3,252,000	325,200	4,077,200	531
1989			22.4	8,170	520,000	3,252,000	325,200	4,097,200	501
1990			24.0	8,760	540,000	3,252,000	325,200	4,117,200	470
1991			25.3	9,230	560,000	3,252,000	325,200	4,137,200	448
1992			26.7	9,750	585,000	3,252,000	325,200	4,162,200	427
1993			28.3	10,330	610,000	3,252,000	325,200	4,187,200	405
1994			29.5	10,750	640,000	3,252,000	325,200	4,217,200	392
1995			31.0	11,310	660,000	3,252,000	325,200	4,237,200	374
1996			32.3	11,700	680,000	3,252,000	325,200	4,257,200	364
1997			33.7	12,300	700,000	3,252,000	325,200	4,277,200	348
1998			35.4	12,920	730,000	3,252,000	325,200	4,307,200	334
1999			36.7	13,400	750,000	3,252,000	325,200	4,327,200	323
2000			38.0	13,300	780,000	1,489,000	148,900	2,417,900	182
2001			39.7	14,500	800,000	1,489,000	148,900	2,437,900	168
2002			41.0	14,960	820,000	1,489,000	148,900	2,457,900	164
2003			42.6	15,530	850,000	1,489,000	148,900	2,487,900	160
2004			44.0	16,050	880,000	1,489,000	148,900	2,517,900	157
2005			45.3	16,540	900,000	1,489,000	148,900	2,537,900	153
2006			47.0	17,150	925,000	1,489,000	148,900	2,562,900	149
2007			48.5	17,700	950,000	1,489,000	148,900	2,587,900	146
2008			50.0	18,250	975,000	1,489,000	148,900	2,612,900	143
2009			51.2	18,700	1,000,000	1,489,000	148,900	2,637,900	141
2010			53.0	19,340	1,022,000	1,489,000	148,900	2,659,900	137
2011			54.0	19,700	1,050,000	1,489,000	148,900	2,687,900	136
2012			55.5	20,300	1,075,000	1,489,000	148,900	2,712,900	133
2013			57.0	20,800	1,100,000	1,489,000	148,900	2,737,900	131
2014			58.5	21,400	1,125,000	1,489,000	148,900	2,762,900	129

ADMINISTRATIVE, LEGAL AND FINANCIAL CONSIDERATIONS

General Criteria for Proposed Administrative Organization for Regional System for Wastewater Disposal

Pertinent administrative and legal arrangements must be selected in order to effect the physical plan of development of the regional system for wastewater disposal. A number of alternatives are available, and an intelligent choice among them can be made only after agreement on certain criteria. Some of these criteria are established by the nature of the problem, and others are optional matters of policy. The various criteria may be summarized as follows:

1. The administrative organization should be able to represent the interests of 26 different municipalities, in whole or in part.
2. It should be adaptable to use over an area including parts of five different counties (Hunterdon, Somerset, Middlesex, Monmouth and Mercer), without encompassing all of any one county.
3. It must have the legal, administrative and financial capability of providing for wastewater collection and disposal facilities upon a regional basis, in accordance with the physical plan.
4. It should be provided with adequate powers to finance the acquisition of the required physical improvements, preferably without recourse to the general credit of the counties and municipalities involved, but in any event, without impairing their borrowing power for other purposes under existing statutory debt limits. (N. J. S. 40A:2-6 et seq.)
5. It should be adaptable to the various present needs and estimated future rates of growth among the constituent municipalities.
6. It should provide for a single executive with full operating responsibility and authority, accountable to a single policy-making body.
7. To the fullest extent feasible, the administrative organization should be accountable for policy decisions to the duly elected representatives of the people affected.

Possible Administrative Organizational Alternatives

Given these criteria, there are five different organizational forms and two basic financial methods which may be considered. The organizational forms may be described as follows:

1. A single municipal or county department, which would develop and operate the system and sell service under contract to the other municipalities.
2. An Intermunicipal Agreement pursuant to the "Consolidated Municipal Service Act" (R.S. 40:48B-1 et seq.).
3. A "Joint Meeting" organized and administered by two or more municipalities, by contract, to develop, construct and operate sewerage facilities, pursuant to the Home Rule Act (R.S. 40:63-68 et seq.).
4. A "Special District" -- A Special Sewerage District may be established by a municipal governing body within its own limits (R.S. 40:63-32 et seq.); by a County Board of Freeholders for all or part of the county (R.S. 40:36A-1 et seq.), for a first or second class county; by the State Department of Health upon petition signed by the Mayor or other chief executive officer of each municipality affected, for such area as the department may define as a sewerage district, pursuant to R.S. 58:12-7.
5. A Sewerage Authority -- Under the Sewerage Authorities Law of 1946, the governing body of any county, of any municipality, of any two or more municipalities, may create or join in the creation of a sewerage authority (R.S. 40:14A-1 et seq.). Under the Municipal Utilities Authorities Law of 1957, the governing body of any county, of any municipality or of any two or more municipalities comprising "an integral body of territory," may create a Municipal Utilities Authority with the power to provide both water supply and sewerage facilities and service.

The Choice Between Taxes and User Charges to Finance Facilities

While a substantial and growing part of the capital cost of waste disposal facilities will be provided by Federal and State aid, the municipalities will undoubtedly be required to finance a major part of the cost. In the coming years, moreover, this is a problem which will be faced by many municipalities throughout the United States, with some \$6 billion in Federal, State and municipal funds to be invested in wastewater treatment facilities by 1972, according to the Department of Health, Education and Welfare. This may pose a number of financing

problems which are beyond the scope of municipal control, including the rising level of interest rates, the threat of inflated costs of construction, and general conditions in the municipal bond market.

It may be anticipated that the part of the capital cost not funded with Federal or State aid will require some form of local borrowing. This raises the question whether annual debt service payments should be met out of the general property tax or out of revenues from user charges.

The municipal bond market tends to direct the choice in favor of using some tax support at least during the early years. While sewer revenue bonds are highly regarded in the bond market, a new and untested sewer project is not likely to inspire the kind of confidence in the investor which would produce the lowest interest cost. A more fundamental way of looking at the problem, however, would be to select a method of financing which best allocates the cost in proportion to the benefits received from the sewerage system. Such a method may justify a combination of tax support and user charges. It thus appears that for the purposes of testing the feasibility of the project, it would be preferable to select a form of administrative organization which might have the capability of using whatever method of financing is best adapted to the conditions at the time.

A Municipal Department

A county has no power to establish a county sewerage department within its regular departmental organization, but any municipality has full power to establish and operate such a department (R.S. 40:63-1 et seq.). The municipality may extend service to other municipalities (R.S. 40:63-19) and intermunicipal contracts are authorized for this purpose (R.S. 40:63-43). This type of organization is normally used by a central city to render service to suburban municipalities. The scope of the administrative and financial commitments by the operating municipality are much too large to be considered for the present drainage basin. Moreover, any such arrangement is apt to prove unsatisfactory in the future when sharply increased populations in the presently undeveloped areas result in a demand for additional facilities which the central service municipality is unwilling or unprepared to render.

An Intermunicipal Agreement Under the Consolidated Municipal Service Act

A statute of 1952 (Chapter 72), as supplemented by Laws of 1960 (Chapter 3), is known as the Consolidated Municipal Service Act of

1952. Under this act, any two or more municipalities could join by contract, for a period not to exceed forty years, to provide sewerage facilities as well as other services and facilities. The statute provides for the appointment of a management committee to consist of one member to be appointed by the governing body of each municipality to hold office for a term of one year. The management committee can apportion the cost of the sewer improvements among the participating municipalities, provide for the operation of the facilities by an executive and staff, and for the apportionment of costs and expenses of operation and maintenance of the facilities. These and other matters may be governed by a joint contract to be entered into pursuant to the statute. Each municipality would then raise its share of the capital and current operating funds in the same manner as it may finance other municipal services.

The powers and duties of the management committee generally, which may be exercised "to the extent provided in the joint contract," are set forth in the statute and are quoted below:

- (a) To sue and to be sued;
- (b) To acquire and hold real and personal property by deed, gift, grant, lease, purchase, condemnation or otherwise;
- (c) To enter into any and all contracts or agreements and to execute any and all instruments;
- (d) To do and perform any and all acts or things necessary, convenient or desirable for the purposes of the joint meeting or to carry out any powers expressly given in this act;
- (e) To sell real and personal property owned by the joint meeting at public sale;
- (f) To operate all lands, public improvements, works, facilities, services or undertakings for the purposes and objects of the joint meeting;
- (g) To enter into a contract or contracts providing for or relating to the use of its lands, public improvements, works, facilities, services or undertakings, or any part thereof, by municipalities, who are not members of the joint meeting, and other persons, upon payment of charges therefor as fixed by the management committee;
- (h) To receive such State or Federal aids or grants as may be available for the purposes of the joint meeting and to

make and perform such agreements and contracts as may be necessary or convenient in connection with the application for, procurement, acceptance or disposition of such State or Federal aids or grants.

(i) To acquire, maintain, use and operate lands, public improvements, works or facilities in any municipality in the State, except where the governing body of such municipality, by resolution adopted within 30 days after receipt of written notice of intention to so acquire, maintain, use or operate, shall find that the same would adversely affect the governmental operations and functions and the exercise of the police powers of such municipality.

Under this plan, the joint body has no borrowing power and no taxing power. In effect, the enterprise would be financed by the separate credit and taxing power of the participating municipalities. This could prove to be quite inefficient, and certainly more costly than borrowing on the common credit of all of them combined. Another weakness of this type of organization is that the statute permits the joint contract to be terminated "upon the adoption of a resolution to that effect by the governing bodies of two-thirds of the municipalities then participating." (R.S. 40:48B-9) The statute is silent as to the effect of such a dissolution upon existing assets and liabilities and service responsibilities. This is hardly a satisfactory alternative for a sewerage system to be planned and constructed upon on a long range basis.

A Sewerage Joint Meeting

A traditional way of providing for regional sewerage systems has been under the provisions of the Home Rule Act authorizing two or more municipalities to form a "joint meeting" to carry out the provisions of a joint contract for the construction and operation of sewerage system improvements (R.S. 40:63-68 et seq.).

The joint meeting may literally be a "meeting or assembly of the members of the governing bodies or boards of the several municipalities" who enter into the joint contract. Each municipality, nevertheless, has one vote. In practice, only one member of the governing body of each municipality actually attends the meetings and casts his municipality's vote.

The joint cost and expense is apportioned among the associated municipalities in the manner provided by the joint contract. A key provision of this plan is that the joint contract and the ordinances authorizing it "shall prescribe and fix the percentage of the capacity of such public

improvement or works to the use of which each municipality shall be entitled, also the percentage of the total cost, damages and expense thereof to be paid by each contracting municipality." (R.S. 40:63-80)

In effect, the joint meeting statute depends for its financing upon the general credit and taxing power of the participating municipalities. The quoted provision which requires that they buy fixed shares in the system makes the available capacity for each municipality in the future depend upon its present financial situation. While a municipality may theoretically sell some of its capacity, if unneeded, to another participating municipality, the experience has not been satisfactory. With the very uneven growth that may be expected in the present drainage basin, this provision of the joint meeting law is likely to make it quite unsatisfactory as present estimates, however well made, are converted to actual growth factors ten or twenty years in the future. A municipality which has grown more rapidly than anticipated may find it impracticable to purchase surplus capacity from any of the other participants, or to induce them to enlarge the system to accommodate its developing needs. Other joint meetings have found this to be a built-in cause of disappointment and friction.

A Special District

The terminology of the statutes is not always clear but it may be premised, for the purposes of discussion, that a special district is a separate public corporation which may exercise taxing power. This may be compared with a public authority which is also a separate public corporation, but which traditionally has no taxing power. With this distinction in mind, there are two types of special districts:

1. A special district created by the municipal governing body to provide for the construction, operation and maintenance of a sewerage system in part of the municipality; and

2. A special district consisting of all or part of two or more municipalities and created by the State Health Department upon petition signed by the mayors or other chief executive officers of the municipalities affected. (R.S. 58:12-7)

(a) Municipal Sewerage District - The municipal sewerage district is a useful device, particularly to finance the initial capital outlay in those municipalities where only part of the municipal area is within the Watershed. As shown on PLATE 2 and listed in TABLE 1, only 9 of the 26 municipalities are 100% within the Watershed. Of the balance, only East Windsor Township and Pennington Borough are 90% or more within the Watershed, while

the other municipalities range downward to as little as 1.6%. This suggests the usefulness of the municipal special sewerage district to allocate the cost within the municipality to those lands which will benefit directly from the improvement.

The special sewerage district in a municipality may be created by the governing body by ordinance designating its boundaries. Such an ordinance may be passed only after public notice to the owners whose lands may be affected, and the district may not be created where objections to it are filed in writing, with the municipal clerk before final passage of the ordinance, by owners of 51% in value of the real property in the district proposed to be assessed. (R.S. 40:63-34). The governing body may, however, overcome the protest by declaring the sewerage district "a public necessity," but in that event, the ordinance must be submitted to referendum at the next general election or at a special election held for that purpose (R.S. 40:63-35). If the sewerage district is established, the cost of the system may be assessed against the benefited real estate in proportion to benefits conferred. The expense of the operation and maintenance of the system may also be met by special assessment within the district (R.S. 40:63-39).

(b) Regional Sewerage District - A regional sewerage district, created by the State Department of Health under the same statute, is an unusual but nevertheless feasible alternative. As already noted, it could be initiated by petition, and would have the following characteristics:

(1) The boundaries of the sewerage district would be established by the Department of Health;

(2) The district would be governed by a board of 5 residents, elected by the voters at the general election. They would be nominated by petition, in the same manner as independents are nominated for a general election, except that they may apparently run under a party label (although the statute is not clear on this point). (See R.S. 58:12-11 and R.S. 58:12-13);

(3) The members of the board are required to serve for a per diem compensation of \$5.00 except that the secretary and treasurer may be paid a salary to be fixed by the board. The board has authority to employ personnel (R.S. 58:12-19), construct sewerage systems, exercise the power of condemnation, borrow money and issue its bonds for

construction purposes with a maturity not exceeding 30 years, and divide and apportion the cost of the project among the municipalities or parts thereof included within the sewerage district in proportion to the benefits received or to be received. There is also statutory provision for review of this apportionment of costs by court-appointed commissioners (R.S. 58:12-32 et seq.).

(4) While the board would have no taxing power of its own, it would be authorized to apportion annual charges for debt service, operation and maintenance to the participating municipalities, and they would be required by the statute to raise the apportioned share by taxation (R.S. 58:12-35 and 58:12-37). Where only a part of the municipality is included in the district, the municipality is required by the statute to levy such taxes only within such part (R.S. 58:12-35).

(5) The statute is notably lacking in any provision for user charges to be imposed by the sewerage board itself, or for the issuance of revenue bonds secured by a pledge of revenues from any such charges. Nor are the participating municipalities permitted to impose user charges to recover either debt service or annual costs of operation and maintenance, since the statute makes it mandatory that property taxes be levied for these purposes (R.S. 58:12-35 and 58:12-37). It thus appears that this statute would be unacceptable if a policy is adopted to finance the recommended facilities, in whole or in part, with user charges rather than from property taxes.

A Public Authority

Because of the legal and administrative limitations of other existing forms of organization which have already been described, the use of a public authority is becoming a more common form of organization to carry out a regional sewerage project. The law presently offers a choice of two different types of authorities: (1) a sewerage authority, or (2) a utilities authority (which includes both water supply and sewage disposal).

1. Sewerage Authority - Under the Sewerage Authorities Law of 1946, the governing body of any of the counties can create a sewerage authority for the county. Under the same statute, the governing bodies of any two or more of the municipalities involved in the study can create a single sewerage authority, provided "the areas of. . . [the municipalities] together comprise an integral body of territory." It is significant that a county sewerage authority is limited by the statute to a

single county, whereas a municipal sewerage authority may include as many municipalities as agree to its formation, provided they satisfy the test of "an integral body of territory." Under the statute, however, it is legally possible for a county sewerage authority to extend service and membership on the authority to any municipality outside the county, by entering into a contract with any such municipality. In the event of such a contract, the county in which the contracting municipality is located is entitled to appoint one member (and only one, regardless of the number of contracting municipalities in the county) to the established county sewerage authority. A municipal sewerage authority, similarly, may extend service by contract to non-member municipalities, but such a contract need not result in adding members to the authority (N. J. S. A. 40:14A-4 and 40:14A-23).

It thus appears that any of the five counties affected by the study, or any two or more contiguous municipalities within the drainage basin, may take the initiative in forming a sewerage authority to carry out the physical plan of development.

(a) Members of the Authority - The authority is governed by five members, in the case of a county authority, appointed by the Board of Chosen Freeholders for overlapping terms of five years each. In the case of a joint municipal authority, the municipalities may determine the representation of each of them at not less than one or more than three members, and such members shall be appointed by their respective governing bodies for overlapping terms of five years.

(b) Corporate Powers - The statute would delegate full power to the sewerage authority to construct, operate, maintain and finance the required physical facilities. Its general powers are summarized in the statute as follows (N. J. S. A. 40:14A-7):

Every sewerage authority shall be a public body politic and corporate constituting a political subdivision of the State established as an instrumentality exercising public and essential governmental functions to provide for the public health and welfare and shall have perpetual succession and have the following powers:

- (1) To adopt and have a common seal and to alter the same at pleasure;
- (2) To sue and to be sued;
- (3) In the name of the sewerage authority and on its behalf, to acquire, hold, use and dispose of its service charges and other revenues and other moneys;

(4) In the name of the sewerage authority but for the local unit or units, to acquire, hold, use and dispose of other personal property for the purposes of the sewerage authority;

(5) In the name of the sewerage authority but for the local unit or units, to acquire by purchase, gift, condemnation or otherwise, real property and easements therein, necessary or useful and convenient for the purposes of the sewerage authority, and subject to mortgages, deeds of trust or other liens, or otherwise, and to hold or to use the same, and to dispose of property so acquired no longer necessary for the purposes of the sewerage authority;

(6) To provide for and secure the payment of any bonds and the rights of the holders thereof, and to purchase, hold and dispose of any bonds;

(7) To accept gifts or grants of real or personal property, money, material, labor or supplies for the purposes of the sewerage authority, and to make and perform such agreements and contracts as may be necessary or convenient in connection with the procuring, acceptance or disposition of such gifts or grants;

(8) To enter on any lands, waters or premises for the purpose of making surveys, borings, soundings and examinations for the purposes of the sewerage authority;

(9) To make and enforce by-laws or rules and regulations for the management and regulation of its business and affairs and for the use, maintenance and operation of the sewerage system and any other of its properties, and to amend the same;

(10) To do and perform any acts and things authorized by this act under, through or by means of its own officers, agents and employees, or by contracts with any persons; and

(11) To enter into any and all contracts, execute any and all instruments, and do and perform any and all acts or things necessary, convenient or desirable for the purposes of the sewerage authority or to carry out any power expressly given in this act.

(c) Financing - The principal feature of the Sewerage Authorities Law is its provision for financing the capital and operating costs of the system from user charges. The authority is authorized by statute to issue bonds payable solely out of revenues of the authority, and specifically providing that any such bonds shall not constitute or create a debt or liability of the county or of any municipality. In order to provide for the payment of principal and interest on such bonds and for the operation and maintenance of the system, the sewerage authorities are authorized by the

statute to "charge and collect rents, rates, fees or other charges for direct or indirect connection with, or the use of services of, the sewerage system." The statute also provides that such service charges "shall as nearly as the sewerage authority shall deem practicable and equitable be uniform throughout the district for the same type, class and amount of use or service of the sewerage system." (N.J.S.A. 40:14A-8)

This method of financing the system with user charges has a number of important advantages. It does not depend upon the general credit of the county or municipality, and thus does not use any of the legally limited borrowing power of these units. It automatically apportions the cost of service to the municipalities, and to the parts of each municipality, in direct proportion to the service benefit received. It also is readily adaptable to the presently uneven need for sewer service and the future uneven growth of need among the different municipalities.

There are also various disadvantages to the sewerage authority type of organization. At the outset, its members are only indirectly responsible to the people, since they are appointed by the respective elected governing bodies, rather than being directly elected. The method of financing, however useful, also could result in a somewhat higher interest cost than bonds issued on the full faith and credit of the municipalities or county and backed by the full taxing power of these political subdivisions.

(d) Priority of Organization - Since both county and municipal sewerage authorities are permissible under the statute, there is appropriate provision to avoid potential conflicts of jurisdiction. While the statutory provisions are somewhat complicated, they follow the simple principle that priority of creation establishes priority of right. (N.J.S.A. 40:14A-4f and 40:14A-29)

2. Water and Sewerage Authority - Under the Municipal Utilities Authorities Law of 1957, it is possible to create an authority which combines both water and sewerage powers. Such an authority may deal with a water system separately and a sewerage system separately or it may construct and operate both. The power to create such an authority, designated a Municipal Utilities Authority, is conferred by the statute upon any county or upon the governing bodies of any two or more municipalities, similar to the sewerage authorities law. In fact, there is provision for reorganizing any existing sewerage authority as a municipal utilities authority. The basic policy and alternatives under both laws are substantially the same, but the municipal utilities

authority law, having been developed some ten years later, does include technical improvements over the earlier sewerage authorities law.

Recommended Administrative Organization, Financing and New Legislation

None of the alternatives offered by existing law provide the exact means by which an appropriate organization can be established to administer the proposed regional system for waste disposal. The most appropriate alternative appears to be a sewerage authority. However, the enactment of legislation by the state legislature is necessary to amend the present sewerage authorities law to permit the creation of a county sewerage authority on a multi-county basis.

In addition, it would be quite feasible to seek improved legislation to reduce some of the disadvantages inherent in the sewerage authority type of organization, especially if there were a reasonable consensus of agreement among the interested parties on the legal improvements to be sought. The examination of the law already discussed suggests two possible changes of a basic nature:

1. Provision for an elected regional board, and
2. Provision for a self-liquidating system of financing, primarily dependent upon user charges, but with the added credit base of power to resort to taxation if it should ever be necessary.

These alternatives are not available under existing law, but could be provided; for example, through amendment of the sewerage authority law which was outlined previously. If it should ever happen that the revenues of the sewerage authority were to be insufficient to cover debt service and operation and maintenance expense, then the provision of the amended law requiring the participating municipalities to support the authority through the exercise of their taxing power should substantially enhance the credit base of the sewerage authority.

The combination of revenue financing backed with ultimate recourse to the taxing power has been successfully used in many major projects. These include the Southern California Water District, the Chicago Sanitary District, and the Washington Metropolitan Sanitary District, as well as some parking authorities, which are common in New Jersey. Such a provision may not be essential to the successful financing of the present project, but it is appropriate to note it at this time as an element of financial feasibility. The actual choice of financing will ultimately depend upon the legal borrowing power of the participating

counties and municipalities. At present, an analysis of the outstanding debt of the 26 municipalities involved in the study indicates that all of them have a satisfactory margin of available borrowing power within the legal limits. These limits, imposed by state statute, provide for the exclusion of bonds issued for self-liquidating projects from the effect of the limitations. There may be some legal question, however, whether the present law excluding bonds from the municipal debt limit where the purposes for which they are issued are self-liquidating (N. J. S. 40A:2-45 through 40A:2-48) would apply to bonds issued by a sewerage authority with the power to apply a combination of user charges and tax support. Since the Local Bond Law applies to bonds issued by the municipality itself, it could be argued that any contingent obligation, implied in the power of the creditors to require a tax levy in the unlikely event that user charges provide insufficient revenues, would not affect municipal debt limits at all. This is a technical question of municipal bond law and statutory interpretation, and it is sufficient for present purposes to observe that the various municipalities involved in the project study do have adequate borrowing power, should the method of financing ultimately prove to be a charge upon that power.

FINANCIAL AID

Federal and State Financial Aid

Communities which need to construct, improve or extend waste-water collection systems and disposal facilities may be able to obtain assistance from the Federal Government or the State of New Jersey.

1. Federal Assistance Available - The Acts listed below make Federal grants or loans available for sewer projects and/or waste treatment facilities:

<u>Act</u>	<u>Sewer Projects</u>	<u>Waste Treatment Facilities</u>
Federal Water Pollution Control Act (as amended (Water Quality Act of 1965)		X
Consolidated Farmers Home Administration Act, as amended	X	X
The Housing Amendments of 1955, as amended	X	X
Public Works and Economic Development Act of 1965	X	X

2. State Assistance Available - The State Public Sanitary Sewerage Facilities Act of 1965 authorizes the State Commissioner of Health to make grants and loans to local government units for the preparation of feasibility studies, reports and engineering designs of public sanitary sewerage facilities.

A summary of Federal and State aid is presented in TABLE 26.

TABLE 26
SUMMARY OF FEDERAL AND STATE AID AVAILABLE
FOR
WASTE WATER DISPOSAL PROJECTS

Name of Legislation	Purpose	Administering Agency	Eligible Recipients	Kind of Aid	Amount of Aid	Eligible Projects
Federal Water Pollution Control Act (Water Quality Act of 1965) Public Law 89-234	Abate stream pollution by building sewage treatment works.	Federal Water Pollution Control Administration, Department of Interior and New Jersey Department of Health.	Any governmental agency with the authority to collect and treat its waste water.	Grant	30% of the eligible cost up to \$1.2 million for a single project and \$4.8 million for multi-municipal projects. A 10% increase in the grant is authorized for projects which are in conformance with a comprehensive metropolitan plan developed by an official state, metropolitan or regional planning agency.	Eligible items are limited to treatment works and necessary facilities and include: 1. Engineering. 2. Legal and fiscal investigations. 3. Studies and designs. 4. Supervision and inspection of construction. 5. Sewage treatment works. 6. Interceptor sewers. 7. Outfall sewers. 8. Pumping. 9. Power and equipment. Costs of land acquisition are excluded.
The Housing and Urban Development Act of 1965 Public Law 89-117	To assist and encourage communities: 1. To construct adequate basic water and sewer facilities. 2. To construct neighborhood facilities for programs of necessary social services. 3. To acquire land for future public works and facilities.	Department of Housing and Urban Development.	Any local public body or agency	Grant	For basic water and sewer facilities: 1. Not to exceed 50% of the development cost of the project. Communities less than 10,000 within metropolitan areas may receive up to 90% aid if unable to finance construction without the increased grants. If there is no public or other adequate sewer facility serving a substantial portion of its inhabitants and its unemployment rate is above the national average. 2. Neighborhood facilities not to exceed 66-2/3% of development cost, 75% in areas designated as a redevelopment area under the Area Redevelopment Act. 3. Advance acquisition of land not to exceed reasonable interest charges on indebtedness necessary for purchases for 5 years from date of indebtedness or to time of construction, whichever is less.	Basic Water and Sewer Facilities 1. Basic water facilities include works for storage, treatment, purification and distribution of water. 2. Basic sewer facilities include all other facilities than defined as treatment works in the Federal Water Pollution Control Act. Neighborhood Facilities 1. Necessary for program of health, recreation, social or similar community service. 2. Consistent with comprehensive planning for development of the community. 3. Available for use of area's low or moderate income residents.
Public Law 560 Section 702 Housing Act of 1954 as Amended	To provide advances to finance planning for local public works	Department of Housing and Urban Development.	Any non-Federal public body or agency with authority to plan, finance and construct public works.	Non-interest bearing loan. (advanced).	Interest free loan for planning costs from a revolving fund. Repayment of advances is made upon the start of construction.	All types of preliminary and final public work planning except public housing. Loans are not made for projects when other planning funds are available.
Consolidated Farmers Home Administration Act Amendments (Rural Water and Waste Disposal Systems) Public Law 89-240	To furnish financial assistance for planning and construction of certain public works facilities for rural residents.	Farmers Home Administration, U.S. Department of Agriculture.	Any city or town which has a population of less than 5,500 inhabitants.	Grant and Loan	No grant shall exceed 50% of development cost of the project, defined as the cost of the construction of a facility and the land, easements, and right of way and water rights necessary to its construction and operation.	a. The development, storage, treatment, purification or distribution of water. b. Collection, treatment or disposal of wastes.
Public Works and Economic Development Act of 1965 Public Law 89-136	To help communities, areas and regions which are suffering from excessive unemployment or under employment by providing financial and technical assistance needed for the creation of new jobs.	Economic Development Administration, Department of Commerce.	Public or private non-profit agencies in redevelopment areas and in areas which were areas of substantial unemployment in the preceding calendar year.	Grant and Loan	Direct grants of up to 50% of total project cost for needed public works; and supplementary grants to this and other Federal grant in aid programs up to 80%.	Water works and lines, sewerage facilities, etc.
State Public Sanitary Sewerage Facilities Act of 1965 (New Jersey)	To encourage and support the promotion, planning, development and construction of public sanitary sewerage facilities, on a stream valley, regional or multi-unit basis.	New Jersey Department of Health	Any New Jersey public agency responsible for constructing and operating a public sanitary sewerage facility.	Grant and Loan	State will provide grants for feasibility studies of future sewage treatment needs and loans for engineering detail and design plans. Loans are to be repaid without interest unless construction does not commence within 3 years, in which case a 2% interest will be levied in addition to repayment.	Feasibility studies and engineering as specified for sewage treatment facilities. 1. Project must be undertaken on an inter-governmental basis unless a municipality can show that it would not be practical to join with other units in the establishment of a multi-unit sewerage facility. 2. Applicants for loans must have filed an approved feasibility study.

APPENDIX A

MISCELLANEOUS TABULATIONS, CRITERIA, ALTERNATIVE
REGIONAL WASTEWATER DISPOSAL PLANS AND LIMITED
REGIONAL SYSTEM FACILITIES

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TABLE A-1

INVENTORY OF MUNICIPAL WATER FACILITIES
STONY BROOK - MILLSTONE WATERSHED AND VICINITY

<u>Community or Facility</u>	<u>1960 Population</u>	<u>Estimated Population Served</u>	<u>Source of Supply</u>	<u>Safe Yield Impounded MGD</u>	<u>Max. Depend- able Draft (Grd. Water) MGD</u>	<u>Rated Plant Capacity MGD</u>	<u>Average Daily Demand MGD</u>
Cranbury Twp. (M)	2,001	1,100	2 Wells	-	0.600	0.200	0.150
East Windsor Twp. (M)	2,298	(600)	Hightstown	-	-	-	-
East Windsor Twp. (P)	-	200	1 Well	-	1.000	0.170	0.020
Southern Gulf W. Co. Franklin Twp. (M)	-	(500)	So. Brunswick	-	-	-	-
Hightstown (M)	4,317	5,000	2 Wells	-	1.800	1.250	0.550
Hillsborough Twp. (P)	7,584	700	2 Wells	-	0.250	NR	0.070
Hillsborough Water Co. Hillsborough Twp. (P)	-	(200)	Manville	-	-	-	-
Hopewell (M)	1,928	2,100	2 Wells	-	NR	0.300	0.180
Hopewell Twp. (M)	7,818	(200)	Hopewell	-	-	-	-
Mercer County Manville (M)	10,995	11,200	18 Wells	-	1.000	1.500	0.840
Monroe Twp. (P)	5,831	250	2 Wells	-	0.600	NR	0.070
Forsgate Farms Inc. Monroe Twp. (P)	-	(150)	Jamesburg	-	-	-	-
Monroe Twp. (M)	9,396		3 Wells	-		-	
Pennington (M)	2,063	2,100	4 Wells	-	0.358	NR	0.150

(M) = Municipal
(P) = Private
NR = Not Reported

(Continued)

TABLE A-1 (Continued)

INVENTORY OF MUNICIPAL WATER FACILITIES
STONY BROOK - MILLSTONE WATERSHED AND VICINITY

<u>Community or Facility</u>	<u>1960 Population</u>	<u>Estimated Population Served</u>	<u>Source of Supply</u>	<u>Safe Yield Impounded MGD</u>	<u>Max. Depend- able Draft (Grd. Water) MGD</u>	<u>Rated Plant Capacity MGD</u>	<u>Average Daily Demand MGD</u>
Princeton (P) Princeton Water Co.	11,890	22,000	Delaware & Raritan Can. 11 Wells	1.000	3.500	4.000	2.500
Princeton Twp. (P)	10,411	(10,000)	Princeton	-	-	-	-
Rocky Hill (M)	528	700	2 Wells	-	0.220	NR	0.120
Roosevelt (M)	764	800	2 Wells	-	1.000	0.610	0.120
So. Brunswick Twp. (M)	10,278	5,000	4 Wells	-	3.000	NR	0.500
So. Brunswick Twp. (P) Kingston Water Co.	-	1,000	2 Wells	-	NR	-	0.087
West Windsor Twp. (P) Prince Col. Pk. Water Co.	4,016	400	2 Wells	-	0.460	0.060	0.050
West Windsor Twp. (P) Prince Junction Water Co.	-	350	2 Wells	-	0.029	NR	0.015
West Windsor Twp. (P) Wildermuth Water Sup.	-	450	1 Well	-	0.025	NR	0.020

TABLE A-2

BOROUGH OF PRINCETON SEWAGE TREATMENT PLANT
ANALYSES OF SAMPLES - FEBRUARY 25, 1964

First Sampling Period, 9:00 A. M. to 1:30 P. M.
Total Flow Over Period - 704,000 Gallons.

Time	Raw Sewage BOD	Primary Effluent BOD	Effluent Trickling Filter			Final Effluent		
			DO	BOD	Cl ₂	COLI	DO	BOD
9-9:30	131	69	5.0	37	0.7	0.5	7.1	21
10-10:30	133	115	9.1	30	1.4	0.5	4.0	22
11-11:30	356	132	8.0	24	1.4	0.5	5.5	28
12-12:30	138	125	8.0	22	1.2	0.0	8.2	23
1-1:30	211	156	6.9	21	1.1	0.0	7.3	27
Averages	194	119	7.4	27	1.1	0.3	6.4	24

First Period Composites	Raw	Primary	Filter	Final
Sample Numbers	S-9922	S-9924	S-10999	S-16001
Suspended Solids	148	118	46	50
(Volatiles)	116	80	30	32
Dissolved Solids	372	300	339	340
(Volatiles)	94	75	55	60
Ammonia Nitrogen	23.0	21.2	16.4	14.0
Organic Nitrogen	15.0	16.8	5.6	6.0
Nitrite Nitrogen	0.2	0.0	0.1	0.1
Nitrate Nitrogen	0.4	0.4	7.3	8.0
pH	7.1	7.1	7.0	7.0
Alkalinity	98	202	137	88
Chlorides	54	53	52	55
A. B. S. Detergents	2.9	2.0	4.5	5.5
Color	-	-	-	Gray
Turbidity, units	-	-	-	32.5
Chemical Oxygen Demand	-	-	-	59.0

Coliform organism content is given as average number of coliforms per milliliter in final effluent. All other results are expressed as milligrams per liter (PPM) except for pH, color and turbidity.

(Continued)

TABLE A-2 (Continued)

BOROUGH OF PRINCETON SEWAGE TREATMENT PLANT
ANALYSES OF SAMPLES - FEBRUARY 25, 1964

Second Sampling Period, 1:30 P. M. to 6:00 P. M.

Total Flow Over Period - 774,000 Gallons

Time	Raw	Primary	Effluent			Final Effluent		
	Sewage	Effluent	Trickling Filter					
	BOD	BOD	DO	BOD	Cl ₂	COLI	DO	BOD
1:30-2:00	156	146	6.0	18	1.0	0.0	4.0	36
2:30-3:00	206	172	4.0	23	1.2	0.0	8.2	19
3:30-4:30	314	311	7.2	27	1.2	1.0	6.0	32
4:30-5:00	271	262	5.2	31	0.9	0.0	5.0	27
5:30-6:00	256	221	3.0	29	0.7	0.0	5.7	42
<u>Averages</u>	241	222	5.1	26	1.0	0.2	5.8	31

<u>Second Period Composites</u>	<u>Raw</u>	<u>Primary</u>	<u>Filter</u>	<u>Final</u>
Sample Numbers	S-9923	S-10990	S-11021	S-16002
Suspended Solids	142	106	22	28
(Volatiles)	120	86	10	10
Dissolved Solids	419	422	408	406
(Volatiles)	100	93	17	94
Ammonia Nitrogen	23.0	21.6	14.4	13.6
Organic Nitrogen	15.0	16.4	8.6	8.4
Nitrite Nitrogen	0.3	0.0	0.2	0.0
Nitrate Nitrogen	0.2	0.5	5.6	3.7
pH	7.0	7.1	7.2	7.0
Alkalinity	218	215	140	120
Chlorides	76	75	52	66
A. B. S. Detergents	3.5	2.5	5.0	5.5
Color	-	-	-	Gray
Turbidity, units	-	-	-	23.0
Chemical Oxygen Demand	-	-	-	60.0

Coliform organism content is given as average number of coliforms per milliliter in final effluent. All other results are expressed as milligrams per liter (PPM) except for pH, Color and Turbidity.

TABLE A-3

BOROUGH OF PRINCETON SEWAGE TREATMENT PLANT
COMPUTED PERCENT REMOVALS

First Sampling Period: 9:00 A. M. to 1:30 P. M.

Total Flow: 704,000 gallons.

Flow Rate: 3.75 MGD.

	<u>Percent Removal By:</u>			
	<u>Primary Settling Tank</u>	<u>Trickling Filters</u>	<u>Final Settling Tank</u>	<u>Plant Overall Efficiency</u>
Five-day BOD	39%	77%	11%	88%
Suspended Solids	20%	61%	incr.	66%
Total Solids	20%	8%	incr.	25%
Total Volatiles	26%	45%	incr.	56%
Total Nitrogen	0%	42%	9%	47%

Second Sampling Period: 1:30 P. M. to 6:00 P. M.

Total Flow: 774,000 gallons.

Flow Rate: 4.13 MGD.

Five-day BOD	8%	89%	incr.	87%
Suspended Solids	26%	79%	incr.	81%
Total Solids	6%	19%	incr.	23%
Total Volatiles	19%	84%	incr.	53%
Total Nitrogen	0%	39%	4%	42%

NEW JERSEY STATE HEALTH DEPARTMENT
DEFINITION AND CRITERIA FOR STREAM CLASSIFICATION
CLASS FW-2

The following has been extracted from the regulation of the State of New Jersey which establishes stream classifications and defines the corresponding standards of quality to be maintained.

Class FW-2

Definition: Fresh surface waters approved as sources of public potable water supply. These waters are to be suitable for public potable water supply after such treatment as shall be required by the State Department of Health. These waters shall be suitable also for all recreational purposes including fishing, the propagation of native fish species desired for angling and other fish and aquatic life necessary thereto as well as any other reasonable uses.

Criteria

<u>Conditions</u>	<u>Allowable Limits</u>
1. Floating solids, settleable solids, oil, grease, artificial coloring matter and turbidity.	None of which are noticeable in the water or are deposited along the shore or on the aquatic substrata in quantities detrimental to the natural biota.
2. Toxic or deleterious substances (including mineral acids, caustic alkali, cyanides, heavy metals, carbon dioxide, ammonia or ammonium compounds, chlorine, etc.).	None of which would affect humans or be detrimental to the natural aquatic biota.
3. Odor and taste producing substances.	None of which are offensive to humans, detrimental to the aquatic biota or capable of producing offensive tastes and/or odors in water supplies and fauna used for human consumption.

<u>Conditions</u>	<u>Allowable Limits</u>
4. pH.	Between 6.5 and 8.5 unless naturally outside thereof.
5. Dissolved oxygen.	Not less than 5.0 p.p.m. for trout waters; otherwise 4.0 p.p.m. None which detrimentally affect the natural aquatic biota, or reasonably anticipated reuse of the waters.

NEW JERSEY STATE HEALTH DEPARTMENT
CRITERIA FOR TREATMENT OF WASTEWATER PRIOR TO
DISCHARGE TO RECEIVING WATERS

The following regulations concerning the treatment of wastewaters prior to discharge into the waters of the study area apply:

1. Domestic wastes, separately or in combination with industrial wastes, shall be treated to a degree providing, as a minimum, ninety percent (90%) of reduction of biochemical oxygen demand at all times, including any four-hour period of a day when the strength of the wastes to be treated might be expected to exceed average conditions.

2. Industrial wastes shall be treated to a degree providing, as a minimum, ninety percent (90%) of reduction of biochemical oxygen demand at all times and such further reduction in biochemical oxygen demand as may be necessary to maintain water in the River after dispersion of treated industrial waste effluents as specified in the rules and regulations entitled "Classification of the Surface Waters of the Raritan River Basin including Raritan Bay," effective April 15, 1965.

SANITARY ANALYSES OF STREAM SAMPLES
AS REPORTED BY N. J. STATE DEPARTMENT OF HEALTH

SAMPLING STATIONS	DATE COLLECTED	COLIFORMS M.P.N. / 100 ML.	COLOR PPM	TUR-BIDITY	SUSPENDED SOLIDS PPM	FREE AMMONIA PPM	pH	A.B.S.	B.O.D.	FIELD D.O.	TEMP. °C	* ODOR**
23	7-7-65	3,500	10	0	0	—	8.0	0.28	3	8.6	23°	0
23	3-18-65	3,500	30	30.5	0	2.24	6.8	0.15	2	11.5	5°	0
23	5-4-64	3,500	30	23	18	0.52	6.2	0.20	4	10.2	—	I E
23	2-4-64	2,400	35	16	10	1.81	7.0	0.22	5	11.2	—	II E
23	11-12-63	5,400	25	23	13	0.78	6.8	0.18	4	10.4	—	II E
23	8-5-63	1,300	35	0	316	0.03	7.4	0.15	—	—	—	III E
23	5-20-63	3,500	20	7	345	0.58	7.0	0.35	?	19.4	—	II M
23	1-30-63	3,500	20	5.5	245	1.60	6.4	0.57	8	14.5	0°	0
23	11-14-62	5,400	30	4.8	306	0.32	7.0	0.25	4	7.0	—	0
23	6-27-62	1,300	20	4.8	283	0.18	7.2	0.25	3	5.2	—	I E
23	4-11-62	3,500	40	20.5	171	0.04	6.9	—	3	10.2	—	I V
23	12-5-61	330	20	13.0	245	0.17	7.5	—	2	10.7	—	II E
23	7-25-61	24,000	100	62.0	214	0.04	7.5	—	3	5.4	—	II V
23	4-11-61	16,000	60	41.0	135	0.09	6.2	—	4	10.9	—	II V
23	12-1-60	3,500	5	0	185	0.08	7.0	—	4	11.5	—	III E
23	8-8-60	24,000	40	54.0	220	0.018	—	—	3	7.1	—	II M
23	6-9-60		20	15.5	325	0.096	7.7	—	3	7.5	—	0

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* INTENSITY

DEFINITION

**ODOR TYPE

0	No odor detectable.	A	Aromatic
I	Odor would not be detected by an average consumer but would be detected by an experienced observer.	B	Balsamic (flowery)
II	Odor might be detected by an average consumer but only if his attention were called to it.	C	Chemical
III	Odor would be readily detected and might cause the water to be regarded with disfavor.	DF	Disagreeable (fishy)
IV	Odor would force itself upon the attention and might make the water unpalatable.	DS	Disagreeable (septic)
V	Odor of such intensity that the water is absolutely unfit to drink. (Used only in extreme cases.)	E	Earthy
		M	Musty (desomposing straw)
		MM	Musty (moldy)
		V	Vegetable
		G	Grassy

SANITARY ANALYSES OF STREAM SAMPLES
AS REPORTED BY N.J. STATE DEPARTMENT OF HEALTH

SAMPLING STATIONS	DATE COLLECTED	COLIFORMS M.P.N. / 100 ML.	COLOR PPM	TURBIDITY	SUSPENDED SOLIDS PPM	FREE AMMONIA PPM	pH	A.B.S.	B.O.D.	FIELD D.O.	TEMP. °C	ODOR
29	11-4-65	5,400	35	7.4	14	0.21	6.8	0.23	3	12.1	13°	V DS
29	8-12-65	3,500	40	12	6	0.16	7.0	NEG.	2	9.7	25°	0
29	7-13-64	24,000 +	GR. BR	320	560	0.70	—	0.40	1	5.0	—	III E
29	11-13-63	16,000	30	5.5	13	1.40	5.0	0.48	4	10.1	—	8.6
29	8-6-63	1,300	60	9.9	140	0.06	7.0	0	—	—	—	II E
29	5-6-63	3,500	40	0	110	0.43	6.5	NEG.	6	10.4	—	I E
29	1-31-63	1,300	15	4.5	247	0.37	6.3	NEG.	2	12.4	0°	I M
29	11-14-62	790	25	0	90	0.12	7.0	NEG.	4	11.0	—	I E
29	7-11-62	790	40	45	100	0.01	8.0	0.18	7	10.0	—	II E
29	4-17-62	790	15	0	105	0.12	6.5	—	2	11.3	—	I E
29	12-6-61	330	20	19.5	103	0.09	6.7	—	2	11.7	—	II E
29	7-18-61	790	50	10.0	150	0.131	7.1	—	3	9.9	—	I E
29	4-12-61	45	0	5.5	100	0.09	5.4	—	3	10.5	—	0
29	8-1-60	24,000 +	70	57.5	130	0.064	6.4	—	5	6.6	—	II M
29	6-8-60	9,200	70	13.0	89	0.184	6.7	—	6	8.7	—	0
30	11-4-65	790	35	26	4	4.60	5.9	0.53	> 7	7.1	11°	IV DS
30	8-12-65	1,300	25	9.2	16	0.42	6.9	NEG.	1	6.9	25°	0
30	3-25-65	< 20	20	9.1	40	0.80	6.1	0.18	3	11.0	4°	0
30	7-13-64	24,000 +	50	4.6	19	1.08	—	0.29	2	5.7	—	III E
30	11-13-63	< 20	30	9.5	22	1.96	6.5	—	3	9.8	—	II C
30	5-6-63	< 20	45	0	140	0.53	6.4	0.75	8	11.8	—	II E
30	1-31-63	9,200	15	5.5	255	1.02	6.6	0.35	5	11.7	0°	III M
30	11-14-62	< 20	30	4.5	120	1.09	7.1	0.45	4	10.0	—	I D
30	7-11-62	5,400	45	7.4	150	0.82	6.1	1.0	2	5.7	—	III E, M
30	4-17-62	790	15	0	108	0.67	6.7	—	4	11.6	—	II E
30	12-6-61	24,000 +	30	16.5	100	0.62	7.0	—	5	11.4	—	III E
30	7-18-61	790	60	13.0	100	0.616	6.7	—	4	7.4	—	I E
30	4-12-61	790	30	16.5	100	0.53	6.1	—	5	11.0	—	I V
30	8-1-60	24,000 +	80	57.5	130	0.448	6.4	—	5	6.4	—	II M
30	6-8-60	1,300	70	23.5	101	1.12	6.0	—	5	7.5	—	I A

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SANITARY ANALYSES OF STREAM SAMPLES
AS REPORTED BY N. J. STATE DEPARTMENT OF HEALTH

SAMPLING STATIONS	DATE COLLECTED	COLIFORMS M.P.N. / 100 ML.	COLOR PPM	TURBIDITY	SUSPENDED SOLIDS PPM	FREE AMMONIA PPM	pH	A.B.S.	B.O.D.	FIELD D.O.	TEMP. °C	ODOR		
31	11-4-65	24,000 +	3	4.5	6	0.10	7.7	0.15	2	9.4	12°	0		
31	8-12-65	5,400	60	24.5	28	0.22	6.8	NEG.	< 1	—	26°	0		
31	3-25-65	490	10	8.3	16	0.10	5.9	NEG.	2	10.0	5°	0		
31	7-14-64	24,000 +	30	5.8	18	0.36	—	NEG.	2	8.3	—	II E		
31	11-13-63	3,500	10	5.2	19	0.19	5.8	NEG.	2	8.9	—	I A		
31	8-6-63	24,000 +	60	9.9	85	0.06	6.6	0	—	—	—	III E		
31	5-6-63	5,400	50	0	95	0.27	6.4	NEG.	8	12.3	—	II E		
31	1-3-63	790	5	4.8	415	0.26	5.7	NEG.	1	7.9	0°	I M		
31	11-14-62	24,000 +	20	4.5	115	0.04	6.7	NEG.	4	11.0	—	I E		
31	7-11-62	24,000 +	40	5.9	95	0.04	6.0	NEG.	5	8.0	—	II E		
31	4-17-62	3,500	5	0	90	0.03	5.3	—	2	11.7	—	0		
31	12-6-61	2,400	10	13.0	112	0.14	6.2	—	3	11.6	—	II V, E		
31	7-18-61	3,500	50	4.5	100	0.968	6.3	—	1	6.5	—	I E		
31	4-12-61	490	15	0	91	0.55	5.2	—	3	11.1	—	I V		
31	8-1-60	24,000	60	23.5	100	0.176	6.5	—	2	7.9	—	0		
31	6-8-60	5,400	5	13.0	116	0.05	4.8	—	1.8	12.0	—	0		
32	11-4-65	9,200	50	16.0	32	2.54	5.1	0.40	2	7.3	12°	II E		
32	8-12-65	9,200	50	26	16	0.19	7.0	NEG.	2	4.2	25°	0		
32	3-25-65	490	15	8.3	40	0.29	5.9	NEG.	2	10.6	6°	0		
32	7-13-64	24,000 +	40	28.5	12	0.64	—	0.21	2	5.5	—	II E		
32	11-13-63	790	20	9.1	4	0.68	6.0	0.15	—	—	—	II E		
32	8-6-63	490	—	—	—	0.43	—	—	—	—	—	—		
32	5-6-63	1,300	100	5.5	215	6.40	7.4	NEG.	7	14.3	—	III E		
32	1-31-63	490	-----BOTTLE BROKEN-----					—	—	—	4	10.8	0°	----
32	11-14-62	470	20	0	100	0.40	6.7	0.15	3	9.0	—	I E		
32	7-11-62	3,500	30	0	119	0.45	6.1	0.59	4	6.0	—	III E		
32	4-17-62	5,400	5	0	100	0.10	6.2	—	3	11.9	—	I E		
32	12-6-61	790	20	14.0	95	0.17	6.5	—	—	11.6	—	II E		
32	7-18-61	790	40	10.0	100	0.077	6.5	—	1	6.3	—	I E		

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SANITARY ANALYSES OF STREAM SAMPLES
AS REPORTED BY N. J. STATE DEPARTMENT OF HEALTH

SAMPLING STATIONS	DATE COLLECTED	COLIFORMS M.P.N. / 100 ML.	COLOR PPM	TURBIDITY	SUSPENDED SOLIDS PPM	FREE AMMONIA PPM	pH	A.B.S.	B.O.D.	FIELD D.O.	TEMP. °C	ODOR
32	4-12-61	2,400	15	4.5	100	1.3	6.2	—	2	11.3	—	II V
32	8-1-60	3,500	70	46.5	89	0.089	6.1	—	1	6.7	—	II M
32	6-8-60	3,500	45	13.0	115	0.264	6.5	—	4	9.3	—	0
33	10-27-65	230	40	38.5	20	0.21	6.6	0.18	7	11.0	9°	0
33	8-11-65	2,400	25	26	23	0.30	7.3	NEG.	6	8.5	24°	0
33	3-23-65	< 20	10	4.5	16	1.24	4.6	NEG.	2	11.9	5°	0
33	5-29-64	2,400	30	4.5	11	0.42	7.4	NEG.	5	10.0	—	I E
33	2-4-64	45	30	8.6	28	0.78	5.6	NEG.	3	7.6	—	II E
33	11-20-63	2,400	CHEMICAL BOTTLE BROKEN						3	10.2	—	—
33	7-22-63	16,000	80	9.9	170	0.03	6.7	0	—	—	—	III E
33	3-25-63	78	10	0	90	0.23	5.3	NEG.	6.5	11.8	11°	II E
33	1-21-63	24,000 +	40	22	143	0.26	4.9	NEG.	1	7.0	0°	II E
33	8-28-62	230	20	15	139	0	6.3	NEG.	2	9.3	—	I E
33	6-6-62	330	30	7.4	127	0.43	6.5	0.18	3	7.4	—	I E, DS
33	4-4-62	78	20	6.3	116	0.28	5.1	—	2	10.0	—	II M
33	10-23-61	2,400	20	26.5	104	0.32	6.0	—	2	9.0	—	I E
33	6-12-61	330	60	19.5	120	0.18	6.0	—	5	10.0	—	III V
33	4-26-61	24,000 +	40	43.0	141	0.46	4.9	—	4	7.4	—	III V
33	12-1-60	1,300	5	0	100	0.14	5.0	—	3	10.6	—	II E
33	8-8-60	78	20	14.0	115	0.21	4.6	—	5	7.6	—	III V
33	6-9-60	78	40	19.5	115	0.432	5.7	—	3	9.4	—	I A
34	10-27-65	16,000	320	92	134	0.38	6.8	NEG.	2	8.1	8°	0
34	8-11-65	2,400	40	16	23	0.66	7.3	28	> 7	6.3	24°	0
34	3-23-65	20	15	4.5	24	0.34	7.4	NEG.	3	12.0	5°	0
34	5-29-64	2,400	50	4.8	19	0.44	7.5	NEG.	3	—	—	I E
34	2-4-64	330	20	8.0	10	0.43	5.9	NEG.	4	8.0	—	II E
34	11-20-63	490	20	8.3	12	0.33	5.9	NEG.	—	9.4	—	II E

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SANITARY ANALYSES OF STREAM SAMPLES
AS REPORTED BY N. J. STATE DEPARTMENT OF HEALTH

SAMPLING STATIONS	DATE COLLECTED	COLIFORMS M.P.N. / 100 ML.	COLOR PPM	TURBIDITY	SUSPENDED SOLIDS PPM	FREE AMMONIA PPM	pH	A.B.S.	B.O.D.	FIELD D.O.	TEMP. °C	ODOR
34	7-22-63	790	70	7.05	105	0.06	6.1	0	—	—	—	II E
34	3-25-63	20	10	0	100	0.22	6.0	NEG.	1	10.7	12°	II E
34	1-21-63	3,500	40	23	135	0.14	6.1	NEG.	4	9.5	—	II E
34	8-27-62	24,000+	60	24.5	110	0	6.2	0.19	>4	3.7	—	I E
34	6-6-62	490	100	5.2	105	0.19	7.1	NEG.	4	4.2	—	II E
34	4-4-62	230	60	6.5	116	0.14	6.4	—	3	8.5	—	II E
34	10-23-61	490	50	26.5	91	0.08	6.4	—	2	6.5	—	I E
34	6-12-61	230	160	97.0	130	0.08	6.7	—	8	8.0	—	II V
34	4-26-61	9,200	80	54.0	127	0.20	6.0	—	3	8.0	—	III E
34	12-1-60	78	20	0	90	0.07	6.5	—	6	10.4	—	II E
34	8-8-60	24,000+	100	2.35	110	0.035	6.2	—	7	7.1	—	III V
34	6-9-60	130	120	23.5	105	0.077	6.6	—	7	7.3	—	0
35	10-27-65	1,300	5	0	18	0.16	6.7	NEG.	2	4.0	7°	0
35	8-11-65	24,000+	10	4.5	10	0.62	7.0	NEG.	1	5.0	20°	0
35	3-23-65	130	15	4.8	8	0.22	6.6	NEG.	2	9.5	5°	0
35	2-4-64	330	30	0	4	0.56	7.4	NEG.	2	9.5	—	II E
35	11-28-63	2,400	20	0	23	0.08	6.8	NEG.	3	11.2	—	II E
35	7-22-63	5,400	20	0	101	0.05	7.1	0	—	—	—	I E
35	3-25-63	130	10	0	69	0.06	6.5	NEG.	2	12.4	13°	II E, F
35	1-21-63	2,400	20	8.6	85	0.12	6.2	NEG.	3	11.6	—	II E
35	8-28-62	16,000	20	0	198	0	7.1	0.23	2	9.6	—	I E
35	6-6-62	5,400	40	0	109	0.06	6.8	NEG.	8.3	8.8	—	II E
35	4-4-62	130	30	0	76	0.04	6.8	—	4	11.8	—	II E
35	10-23-61	330	40	23.5	94	0.06	7.2	—	2	9.4	—	0
35	6-12-61	790	200	9.0	95	0.12	6.8	—	3	6.8	—	III V
35	4-26-61	3,500	40	15.5	100	0.17	5.6	—	3	10.0	—	II V
35	12-1-60	78	25	6.5	70	0.096	6.7	—	4	10.9	—	I E
35	8-8-60	9,200	120	18.0	80	0.04	6.0	—	2	3.6	—	III MM
35	6-9-60	1,300	120	14.0	95	0.144	6.7	—	5	9.0	—	0

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SANITARY ANALYSES OF STREAM SAMPLES
AS REPORTED BY N. J. STATE DEPARTMENT OF HEALTH

SAMPLING STATIONS	DATE COLLECTED	COLIFORMS M.P.N. / 100 ML.	COLOR PPM	TURBIDITY	SUSPENDED SOLIDS PPM	FREE AMMONIA PPM	pH	A.B.S.	B.O.D.	FIELD D.O.	TEMP. °C	ODOR
36	10-22-65	9,200	10	0	14	0.92	6.6	NEG.	4	7.0	8°	0
36	8-11-65	790	5	7.8	11	0.38	7.4	NEG.	2	6.1	16°	0
36	3-23-65	20	20	4.5	32	0.30	6.5	NEG.	2	9.1	6°	0
36	5-28-64	1,300	25	7.8	12	0.42	7.2	NEG.	7	13.0	—	I E
36	2-4-64	790	35	5.5	15	0.90	5.9	0	8	10.1	—	I E
36	11-20-63	790	20	9.1	9	0.40	5.6	NEG.	9	12.0	—	II E
36	7-22-63	16,000	80	9.05	245	1.38	7.1	0	—	—	—	II E
36	3-25-63	230	5	0	110	0.18	6.5	NEG.	—	11.5	12°	II E
36	1-21-63	2,400	40	4.8	145	0.94	6.5	NEG.	5	—	—	II E
36	8-27-62	9,200	50	0	120	0.01	6.3	NEG.	2	4.6	—	I E
36	6-6-62	16,000	40	45	220	1.68	—	0.15	2	2.9	—	I E
36	4-4-62	490	40	0	90	0.11	6.6	—	4	14.2	—	I E
36	10-23-61	2,400	40	19.5	125	0.15	6.6	—	1	6.0	—	I E
36	6-12-61	5,400	100	4.5	140	1.1	7.1	—	2	2.0	—	IV V
36	4-26-61	1,300	60	11.5	120	0.22	6.3	—	3	9.9	—	II V
36	12-1-60	2,400	5	0	86	0.08	6.9	—	3	11.5	—	I E
36	8-8-60	24,000 +	200	2.65	135	0.98	6.5	—	2	2.0	—	III M
36	6-9-60	2,400	100	23.5	145	3.2	6.7	—	6	6.3	—	0
37	10-27-65	3,500	20	4.5	16	0.18	6.3	NEG.	2	8.6	7°	0
37	8-5-65	16,000	35	7.1	14	0.04	6.7	NEG.	2	6.1	21°	0
37	3-23-65	330	10	9.9	14	0.21	7.0	NEG.	3	12.2	3°	I E
37	5-28-64	5,400	30	7.8	11	0.38	7.3	NEG.	10	16.0	—	I E
37	2-4-64	490	30	7.6	20	0.23	7.1	NEG.	4	8.8	—	I E
37	11-20-63	790	20	9.9	15	0.21	6.1	NEG.	3	8.6	—	II E
37	7-22-63	230	30	0	107	0.18	6.8	0	—	—	—	I E
37	3-25-63	790	15	6.3	185	0.14	7.1	NEG.	2	11.6	16°	II E
37	1-21-63	9,200	25	7.8	170	0.22	6.9	NEG.	5	13.3	—	II E
37	8-27-62	16,000	20	0	236	0.01	7.5	NEG.	3	9.6	—	I E
37	6-6-62	3,500	35	5.9	227	0.24	7.5	—	2	4.9	—	I E
37	4-4-62	490	20	5.9	151	0.06	7.0	—	5	12.6	—	II E

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SANITARY ANALYSES OF STREAM SAMPLES
AS REPORTED BY N. J. STATE DEPARTMENT OF HEALTH

SAMPLING STATIONS	DATE COLLECTED	COLIFORMS M.P.N. / 100 ML.	COLOR PPM	TURBIDITY	SUSPENDED SOLIDS PPM	FREE AMMONIA PPM	pH	A.B.S.	B.O.D.	FIELD D.O.	TEMP. °C	ODOR	
37	10-23-61	2,400	40	36.5	184	0.04	7.2	---	3	10.5	---	I E	
37	6-12-61	3,500	60	10.0	200	0.62	7.3	---	5	5.8	---	III V	
37	4-26-61	9,200	---CHEMICAL BOTTLE BROKEN---					---	---	4	8.7	---	---
37	12-1-60	790	10	13.0	105	0.09	7.0	---	4	10.2	---	I E	
37	8-8-60	2,400	50	23.5	110	0.104	---	---	4	5.7	---	II M	
37	6-9-60	2,400	25	15.5	215	0.144	7.2	---	5	8.2	---	0	
38	3-23-65	130	10	27	26	0.11	6.8	---	2	12.4	5°	0	
38	5-28-64	24,000 +	40	8.3	22	7.60	7.2	2.80	0	0	---	I E	
38	2-4-64	1,600	15	9.1	8	1.22	6.0	---	6	9.2	---	II E	
38	11-20-63	5,400	5	9.9	5	0.38	5.2	NEG.	4	9.0	---	II E	
38	7-22-63	230	50	0	405	12.8	7.7	5.50	4	9.0	---	III E	
38	1-21-63	790	20	5.9	160	3.50	6.8	0.65	6	12.5	---	III E	
38	8-28-62	16,000	30	0	401	3.36	7.2	4.90	5	7.5	---	I E	
38	6-6-62	24,000 +	40	5.2	350	---	7.6	8.20	6	6.7	---	II E	
38	4-4-62	790	10	4.5	135	0.98	6.9	---	3	10.7	---	I E	
38	10-23-61	1,300	30	16.5	225	2.0	7.1	---	8	8.0	---	I E	
38	6-12-61	3,500	40	43.0	290	7.3	7.5	---	5	5.0	---	III V	
38	4-26-61	24,000	40	23.5	135	0.38	6.3	---	6	9.1	---	I M	
39	10-28-65	230	20	0	4	0.11	7.0	NEG.	1	10.6	12°	0	
39	8-11-65	2,400	50	6.3	13	0.12	7.0	NEG.	2	4.3	23°	0	
39	3-24-65	< 20	10	5.5	3	0.36	6.2	NEG.	3	11.4	5°	0	
39	12-17-63	230	20	5.5	20	0.80	6.1	NEG.	3	7.3	---	I E	
39	8-1-63	790	40	0	85	0.03	7.2	0	---	---	---	II E	
39	5-6-63	490	35	6.5	100	0.22	6.5	NEG.	4	11.9	---	0	
39	1-23-63	790	25	5.5	129	0.40	6.3	NEG.	4	11.9	---	II E	
39	11-9-62	230	10	0	110	6.03	6.7	NEG.	3	11.0	---	I M	
39	6-20-62	790	20	0	92	0.01	6.6	NEG.	< 1	5.3	---	III E	
39	4-9-62	20	20	0	99	0.22	6.0	---	1	7.8	---	0	

SANITARY ANALYSES OF STREAM SAMPLES
AS REPORTED BY N.J. STATE DEPARTMENT OF HEALTH

SAMPLING STATIONS	DATE COLLECTED	COLIFORMS M.P.N. / 100 ML.	COLOR PPM	TURBIDITY	SUSPENDED SOLIDS PPM	FREE AMMONIA PPM	pH	A.B.S.	B.O.D.	FIELD D.O.	TEMP. °C	ODOR
39	11-15-61	78	20	8.0	89	0.07	6.6	—	2	8.8	—	III E
39	6-22-61	45	60	6.5	80	0.06	6.7	—	3	7.8	—	III E
39	4-17-61	9,200	40	55.5	100	0.14	5.5	—	2	8.0	—	I M
39	12-29-60	< 20	5	0	101	0.17	5.4	—	3	11.1	—	II E
39	11-29-60	790	10	8	90	0.12	6.3	—	8.1	10.3	—	I E
39	10-13-60	330	20	8.0	106	0.109	6.6	—	3	8.8	—	I V
39	7-10-60	330	50	26.5	83	0.24	6.9	—	4.4	6.9	—	III E
A-17 40	10-28-65	5,400	25	5.5	4	0.27	7.0	NEG.	2	9.0	9°	0
40	8-11-65	24,000+	15	14	12	0.24	7.2	NEG.	2	6.4	22°	0
40	3-24-65	230	15	7.4	0	0.11	6.1	NEG.	3	12.0	8°	0
40	6-4-64	9,200	20	8.6	12	0.50	7.3	NEG.	1	10.7	—	0
40	12-16-63	330	GR. BR.	28.5	220	1.10	6.0	NEG.	2	6.9	—	II C
40	8-1-63	2,400	35	0	113	0.07	6.8	0	—	—	—	II E
40	5-6-63	790	40	9.7	101	0.18	6.8	NEG.	5	11.2	—	0
40	1-23-63	5,400	35	7.8	115	0.13	6.5	NEG.	4	11.7	—	II E
40	11-9-62	490	15	0	115	0.14	6.7	NEG.	5	10.0	—	I M
40	6-20-62	1,300	40	0	100	0.07	6.9	NEG.	6	11.3	—	III E, π
40	4-9-62	2,400	30	5.2	108	0.07	6.5	—	3	8.6	—	I E
40	11-15-61	1,300	40	19.5	135	0.17	7.0	—	2	9.2	—	II E
40	6-22-61	130	40	6.5	89	0.14	6.9	—	2	7.7	—	III E
40	4-17-61	230	50	34.5	112	0.06	6.0	—	3	8.1	—	I M
40	12-29-60	330	5	8	105	0.19	6.0	—	3	11.7	—	III V
40	11-29-60	230	0	8	130	0.08	6.5	—	2	10.9	—	I V
40	10-13-60	9,220	20	0	100	0.083	6.6	—	3	8.7	—	II V
40	12-15-60	—	15	5	170	0.30	7.4	—	—	13.1	—	II C
40	7-10-60	9,200	35	10	91	0.28	6.4	—	2.3	4.0	—	III E
41	10-28-65	3,500	15	0	4	0.24	7.0	NEG.	1	7.6	10°	0
41	8-11-65	790	30	6.3	9	0.24	4.6	NEG.	1	4.6	23°	0
41	3-24-65	230	10	4.5	3	0.18	6.5	NEG.	2	9.8	5°	II DF

SANITARY ANALYSES OF STREAM SAMPLES
AS REPORTED BY N. J. STATE DEPARTMENT OF HEALTH

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SAMPLING STATIONS	DATE COLLECTED	COLIFORMS M.P.N. / 100 ML.	COLOR PPM	TUR-BID-ITY	SUSPENDED SOLIDS PPM	FREE AMMONIA PPM	pH	A.B.S.	B.O.D.	FIELD D.O.	TEMP. °C	ODOR
41	6-4-64	—	20	7.4	9	0.56	7.7	NEG.	1	10.4	—	I E
41	12-16-63	5,400	GR. BR.	2000	2620	21.60	6.9	NEG.	2	4.8	—	III A
41	8-1-63	790	30	0	176	0.10	6.9	0	—	—	—	II E
41	5-6-63	490	30	6.3	100	0.22	6.3	NEG.	—	—	—	0
41	1-23-63	230	20	4.5	120	0.31	6.4	NEG.	4	11.2	—	II E
41	11-9-62	790	20	0	131	0.20	6.6	NEG.	5	9.0	—	I M
41	6-20-62	230	30	0	100	0.10	6.5	NEG.	4	4.5	—	III E
41	4-9-62	330	5	0	104	0.18	6.1	—	4	9.2	—	I E
41	11-15-61	2,400	25	9.0	97	0.11	6.7	—	4	6.5	—	III E
41	6-22-61	9,200	60	6.5	98	0.18	6.7	—	3	4.1	—	III E
41	4-17-61	490	30	26.5	105	0.06	6.0	—	3	9.5	—	I V
41	12-29-60	490	15	0	115	0.24	5.9	—	2	9.6	—	II E
41	11-29-60	1,300	10	—	98	0.07	6.5	—	3	8.4	—	I E
41	10-13-60	790	20	0	100	0.096	6.5	—	2	6.1	—	I M
41	7-10-60	5,400	40	26.5	79	0.15	6.4	—	2.3	4.5	—	II E, C
42	10-28-65	330	50	10.7	8	14.40	6.6	NEG.	2	6.5	7°	0
42	8-5-65	9,200	30	8.6	4	7.80	6.7	NEG.	4	6.4	24°	II DS
42	3-24-65	230	25	7.1	1	1.58	5.3	NEG.	3	10.7	4°	I E
42	6-4-64	330	30	6.6	7	0.48	7.1	NEG.	—	12.5	—	0
42	12-16-63	24,000	40	24.5	39	1.44	—	NEG.	5	1.7	—	II A
42	8-1-63	790	10	0	179	0.53	6.5	NEG.	—	—	—	II E
42	5-6-63	790	50	29	115	3.44	6.5	NEG.	4	12.4	—	II B
42	1-23-63	2,400	20	0	275	1.76	6.6	NEG.	4	11.5	—	II E
42	11-9-62	1,300	20	0	403	3.04	6.3	NEG.	3	10.0	—	I E
42	6-20-62	16,000	30	0	436	7.84	6.6	NEG.	—	8.1	—	II E
42	4-9-62	330	15	0	129	0.86	5.8	—	3	10.0	—	I E
42	11-15-61	790	60	0	315	5.28	7.3	—	3	9.6	—	II M, E
42	6-22-61	24,000	100	21.5	225	0.54	6.9	—	4	7.4	—	III A, E
42	4-17-61	230	30	18.0	108	0.06	4.9	—	3	10.1	—	I V

SANITARY ANALYSES OF STREAM SAMPLES
AS REPORTED BY N. J. STATE DEPARTMENT OF HEALTH

SAMPLING STATIONS	DATE COLLECTED	COLIFORMS M.P.N. / 100 ML.	COLOR PPM	TURBIDITY	SUSPENDED SOLIDS PPM	FREE AMMONIA PPM	pH	A.B.S.	B.O.D.	FIELD D.O.	TEMP. °C	ODOR
42	12-29-60	2,400	10	—	122	0.18	6.3	—	5	12.6	—	II V
42	11-29-60	490	40	10	122	0.22	6.6	—	2	9.9	—	I E
42	10-13-60	3,500	40	15.5	245	0.26 ⁴	6.5	—	3	8.9	—	II V
42	7-10-60	2,400	20	31.0	155	0.35	6.0	—	7.2	8.4	—	II E
43	10-28-65	130	10	5.2	6	0.88	6.8	NEG.	2	8.9	10°	0
43	8-5-65	230	20	22	4	0.11	7.9	NEG.	4	7.7	24°	0
43	3-24-65	330	20	12.4	1	0.54	6.0	NEG.	3	12.2	4°	0
43	12-17-63	790	40	20.5	20	1.60	6.6	NEG.	3	4	—	I E
43	8-1-63	130	40	0	147	0.25	7.2	0	—	—	—	II V
43	5-6-63	1,300	35	8.2	200	0.36	6.8	NEG.	5	9.7	—	I B
43	1-23-63	490	25	5.2	105	0.38	6.5	NEG.	4	13.0	—	II E
43	11-9-62	490	15	0	130	0.04	7.0	NEG.	5	12.0	—	II E
43	6-20-62	330	20	0	114	0.31	6.6	NEG.	7	11.7	—	II E
43	4-9-62	5,400	40	17	130	0.15	6.6	—	4	8.5	—	0
43	11-15-61	3,500	20	16.5	130	0.06	7.1	—	4	11.5	—	II E
43	6-22-61	2,400	60	10	110	0.12	7.2	—	4	6.8	—	II A, E
43	4-17-61	5,500	120	81.5	136	0.06	6.4	—	3	9.9	—	II V
43	12-29-60	2,200	15	0	119	0.17	6.4	—	4	12.4	—	I V
43	10-13-60	300	35	14.0	116	0.03 ⁸	6.8	—	5	9.2	—	II V
43	7-10-60	5,400	35	14.0	90	0.17	6.5	—	1.4	4.2	—	II E
43	2-10-60	1,300	30	28.5	130	0.10	6.5	—	5.4	12.2	—	I V
44	10-28-65	20	20	6.6	4	3.28	6.6	0.23	6	6.0	9°	0
44	8-11-65	790	25	17	23	0.34	7.5	0.18	5	6.9	22°	0
44	3-24-65	2,400	25	9.9	7	0.30	6.5	NEG.	4	9.7	4°	0
44	6-4-64	5,400	70	30.5	25	0.70	6.9	NEG.	2	9.0	—	0
44	12-16-63	3,500	40	19.5	32	0.52	6.9	NEG.	1	8.7	—	II E
44	8-1-63	490	40	9.1	141	0.18	7.7	0	—	—	—	II E
44	5-6-63	230	35	8.6	110	0.27	6.6	NEG.	6	11.5	—	I E

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SANITARY ANALYSES OF STREAM SAMPLES
AS REPORTED BY N. J. STATE DEPARTMENT OF HEALTH

SAMPLING STATIONS	DATE COLLECTED	COLIFORMS M.P.N. / 100 ML.	COLOR PPM	TUR-BID-ITY	SUSPENDED SOLIDS PPM	FREE AMMONIA PPM	pH	A.B.S.	B.O.D.	FIELD D.O.	TEMP. °C	ODOR	
44	1-23-63	790	25	0	130	0.38	6.6	NEG.	4	12.5	—	I	E
44	11-9-62	230	20	0	155	0.16	7.2	NEG.	4	11.0	—	I	E
44	6-20-62	790	25	0	104	0.22	6.6	NEG.	6	8.9	—	I	E
44	4-9-62	5,400	40	18	81	0.26	6.6	—	3	9.7	—	I	E
44	11-15-61	16,000	20	15.5	115	0.38	7.3	—	4	10.8	—	III	E
44	6-22-61	5,400	60	14	117	0.25	7.1	—	4	6.9	—	III	A, E
44	4-17-61	3,500	120	81.5	136	0.06	6.4	—	3	9.9	—	II	V
44	12-29-60	1,700	10	5.5	130	0.19	6.5	—	4	13.0	—	I	V
44	11-29-60	230	20	0	105	0.07	6.9	—	8.1	10.9	—	II	E
44	10-13-60	330	40	33.0	143	0.083	6.9	—	4	9.6	—	IV	E
44	7-10-60	9,200	30	38.0	101	0.16	6.8	—	2.1	6.2	—	III	E
45	10-28-65	790	15	4.8	2	4.00	6.4	NEG.	3	4.2	10°	0	
45	8-5-65	330	25	9.5	12	0.96	7.1	0.23	4	3.3	23°	0	
45	3-24-65	16,000	25	10.7	1	0.34	7.1	NEG.	4	11.6	4°	I	E
45	6-4-64	16,000	40	20.5	20	2.36	6.6	0.45	3	5.9	—	0	
45	12-16-63	490	40	12.4	20	1.60	6.5	0.20	1	6.0	—	0	
45	8-1-63	5,400	50	5.5	190	1.02	7.8	0.50	—	—	—	II	E
45	5-6-63	16,000	40	11.3	133	0.78	—	0.32	9	8.7	—	II	E
45	1-23-63	790	20	5.5	135	0.62	6.8	NEG.	5	13.4	—	II	E
45	11-9-62	1,300	20	0	163	0.86	6.8	0.33	7	8.0	—	II	D
45	6-20-62	3,500	20	0	115	0.08	6.5	0.50	—	6.3	—	II	E, V
45	4-9-63	24,000	40	9.9	129	0.38	6.4	—	4	9.2	—	I	E
45	11-15-61	9,200	40	11.5	130	0.85	7.2	—	7	8.3	—	II	E
45	6-22-61	3,500	50	14	123	0.41	7.2	—	6	5.5	—	III	E
45	4-17-61	24,000 +	60	52.4	130	0.34	6.3	—	4	9.8	—	I	V
45	12-29-60	5,400	5	10	124	0.28	6.5	—	4	12.5	—	II	V
45	11-29-60	2,400	20	0	120	0.77	—	—	4	10.5	—	II	E
45	10-13-60	24,000 +	40	25.0	129	1.80	6.8	—	7	7.2	—	III	V
45	7-10-60	5,400	30	48.5	107	2.80	6.6	—	4	3.8	—	III	E

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SANITARY ANALYSES OF STREAM SAMPLES
AS REPORTED BY N. J. STATE DEPARTMENT OF HEALTH

SAMPLING STATIONS	DATE COLLECTED	COLIFORMS M.P.N. / 100 ML.	COLOR PPM	TURBIDITY	SUSPENDED SOLIDS PPM	FREE AMMONIA PPM	pH	A.B.S.	B.O.D.	FIELD D.O.	TEMP. °C	ODOR
46	10-28-65	790	10	0	22	0.88	6.1	NEG.	2	5.0	10°	0
46	8-5-65	790	15	4.5	2	0.07	6.3	0.15	2	4.8	23°	0
46	3-24-65	3,500	20	8.6	10	0.96	7.1	NEG.	4	10.9	4°	I DF
46	6-4-64	2,400	40	16	19	1.48	6.6	0.33	1	5.1	—	0
46	12-16-63	330	40	16	32	2.08	6.9	0.20	3	6.5	—	I E
46	8-1-63	330	40	9.4	165	0.08	7.0	0.25	—	—	—	II E
46	5-6-63	2,400	35	10.7	135	0.73	6.6	0.28	5	6.5	—	II B
46	1-23-63	790	25	4.5	141	0.73	6.7	NEG.	5	12.1	—	II E
46	11-9-62	330	20	0	170	0.42	6.7	0.30	6	8.0	—	I D
46	6-20-62	790	30	0	216	0.50	6.6	0.28	7	9.6	—	I E
46	4-9-62	3,500	40	11.5	145	0.26	6.7	—	3	9.6	—	0
46	11-15-61	490	20	6.5	150	1.46	7.2	—	4	6.1	—	II E
46	6-22-61	5,400	50	10	140	0.41	7.0	—	3	4.6	—	II E
46	4-17-61	24,000 +	60	72	125	0.08	6.2	—	4	10.0	—	I M
46	12-29-60	2,200	15	5.5	122	0.60	6.6	—	4	12.8	—	III V
46	11-29-60	490	20	4.5	115	0.22	6.9	—	5.4	9.5	—	II V
46	10-13-60	3,500	50	15.5	140	0.816	6.6	—	5	6.2	—	III V
46	7-10-60	330	35	28.0	120	14.	6.8	—	1.7	5.9	—	III E, A
47	11-7-64		25	19	148	0.144	7.3	—	0.2	7.5	—	III M
47	2-7-64		18	14	132	0.060	7.2	—	2.3	12.2	36°	I M
47	12-17-63		25	12	156	0.148	7.5	—	2.8	7.2	—	III M
47	7-5-62		22	1	182	0.024	7.0	—	—	6.6	70°	I M
47	6-7-62		20	8	230	0.130	6.7	—	—	5.2	69°	I M
47	5-10-62		30	95	182	0.152	7.0	—	—	9.1	52°	I M
47	4-5-62		25	14	156	0.106	6.8	—	1.6	10.7	48°	—
47	3-8-62		25	20	100	0.158	6.8	—	—	12.8	36°	I M
47	2-5-62		15	4	174	0.236	6.9	—	—	14.5	34°	I M
47	12-21-61		30	10	128	0.107	6.6	—	—	12.1	38°	I M
47	11-16-61		20	5	140	0.106	6.9	—	—	8.0	50°	I M
47	9-4-61		23	8	162	0.174	6.9	—	1.8	7.2	—	I M

SANITARY ANALYSES OF STREAM SAMPLES
AS REPORTED BY N. J. STATE DEPARTMENT OF HEALTH

SAMPLING STATIONS	DATE COLLECTED	COLIFORMS M.P.N. / 100 ML.	COLOR PPM	TURBIDITY	SUSPENDED SOLIDS PPM	FREE AMMONIA PPM	pH	A.B.S.	B.O.D.	FIELD D.O.	TEMP.	ODOR
											°C	
47	9-7-61		25	5	168	0.024	6.9	—	—	5.8	78°	I M
47	8-10-61		32	12	180	0.048	6.9	—	—	7.5	76°	I M
47	5-1-61		21	7	144	0.048	7.0	—	—	9.5	52°	I M
47	4-28-61		19	7	122	0.082	6.9	—	—	10.6	46°	I M
47	3-30-61		40	105	212	0.10	6.7	—	—	11.7	48°	I E
47	2-9-61		11	3	146	0.470	6.6	—	—	12.3	35°	I M
47	1-12-61		15	6	126	123.	6.7	—	—	13	33°	I M
47	11-3-60		22	5	120	0.006	8.4	—	—	11.2	51°	II E
47	9-6-60		15	3	175	0.004	8.2	—	2.7	9.3	60°	II E
47	9-19-60		20	18	153	0.002	7.2	—	27	8.3	64°	I M
47	8-11-60		25	5	126	0.016	7.0	—	2800	7.1	73°	I M
47	10-6-60		15	3	175	0.004	8.2	—	27	9.3	60°	II E
47	9-19-60		25	18	136	0.040	6.1	—	19	7.6	64°	I M
47	7-10-60		120	16.5	445	0.43	7.0	—	25	6.5	—	III E,A
47	2-10-60		40	48.5	174	0.08	6.8	—	2400	12.3	—	I E
	2-7-64		18	14	132	0.60	7.2	—	2.3	12.2	36°	I M
	12-16-63		20	7	158	0.230	7.0	—	1.6	6.4	—	I M
	7-5-62		20	8	232	0.004	7.9	—	—	6.9	72°	I M
	6-7-62		20	7	200	0.108	7.4	—	—	7.1	70°	I M
	5-10-62		30	30	146	0.114	7.3	—	—	10.0	52°	I M
	4-5-62		20	12	142	0.028	7.2	—	2.1	11.3	48°	I M
	3-8-62		28	20	98	0.066	7.2	—	—	12.5	36°	I M
	1-11-62		20	13	124	0.112	7.0	—	—	13.3	55°	I M
	2-5-62		16	5	190	0.094	7.4	—	—	14.1	34°	I M
	12-21-61		32	10	132	0.090	7.2	—	—	12.4	38°	I M
	11-16-61		20	5	148	0.012	7.6	—	—	10.3	52°	I M
	9-4-61		21	7	180	0.024	7.8	—	1.2	8.9	60°	I M
	9-7-61		25	5	214	0.032	7.6	—	—	6.1	78°	I M
	8-10-61		23	10	204	0.006	7.6	—	—	7.3	77°	I M
	10-6-60		20	7	149	0.126	6.9	—	—	8.6	60°	I M

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SANITARY ANALYSES OF STREAM SAMPLES
AS REPORTED BY N. J. STATE DEPARTMENT OF HEALTH

SAMPLING STATIONS	DATE COLLECTED	COLIFORMS M.P.N. / 100 ML.	COLOR PPM	TURBIDITY	SUSPENDED SOLIDS PPM	FREE AMMONIA PPM	pH	A.B.S.	B.O.D.	FIELD D.O.	TEMP. °C	ODOR
	9-9-60		25	18	136	0.040	6.7	—	—	7.6	64°	I M
	8-11-60		25	7	140	0.002	7.9	—	—	7.4	74°	I M
49	10-18-65	230	20	0	36	0.11	7.6	NEG.	3	8.9	9°	0
49	8-2-65	3,500	10	0	16	0.08	8.8	NEG.	1	10.9	21°	0
49	3-8-65	330	25	31.5	17	0.07	7.2	NEG.	3	11.8	—	0
49	12-17-63	330	35	9.5	23	0.24	7.4	NEG.	3	7.5	—	0
49	7-30-63	330	40	6.3	160	0.04	7.3	0	—	—	—	I E
49	3-20-63	16,000	45	19.5	164	0.17	6.8	NEG.	2	—	4°	II E
49	1-15-63	9,200	30	6.6	145	0.11	6.5	NEG.	5	13.5	—	II E
49	8-29-62	24,000 +	70	33	148	0.07	6.9	0.18	—	2.6	—	II F
49	6-5-62	230	20	0	145	0.04	7.0	0.18	5	5.3	—	I E, F
49	3-19-62	490	15	6.3	121	0.19	6.5	0.19	3	12.5	—	II E
49	9-27-61	490	30	6.5	131	0.25	7.5	—	3	9.1	—	II E
49	5-29-61	300	35	9.0	126	0.14	7.8	—	4	10.6	—	I E
49	3-28-61	5,400	20	15.5	110	0.04	6.7	—	4	10.3	—	II V
49	11-30-60	230	5	0	125	0.03	7.2	—	—	8.6	—	II E
49	10-17-60	1,300	30	10.0	153	0.077	7.4	—	5	—	—	II V
49	7-11-60	45	25	28.0	124	0.28	7.4	—	3	7.1	—	III 4, 5
50	10-18-65	130	20	0	12	0.36	7.6	NEG.	2	10.2	8°	0
50	8-2-65	330	20	0	80	0.02	9.5	NEG.	1	14.0	24°	0
50	4-5-65	230	15	7.4	1	0.18	7.8	NEG.	4	13.0	9°	0
50	12-17-63	2,400	45	30.5	30	0.19	7.2	0.30	4	11.5	—	II E
50	7-30-63	790	40	6.3	165	0.05	7.6	0	—	—	—	III E
50	3-20-63	2,400	40	22	200	0.18	6.9	NEG.	4	13.2	5°	II E
50	1-15-63	16,000	30	8.2	140	0.12	6.9	NEG.	5	13.1	—	I E
50	8-30-62	24,000	100	80	170	0.10	6.6	NEG.	5	7.5	—	II F
50	6-5-62	230	20	0	135	0.01	7.3	0.18	1	8.5	—	II E
50	3-19-62	33	20	5.2	141	0.06	6.6	—	5	13.0	—	II E

SANITARY ANALYSES OF STREAM SAMPLES
AS REPORTED BY N. J. STATE DEPARTMENT OF HEALTH

SAMPLING STATIONS	DATE COLLECTED	COLIFORMS M.P.N. / 100 ML.	COLOR PPM	TURBIDITY	SUSPENDED SOLIDS PPM	FREE AMMONIA PPM	pH	A.B.S.	B.O.D.	FIELD D.O.	TEMP. °C	ODOR
50	9-27-61	330	40	6.5	140	0.04	7.9	—	5	5.8	—	II E
50	5-29-61	2,400	40	11.5	125	0.08	7.2	—	3	—	—	I E
50	3-28-61	5,400	20	14.0	114	0.08	7.0	—	3	9.8	—	I V
50	11-30-60	330	0	I E	130	0.04	7.4	—	4	13.1	—	0
50	10-17-60	2,400	35	13.0	146	0.109	8.1	—	6	11.3	—	I V
50	7-11-60	2,400	25	29.5	87	0.18	7.0	—	4	7.6	—	III E,A
51	10-18-65	45	15	0	16	0.33	7.6	NEG.	3	10.4	11°	0
51	8-2-65	330	15	5.9	28	0.04	7.4	NEG.	2	7.5	22°	0
51	3-11-65	490	25	31.5	56	0.14	7.2	NEG.	3	11.6	—	II E
51	12-17-63	2,400	20	0	9	0.16	7.4	0.18	1	12.5	—	I C
51	7-30-63	330	40	5.5	160	0.05	8.2	0	—	—	—	II E
51	3-20-63	5,400	80	34	206	0.27	6.7	NEG.	4	—	4°	II E
51	1-5-63	5,400	25	5.5	165	0.11	6.6	NEG.	5	13.7	—	II E
51	8-29-62	24,000 +	140	85	167	0.09	6.6	0.18	6	7.5	—	III F
51	6-5-62	230	25	0	135	0.07	7.2	NEG.	7	8.0	—	II E,F
51	3-19-62	230	15	6.3	134	0.06	6.7	—	3	12.1	—	I E
51	9-27-61	790	40	8.0	131	0.04	7.9	—	4	9.7	—	I E
51	5-29-61	2,400	40	25.0	130	0.14	7.2	—	3	9.1	—	I G
51	3-28-61	2,400	15	25.0	114	0.04	6.6	—	3	9.7	—	I V
51	11-30-60	490	20	65	138	0.08	7.3	—	9.4	8.8	—	II E
51	10-17-60	1,300	30	14.0	140	0.083	8.2	—	4	9.7	—	III V
51	7-11-60	230	30	21.0	134	0.18	7.8	—	6	9.0	—	III E,A
52	10-28-65	130	25	7.4	4	0.22	7.9	NEG.	3	10.0	11°	0
52	8-2-65	790	50	17	10	0.34	7.2	NEG.	5	4.8	23°	0
52	3-8-65	790	30	20.5	38	0.04	7.2	NEG.	3	11.1	—	III DF
52	12-17-63	230	10	0	10	0.25	7.2	NEG.	0	11.3	—	0
52	7-30-63	2,400	50	6.6	155	0.10	7.5	0	—	—	—	III E
52	3-20-63	2,400	25	17	157	0.14	6.5	NEG.	4	12.6	5°	II E
52	1-15-63	5,400	35	5.9	144	0.10	6.6	NEG.	5	12.8	—	I E
52	8-29-62	24,000 +	120	80	180	0.08	6.5	0.18	5	5.7	—	II F

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SANITARY ANALYSES OF STREAM SAMPLES
AS REPORTED BY N. J. STATE DEPARTMENT OF HEALTH

SAMPLING STATIONS	DATE COLLECTED	COLIFORMS M.P.N. / 100 ML.	COLOR PPM	TURBIDITY	SUSPENDED SOLIDS PPM	FREE AMMONIA PPM	pH	A.B.S.	B.O.D.	FIELD D.O.	TEMP. °C	ODOR
52	6-5-62	78	40	10.3	160	0.15	7.1	NEG.	5	7.2	—	II E
52	3-19-62	490	20	5.9	126	0.06	7.0	—	2	11.5	—	II E
52	9-27-61	3,500	70	13.0	150	0.02	7.4	—	4	10.3	—	III E
52	5-29-61	2,400	50	26.5	136	0.14	7.2	—	4	9.9	—	I G
52	3-28-61	2,400	30	13.0	115	0.04	6.4	—	4	9.8	—	I V
52	11-30-60	1,300	10	0	110	0.06	7.0	—	7.6	9.7	—	I E
52	10-17-60	24,000 +	30	46.0	165	0.288	7.0	—	6	6.1	—	IV V
52	7-11-60	230	30	31.0	146	0.69	7.2	—	6	10.0	—	III E,A
53	10-18-65	16,000	15	5.5	18	0.19	8.1	NEG.	3	8.0	10°	0
53	8-2-65	24,000 +	20	4.5	28	0	7.5	NEG.	2	7.5	2°	0
53	3-8-65	230	15	12.4	20	0.10	7.1	NEG.	3	12.2	—	III DF
53	12-17-63	2,400	30	8.5	13	0.06	7.1	NEG.	5	12.2	—	0
53	7-30-63	9,200	80	9.5	145	0.06	7.3	0	—	—	—	III E
53	3-20-63	2,400	40	17	154	0.18	6.6	NEG.	5	13.4	4°	II E
53	1-15-63	3,500	15	0	126	0.02	6.5	NEG.	4	13.7	—	0
53	8-30-62	24,000 +	50	18	126	0.01	6.9	NEG.	4	8.6	—	I F
53	6-5-62	9,200	20	4.5	134	0.04	7.1	NEG.	4	6.7	—	II E,C
53	3-19-62	130	15	5.5	102	0.04	6.8	—	4	12.9	—	II E
53	9-27-61	2,400	20	6.5	130	0.04	7.5	—	2	11.0	—	I E
53	5-29-61	2,400	30	9.0	130	0.06	7.1	—	3	10.7	—	I G
53	3-28-61	790	20	10.0	89	0.06	6.6	—	4	11.0	—	I M
53	11-30-60	490	0	0	110	0.08	7.1	—	8.9	11.2	—	I E
53	10-17-60	2,400	20	10.0	160	0.090	7.1	—	4	9.7	—	II V
53	7-11-60	2,400	25	31.0	120	0.160	7.1	—	3	7.6	—	III E,A
54	10-18-65	2,400	20	4.5	8	0.09	7.8	NEG.	2	8.4	11°	0
54	8-2-65	490	10	4.5	26	0.04	8.0	NEG.	2	7.8	22°	0
54	3-8-65	2,400	10	12	10	0.14	7.2	NEG.	2	12.3	—	0
54	12-17-63	2,400	15	0	5	0.20	7.2	NEG.	0	11.7	—	I C
54	7-30-63	2,400	40	5.5	190	0.08	7.5	0	—	—	—	I E

SANITARY ANALYSES OF STREAM SAMPLES
AS REPORTED BY N. J. STATE DEPARTMENT OF HEALTH

SAMPLING STATIONS	DATE COLLECTED	COLIFORMS M.P.N. / 100 ML.	COLOR PPM	TURBIDITY	SUSPENDED SOLIDS PPM	FREE AMMONIA PPM	pH	A.B.S.	B.O.D.	FIELD D.O.	TEMP. °C	ODOR
54	3-20-63	1,300	25	4.5	109	0.09	6.5	NEG.	2	12.7	5°	II E
54	1-15-63	9,200	5	5.2	145	0.35	6.6	NEG.	5	12.8	—	I E
54	8-30-62	24,000 +	35	12.5	176	0.07	7.0	0.20	3	8.3	—	I F
54	6-5-62	2,400	40	7.4	187	0.20	7.2	0.30	4	4.9	—	I F, E
54	3-19-62	330	5	4.5	130	0.09	6.8	—	4	12.4	—	II E
54	9-27-61	9,200	20	5.5	180	0.03	7.6	—	2	11.5	—	I E
54	5-29-61	3,500	10	16.5	136	0.06	7.6	—	4	12.1	—	I G
54	3-28-61	2,400	15	5.5	123	0.07	6.7	—	4	11.3	—	I V
54	11-30-60	2,400	5	0	135	0.14	8.7	—	11.4	14.1	—	I E
54	10-17-60	5,400	35	10.0	192	0.044	7.3	—	5	7.8	—	II M
54	7-11-60	78	25	25.0	186	0.13	8.5	—	2	10.0	—	III E, A
55	10-18-65	790	20	0	4	0.38	7.5	NEG.	2	8.4	8°	0
55	8-2-65	5,400	35	27	76	0.04	8.2	NEG.	5	11.0	22°	0
55	3-11-65	490	10	30	10	0.14	7.2	NEG.	2	—	—	II E
55	12-17-63	3,500	20	5.5	13	0.21	7.2	NEG.	3	9.8	—	0
55	7-30-63	9,200	80	19.5	185	0.30	7.1	0	—	—	—	II E
55	3-20-63	9,200	60	16	237	0.28	6.7	NEG.	4	12.5	7°	II E
55	1-15-63	16,000	5	4.5	145	0.24	7.2	NEG.	3	14.7	—	I E
55	8-29-62	24,000 +	60	16	165	0.01	6.8	0.18	4	8.3	—	0
55	6-5-62	2,400	20	5.5	175	0.08	7.0	0.24	3	7.1	—	I E, F
55	3-19-62	330	10	4.8	123	0.09	6.6	—	3	12.0	—	I E
55	9-27-61	1,300	30	8.0	165	0.13	7.4	—	3	10.0	—	II E
55	5-29-61	3,500	20	11.5	125	0.08	7.2	—	2	10.4	—	I G
55	3-28-61	790	15	5.5	130	0.10	6.7	—	3	10.7	—	I V
55	11-30-60	3,500	10	0	125	0.14	7.0	—	7.7	11.2	—	0
55	10-17-60	3,500	25	14.0	170	0.102	7.1	—	6	6.8	—	IV M
55	7-11-60	78	40	25.0	195	0.26	8.9	—	6	14.5	—	III E, A

SANITARY ANALYSES OF STREAM SAMPLES
AS REPORTED BY N. J. STATE DEPARTMENT OF HEALTH

SAMPLING STATIONS	DATE COLLECTED	COLIFORMS M.P.N. / 100 ML.	COLOR PPM	TURBIDITY	SUSPENDED SOLIDS PPM	FREE AMMONIA PPM	pH	A.B.S.	B.O.D.	FIELD D.O.	TEMP.	
											°C	ODOR
56	10-18-65	790	25	4.5	22	0.34	7.5	NEG.	4	8.4	9°	0
56	8-5-65	16,000	30	9.9	2	0.04	6.9	NEG.	1	6.3	20°	0
56	3-8-65	330	20	26	20	0.08	7.2	NEG.	3	11.7	—	0
56	12-17-63	2,400	25	7.1	11	0.23	7.2	NEG.	2	10.9	—	IV DF
56	7-30-63	24,000 +	100	9.9	185	0.26	7.1	0	—	—	—	II E
56	3-20-63	9,200	60	16	237	0.28	6.7	NEG.	4	12.5	7°	II E
56	1-15-63	790	10	5.9	157	0.22	6.5	NEG.	2	12.9	—	I E
56	8-30-62	24,000 +	60	22	179	0.04	6.8	0.15	6	8.0	—	I F
56	6-5-62	490	20	4.5	245	0.06	7.2	0.15	2	6.9	—	I E,F
56	3-19-62	490	10	5.9	124	0.08	6.9	—	4	12.9	—	II E
56	9-27-61	490	30	8.0	184	0.15	7.3	—	1	8.9	—	I E
56	5-29-61	3,500	20	13.0	150	0.06	7.2	—	4	9.6	—	I G
56	3-28-61	790	15	11.5	102	0.11	6.5	—	2	10.3	—	III V
56	11-30-60	3,500	20	0	151	0.11	7.4	—	8.5	11.6	—	I E
56	10-17-60	2,400	30	9	195	0.077	7.1	—	5	7.3	—	I M
56	7-11-60	2,400	60	16.5	180	0.23	7.0	—	4	6.6	—	III E

ALTERNATIVE REGIONAL PLANS
FOR
WASTEWATER DISPOSAL

Alternative Plans Considered

There are several alternative plans for regional disposal facilities which have been considered and compared to the recommended plan.

Following page A-29, two workable alternative plans are shown on PLATES 22A and 22B. Descriptions and cost estimates for each accompany each plan. For comparative purposes, the recommended plan (shown on PLATE 22) and descriptive data are also included. Estimated costs for both of these alternatives are higher than those estimated for the proposed plan.

In addition, the alternative of collection of the wastewater for ultimate disposal outside of the watershed has also been considered, as follows:

Ultimate Disposal Outside of Watershed - Two possibilities of disposal are:

1. Pumping the collected wastewater to the Middlesex County Sewerage Authority trunk sewer for subsequent treatment and disposal, and
2. Pumping treated wastewater effluent to Raritan Bay for dispersion.

These possibilities have been rejected for the following reasons:

1. Wastewater would not be available for reclamation and would not be conserved within the Stony Brook-Millstone Watershed.
2. The Middlesex County Sewerage Authority's Central Treatment Plant is capable of treating 78 MGD average daily flow. The present average daily flow to the plant is approximately 50 MGD. The anticipated plant flow from the study area (30 MGD by the year 1990), plus the normal addition of participants to the Middlesex system would require a major expansion of the existing facilities of the Middlesex County Sewerage Authority. There obviously appears to be little economic advantage in eliminating a treatment plant from the study area only to

incur the costs of expansion in another area plus the cost of transmission facilities.

3. Pumping treated effluent to Raritan Bay will require approximately 22 miles of large diameter force main. The monies for such a project, estimated at 20 million dollars (assume 117,000 L. F. of 2-36" diameter Force Mains @ \$140/L. F. + 20% Development Expense = \$20,000,000) could be used more advantageously for the planned reclamation of wastewaters within the study area.

RECOMMENDED REGIONAL SYSTEM
FOR
WASTEWATER DISPOSAL

The recommended regional system details and costs are reproduced here to permit facility of comparison to the subsequent alternatives shown.

Description

1. Wastewater Collection Facilities, Water Pollution Control Facilities and Wastewater Reclamation Facilities sized for ultimate population of Stony Brook-Millstone Watershed. This plan is shown on PLATE 22.

2. Design Capacity:

Wastewater Collection Facilities	612,400 people
Water Pollution Control Plant	60 MGD
Wastewater Reclamation Facilities	60 MGD

Ultimate Project Capital Cost Summary

Wastewater Collection Facilities	\$33,925,000
Water Pollution Control Facilities	19,050,000
Wastewater Reclamation Facilities	<u>24,850,000</u>
Total Ultimate Cost	\$77,825,000

STONY BROOK-MILLSTONE WATERSHED
REGIONAL SEWERAGE FEASIBILITY STUDY

PROPOSED REGIONAL SYSTEM
FOR WASTEWATER DISPOSAL

SEELYE STEVENSON VALUE & KNECHT
CONSULTING ENGINEERS
PRINCETON, N. J. NEW YORK, N. Y.



ALTERNATE NO. 1

REGIONAL DISPOSAL SYSTEM WITH
WATER POLLUTION CONTROL FACILITIES
AT WATERSHED OUTLET

Description

1. Alternate No. 1 differs from the recommended regional system in that the Water Pollution Control Plant is located further downstream along the Millstone River at the outlet of the Watershed in the vicinity of Manville Borough. This plan is shown on PLATE 22A.

2. Design Capacity:

Wastewater Collection Facilities	612,400 people
Water Pollution Control Facilities	60 MGD
Wastewater Reclamation Facilities	60 MGD

Ultimate Project Capital Cost Summary

Wastewater Collection Facilities	\$35,538,000
Water Pollution Control Facilities	19,050,000
Wastewater Reclamation Facilities	<u>33,732,000</u>
Total Project Cost	\$88,320,000

STONY BROOK-MILLSTONE WATERSHED
REGIONAL SEWERAGE FEASIBILITY STUDY
ALTERNATE REGIONAL DISPOSAL SYSTEM NO. I
WATER POLLUTION CONTROL FACILITY
LOCATED AT WATERSHED OUTLET

SEELYE STEVENSON VALUE & KNECHT
CONSULTING ENGINEERS
PRINCETON, N. J. NEW YORK, N. Y.



ALTERNATE NO. 2

REGIONAL DISPOSAL SYSTEM WITH
WATER POLLUTION CONTROL FACILITIES
IN TWO LOCATIONS

Description

1. Alternate No. 2 is similar to the recommended regional system, except that in lieu of a pumping station and force main at the Watershed outlet, a second Wastewater Pollution Control Facility is provided. This plan is shown on PLATE 22B.

2. Design Capacity:

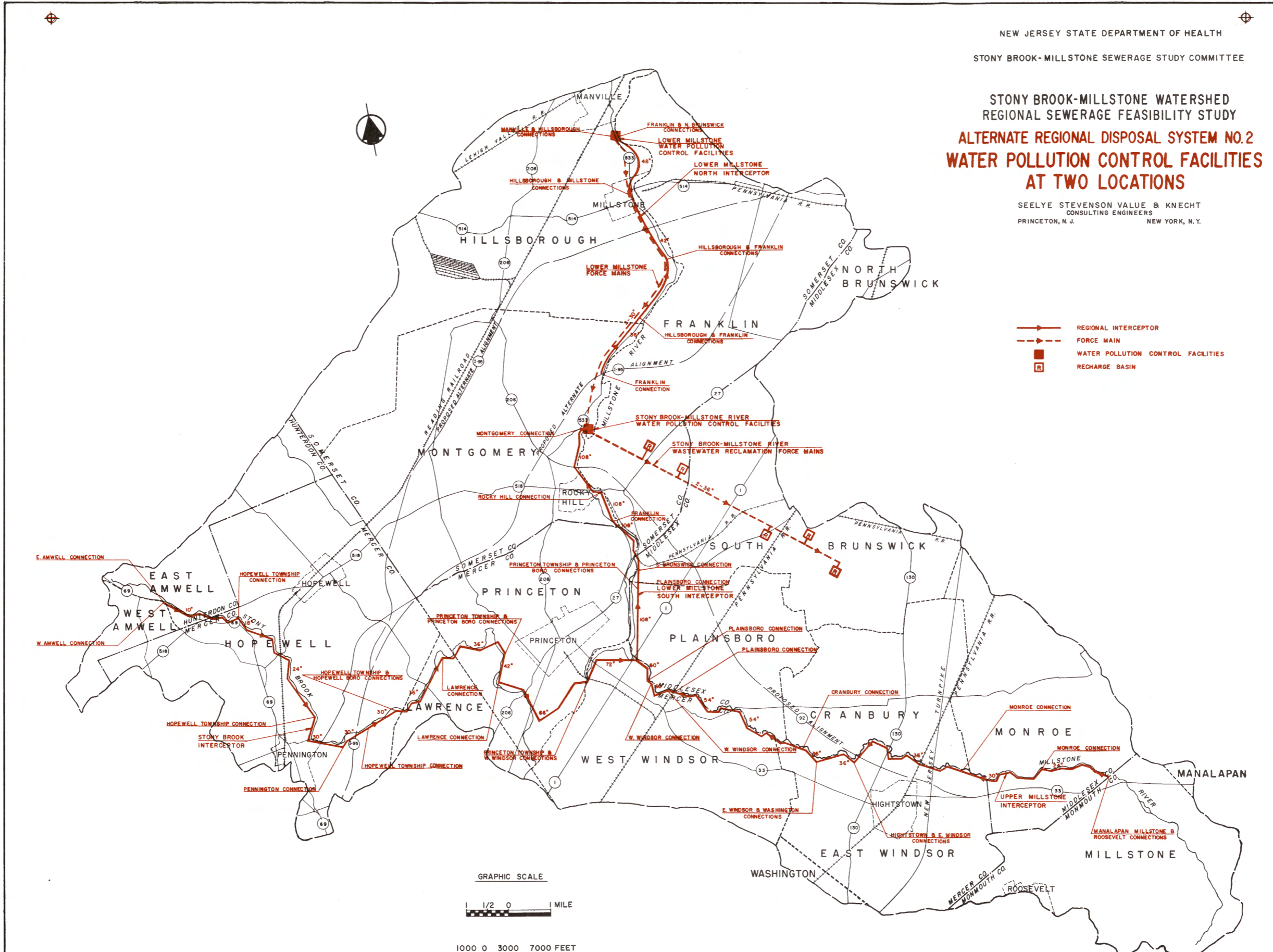
Wastewater Collection facilities	612,400 people
Water Pollution Control Facilities:	
Stony Brook-Millstone River	50 MGD
Lower Millstone	10 MGD
Wastewater Reclamation Facilities	60 MGD

Ultimate Project Capital Cost Summary

Wastewater Collection Facilities	\$26,164,000
Water Pollution Control Facilities:	
Stony Brook-Millstone River	16,400,000
Lower Millstone	5,600,000
Wastewater Reclamation Facilities	<u>32,400,000</u>
Total Project Cost	\$80,564,000

STONY BROOK-MILLSTONE WATERSHED
 REGIONAL SEWERAGE FEASIBILITY STUDY
ALTERNATE REGIONAL DISPOSAL SYSTEM NO.2
WATER POLLUTION CONTROL FACILITIES
AT TWO LOCATIONS

SEELYE STEVENSON VALUE & KNECHT
 CONSULTING ENGINEERS
 PRINCETON, N. J. NEW YORK, N. Y.



LIMITED REGIONAL SYSTEM
FOR
WASTEWATER DISPOSAL

As previously discussed in the main body of the report under the section dealing with the Estimate of Capital Costs for Initial Facilities Constructed, the facilities proposed for initial construction include wastewater collection system interceptors sized to receive flow from the ultimate contributing population. Pipe diameters in certain sections of the system are therefore larger than those which would be required if the system were to be designed with capacity limited to that necessary to handle only waste delivered by the immediate contributors to the system.

For comparative purposes, PLATE 31A has been prepared to illustrate the reduction in interceptor pipe size which would prevail if a limited regional system for the immediate contributors were to be constructed in lieu of the proposed initial facilities. TABLE A-4 indicates the capital costs of facilities for the limited regional system.

The total capital cost differential is as follows:

Proposed Initial Construction Cost (Table 22)	\$34,877,000
Limited System Initial Cost (Table A-4)	<u>33,237,000</u>
Estimated Total Cost Difference	\$ 1,640,000

The total cost difference involved amounts to about 10% of the estimated cost for the wastewater collection facilities, or about 5% of the total cost of the recommended initial facilities to be constructed. By providing over-sized interceptors to enable future extension of service to additional future contributors, the immediate contributors are thereby financing about 5% in added construction costs. It is, of course, possible to recover the 5% premium cost by suitable adjustment of charges to future contributors as they join the regional system.

The additional cost for over-sized interceptors is an extremely small premium to pay at this time for this purpose. Future costs of additional parallel interceptor pipe lines, required for future expansion if pipe diameters were initially limited, can be estimated at perhaps \$20,000,000, assuming the prevailing trend of increasing construction and material cost will continue in the future.







NEW JERSEY STATE DEPARTMENT OF HEALTH
STONY BROOK-MILLSTONE SEWERAGE STUDY COMMITTEE

STONY BROOK-MILLSTONE WATERSHED
REGIONAL SEWERAGE FEASIBILITY STUDY

LIMITED REGIONAL SYSTEM
FOR WASTEWATER DISPOSAL

SEELYE STEVENSON VALUE & KNECHT
CONSULTING ENGINEERS
PRINCETON, N. J. NEW YORK, N. Y.

-  REGIONAL INTERCEPTOR
-  FORCE MAIN
-  WATER POLLUTION CONTROL FACILITIES
-  RECHARGE BASIN

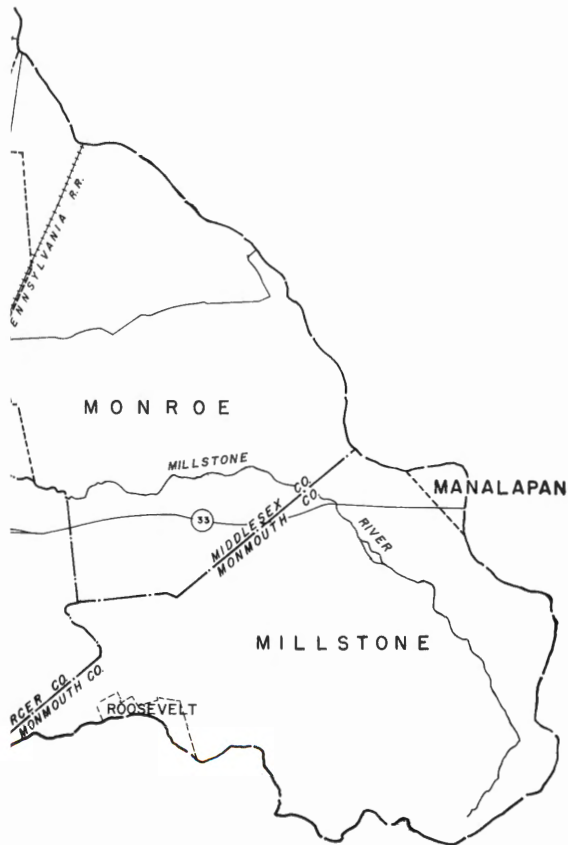


PLATE 31A

TABLE A-4

DETAILED COST SUMMARY FOR INITIAL CONSTRUCTION
OF LIMITED REGIONAL SYSTEM FACILITIES

<u>Facilities</u>	<u>1970 Construction Cost*</u>	<u>Land & R. O. W.</u>	<u>Total Project Cost</u>
Water Pollution Control	\$10,554,000	\$360,000	\$10,914,000
Wastewater Collection:			
Stony Brook Interceptor	\$ 5,725,000		
Upper Millstone Interceptor	3,345,000		
Lower Millstone So. Interceptor	<u>6,743,000</u>		
Collection Sub-Total	\$15,813,000	\$354,000	\$16,167,000
Wastewater Reclamation:			
Force Main	\$ 4,442,500		
Basins 15 Acres	1,057,500		
Pumping Station	<u>450,000</u>		
Reclamation Sub-Total	\$ 5,950,000	\$206,000	\$ 6,156,000
 TOTAL CONSTRUCTION COST (1970 ENR 1175)			<u>\$33,237,000</u>

* Includes 20% Development Expense

APPENDIX B

EXPERIMENTAL RESEARCH AND PRACTICAL
EXPERIENCE IN CONNECTION WITH
TERTIARY TREATMENT AND RECLAMATION OF
WASTEWATER EFFLUENTS

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PLANNED WASTEWATER RECLAMATION

Introduction

The augmentation of water resources by recharging ground waters through cesspools and septic tanks is well known. Such reuse of wastewater is incidental to waste disposal, and is common practice in areas where the water supply is derived from porous subsoil.

Intentional or planned wastewater reclamation is a more recent development. Planned reclamation involves the production of a useable water for direct application to a beneficial use, with treatment facilities financed and constructed specifically for this purpose.

Partial History of Planned Wastewater Reclamation

One of the first planned projects for the reclamation of wastewater was initiated in Los Angeles, California, in 1930. Tests by Goudey (2) demonstrated that a highly polished sewage treatment plant effluent could be spread on soil, thereby contributing significantly to the ground water supply without impairing its quality.

In 1932, a pioneering reclamation project was constructed in San Francisco's Golden Gate Park and is still in operation. One MGD of reclaimed wastewater is used for irrigation and for the supply of lakes and streams within the park. Until 1953, this was the only known instance of large scale use of wastewater for purposes other than agriculture and industry (1) (3).

The principal reasons for the lag in planned wastewater reclamation projects were:

1. Availability of large supplies of low cost water;
2. Lack of technical information on water quality requirements and effectiveness of treatment methods; and
3. Esthetic objections.

A significant change in the trend was noted in the findings of a 1951 University of California publication that stated that planned reclamation works in water deficient areas were definitely competitive in cost with other methods of obtaining additional water (4). Reports issued in 1955 and 1957 (5) (6) presented similar conclusions, and surveys conducted in the mid-1950's reflected increased use of wastewaters. With the exception of domestic supply, all broad categories of beneficial use were reported being served.

In January, 1957, the Board of Directors of the County Sanitation Districts of Los Angeles County authorized a Board of Engineers to report upon "The Potential Reclamation of Sewage Now Wasting to the Ocean in Los Angeles County" (7). Based on an anticipated water shortage by 1975, the report recommended specific steps for the implementation of a program to reclaim and re-use wastewater as a means of supplementing and augmenting other water supplies. It was recommended that water reclamation envision the construction and operation of a demonstration plant at the Whittier Narrows Reservoir area to provide 10 MGD of reclaimed water for recharge of ground water and, most important, that legislation be enacted at the state level to enable a county to finance the construction of a water reclamation project.

These recommendations were accepted and the Whittier Narrows demonstration wastewater reclamation plant was constructed and started operation on July 10, 1962. The plant effluent is pumped to a spreading field for percolation to an underground aquifer that is used for domestic, industrial, and agricultural purposes. It should be noted that the effluent is sold to a water replenishment district at a rate equal to the cost of an imported supply. The rate is expected to be sufficient to defray operating costs and permit amortization of construction costs in a period not to exceed 30 years (1).

During the three year period 1955 through 1958, tests were conducted at the Los Angeles Hyperion Treatment Plant (8) to reclaim the plant effluent for the dual possibilities of reducing the cost of recharge water for the salt water barrier program and conserving potable waters for higher beneficial uses. One of many significant conclusions reached was that intermittent filtration in spreading basins, followed by chlorination, produced a reclaimed water that met the chemical and bacteriological standards for potable water promulgated by the U.S.P.H.S., and the irrigation water standards of the United States Department of Agriculture.

The re-utilization of wastewaters has been increasing in semi-arid areas. There has been an increased use of reclaimed wastewater for recreational purposes, such as irrigation of parks and golf courses (5). Recently, two engineering reports have been prepared in California calling for park irrigation with reclaimed wastewater (9) (10).

The pattern for many years has been a steady improvement in treatment technology in the understanding of water quality requirements. With increased attention being given to water pollution abatement, an accelerated rate of improvement appears in the offing.

In 1960, Congress authorized the construction of, at least, seven regional water pollution research facilities and the initiation of an extensive and long range Advanced Waste Treatment Research (hereafter referred to as AWTR) Program by the U.S. Public Health Service. The principal objective of this project is ". . .to develop and demonstrate practicable means of treating municipal sewage and other water-borne wastes to remove the maximum possible amounts of physical, chemical and biological pollutants in order to restore and maintain the maximum amount of the Nation's water at a quality suitable for repeated re-use." (11)

Current investigations under the AWTR Program include treatment by adsorption, foam separation, electro dialysis, reverse osmosis, distillation, freezing, eutectic freezing, ion exchange, solvent extraction and oxidation.

Municipal Waste Effluents as a Source of Re-usable Water

A major factor favoring the use of municipal waste effluents as sources of re-usable water is their ready availability in substantial and consistent quantities. Many communities have taken advantage of these factors.

The re-use of reclaimed wastewater is limited only by the inability of conventional treatment methods to guarantee complete inactivation of potentially pathogenic organisms that could create a health hazard. To protect the public, State Health Departments have adopted regulations establishing limits of bacterial and viral counts, not only in domestic supplies, but also in waters used either for body contact, sports, or for irrigation of consumable foods. As a result of these restrictions, irrigation of crops such as alfalfa and cotton and industrial cooling uses have become the principal applications of municipal effluents.

The following is a partial summary of current practice of municipal wastewater re-use in the United States:

Irrigation of Crops:

(a) Las Vegas, Nevada sewage treatment plant supplies reclaimed water for 960 acres of alfalfa.

(b) Over 200 treatment plants in Texas provide reclaimed water for cotton or cattle feed crops.

Irrigation of Public Parks and Golf Courses:

- (a) Prescott, Arizona.
- (b) Jal, Carlsbad, Santa Fe, Los Alamos and Gallup, New Mexico.
- (c) Winslow, Arizona.
- (d) Sunnyside, Utah.
- (e) Golden Gate Park, San Francisco, California.
- (f) Flamingo Hotel in Los Vegas, Nevada.

Industrial Re-use:

- (a) Bethlehem Steel Company's Sparrow Point Plant near Baltimore, Maryland - cooling water.

Recreational Re-use:

- (a) Santee Wastewater Reclamation Project near San Diego, California - Highly treated wastewater is being discharged to scenically landscaped, artificial lakes without appreciable dilution. Activities include boating, picnicking, fishing and golf. After completion of extensive microbiological studies, water contact sports are now permitted and fish caught may be kept.

Re-use for Salt Water Barrier

- (a) Los Angeles' Hyperion Sewage Treatment Plant, Santa Monica Bay Area, California.
- (b) Nassau and Suffolk Counties, Long Island, New York (pilot test programs).

Replenishing Ground-Water Supplies

- (a) Whittier Narrows Water Reclamation Plant, Los Angeles, California.
- (b) Long Island, New York.
- (c) Leisure World, Monroe Township, New Jersey.

During the past three years, scientists and engineers at the Pennsylvania State University have been engaged in a novel project with a two-part purpose:

1. To reduce pollution of surfact waters.
2. To increase fresh ground supplies.

Both objectives have been accomplished by spraying renovated wastewater on trees and cropland rather than discharging it into the waterways. Results to date indicate:

1. Area streams are less polluted;
2. A high quality potable water is recharging the groundwater reservoir with the water table dropping only a few feet in irrigated areas as opposed to nearly 75 feet per year in non-irrigated areas;
3. Crops such as corn and hay have increased their yields over the past three years by as much as 300%.

WASTEWATER RECLAMATION
BY
ARTIFICIAL RECHARGE

Introduction

The purpose of wastewater reclamation by artificial recharge is to conserve underground water. Not all waste effluents will be acceptable for recharging ground water supplies after only nominal treatment. Among the factors affecting their suitability for this purpose is the concentration of dissolved solids in both the reclaimed water and the receiving ground water supply (11).

The mineral increment in a water passing through a municipal system from source to point of disposal, where industry is not a significant factor, ranges from 100 to 300 mg per l of total dissolved solids. Where existing ground waters have a high mineral content, the mineral salt increment appears to be the principal quality impact on reclamation. In such circumstances, the benefits of dilution are small.

The mineral salt content of water used to recharge ground water must be evaluated not only from the standpoint of immediate effects, but also the long range impact. Should the mineral input exceed the withdrawal rate, mineral salts will accumulate in the soil or aquifer. This problem is a major consideration where ground waters are recharged with reclaimed wastes.

Where industrial wastes are not significant, common sewage treatment methods have been used for the removal of organics from sewage to the degree necessary for direct recharge of ground waters. The degree of treatment and/or type of treatment process depends on (12):

1. The method of recharge.
2. The ultimate use of the recharged groundwater.
3. Geological nature and characteristics of the soils above the water table and of the aquifer itself.
4. The hydrological conditions pertaining to the velocity of ground water movement toward the withdrawal wells and the elapsed time between recharge and withdrawal.

Methods of Recharge

Planned wastewater reclamation projects for ground water recharge are fairly recent and make use of the following methods:

1. Injection wells
2. Spreading basins

Experience with Injection Wells for Artificial Ground Water Recharge

Injection wells for artificial recharge are usually used only where some other benefit is derived as well. Their main use is to create a pressure barrier against saline-water intrusion underground. The use of injection wells is limited by two factors:

1. Relatively small capacity
2. High cost of method in comparison to surface spreading systems.

A. W. W. A. Task Group 244OR reported (13) that injection wells may become clogged quite easily due to the fact that the water soil interface is essentially a cylindrical "sand filter". The velocity of flow and the volume of water passing through the "filter" is comparable to the lower ranges of rates used on conventional rapid sand filters. The backwashing mechanism, however, is not readily available. Clogging may occur for many reasons, some acting simultaneously. Some of the following clogging mechanisms are known to occur, others are only suspect and are in need of more study:

1. Biologic -- dissolved solids, both organic and inorganic, may promote biologic growth. These growths may occur anywhere in the well casing, the aquifer face, or in pores of aquifers some distance from the well. The most troublesome is the slime forming type. Growth may be caused by either new organisms introduced by injection, or stimulation of previously dormant micro-organisms within the formation. Clogging may be caused by slime growths or chemical products resulting from bacterial growth or chemical action.

2. Mechanical -- due to factors inherent in well installation and development, minute particles carried in the injected water may cause clogging. In some types of soils, expansion of clay minerals may occur upon contact with a water with new chemical characteristics.

3. Chemical -- admission of free air injected as bubbles in the injected water may cause binding in the formation. Gas binding in

the aquifer may result from gas coming out of solution when the temperature of the injected water is less than the temperature of the underground formation. Chemical clogging may occur due to precipitations, chemical interactions, solution and redeposition of gypsum and reaction of high sodium water with soil particles causing deflocculation of the soil.

Because of the filter bed nature of injection wells, water to be used for injection must be highly treated for the removal of suspended matter. The dissolved constituents must be reasonably compatible with the native underground water and the soils of the water-bearing formation.

When the injection head in an injection well reaches the maximum desirable level or limit of water pressure, some type of redevelopment is necessary. Well redevelopment methods, in order of severity of treatment, include:

1. Bailing and surging with a cable tool rig.
2. Jet pumping and surging with an air lift.
3. Pumping and surging with a deep well turbine.

The cost of well redevelopment varies greatly, depending upon the system used and length of time required. Turbine pumping, usually the most expensive method, is the most effective. Redevelopment of injection wells in the Los Angeles County Area have averaged \$1,500 per well.

Costs of drilling injection wells are presented in TABLE B-1, which gives comparative cost information on the several types of wells constructed for the Los Angeles County Flood Control District. No attempt has been made to equalize the cost data on the basis of construction cost indexes.

Experience with Spreading Basins for Artificial Ground Water Recharge

Operating experiences with spreading basins indicate that soil permeability and method of basin management are two important factors affecting the percolation rate.

Spreading tests were undertaken at Whittier, California, in 1948 using trickling filter effluent from the Whittier sewage treatment plant (8) (15) (16). The plant effluent was high in quality, approximating 10 ppm 5-day BOD and 39 ppm suspended solids. It was spread continuously

TABLE B-1

COMPARATIVE CONSTRUCTION COSTS OF INJECTION WELLS (13)

<u>Type of Well</u>	* <u>Cost/Ft.</u>	<u>Average Depth (Ft.)</u>	<u>No. of Wells</u>	<u>Year Drilled</u>
Cable tool, 12", steel cased, non- gravel packed.	\$17.35	266	8	1952-53
Cable tool, 12", steel cased, gravel packed.	32.35 32.28	249 310	2 4	1953-54 1957-58
Reverse-rotary, 12", asbestos cement, gravel packed.	36.80 47.61 52.16	270 367 646	1 8 4	1960 1963 1963

* Includes cost of well only; does not include surface equipment or pipeline connections.

to a depth of 0.5 feet to 1.0 feet in a small test basin having a bed of fine sandy loam. After seven days, the percolation rate had fallen from 0.75 cfs per wetted acre (cfs per wa) to 0.30 cfs per wa. Examination of the percolate recovered from sampling pans demonstrated that the degree of polishing increased with depth below the basin surface. At the 7 foot depth, the suspended solids averaged only 1(+) ppm and the BOD and B. Coli had been completely removed.

A second study was performed in 1949 at the city of Azusa, California (8) (15) (16). Trickling filter effluent from the Azusa plant, averaging 35 ppm BOD and 61 ppm suspended solids, was spread in a small plot located in coarse, non-uniform, highly permeable sand and gravel. A percolation rate averaging 0.6 cfs per wa under a head of 1.0 feet was maintained for two months. Samples of percolate 7 feet below the basin surface averaged 11 ppm suspended solids and 2.5 ppm BOD. Removal of coliform bacteria was nearly completed.

Both of these tests indicated that satisfactory percolation rates could be maintained by spreading continuously, for periods of 7 days to 30 days depending on soil permeability, followed by bed rehabilitation by means of drying and cultivation. Disposal at Azusa has been practiced continuously in this manner since 1949, and water pumped from nearby wells has never shown signs of contamination.

Spreading basin operation at the Whittier Narrows Water Reclamation Plant includes three days of spreading in sandy areas followed by drying for a minimum of six days. Percolation rates have been somewhat higher than when Colorado River waters are used. Algae growth in the basins has been minimal (17).

In connection with a project to reclaim the wastewater produced in the Tel Aviv metropolitan area following treatment in lagoons, the operating cycle consists of five to six days of wetting and nearly twice that time for resting (12). Soil samples along the basin profile taken at intervals showed that organic matter accumulated only at the top layer of 0 to 10 cm. There was no progressive build-up of organic matter with time. Intermittent application of the lagoon effluent was effective, not only in restoring the infiltrative capacity of the basin (dune sand) but also in unclogging the top of the clayey-loam stratum underlying the dune sand of the organic material which may have been carried down through the sand and retained on top of the stratum. On the basis of the research carried out to date, to be supplemented by studies now underway, it has been concluded that, for the Tel Aviv conditions, it is not necessary to subject the wastewater to "conventional" methods of biological treatment in order to produce an effluent suitable

for ground recharge by spreading. Instead, the less expensive method of sewage treatment by lagoons, at loadings far in excess of those used in the U.S.A., is sufficient for the purpose without danger of clogging or material diminution of the infiltration rate and producing recharged water of potable quality from properly spaced wells, provided the spreading basins are operated intermittently.

Test Results -- Reclaiming Hyperion Effluent (8)

A comprehensive, three-year investigation was completed by the Los Angeles County Flood Control District to determine the feasibility of reclaiming variable quality sewage effluent from the city of Los Angeles Hyperion Treatment Plant for injection well recharge. Following is a summary of the major conclusions from this investigation:

1. Reclamation of high-rate activated sludge-type sewage effluent from the Hyperion Treatment Plant by means of normal practices of continuous surface spreading on well-sorted dune sand was unsuccessful due to gradual sealing off of the surface by anaerobic slimes. Neither chlorination of the effluent before spreading nor increased water depth resulted in practical improvement of percolation rates.

2. Continuous spreading accompanied by raking of the test basin surfaces permitted operation at average percolation rates of 0.6 - 1.0 cfs per wa for several months, but demanded excessive maintenance. Reclaimed water produced by the wet-raking process fouled the experimental injection well.

3. It was found feasible to reclaim high-rate activated sludge effluent containing suspended solids and BOD as high as 87 ppm and 59 ppm, respectively, by means of intermittent surface spreading in small basins at an average of 0.5 cfs per wa. The water produced averaged 7.2 ppm suspended solids and 3.5 ppm BOD.

4. Intermittent spreading of an experimental standard-rate activated sludge (SRAS) effluent of higher quality than the high-rate activated sludge (HRAS) plant effluent yielded a reclaimed water containing 2.5 - 5.7 ppm suspended solids and 0.3 - 1.2 ppm BOD.

5. Storage of Hyperion effluent in oxidation basins for two days prior to surface spreading improved its quality but had no significant influence on the recharge characteristics of the final reclaimed water.

6. Water reclaimed by intermittent spreading was well stabilized, of sparkling clarity, and odor-free.

7. Water reclaimed by intermittent spreading in small basins of both HRAS and SRAS sewage effluent was successfully substituted for filtered potable water in a test recharge well and displayed similar hydraulic characteristics over a 6-month period.

8. Injection well tests demonstrated that a suitable injection water could contain about 6 ppm suspended solids and 2 ppm BOD, provided the solids were of a suitable particle size, fully oxidized, and contained a minimum of inert clay or silt.

9. Intermittent filtration in spreading basins followed by chlorination produced a reclaimed water that met the chemical and bacteriological standards for potable water promulgated by the USPHS, and the irrigation water standards of the United States Department of Agriculture.

10. No significant public health problems including odors, flies, or mosquitoes occurred during the Hyperion tests.

11. Chlorine dosages sufficient to maintain a free chlorine residual of 0.1 ppm at the injection well appeared suitable for effluent injection operation, while at the same time affording adequate protection against contamination of ground water.

12. Detergents were reduced by conventional waste treatment followed by intermittent sand filtration of an average of 1.12 ppm. No foaming nuisance was encountered at this detergent concentration.

13. Standard-rate activated sludge effluent containing 25 ppm suspended solids was entirely unsatisfactory for direct recharge into an injection well. Additional or tertiary treatment was found necessary.

14. Special investigations on a number of potential processes for rapid-rate reclamation were undertaken, including intermittent filtration through coarse gravel, rapid sand filtration, trickling filter operation, limited storage in an open reservoir, and up-flow sludge blanket, all accompanied by both shock and continuous chlorination. The technical operating problems encountered with these methods were not solved within the test period, although it appeared that rapid sand filtration at rates up to 200 cfs per wa would be feasible.

15. Water quality achieved by rapid sand filtration averaged 6.5 ppm suspended solids and 2.4 ppm BOD during one 7-week run.

Further investigation of this and other high-rate processes is indicated.

16. Test observation wells located at 20 ft., 50 ft., and 70 ft. distances from the injection well enabled the collection of injected water samples that had traveled through the restricted aquifer. After correcting for ground water dilution, the nitrogen, phosphate, and ABS detergent concentrations in the reclaimed water were found to decrease measurably with lateral distance from the injection well.

17. Both prototype and lysimeter test facilities were useful in obtaining realistic wastewater operation data applicable to full scale test procedures.

TERTIARY TREATMENT FOR WASTEWATER RECLAMATION

Introduction

Conventional secondary sewage treatment processes do not remove most inorganic soluble salts. They remove about 90% of the 5 day BOD and suspended solids. The effluent contains the BOD which escaped biochemical decomposition, and part of the BOD is exerted by the remaining suspended solids in the effluent. The effluent still has a considerable chemical oxygen demand (COD) by dissolved organics that resist biodegradation in the plant. When effluent is discharged to a water course, these residual contaminants continue in the natural cycle of decomposition and recomposition.

Data on secondary-effluent composition and tap water analyses have been compiled by the AWTR Program of the U.S. Public Health Service. From these data, 22 cities were selected for which incremental increase of contaminants during water use could be determined. The results of this compilation are shown in TABLE B-2.

The domestic use of water usually results in an increase of from 100 to 300 parts of dissolved solids per million parts of water by weight (ppm). A prerequisite to the reclamation of wastewater is the removal of some of the dissolved solids.

Tertiary Treatment - Scope and Methods

Tertiary treatment of wastewater involves additional treatment beyond secondary treatment to provide a higher quality effluent. The degree of tertiary treatment required is dependent on the specific watercourse in which the effluent is dispersed or by the specific re-use purpose for which the water is intended.

Data is presented herein on the results of the following methods of tertiary treatment (18):

1. Rapid sand filtration
2. Polishing intermittent sand filtration
3. Microstraining
4. Effluent ponding

TABLE B-2

COMPARISON OF TAP WATER QUALITY WITH SECONDARY EFFLUENT QUALITY

PPM	Tap Water			Secondary Effluent			Incremental Increase		
	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.
Organics:									
BOD	2.0	6.0	0.0	19.0	45.0	9.0	16.0	27.0	8.5
COD	12.0	42.0	0.0	101.0	163.0	44.0	87.0	159.0	22.0
ABS	0.37	4.2	0.0	6.8	10.1	2.4	6.4	10.0	2.4
Cations:									
Na	49.0	269.0	8.0	124.0	232.0	29.0	66.0	101.0	8.0
K	3.0	5.0	1.6	12.0	20.0	9.0	10.0	15.0	7.0
NH	0.1	2.0	0.0	17.0	44.0	0.0	15.0	36.0	0.0
Ca	42.0	108.0	12.0	66.0	109.0	33.0	18.0	50.0	1.0
Mg	16.0	37.0	0.0	19.0	30.0	Tr.	6.0	15.0	Tr.
Fe	-	-	-						
Anions:									
C ¹	66.0	518.0	6.0	143.0	532.0	52.0	74.0	200.0	6.0
NO ₃	5.0	9.0	0.0	12.0	26.0	0.04	10.0	25.9	-4.7
NO ₂	0.14	0.30	0.01	1.5	2.0	0.26	1.0	2.0	0.1
HCO ₃	198.0	379.0	27.0	296.0	428.0	110.0	100.0	265.0	-44.0
CO ₃	0.1	10.0	0.0	0.0	0.0	0.0	-1.0	0.0	-10.0
SO ₄	56.0	291.0	0.0	84.0	300.0	20.0	28.0	57.0	12.0
SiO	29.0	71.0	11.0	43.0	80.0	22.0	15.0	22.0	9.0
PO ₄ Total	8.1	3.8	0.0	25.0	50.0	5.0	24.0	50.0	7.0
PO ₄ Ortho	0.3	3.3	0.0	25.0	40.0	8.0	25.0	40.0	7.5
Other:									
Hardness									
(CaCO ₃)	158.0	337.0	55.0	235.0	411.0	100.0	79.0	261.0	6.0
Alkalinity									
(CaCO ₃)	164.0	341.0	24.0	242.0	351.0	90.0	81.0	217.0	-36.0
Total Dis-									
solved solids	382.0	917.0	98.0	703.0	1362.0	410.0	320.0	541.0	128.0
pH	8.0	9.0	7.2	7.4	8.0	6.5	-0.6	0.0	-1.7

5. Advanced waste treatment

Rapid Sand Filtration

Limited use has been made for some time of rapid sand filters for tertiary treatment. The treatment action depends on mechanical straining of suspended solids, plus some adsorption of smaller particles. Biological action is negligible, so little dissolved organic matter is removed.

Suspended solids accumulate in the filters, simultaneously reducing the BOD and, hence, the amount of BOD reduction will vary depending on the stage of oxidation of the suspended solids in the plant effluent.

These filters must be backwashed to remove accumulated suspended solids and the frequency of backwashing will depend on the surface application rate, the media size, and the type and quantity of suspended solids in the feed.

Media used may be about 24 inches of 0.5 - 0.8 mm. sand; or it may be a mixed bed of 3/16" x 3/32" anthracite of about 12" depth over a 12" layer of 0.5 - 0.8 mm. sand, with the coarse top layer holding the bulk of suspended solids to increase the time between backwashing. Only additional field operating experience will establish the best media combination for various qualities of effluent.

Backwashing may be by water only, at 24-30 GPM/sq. ft., or would preferably be a combination air-water backwash with water at 10-15 GPM/sq. ft. and air at about 4 cfm/sq. ft. The air serves to agitate the filter and loosen the suspended solids retained in the filters.

Surface application rate will vary from 2-4 GPM/sq. ft. and should not exceed 6 at maximum hourly or pumped flow rate.

At Luton, England (19) (20), trickling filter humus tank effluent has been treated through rapid sand filters at rates from about 2.5 to 4 GPM/sq. ft. About 9 MGD is so treated. Each filter contains two layers of sand, supported on porous filter bottoms. Initial head loss of 1-1.5 ft. increases to 8-9 ft. before backwashing with water and air at 2 ft./min. rise rate. The wash water use is 2.5% of the sewage flow, and backwashing is done twice daily. The BOD removal for 3 years was about 50% and suspended solids removal about 72%, with a final filtered effluent of 6.3 mg./l BOD and suspended solids of 4.6 mg./l.

An installation at the Pretoria plant at Johannesburg, South Africa (19),

in a 3 MGD trickling filter plant, uses rapid sand filters at about 3 GPM/sq. ft. Some filters use 21 inches of 20 to 30 mesh (Tyler) filter sand over 6 inches of coarse sand, 1/8 inch to 20 mesh (Tyler), on a carborundum block floor. Some of the filters used distribution nozzles at 6-inch centers on a steel floor used to support 21 inches of 20-30 mesh (Tyler) filter sand over graded gravel. A porous bottom was preferred because it was easier to remove and replace the filter media. An air-water backwash is used at a rate of about 25 GPM/sq. ft. with 9.5% of the effluent used for backwashing at 8-10 hour intervals. Chlorine is fed at 4.7 mg./l. Suspended solids were reduced from 22 to 4.6 mg./l. The effluent is used for cooling water at a power station.

Recent work on rapid sand filtration has been done on the effluent of the Hyperion activated sludge plant at Los Angeles (21) by the Los Angeles County Flood Control District to prepare the effluent for recharge into the ground through injection wells. Tests were run on rapid sand filters, diatomite filters, and pressure sand filters on standard rate activated sludge plant effluent, which contained 10 mg./l suspended solids and 9 mg./l BOD. Pressure sand filtration did not give a satisfactory effluent. Rapid sand filters and diatomite filters both reduced suspended solids to 3 mg./l, at an application rate of 1.5 GPM/sq. ft. They used alum pre-treatment with the rapid sand filters to get the turbidity down to 1, which was desired for the recharge operation.

Polishing Intermittent Sand Filtration

Polishing intermittent sand filters are sometimes used for tertiary treatment, particularly for the effluent from small extended aeration plants. The Ten States Code allows about 435,600 gal./acre/day (10 gal./sq. ft./day) for these units following trickling filters. These units are expensive to build and to maintain, and have a rather high clogging incidence.

The New England Interstate Water Pollution Control Commission (22) points out that the data collected on their study of extended aeration plants in Massachusetts indicate that the excess solids will clog the sand filter and result in its failure. They point out that the problem appears to be related to the inert solids, both organic and inorganic. Since most of the suspended solids are inert, biological action is at a minimum and the sand filters clog rather quickly after the system builds up its solids initially.

Microstraining

Another method of tertiary treatment that has been used is by means of microstrainers -- rotating drum screens with extremely fine stainless steel mesh, with 80-100,000 perforations/sq. in. The flow of liquid enters one end of the drum, which is open, and the flow passes outward through the mesh into the chamber which supports the filter. The mesh is washed with filtered effluent from jets fitted over the drum. It is usually necessary to wash the wire mesh with chlorine water at intervals of 7-28 days to control slime growths on the mesh, with the interval depending on the quality of the effluent being treated. Mesh openings may range from 23-65 microns.

An installation of microstrainers at Luton, England (19) (20), uses three units 7-1/2 ft. dia. x 5 ft. long. They rotate at 12.5 - 50 ft./min. The trickling filter final effluent of 3 MGD passes through the three filters at an application rate of 4-7 GPM/sq. ft. of strainer area. They use a chlorine wash once per week to control slime growths. They are able to reduce the suspended solids content from 17 to less than 9 mg./l, and effect a BOD reduction of 21-32%.

There are other microstrainer installations in England and South Africa giving comparable results (19) (23).

A pilot plant microstrainer was tested at Brampton, Ontario in the summer of 1960 on the effluent from an activated sludge plant. BOD and suspended solids removals averaged 53.5 and 57% respectively. The operation was discontinued due to fabric clogging, reportedly due mainly to algae (24).

Effluent Ponding

Effluent polishing ponds are required by some states following extended aeration plants. Detention times may vary from 6 hours up to several days. The Ten States Code indicates that for such ponds they will establish BOD loadings after due consideration of the efficiencies of the preceding treatment units. Short detention ponds of 6-12 hours will settle the excess suspended solids. The settled solids will continue to demand oxygen, but the anaerobic metabolism in the settled solids will proceed at a slow rate, due to the low concentration of biodegradable solids. As the soluble end products diffuse from the settled solids in the liquid layer above, aerobic bacteria will be able to oxidize these organic materials with the assistance of the nitrates discharged from the extended aeration unit (22). With short detention periods, it may be necessary to clean the pond of accumulated solids every few years.

Tertiary ponds of longer detention periods are also used for additional BOD removal. Since the sewage effluent contains nitrogen and phosphorous nutrients, these ponds of about 2-5 days' retention will develop considerable algae growth, and there will be a continuous algae discharge in the effluent from the pond. The algae may affect the use of the receiving water as a source of water supply, and it may be detrimental to recreational uses of the stream. Part of the nitrogen and phosphorous are assimilated into algal cells, but retention times and seasonal variations are such that not a big enough proportion of the phosphorous would be assimilated in these short detention times to control effluent nutrients merely by harvesting the algae. Bogan (25), in field pilot plant studies, found that in lagoons having a depth of 3-4 ft., algal cell tissue concentrations ranged from 25-50 mg./l, and he estimated lagoon retentions of 14-28 days would be required to biologically extract 5 mg./l of phosphorous from the sewage.

Loehr and Stephenson (26) reported on results of a tertiary pond following a trickling filter plant at Johnson County, Kansas. This pond handled 1.5 to 2.8 MGD of effluent in an area of 6.2 acres. The pond was 30 inches deep and had a retention range of 1.8 to 3.3 days. The pond had a BOD loading of about 30-60 lbs./acre/day. The effluent DO was supersaturated during the day and saturated at night during the summer months. During the winter, the effluent DO was less than in the influent to the pond due to decreased numbers of algae and decreased algal activity because of lower water temperature. BOD removal ranged from 20 to 70%, averaging slightly over 50%. Suspended solids removals were around 50% during the colder months and were negative due to algal dragout in the summer months to the extent of about twice the incoming suspended solids. In spite of the highly aerobic condition of the pond, some rising chunks of septic sludge occurred in the Spring.

Fall and Kraus (27) reported on a tertiary pond of 0.45 acres' area by 10 ft. WD for treatment of 0.67 MGD of high rate activated sludge effluent with a BOD of 63 mg./l and suspended solids of 59 mg./l. These were reduced to 35 and 16 mg./l, respectively, in a 1.77 days' detention time at a BOD loading of 782 lbs./acre/day. A COD reduction of about 26% occurred. Bottom sludge deposits after 16 months of operation were only 61.4% volatile and compacted to 3.3% total solids, and occupied about 1 ft. of depth. No odors occurred and no scum removal was required. Data as to dissolved oxygen or algae concentration were not reported.

An extreme case illustrating the usefulness of pond storage of effluent occurred at Chanute, Kansas (28), in 1956-57 when there was no flow in the river for the city water supply. The sewage effluent from a

trickling filter plant was diverted to a 3-ft. deep impounding reservoir with 17 days detention time. The reservoir reduced the BOD from 29 to 7 mg./l (75%), the COD from 156 to 56 mg./l (64%), ammonia from 29 to 12 mg. (58%), and ABS from 10.4 to 4.6 mg./l (56%). During 5 months of recycling, the chlorides increased from 40 to 670 mg./l. The tap water had a pale yellow color and a musty taste, but it met the U.S.P.H.S. bacteriological standards and there were no cases of water-borne disease.

The use of ponds to reclaim activated sludge effluent for recreational use, including swimming, has been approved by the California State Department of Public Health for the Santee Water Reclamation Project, Santee, California (29). The Santee project has been a pioneer in reclamation studies. The effluent from a 1 MGD activated sludge plant is first treated in a 25-day detention stabilization pond, followed by percolation through 10-12 ft. layer of sand and gravel, underlain by impervious clay. The water is then intercepted in a trench and flows into another 11-acre pond (12 days detention). At this point, the BOD is 3 to 6 mg./l, P is 2 mg./l, ABS is 2 mg./l. It then flows into two additional lakes of 7.5 and 6.8 acres, where fishing and boating are permitted. Finally, it flows into a 16-acre lake where a swimming area has been developed in accordance with standards of the State for artificial pools. Constant laboratory and epidemiological surveillance are being maintained by the State.

Advanced Waste Treatment Processes

Studies conducted under the AWTR Program have provided a sound basis for the development of several physical-chemical separation processes leading to complete tertiary treatment.

1. Adsorption - Stephanson (38) reported that the furthest developed of the advanced waste treatment processes is "adsorption" utilizing granular activated carbon. Activated carbon will adsorb up to 20 to 30% of its weight of mixed organics in staged, counter-current, fixed-bed contactors. Mass velocities of 4 to 10 gal./sq. ft./min. and contact times of 30 to 40 min. will result in 70 to 80% removal of gross organic matter from most secondary effluents. On an overall basis, then, organic removal may be increased from the 80 to 90% achieved by conventional processes to as much as 97 or 98%.

The 2 to 3% "leakage" that occurs continuously, even from the very beginning of an adsorption run, is due partly to the presence of some non-adsorbable organics and some organics that are adsorbed very slowly. Largely, however, it is due to colloidal particles (either

organic colloids such as bacterial cell-wall fragments or inorganic colloids that have adsorbed organic molecules) which do not follow the "rules" for separation by adsorption.

It has been established that pretreatment of the feed for removal of gross suspended solids is generally necessary to avoid excessively rapid increases of pressure losses across an adsorption bed. Without this pretreatment, prohibitive flow resistances will be reached in a relatively short time because of the deposition of suspended floc particles, etc., on the surface of the adsorption bed. Various solutions to this problem, such as backwashing or surface washing, are possible, but their effectiveness has not yet been established on any long-term basis. If coagulation-sedimentation is utilized as a pretreatment, the removal of gross organics by the combined treatment system (primary treatment, plus secondary treatment, plus coagulation-sedimentation, plus activated-carbon adsorption) may well increase to 99+ percent.

It can be shown rather easily that the use of activated carbon to remove roughly 50 ppm (as chemical oxygen demand) of organic material from water will be economically prohibitive unless the carbon can be effectively regenerated for multiple use. The feasibility of this regeneration of granular carbon by conventional thermal techniques has been established through a series of 15 successive saturations and regenerations. To be competitive with regenerable carbons currently available at 25¢ to 30¢/lb., a non-regenerable carbon exhibiting the same or better adsorptive properties would have to be available at less than 5¢ per lb. At the present time, no activated carbons of this sort are available and the carbon regeneration step must therefore remain an essential part of the process.

A complete tertiary treatment plant has recently been placed in operation at Lake Tahoe, California, to prepare the activated sludge plant effluent for export across the mountains into Nevada (30). The plant includes the first commercial scale activated-carbon adsorption units as final polishing filters. The plant was designed for 2.5 MGD at a cost of \$568,000 and, based on pilot plant studies, operating costs are estimated at \$64 per MGD. This process first uses alum coagulant and polyelectrolyte filter aids, added ahead of an in-line flash mixer. The flow then passes through two pressure filters, each 10-ft. dia. x 38-ft. long, in series, each containing 3 ft. of special Micro-Floc filter media supported on graded gravel. The media consists of a mixture having variations in grain size and density with pore spaces reducing from coarse (1 mm) to fine (0.15 mm) in the direction of filtration. Filter rate is 5 GPM/sq. ft., and backwashing at 15 GPM/sq. ft., including a special surface wash.

The flow is then sent to two activated carbon columns, 12 ft. dia. x 24 ft. high, that operate upflow in parallel to remove dissolved organics. Activated carbon of 8 x 30 mesh, granular, is used to a depth of 14 ft., and maximum flow rate is 8 GPM/sq. ft. The carbon gradually moves downward and is eventually withdrawn from the bottom for regeneration in an atmosphere of steam in a propane-fired furnace at 1700°F.

It is estimated that if alum is reclaimed from the sludge operating costs might drop to \$36 per MGD and, if phosphate removal by the alum were not necessary, costs might drop to \$25 per MGD.

BOD of the activated sludge effluent is reduced from 15-35 down to 2-5 mg./l, suspended solids from 5-20 down to below 0.5 ppm, phosphates from 10-30 down to 0.20-1 mg./l, ABS from 3-6 down to 0.05 mg./l, coliform bacteria (MPN/100 ml.) from 150,000 to less than 2.2, and COD from 40-60 down to 2-10 mg./l.

Regarding costs for carbon adsorption, projected figures for capital costs for a 10 to 20 MGD plant are about 15¢ per daily gallon capacity. Operating costs for such a plant, including 20-year capital amortization at 6%, should be less than 10¢ per 1,000 gallons (38).

2. Foam Separation (18) (38) - The foaming tendency of many wastewaters can itself be utilized to achieve the removal of organic contaminants by deliberately generating a foam on such waters and then physically removing the foam from the liquid phase. A variety of contaminants are removed in significant amounts. The removal mechanism includes both interfacial adsorption for the soluble components and flotation for suspended materials. Removal efficiencies for soluble contaminants are related to their surface activities. Commercial detergents, for example, can be removed at efficiencies of 80 to 90 percent down to residual concentrations of 0.5 to 1 mg per liter in laboratory-scale equipment. At the Whittier Narrows Water Reclamation Plant, foam separation quite routinely produces an effluent with less than 1.8 mg per l of apparent methylene blue active substance (ABS) at 10 MGD. At San Ramon Village, California, foaming allows the plant operator to meet a 1 mg per ABS effluent requirement. More significantly, in the light of the current introduction of "soft" detergents, between 25 and 40 percent of the gross organic material in municipal secondary effluents is concentrated in the foam. Foam separation, therefore, can increase gross organic removal from about 90 percent for conventional biological treatment, to perhaps 93 or 94 percent.

Los Angeles County Sanitation Districts and the U. S. Public Health Service are making joint studies that involve activated carbon treatment preceded by foam fractionation on 0.5 MGD of the activated sludge plant effluent at Pomona.

The foaming unit removes 60-65% of the ABS and 40-45% of suspended solids at a cost of \$14 per million gallons (31). Leaving the foamer, the flow passes through a diatomaceous-earth filter before passing through five columns, each 16-ft. high x 6-ft. dia., containing high-porosity granular carbon (16 x 40 mesh) supported on grids. Four columns operate in series while the fifth is regenerated by burning of adsorbed materials in a small multiple-hearth furnace. The Pomona installation reduced the organic content of the effluent from 50-60 down to 10-15 mg./l.

At this point in time, the potential utility of foam separation is in some question because of the unknown effect soft detergents will have on this process. In some cases, it is expected that the foaming tendencies of municipal effluents will remain sufficient to allow foam separation to be applied. In others, foamability may well be reduced to the point where stable foams cannot be generated. The actual answer, however, must await the large-scale introduction of soft detergents into our economy.

Capital cost for 10 to 20 MGD foam separation units should be about 3¢ per daily gallon capacity; operating costs (including 6% interest for 20 years) will be between 1¢ and 2¢ per 1,000 gallons (38).

3. Electrodialysis (38) - A very promising method for reducing the total dissolved solids (TDS) content of used water is electrodialysis. Single-pass electrodialysis will reduce the TDS concentration in water by about 40-50%; this is just what is needed for many renovation purposes since, as a rule of thumb, the TDS concentration in water will approximately double with each use. It has been shown that electrodialysis is generally impractical for removing organic ions because of irreversible fouling of the membrane by ABS, humic acids, and other organic ions. These interfering organics, however, can be removed by activated-carbon pre-treatment.

Power requirements for electrodialysis of waste effluents are relatively low (6 to 10 kwhr per 1,000 gal.) because of the small amount of mineral solids to be removed (perhaps 300 to 400 mg per l). The required effective cell pair area is about 0.004 sq. ft./gal./day, and polarization can be avoided when current density-to-concentration ratios of 750 milliamps per cm^2 per gram equivalent per liter are

not exceeded. Test runs with actual secondary effluents have shown that concentration ratios (product volume to waste volume) of 10:1 can be readily achieved with proper pH control. Concentration ratios of 50:1 have been obtained in some instances.

It is essential to remove both suspended solids (to avoid plugging) and dissolved organics (to avoid fouling) from the influent to the electro dialysis stacks. This can be accomplished by coagulation-sedimentation or filtration and carbon adsorption, for example.

In tests to date, removal of ions by electro dialysis has been generally non-selective. The concentrations of all ions present are reduced by roughly the same fraction. This is fortunate, since this type of removal is satisfactory to provide water of suitable quality for most reuse purposes. An exception, however, is the ammonium ion, which can be tolerated in water supplies in concentrations of only a few milligrams per liter. Since typical waste effluents from municipalities contain about 20 mg per l of NH_4^+ , 90 to 95 percent removal would be required during renovation. The cost of electro dialysis to achieve this removal would be prohibitive without some type of NH_4^+ selective membrane. The best available answer appears to lie in operation of the biological treatment step under nitrifying conditions to convert NH_4^+ to NO_3^- . In this way, ammonia concentrations can be held to satisfactory levels in the electro dialysis feed stream.

The capital costs of electro dialysis are projected to be less than 15¢ per daily gallon for 10 to 20 MGD plants. Operating costs should be less than 15¢ per 1,000 gallons for this new process.

Only limited experimentation on evaporation as a wastewater renovation process has been conducted up to now. From this work, however, it has been established that volatile contaminants are carried over into the distillate. Even though present in concentrations of only 1 or 2 mg per l, they will produce noticeable tastes and odors. Fortunately, these taste-and-odor-causing organics can be effectively removed by activated carbon adsorption.

4. Distillation - While particularly suited to feeds containing only non-volatile contaminants, distillation is expected to be adaptable to municipal wastewaters containing certain volatile contaminants that may be carried over into the product. Although this situation constitutes a significant drawback to this process, the possibility of using follow-up polishing treatments to remove trace impurities offers a practical solution. Costs for treatment by distillation are still uncertain, but probably will be something less than \$1 per 1,000 gallons at a 10 MGD capacity. Even though this is a much higher unit cost than

those for other processes under consideration, application of a "blending principle" can lead to very sizable savings (perhaps 50% or more) when a "total removal" process such as distillation is employed in the proper system configuration.

The U. S. Public Health Service and the District of Columbia have signed an agreement to construct pilot treatment facilities at the District's Blue Plains plant to treat part of the plant effluent with some of the most advanced waste treatment methods known (27). These are expected to remove up to 99% of the impurities from the effluent.

The project, to cost \$150,000 the first year, will involve laboratory studies of new treatment methods, construction of the pilot facilities, and analysis of the results. Included will be development of techniques for the ultimate disposal of the concentrations of wastes left after the complete treatment.

A summary of the estimated removal efficiencies for water renovation processes is presented in TABLE B-3.

Tertiary Treatment for Nutrient Removal

A major problem in water resource protection for water supply, industrial or recreational use is that of the growth of algae and aquatic weeds in lakes and watercourses. These growths are stimulated by nitrogen and phosphorus compounds discharged with sewage effluents and agricultural land run-off. It is almost impossible to control run-off, but it is possible (though expensive) to reduce N and P in sewage effluents.

It is impractical to completely remove nitrogen from sewage because of the several forms in which it occurs (32). Even if nitrogen were removed, certain blue-green algae can fix atmospheric nitrogen; hence, it seems that removal of phosphorous is the proper approach where circumstances require nutrient removal. Partial removal of phosphorous from the effluent will control both green and blue-green algae to a degree commensurate with the degree of removal (36).

Considerable work has been done on nitrogen removal by various methods of causing denitrification in activated sludge plants. Work in Switzerland by Wuhrmann (34) has indicated a fairly effective removal by using about a 4-hour denitrification tank on the return sludge. Faculative aerobes reduce nitrites and nitrates and release free nitrogen gas to the atmosphere. Johnson and Schroepfer (35) did pilot plant work on nitrogen removal and proposed two different

TABLE B-3

Estimated removal efficiencies for water renovation processes
Percentage removals based on raw-waste concentration

C = conventional primary and secondary treatment
 A₁ = foam separation

A₂ = lime-alum coagulation, sedimentation, and rapid sand filtration

A₃ = adsorption
 A₄ = electro dialysis
 A₅ = evaporation

PROCESS	SUSPENDED SOLIDS	B.O.D. (Carbonaceous)	CHEMICAL OXYGEN DEMAND	METHYLENE BLUE ACTIVE SUBSTANCE (Apparant ABS)	TOTAL PHOSPHATE	TOTAL NITROGEN	TOTAL DISSOLVED SOLIDS
C	90 } 90	90 } 90	80 } 80	50 } 50	10 } 10*	50 } 50	5 } 5
C + A ₁	90 } 92 2 }	90 } 93 3 }	80 } 85 5 }	50 } 85 35 }	10 } 10 0 }	50 } 50 0 }	5 } 5 0 }
C + A ₂	90 } 99 9 }	90 } 93 3 }	80 } 85 5 }	50 } 55 5 }	10 } 95 85 }	50 } 50 0 }	5 } 10 5 }
C + A ₂ + A ₃	90 } 99 9 } 0 }	90 } 99 3 } 6 }	80 } 99 5 } 14 }	50 } 95 5 } 40 }	10 } 95 85 } 0 }	50 } 55 0 } 5 }	5 } 15 5 } 5 }
C + A ₂ + A ₃ + A ₄	90 } 99 9 } 0 } 0 }	90 } 99 3 } 6 } 0 }	80 } 99 5 } 14 } 0 }	50 } 98 5 } 40 } 3 }	10 } 97 85 } 0 } 2 }	50 } 75 0 } 5 } 20 }	5 } 50 5 } 5 } 35 }

50% C 50%	SUSPENDED SOLIDS	B.O.D. (Carbonaceous)	CHEMICAL OXYGEN DEMAND	METHYLENE BLUE ACTIVE SUBSTANCE (Apparant ABS)	TOTAL PHOSPHATE	TOTAL NITROGEN	TOTAL DISSOLVED SOLIDS
A ₂ + A ₃ + A ₅ †	90 } 99 0.5x9 } 0.5x9 } 0.5x0 }	90 } 99 0.5x3 } 0.5x9 } 0.5x6 }	80 } 99 0.5x5 } 0.5x19 } 0.5x14 }	50 } 97 0.5x5 } 0.5x49 } 0.5x40 }	10 } 96 0.5x85 } 0.5x87 } 0.5x0 }	50 } 75 0.5x0 } 0.5x45 } 0.5x5 }	5 } 55 0.5x5 } 0.5x90 } 0.5x5 }

* 10% is a nominal minimum removal; variability among plants is great and removals of over 70% have been reported.
 † Values for A₅ appear in the second line from the bottom of each column.

modifications of activated sludge flow sheets to effect denitrification involving additions of some raw wastes to the denitrification tanks. The pilot plant work indicated overall nitrogen removals of 63% to 69%.

The most effective method of phosphorous removal is apparently by treating the sewage effluent with alum, mixing for about 15 minutes, and settling for 2 hours (33). The phosphorous is removed by adhering to the aluminum hydroxide floc as $Al(OH)_3 \cdot PO_4$. A dosage of 100 mg./l will remove 66%, 200 mg./l will remove 96%, and 300 mg./l will remove 99% of the phosphorous. The pH must be in a range of 7.1 - 7.7 for best removal. In addition to P removal, 87% of the BOD was removed and 62% of organic nitrogen. There was no effect on ammonia or nitrates. To be reasonably economical in a large plant, regeneration of the alum could be employed and would cut the chemical cost about in half.

Regeneration of alum would be by addition of sodium hydroxide to form sodium aluminate, and then adding calcium chloride to precipitate the phosphorous as insoluble tricalcium phosphate.

Pilot plant studies are under way by the Los Angeles County Sanitation Districts at Lancaster, California, under a joint contract with the U. S. P. H. S. Advanced Waste Treatment Research Program, involving the use of chemical and mechanical processes for the removal of the algae and algae nutrients from oxidation pond effluents to prepare the water for use in recreational lakes (31). They are desiring a process that can, in a relatively short period of time, produce a water quality comparable to that obtained by the highly successful Santee Project described above. The water from this project is to be used in a 40-acre recreational area to irrigate a golf course and for an industrial supply.

This pilot plant work involves alum flocculation followed by gravity settling, and by a parallel operated air flotation unit for floc separation. Excellent algae and phosphorous removal are reported. This study is still in progress.

Effect of Ground Water Travel on Reclaimed Wastewater

Laverty, et al. (8), reported the effect of ground water travel on nitrogen cycle, detergents and mineral constituents for tests made at the Hyperion Plant. Data was collected from observation wells 20 ft., 50 ft., and 70 ft. distance from an injection well receiving plant effluent after tertiary treatment by intermittent spreading. The nitrogen, phosphate and ABS detergent concentration in the reclaimed water were found to decrease measurably with lateral distance from

the injection well. The results of these investigations are summarized as follows:

TABLE B-4

EFFECT OF GROUND WATER TRAVEL
ON
RECLAIMED WASTEWATER QUALITY

Chloride:	Predominantly soluble; negligible loss due to precipitation with aquifer.
Nitrate:	Considerable removal in anerobic environment; minor removal at a slower rate in aerobic environment.
Nitrite:	In view of small concentrations involved and transient nature, its effect on nearest permissible water supply well would be negligible.
Ammonia:	High reduction rate, rapidly depleted, having little effect on domestic water supply.
Sulfates:	No change, little public health significance.
Phosphates:	Essential to bacterial metabolism and is used and depleted thereby. Has little public health significance.
Phenols:	Insufficient data. Some strains of soil bacteria are capable of utilizing dilute phenol as a nutrient.
ABS:	Relatively stable underground.

Flynn (37) reported on the relationship of well depth and contamination and the relationship of the distance between well and sewage disposal facilities and contamination. The results are indicated in TABLES B-5 and B-6.

None of these well waters contained ABS at the time of their approval. The concentrations of ABS are low with a tendency for larger amounts to appear in shallower wells. Fifty percent of the nitrate-nitrogen values are in excess of the amount normally assumed to indicate satisfactory sanitary quality. The results indicated that protective distances,

TABLE B-5

RELATIONSHIP BETWEEN WELL DEPTH AND CONTAMINATION

Well depth, ft	Number of wells	Wells with ABS	ABS, ppm			NO ₃ -N, ppm				Free ammonia-nitrogen, ppm		
			0.02-0.4	0.4-0.9	0.9-1.4	<1.0	1.0-5.0	5.0-10.0	>10.0	<0.5	0.5-1.0	5.0-10.0
50-55	4	3	3	0	0	1	2	1	0	4	0	0
55-60	1	1	1	0	0	1	0	0	0	1	0	0
60-65	11	5	2	2	1	8	2	0	1	8	3	0
65-70	7	3	2	1	0	3	2	2	0	6	0	1
70-75	23	11	11	0	0	10	5	4	4	22	1	0
75-80	<u>1</u>	<u>1</u>	<u>1</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>1</u>	<u>0</u>	<u>0</u>	<u>1</u>	<u>0</u>	<u>0</u>
Totals	47	24	20	3	1	23	12	7	5	42	4	1

TABLE B-6

RELATIONSHIP BETWEEN WELL DISTANCE FROM CESSPOOL AND CONTAMINATION

Cesspool distance, ft	Number of wells	Wells with ABS	ABS, ppm			NO ₃ -N, ppm				Free ammonia-nitrogen, ppm		
			0.02-0.4	0.4-0.9	0.9-1.4	<1.0	1.0-5.0	5.0-10.0	>10.0	<0.5	0.5-1.0	5.0-10.0
65-75	16	9	5	3	1	9	6	1	0	12	3	1
75-85	1	0	0	0	0	0	0	1	0	1	0	0
100	<u>30</u>	<u>15</u>	<u>15</u>	<u>0</u>	<u>0</u>	<u>14</u>	<u>6</u>	<u>5</u>	<u>5</u>	<u>29</u>	<u>1</u>	<u>0</u>
Totals	47	24	20	3	1	23	12	7	5	42	4	1

unless extreme, are no assurance of the freedom of a well from ABS. However, the greater concentration occurred at the shorter protective distance.

Effect of Secondary and Tertiary Treatments on Quality of Reclaimed Wastewater

The authors of the Hyperion report (8) noted that the reclaimed wastewater met the chemical and biological standards for potable water promulgated by the U.S.P.H.S. and the irrigation water standards of the U.S. Department of Agriculture. The bacterial, organic, physical, and chemical quality of the injected water compared with the recommended standards of water quality for domestic and agricultural uses are shown in TABLE B-7.

TABLE B-7

HYPERION EFFLUENT
EVALUATION OF WATER QUALITY
(Data in ppm except as noted) (8)

Analysis	Recommended Limiting Standards		Rep. Injection Well Water (Well Run 5)
	USPHS Potable Water	USDA ^a Irrigation Water	
Bacteria			
Coliform mpn/ml	0.22	100	.022
Organic			
BOD (5 day 20° C)	—	—	1.2
Ether Solubles	—	5.0	1.0
Volatile Acids	—	—	7.8
Physical			
pH	—	6.0 to 9.0	7.1
Color	20	—	9.4
Suspended Solids	—	—	6.3
Odor	Minimum	Noxious	Negligible
Taste	Minimum	—	Negligible
Turbidity as SiO ₂	—	—	—
Chemical			
Calcium, Ca	—	—	77
Magnesium, Mg	—	—	28
Sodium, Na	—	—	213
Iron & Manganese Fe & Mn	0.3	—	—
Chlorides, Cl	250	500	223
Sulfates, SO ₄	250	—	154
Ammonia, NH ₃	—	—	1.8
Nitrites, NO ₂	—	—	0.03
Nitrates, NO ₃	—	—	94.3
Fluorides	1.5	—	—
Dissolved Solids	1000	3200	1050
Volatile Suspended Solids	—	—	4.9
Hardness as CaCO ₃	—	—	305
Boron, B	—	4	0.8
Phenols	0.001	—	0.001-0.02
Toxic Metals	0.05	—	—
Detergents, ABS	—	—	1.12

^a See Limitations and Definitions in USDA Salinity Laboratory, Circular #969.

^b Average of Well Runs 6-10. No determinations during Run 5.

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