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*The Study Area, shown at the left, is the geographic context of the Association's current work on a Second Regional Plan, a successor to the pioneering Plan of New York and its Environs of the 1920's. The Study Area is deliberately drawn larger than would be required to accommodate the most extensive of several development patterns being evaluated for the year 2000, the time horizon of the new plan. The area includes 31 counties in New York, New Jersey and Connecticut with a population in 1965 of 19 million and a land area of 12,748 square miles.*

# WASTE MANAGEMENT

## GENERATION AND DISPOSAL OF SOLID, LIQUID AND GASEOUS WASTES IN THE NEW YORK REGION

*Prepared for Regional Plan Association*
*by Blair T. Bower, P.E., Gordon P. Larson,*
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*Edited by Richard T. Anderson.*
*Cosponsored by the*
*Metropolitan Regional Council.*

A REPORT OF THE SECOND REGIONAL PLAN MARCH, 1968

# Regional Plan Association


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# FOREWORD

When the Committee on the Second Regional Plan —a distinguished group of advisors to Regional Plan Association—was confronted by the projection of a 60 percent increase in population for the New York Metropolitan Region between 1965 and 2000, some members asked whether the 30 million people expected by the end of the century would not desecrate the environment by the sheer volume of their own wastes.

This report responds to that question.

The study was financed by the Old Dominion Foundation. It was sponsored by Regional Plan in conjunction with the Metropolitan Regional Council, the forum of chief elected officials of the Region's local governments. Mayor John V. Lindsay is the Council's chairman, and the Executive Director is Robert P. Slocum. Executive Secretary Mathias L. Spiegel served as liaison on the project.

This report on waste management is an integral part of the Association's Second Regional Plan. First, it indicates that waste disposal problems need not require limiting population growth in order to protect the quality of the environment—the quality of the air from gaseous wastes, rivers from liquid wastes, countryside from solid wastes. We can handle our waste problems even as the population increases, the study concludes.

It further concludes that the costs of managing wastes can vary greatly. Both the quality of air, water, and land that is achieved and the methods by which wastes are managed affect costs.

Finally, it relates regional planning projections of population, jobs, and their patterns of location to alternative methods and costs of waste handling.

The whole Region, then, has a stake in efficient waste management. It is the only sound way to attack air and water pollution and the misplacement of solid wastes. Large sums of money that may be spent needlessly on inefficient waste-handling programs inevitably would be subtracted from other urgent public investments in a better environment.

Other elements in the Second Regional Plan—regional centers, regional transportation, urban design and public services for the older cities—are analyzed in the rest of the volumes in this series.

Preparation of the Second Regional Plan began with basic projections of the Region's future prepared for the Association by the Harvard Graduate School of Public Administration (published in ten volumes between 1959 and 1961). The Association staff added an analysis of prospective land use and its implications in **Spread City** (1962).

The Second Regional Plan is a response to the problems identified in these earlier projections. The Plan will propose directions toward which development should be guided and will set out a strategy for changing unplanned trends toward patterns better suited to the Region. It will not be a rigid blueprint for the year 2000; it will be a basis for judging the long-term validity of current decisions.

Previous reports of the Second Regional Plan were **The Lower Hudson** (1966), a study of the changing waterfront; **The Region's Growth** (1967), which projects economic and demographic characteristics of the Region to the year 2000; and **Public Participation in Regional Planning** (1967), a description of the pioneering public participation process which began with the Goals for the Region Project in 1963.

The first Regional Plan, **Regional Plan of New York and Its Environs,** was financed by Russell Sage Foundation in 1922 and published by Regional Plan Association in two volumes (1929 and 1931) after the completion of ten survey volumes. It was the first metropolitan plan in the world. This civic effort was a landmark in its advancement of the art and science of urban economics and planning and in the beneficial impact it was to have on the development of the New York Region.

Regional Plan Association, an unofficial citizens group organized in 1929 to foster and develop the first Regional Plan, has continued to pursue the goal of improving the lives of the people of the tri-state Region surrounding the Port of New York.

Most of the broad development policies of the first Regional Plan, such as the expressway and river crossing system, most of the local planning standards and many specific regional park and other projects, have been carried out.

Second Plan research is being financed by the Avalon, Ford, Old Dominion, Rockefeller Brothers and Taconic foundations. Other stages of Association work leading to the Plan were also financed by these foundations and the Merrill, New York, Twentieth Century and Victoria Foundations.

In the decade 1957-67 during which this work was conducted, the Association was led by Harold S. Osborne, Amory H. Bradford, James S. Schoff and Max Abramovitz. Each has contributed significantly to the making of the Second Regional Plan.

This publication has been reviewed and accepted by Regional Plan's Executive Committee for transmittal to the Committee on the Second Regional Plan, the Metropolitan Regional Council, and the public.

C. McKim Norton
President

# CONTENTS


FOREWORD 5

A PREFACE AND SOME CONCLUSIONS 8

1. **Introduction** 13
   - Waste generation
   - Assimilative capacity of the environment
   - Interrelationships among forms of wastes
   - Regional planning and waste management
   - Objectives of the study

2. **Underlying Concepts and Principles** 23
   - Waste management system
   - Types of wastes
   - The effects of wastes discharged to the environment
   - Controls on waste discharges
   - Reducing wastes and modifying assimilative capacity

3. **Procedures for Analysis of Waste Management** 37
   - Basic projections
   - Major sources of wastes
   - Estimating wastes generated and discharged
   - Estimating waste management costs
   - Assessing the impact of waste discharges
   - Policy problems

4. **Waste Generation: Present and Future** 45
   - Present waste generation
   - Future waste generation
   - Impact of effluent charges and water intake prices
   - Waste generation in the year 2000
   - Impact of waste discharges on environmental quality

5. **Waste Management Methods and Residual Wastes Discharged: Present and Future** 53
   - Present residual waste discharges and handling methods
   - Future residual waste discharges and handling methods
   - Some implications of the results
   - Comments on waste management costs

6. **Implications for Governmental Organization** 67

7. **Summary and Suggestions** 73
   - What next?
   - Short-run suggestions
   - Long-run suggestions

APPENDIX 81

1. **Waste management costs** 81
2. **Assumptions used in developing variants for 2000** 86
3. **Background data: generation and handling of wastes** 90
4. **Uncertainty in environmental quality management** 104

LIST OF TABLES, CHARTS, AND MAPS 107

# A PREFACE AND SOME CONCLUSIONS
## by the Staff of Regional Plan Association

Pollution of air and water and the defacement of the landscape with refuse are now major matters of public concern. This report presents an approach to the control of pollution on a comprehensive basis. It does not use the word pollution—a vague term expressing an unspecified degree of impurity—but rather analyzes its causes: inadequate management of the wastes from human activities.

Urban man has always had difficulty disposing of wastes. At times, concentrations of wastes have endangered his health so acutely as to hold down the growth of cities. Only when settlement was sparse and dispersed could the natural environment—air, water and land—absorb and dissipate the wastes without some form of management by man.

The New York Region developed in a magnificent natural environment, which was not easy to spoil. Close to 3,000 miles of tidal shoreline break up the land mass with numerous bodies of water, backed up by the Atlantic Ocean. Several mountain chains, rising to elevations as high as 4,000 feet, form a backdrop to the coastal plain 25 to 90 miles inland. With ample precipitation and a rich forest cover, these highlands are a major source of fresh water. Prevailing winds provide natural ventilation superior to that of many other large metropolitan areas.

But a concentration of 19 million people on 2,300 square miles of built-up land has led to increasing concentrations of wastes in water, on land, and in the air. The prospect of 30 million people living here by the year 2000 threatens much more serious deterioration of the environment unless waste management is substantially reorganized.

### The problem: some examples

A dome of haze hovers over built-up parts of the Region—especially on a calm sunny day. For the most part, these are automobile fumes. In 1965, some 6.5 million motor vehicles spewed 1.2 million tons of hydrocarbons into the air over the Second Regional Plan Study Area.[1]

In and around New York City, there is no escape from the patina of dust and soot. Nearly 300,000 tons of particulate matter are discharged annually to the Region's atmosphere. Two-thirds of this comes from the burning of refuse, either in apartment house and municipal incinerators or open dumps. The burning of fuels for heat and power generation produces particulates and sulphur dioxide gas. About two million tons of $SO^2$ are discharged each year, which, when combined with air moisture to produce sulphuric acid, lead to deterioration of masonry, paint, and clothing.

The potential damages of liquid wastes are measured by the amount of oxygen needed to oxidize them. About 700,000 tons of this biochemical oxygen demand (BOD) are generated in the Study Area each year, and less than 40 percent of it is removed by various waste reduction facilities. The 138 sewage treatment plants within the Interstate Sanitation District, which covers the inner portion of the Region, give some form of treatment to an average of 1.7 billion gallons of sewage per day; several hundred million gallons are still discharged without any waste reduction. However, the 49 plants in the District which are presently under design or construction are expected to eliminate the discharge of raw sewage, except during heavy storm runoff, and improve the quality of treated effluent by the early 1970's.

Solid wastes, of which about half are paper and paper products, amounted to 17 million tons in the Study Area in 1965. About 30 percent is incinerated; most of the remainder is disposed of in sanitary landfills and open dumps. Only some 4 percent is salvaged. Generation of solid wastes, particularly disposable consumer products, has increased rapidly.

By the end of the century the Region's population will have increased by about 60 percent, from 19 to 30 million. Per capita income is expected to double. Both trends imply substantial increases in waste generation. If present trends and policies continue, vehicle-miles traveled will more than double and electric power demand will increase at least fivefold.

Solid wastes requiring disposal could more than triple by the year 2000. As urbanization engulfs greater segments of the Region's vacant land, disposal space has become increasingly rare, especially in the developed core where most wastes are produced. New

[1] The 31-county Study Area used for the Second Regional Plan is shown on the map inside the front cover. "New York Region" and "Study Area" are used synonymously in this report.

York City already is facing this situation.

The Public Health Service sees municipal sewerage systems doubling their effluents before 1990, and the complex chemical composition of new industrial wastes may result in some difficult treatment problems.

The public already is loudly protesting the pollution of our rivers and streams, of the air over a broad span at the Region's center, of many wetlands along bays and other waterways, and of many natural areas.

There is no doubt that poor waste disposal practices have led to the destruction of amenities. There also are some proven damages to crops, buildings, and the fishing industry. And there is a possibility of immediate dangers to human health and cumulative damages from long-term exposure to waste concentrations in the environment. But these have not yet been proven. Nor do we fully understand the effects of waste concentrations on the total ecology of the Region.

The certain damages as well as those about which we are uncertain strongly suggest an end to the complacency with which this metropolitan area generally has undertaken its waste disposal.

## Findings

While this is a preliminary study, focused mainly on developing a procedure for waste management analysis, some tentative conclusions emerge.

1. Even without added population, upward trends in per capita waste generation and increasing public demands for improved environmental quality—particularly the cutting down of air and water pollution—will require much greater attention to waste management.

2. However, the potential for improving waste management is so great that higher levels of environmental quality can be achieved even while the Region's population increases substantially. In other words, projected waste quantities are manageable and do not seem so economically burdensome as to require efforts to limit population growth.

3. Different patterns of urban growth do not seem to change waste management costs sufficiently to justify basing a regional plan solely on the differences.

4. However, efficient waste management must be based on what is known about the prospective urban pattern of the Region.

5. Efficient management of wastes requires analysis of the entire waste management system, beginning with waste generation (illustrated by Chart 6 on page 23). Limiting waste generation offers a great opportunity for improved waste management. The usual approach to waste control—limiting waste discharges—may be less effective than controlling the generation of wastes. For example, limiting the sulphur content of fuel oil may be a better waste management technique than limiting $SO^2$ discharges.

6. One form of waste can be transformed to another during handling and disposal. Solid wastes, for example, may result in gaseous wastes when incinerated, liquid wastes when ground in garbage grinders, or remain as solid material disposed of in landfills. This suggests that integrated policies should be formulated for all forms of wastes at all stages in the waste management system, rather than separate policies for solid waste disposal, air pollution control, and sewage disposal—although administration of these programs might well remain separate.

7. Waste management policies should apply to the entire metropolitan area, even though elements of an efficient waste management system, such as refuse collection, can be carried out on a less-than-regional basis.

8. Federal participation is required for effective waste management, including regulations for environmental quality control. For example, control of automobile emissions must be national to be fully effective, although standards in individual states might be more stringent.

9. Waste management decision-making can be improved if costs and benefits are viewed in terms of a regional waste management system and, in some instances, the national economy.

10. One way to achieve more economical waste management is to place the costs of waste handling and disposal on those who produce the wastes. It may be that changes in production processes are less costly than handling and disposing of wastes after they are

produced. For example, if a manufacturer is charged for dumping effluent into a stream, he may find it cheaper to recycle water he is using for cooling purposes rather than drawing in fresh water and discharging it as a waste.

11. Greater reuse of water will be economically justified in this Region as the demand for water increases.

## About this study

The consultants who wrote this report were asked to sketch the dimensions of the waste disposal problem in the Second Regional Plan Study Area between 1965 and 2000 and to set out a method for more precise waste projections, to suggest the costs and uncertainties of alternative management policies, to outline the information needed for a systematic approach to waste management, and to relate different patterns of urban growth to the quantities of wastes each might generate and to differences in management costs. Basically, Regional Plan wanted to know what effect waste management problems might have on the Region's future and hence on the Second Regional Plan.

The major contribution of this study is a process for developing waste management policies for a metropolitan area. This process has four steps: (1) projections of total population and employment for the Region to the year 2000; (2) selection of different distributions of total population, jobs, and other activities—termed Variants I, II, and III in this study—to show the impact of alternative settlement patterns within the Study Area; (3) selection of various "generation conditions" to analyze the effects of factors contributing to waste production—such as changing technology, consumer preferences, and packaging practices—which yield assumed quantities of wastes that will be generated; (4) choice of "management conditions" to show the impact of different techniques and policies for handling and disposing of the generated wastes, including waste reduction, transformation of a waste from one form to another, different handling or disposal costs, or salvage and reuse. The multiplicity of possible variants and assumptions about waste generation and waste management yield many combinations. This analytical framework can be used to test the costs and benefits of policy proposals.

The data and assumptions used in the study only illustrate the analytical procedure. They are not firm figures, either for waste quantities or management costs. Few of the necessary data are now available; among the objectives of the study are to point out what information is necessary for efficient waste management and how it might be obtained and used.

Although this report is a response to environmental pollution, a basic premise of the study is that the discharge of wastes does not necessarily result in "pollution." Pollution only occurs when discharges are of such duration and concentration that they have deleterious consequences for users of air, water, or land. This study emphasizes the effects of policy alternatives. It does not suggest how "clean" the environment should be, nor what levels of "cleanliness" are desirable. These are qualitative goals which require political determination. But the determination is best made when the facts about alternatives and their costs are clear. Making these facts and alternatives clear is one purpose of the study.

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# 1. INTRODUCTION

In its daily production and consumption of goods and services, society generates wastes—solid, liquid, and gaseous. Unlike an astronaut in his capsule, who is constrained within a small environment and must recycle his wastes into productive uses to the maximum extent possible, society has few incentives at present to recycle its wastes. Thus, wastes must be disposed of, often at locations other than where they were generated. Wastes are discharged into the atmosphere, into surface and groundwater courses, and on the land. The generation and discharge of wastes is illustrated in Chart 1. Various forms of wastes are produced at many points, from the production of initial raw materials to consumer use of finished products.

The definitions of three terms, basic to this study, are as follows:

**Waste.** A waste is a substance for which, at a given point in time, there is no economic use.[1]

**Waste generation.** Wastes are generated during production and consumption of goods and services. For example, dust is generated in the production of steel ingots; waste paper is generated in office buildings; households generate gaseous wastes from fuel burned for heating, solid residue from vegetation in yards, and liquid wastes from washing.

**Residual waste.** A final quantity of waste discharged into the environment—air, water, or land—is called residual waste. It is the quantity that remains after measures, if any, are undertaken at the site of waste generation and in collective waste handling facilities to reduce the waste prior to discharge.

There are three fundamental aspects of the problem of waste generation and waste management: (1) factors affecting generation and recycling of wastes in society; (2) capacity of air, water, and land to assimilate residual wastes; (3) relationships among the three basic forms of wastes—solid, liquid, and gaseous.

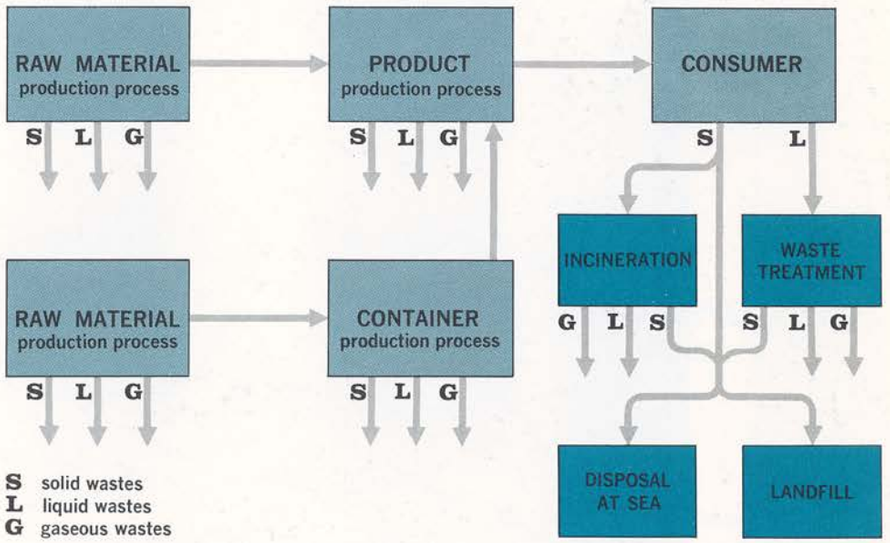
## Waste generation

Per capita generation of solid wastes since the end of World War I has increased by about 60 percent. Contributors to this increase have been greater per capita consumption of paper products, the "packaging revolution" which has virtually eliminated the purchase of goods in bulk, decreased durability of many consumer goods, and the general proliferation of consumer goods. These are clear reflections of the spreading affluence of society.

An important factor in waste generation is that many decisions concerning the production of goods for consumer use are made without consideration of the impacts on waste generation or waste disposal costs. An obvious example is the decision to use nonreturnable bottles rather than returnable bottles. Instead of a container which is recycled into the production-consumption process, the bottle becomes a waste which must be handled and disposed of after its contents are used.

The recycling of wastes, as illustrated by the environment of a space capsule, can have important effects on waste management costs. Although this will be evident from subsequent analyses, it is of sufficient importance to merit illustration here.

Chart 1
WASTE GENERATION AND DISPOSITION




[1]The word "wastes" (plural) is a more accurate term than the singular, because the appropriate reference is usually to one or more wastes of any form—solid, liquid, and gaseous—or any combination of them. However, for simplicity, the singular form is used in reading for adjectives and adverbs.

Interstate Sanitation Commission






Above: A major reason for the 60 percent increase in per capita generation of solid wastes since 1920 is greater use of disposable paper products. These overflowing paper cartons, delivered with goods to a supermarket in Howard Beach, Queens, became wastes when their purpose was fulfilled.

Left: While consumption of paper products is increasing rapidly, the reused portion of waste paper has declined continuously since the Korean War. No more than 20 percent of the paper wastes presently collected by members of the Greater New York Waste Paper Association are reused, compared to more than 60 percent just fifteen years ago. Here a load of waste paper is removed from a Manhattan loft building.

One system for handling and disposing of solid wastes, including the option of recycling the paper component, is illustrated in Chart 2. In the United States, paper currently accounts for about 50 percent, by weight, of the collected solid wastes generated per capita. Between 10 percent and 20 percent of this paper is salvaged and reused. If we assume there is a market for recycled paper, waste management costs can be estimated for each level of recycling. Assuming that the paper which is not recycled is disposed of with the rest of the solid wastes by incineration, with subsequent disposal of the incinerator residue to sanitary landfill, the annual cost of solid waste disposal, with only 20 percent of the paper recycled, is about 1.5 times the annual cost if 80 percent of the paper were recycled, a difference of almost 100 million dollars for the New York Region.[2] These costs, shown in Table 1, refer to the system shown in Chart 2.

Table 1

**EXAMPLE OF EFFECT OF RECYCLING PAPER ON WASTE MANAGEMENT COSTS IN THE NEW YORK REGION**

| QUANTITIES TO BE MANAGED | VARIANT I, YEAR 2000[a] 20 percent paper recycled | 80 percent paper recycled |
|---|---|---|
| Total solid wastes incinerated annually[b] | 51 million tons | 34 million tons |
| Incineration capacity required[c] | 204 thousand tons /day | 136 thousand tons /day |
| Particulates discharged to atmosphere[d] | 1,020 tons/day | 680 tons/day |
| Particulates discharged in waste water from wet scrubber[e] | 408 tons/day | 288 tons/day |
| Residue from incineration, to landfill | 14 million tons | 14 million tons |
| **MANAGEMENT COSTS IN MILLIONS OF DOLLARS** | | |
| Capital investment in incineration capacity[f] | 1,428 | 1,088 |
| Annual operation and maintenance costs of incineration | 153 | 102 |
| Annual cost of makeup water[g] | 2.55 | 1.70 |
| Total annual cost of solid waste disposal[h] | 300 | 210 |

[a]For explanation of variants, see Chapter 3 and also the Appendix, Section 2.
[b]Based on total solid waste generation of 56.8 x $10^6$ tons, 50 percent of which is assumed to be paper.
[c]Collective incineration; no on-site incineration permitted; 250 days/year of 24 hours/day operation.
[d]Assuming good incineration, i.e., 10 pounds of particulates discharged/ton of waste incinerated.
[e]Assuming good incineration, i.e., 50 pounds of particulates generated/ton of waste incinerated, 80 percent removal in the wet scrubber, and 90 percent removal in the settling basin.
[f]$7,000/ton/day of capacity and $8,000/ton/day for the two conditions, respectively,
[g]Makeup water for wet scrubber is 1,000 gallons/ton incinerated at $0.05/ 1,000 gallons.
[h]With annual charge of 10 percent on capital investment in incineration capacity.

[2]"New York Region" and "Study Area" are used synonymously in this report. They refer to the 31-county area in New York, New Jersey, and Connecticut shown on the map inside the front cover.

Chart 2

**A SOLID WASTE DISPOSAL SYSTEM**

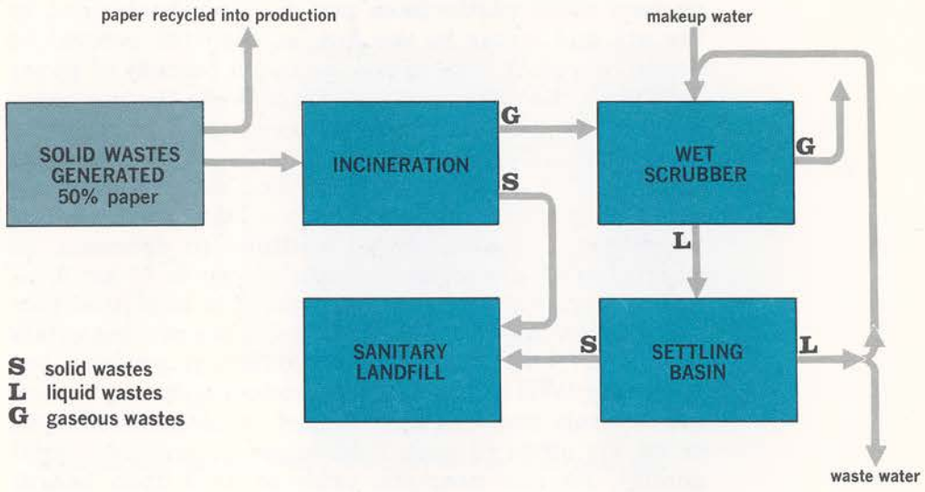
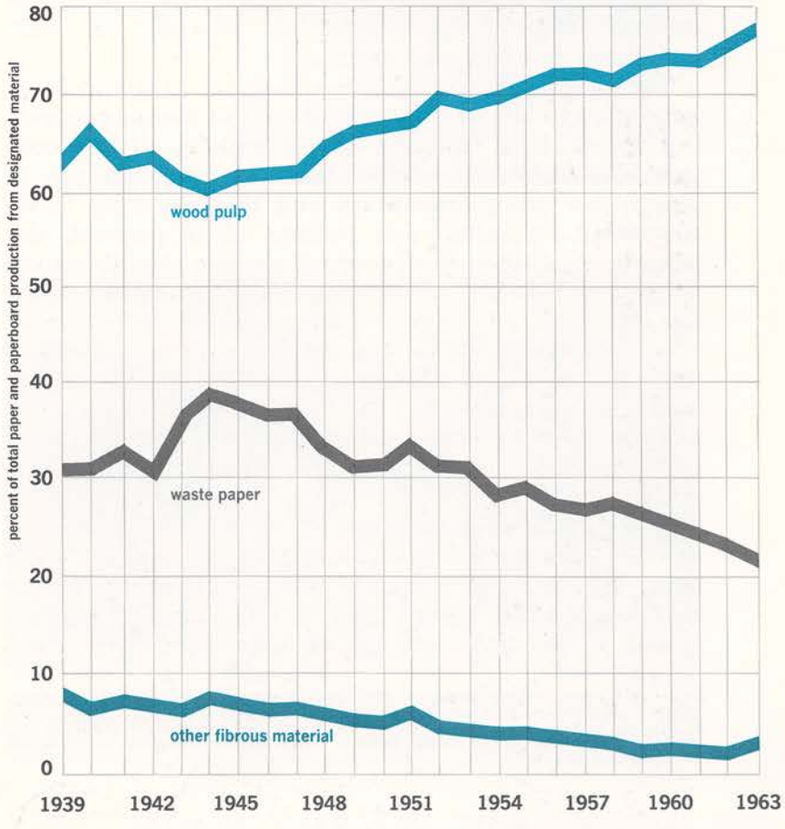



Chart 3

**PERCENT OF PAPER AND PAPERBOARD PRODUCTION IN THE UNITED STATES FROM DESIGNATED MATERIALS**




NOTE: Total paper and paperboard production was about: 13 million tons in 1939
26 million tons in 1951
39 million tons in 1963

Residual wastes discharged into the environment differ significantly between the two cases. About 50 percent more particulates per day are discharged to the air and water in the former case (20 percent of paper recycled) than in the latter (80 percent of paper recycled). The difference in costs between the two cases is so large that incentives could be paid in order to induce extensive recycling. Without such incentives or some specific government regulation requiring the use of waste paper as a raw material, the proportion of paper recycled is likely to continue to decrease, as suggested by the historical data shown in Chart 3.

The magnitude of wastes generated in industrial production is a function of the nature of the raw materials used, the technology of the production process, the operating level of a plant, the product output mix, and the controls imposed specifically on plant discharges or on the effect of such discharges on environmental quality. As one example, prior to 1950 open hearth furnaces discharged about 8 to 12 pounds of dust per ton of steel. Subsequent developments in steel-making technology, particularly the adoption of the basic oxygen furnace, have resulted in doubling the waste dust generated per ton of steel produced. The latest oxygen steel-making method will increase the dust generated per ton still further.[3]

To cite another example, the quantity of particulates generated in the combustion of coal at steam generating plants is a function of the quality of the coal (particularly the ash and volatiles content), the type of boiler, the firing conditions, and the operating level. Assuming an initial ash content of 10 percent, the pounds of particulates generated per ton of coal burned range from about 20 pounds per ton to about 240 pounds per ton, a ratio of 12 to 1.[4] Depending on the nature of the production process, the product mix, and the raw materials used, the pounds of biochemical oxygen demand (BOD) generated in the paper industry vary among plants by a ratio of at least 20 to 1. In the canning of fruits, the waste load in pounds of BOD per ton of raw product processed varies significantly in relation to the quality of the fruit, the method of processing, and the product mix. The waste load from peach canning, for example, varies according to whether only halves and slices are canned or, in addition, irregular pieces, concentrate, and nectar are packed.

[3]H. J. Dunsmore, "Waste Diffusion Problems of Allegheny County," **Proceedings of the Fourth Pittsburgh Sanitary Engineering Conference** (Pittsburgh, 1963), p. 74.
[4]G. Ozolins and R. Smith, **Rapid Survey Technique for Estimating Community Air Pollution Emissions** (Public Health Service Publication No. 999-AP-29; Washington: GPO, 1966), p. 56.

Consideration of waste management must begin with analysis of the factors which influence waste generation in the first place. Changing technology, changing consumer tastes, and increasing per capita income are the critical factors involved. If present governmental policies continue, such as not assessing the external costs of waste discharges against the producers of goods and services, an increasingly affluent society is likely to spawn greater per capita quantities of wastes, thus straining the assimilative capacity of the environment and increasing waste management costs.

## Assimilative capacity of the environment

The second important facet of waste management is the assimilative capacity of the environment. Discharge of wastes may or may not affect environmental quality. Whether it does or does not depends on the assimilative capacity of the environment and the nature of the wastes themselves. For example, the discharge of several tons of organic material into the ocean 20 or 30 miles from shore may have no measurable impact on water quality. The discharge of the same quantity of organic material into the Hudson River at Albany may result in a significant deterioration of water quality in the River downstream from Albany.

The impact of a waste discharge on subsequent users of water, air, and land is a function of the concentration of the waste. It is crucial to identify the effects of a given waste quantity discharged from a single source or of various quantities discharged from many sources on air and water quality "downstream" from the discharges. If the concentration of sulphur dioxide at a particular point in the air is of concern, the problem is to determine the concentration at that point stemming from the discharge of given quantities of sulphur dioxide at other points. If the concern is with the dissolved oxygen in a stream, the problem is to determine the amount of dissolved oxygen which results from the discharge of organic waste materials at various points upstream from the location of concern. The complex interrelationships between quantity and location of waste discharges and impact on environmental quality are considered further in Chapter 2.

Three further points should be mentioned. First, since it is the quality of air, water, and land which affects subsequent users, not the discharge of wastes per se, "pollution" can be said to occur only when the discharge of wastes significantly impairs subsequent uses of air, water, or land. Thus, if a general relation-

ship as illustrated in Chart 4 is known, whether or not pollution occurs is a function of the general relationship shown in Chart 5. That is, until some level of concentration is reached, there are no measurable damages from sulphur dioxide. Of course, the level of concentration at which damage begins to occur varies greatly depending on the waste and on the use of the "environmental element"—air, water, land—involved. For example, concentrations of total dissolved solids in water of 500 to 600 parts per million (ppm) generally have no adverse effects on human beings when the water is used for drinking. In contrast, a concentration of phenols in water of less than 1 part per billion will result in objectionable taste and odors in drinking water.

Second, the concentration of a waste in the environment is a function not only of the quantity of a given waste discharged but, also, of the occurrence of other wastes in the water or air. For example, a certain waste at a given concentration may be extremely toxic to fish if other wastes are present in the water, but the same concentration may have no deleterious effects if the other wastes are not present.[5] Similar behavior occurs with respect to gaseous wastes.

The concentration at a given point resulting from the discharge of a waste is also dependent on whether the waste is degradable or nondegradable. Organic materials in liquid wastes are degradable; they change form and quantity over time after discharge into the water. Other wastes, such as chlorides, are nondegradable; the quantity originally discharged does not change. Gaseous wastes, such as sulphur dioxide and nitric oxide, may change form over time as a result of chemical reactions in the atmosphere. In contrast, dust particles do not undergo transformation in the atmosphere. Garbage discharged to sanitary landfill will degrade (decompose over time), but demolition materials, such as concrete and asphalt, will not.

Third, the assimilative capacity of the air and water changes with time—within a day, from day to day, season to season, and year to year. These fluctuations result from changing hydrologic and atmospheric conditions. During a low-flow period, a stream has much less capacity to assimilate wastes than does the same stream during high flow. Fluctuations in the environment, therefore, are important factors to be considered in waste management.

[5]See J. E. McKee and H. W. Wolf, **Water Quality Criteria** (California State Water Quality Control Board Publication No. 3-A; Sacramento, 1963), pp. 113-115.

Chart 4
**RELATIONSHIP BETWEEN $SO_2$ DISCHARGED AND $SO_2$ CONCENTRATION**

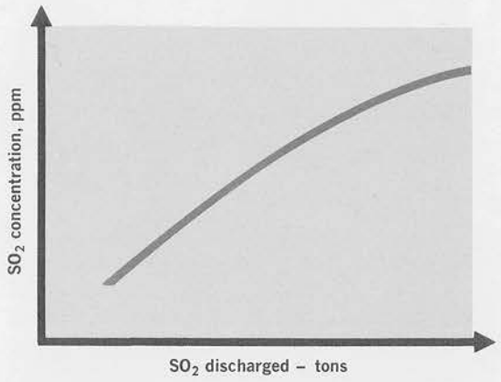
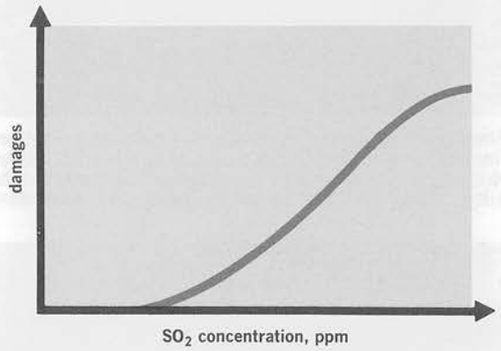



Chart 5
**RELATIONSHIP BETWEEN $SO_2$ CONCENTRATION AND DAMAGES**






Nondegradable demolition materials often provide good landfill for building projects such as airports. But they also present special removal problems in congested urban areas, as with the demolition of the Astor Hotel on Times Square, and demolition often contributes dust to the air.



The provisions of New York City Local Law 14 illustrate the interrelation of forms of wastes. Apartment house incinerators in the city are now controlled by strict emission standards. Owners must meet the new regulations or close their incinerators. Where the latter option is chosen, a much larger quantity of solid wastes must be collected and disposed of than previously.




## Interrelationships among forms of wastes

The third important aspect of the waste management problem involves the relationships among different forms of wastes. One form of waste may be transformed into another form in the process of handling and disposal. For example, waste fiber from the production of paper can be discharged into a water course as a liquid waste. If stringent controls are placed on such discharge, an alternative is to incinerate the waste fiber. This may result in undesirable gaseous waste discharges, with resulting deterioration of air quality. If stringent controls are imposed on gaseous waste as well as liquid waste discharges, another option is to dispose of the waste fiber in solid form, for example, by sanitary landfill.

It is also possible to use one form of waste to modify another form. This is exemplified by the utilization of flue gas from catalytic crackers in petroleum refining to strip sulphides from caustic treatment operations.

An interrelationship among the three forms of wastes can be illustrated by an incinerator operation. Assuming that a wet scrubber is used with an incinerator,[6] and that the wastes put into the incinerator remain the same in quality and composition, as the degree of particulate removal is increased, there are corresponding increases in the quantities of water required for scrubbing and of solid residue requiring disposal.

## Regional planning and waste management

If all economic activities and households were scattered uniformly over a featureless plain and the distance between any two points of activity were large enough so that the discharge of wastes would have no adverse effects on the quality of air, water, and land, and hence no adverse effects on users of them, there would be no waste management problem. As the concentration of population and productive activities increases in an area, there are more and more demands on the assimilative capacity of that area. Consequently, spatial arrangement is an important factor in the impact of waste discharges on environmental quality.

The discharge of any form of waste may have effects external to the unit generating the waste.[7] Examples in-

[6] A wet scrubber is an air pollution control device which utilizes water for trapping, absorbing, and removing fly ash, dust, and gases from a process effluent gas stream.

[7] This is an illustration of what the economist calls "externalities." See the discussion of externalities with respect to water quality in A. V. Kneese, **The Economics of Regional Water Quality Management** (Baltimore: Johns Hopkins Press, 1964), Chapter 3.

clude: an upstream plant discharging dye which causes a downstream plant to incur significant water treatment costs in order to use the water; a rendering plant producing odors which are objectionable to residents in the immediate neighborhood; uncontrolled dumping of refuse leading to rodent and insect breeding, deterioration of air quality from open burning, deterioration of water quality from drainage through the dump, and general ugliness.

Two aspects of activity location in a region are particularly relevant to waste management. The first involves the location of activities in relation to each other. The second involves the location of waste generating activities relative to waste management costs.

First, substantial damages would be likely if a plant generating and discharging significant quantities of organic wastes were located immediately upstream from a major trout-fishing area. Similarly, water-based recreation activities should not be located near an area of heavy industrial concentration. Because the cost of waste reduction increases rapidly as the degree of waste reduction approaches 100 percent, it is not economically feasible to remove all wastes or to preclude all waste discharges to the environment. Consequently, as production increases in a given area, the quantity of wastes generated and discharged in that area will increase almost inevitably. Therefore, when planning the location and density of economic activities, the generation of wastes, the discharge of wastes, the impact of such discharges on environmental quality, and the impact of the resulting quality on other users should be considered.

Second, activity location also affects costs of waste management. Since there are economies of scale in many waste reduction and waste treatment measures and in measures to improve the assimilative capacity of water courses, concentrating major waste generating activities in special areas may result in fewer resources to achieve a given level of environmental quality than if the same activities were widely scattered. For the same total quantity of solid wastes to be collected and disposed of, the cost of collection and disposal per ton will be less for a more concentrated area of waste generation. On the other hand, since there is a finite assimilative capacity in both air and water, and since some types of wastes degrade with time, a dispersed pattern of waste generation also has advantages.



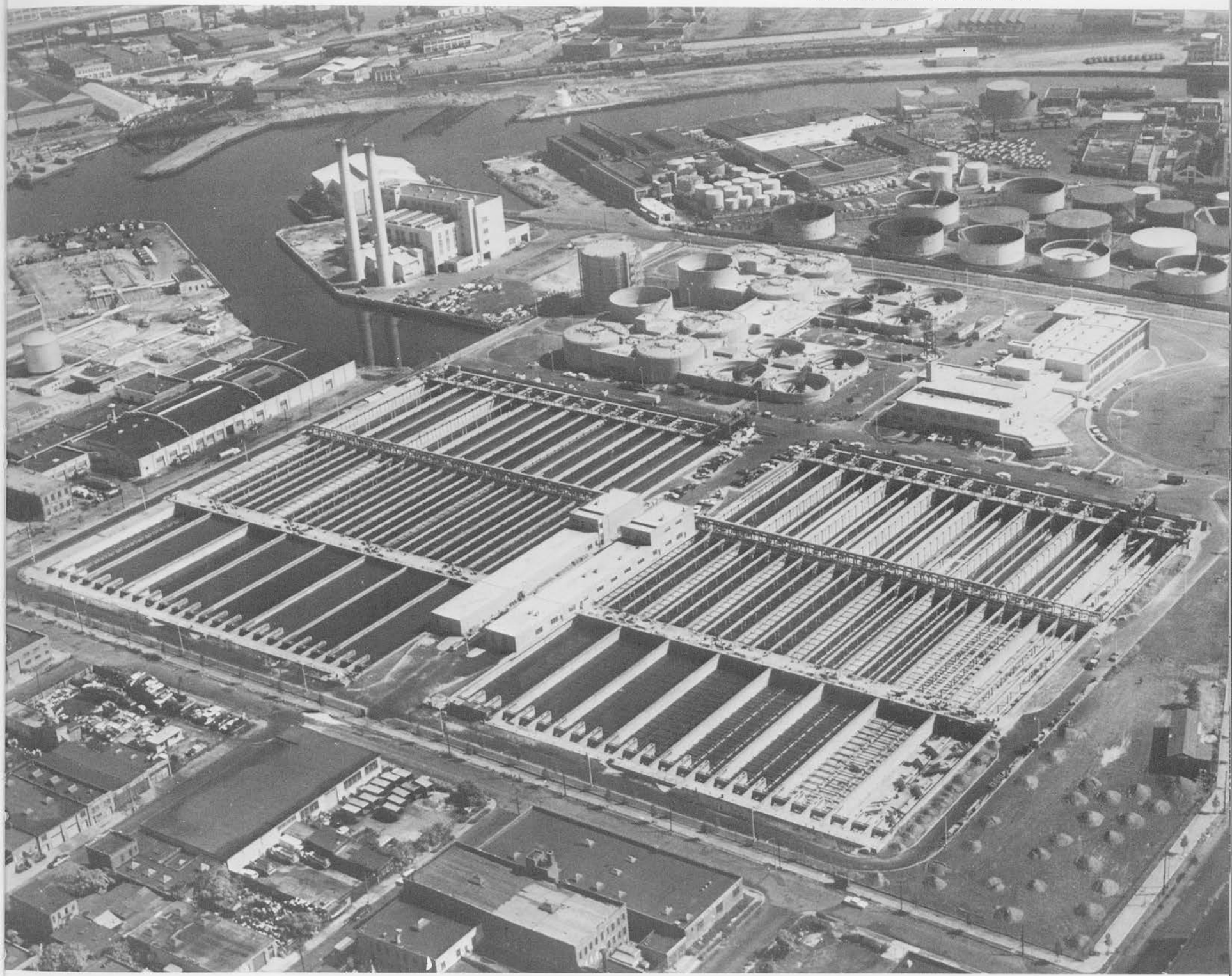
Generation and discharge of wastes and their impact on environmental quality are directly related to concentrations of people and activities. The prohibition of motor vehicles in Central Park on weekends reduces the levels of carbon monoxide and hydrocarbons in the park compared to weekdays, in addition to freeing the drives for pedestrians, carriages, and cyclists.





Concentrations of people permit economies of scale in many waste collection and reduction methods. With liquid waste treatment, the larger the plant, the cheaper the cost per gallon. The Ward's Island Water Pollution Control Plant, opened in 1937, was New York City's first modern plant providing secondary treatment. It now handles 200 million gallons per day, the wastes from 1.25 million people.

New York City Department of Public Works



Newtown Creek, the City's thirteenth plant, began operation in mid-1967. It is designed to serve an equivalent of 2.5 million people, with an average flow of 310 million gallons per day. These discharges formerly flowed without any treatment from 83 outlets into the Hudson and East Rivers.

Waste management costs comprise only one factor to be considered in the location of productive activities. For example, the location of a firm at a particular site might minimize waste handling costs but result in additional transportation costs greater than the savings in waste management costs.

Thus, the costs of achieving desired levels of quality are dependent on activity location and the interrelationships among wastes generated, wastes discharged, environmental quality, impact on other users, and methods of waste management. Sensitivity of waste management costs to the location of activities is one of the questions investigated in this study.

## Objectives of the study

This study is concerned with regional planning in the 31-county Study Area of the Regional Plan Association; nevertheless, it is relevant for regional planning in general. The first objective of the study is to specify procedures by which the problems of waste generation and waste management can be explicitly incorporated in regional planning. This implies several questions. For example, what types of data are necessary for an assessment of a region's waste problem? What methods can be used for analyzing the data? What are the impacts of technology and the implications of governmental policy decisions on waste generation and management? What alternatives are available for waste management? What are their costs and economic and social consequences?

The second objective is to examine the impact of alternative settlement patterns on generation of wastes, environmental quality, and costs of waste management in the New York Region. For instance, for the same level of economic activity, do different distributions of population, employment, and industrial production have significantly different effects on environmental quality? Do they result in significantly different costs of waste management? The costs developed herein are not definitive; the objective is only to discover whether or not they vary significantly with alternative land use patterns.

The third objective is to indicate the impact of different waste management policies on waste generation, environmental quality, and the costs of waste management. For example, if government policies were adopted to encourage waste recycling back into the production process, such policies would have important consequences for the costs of waste management. If effluent charges were adopted,[8] they would stimulate production units to reassess their production processes to reduce the generation of wastes, if the costs of such reduction were less than the charges imposed. A ban on all incineration, both on-site and collective, would have significant implications for waste management costs. Our purpose is not to advocate a particular policy or set of policies but to illustrate the potential effects of alternative policies and to show how these effects can be analyzed.

The final objective of the study is to indicate the types of data and the functional relationships among variables required for the analysis of waste management in the New York Region. Currently, there are significant gaps in the data necessary for rational waste management in the Region.

[8]An effluent charge is a fee for the discharge of each unit of waste—pound of BOD, pound of particulate matter, or pound of nonreturnable bottles. Such charges are discussed further in Chapter 4.

# 2. UNDERLYING CONCEPTS AND PRINCIPLES

This chapter contains some concepts and principles of waste management and discussion of physical relationships between the discharge of wastes and environmental quality. No attempt is made to be all-inclusive. It is hoped that sufficient background is presented in this chapter to provide an adequate basis for understanding the subsequent discussion and analyses.

## Waste management system

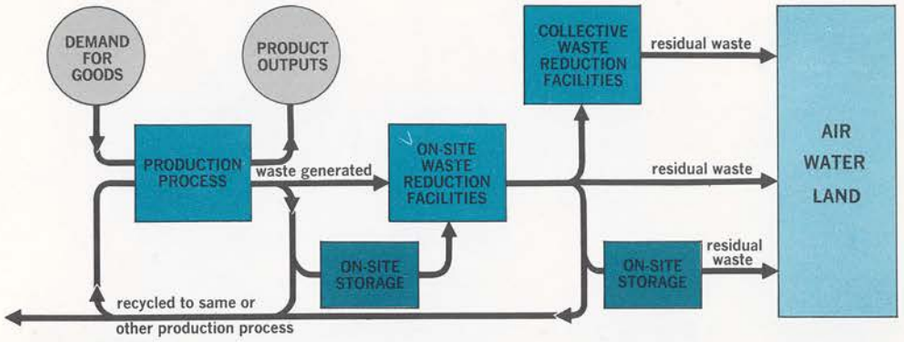
A waste management system consists of (1) facilities for handling, treating, and disposing of wastes; (2) facilities for modifying the assimilative capacity of the environment; (3) regulations for modifying the generation and discharge of wastes (such as standards, charges, and controls on location of waste generating activities and treatment facilities); and (4) facilities and procedures for collection and analysis of data necessary in monitoring environmental quality and performance of individual waste generators and waste reduction facilities. A simplified waste management system and its relation to waste generating units and to the environment is illustrated in Chart 6.

The waste management system does not include direct regulation of how the individual production unit, such as a steel mill, produces its product. The responsible management agency, whether governmental or quasi-governmental, does not control the method of producing final products. The waste management system, however, does include incentives and/or standards imposed on wastes discharged and/or on raw materials used in production processes, such as fuel type. Standards may also be expressed in terms of the environment; for example, a discharge shall not result in a dissolved oxygen level in a stream of less than 3 parts per million. Further, the government agency normally will not have control over the type of waste reduction facility, such as a treatment plant, which may be installed on the site. It may specify the level of waste reduction to be achieved, the quantity of wastes to be removed prior to discharge, or the quantity of wastes which can be discharged, but usually not how removal is to be accomplished.

Measures which modify the assimilative capacity of the environment or allow better use of the existing assimilative capacity are important possible components of waste management systems. Examples of such mea-

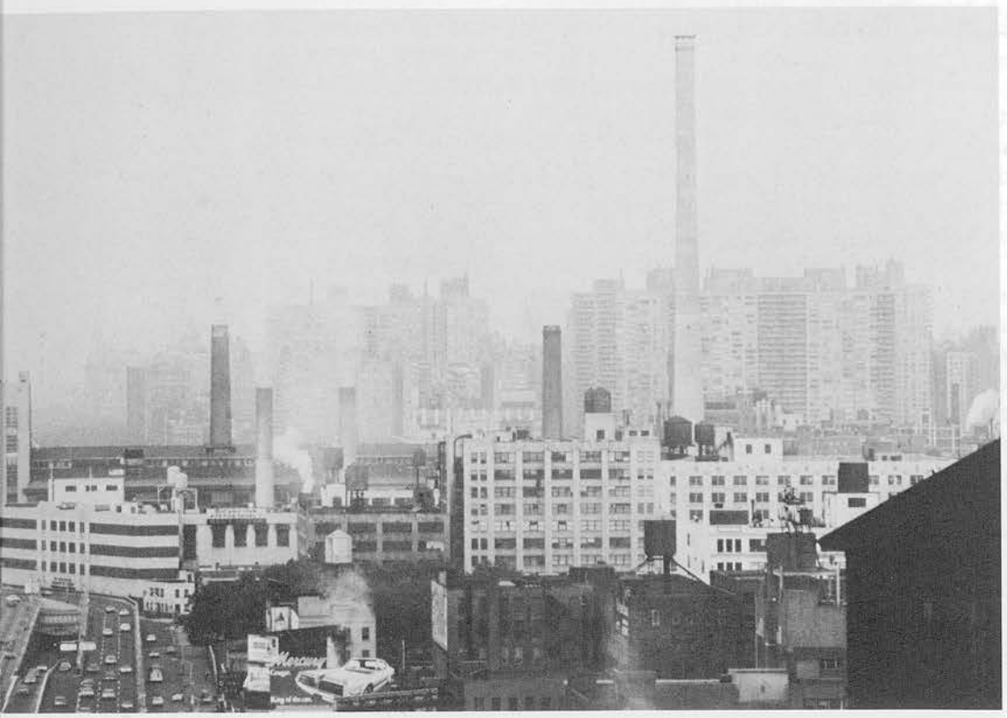
Chart 6

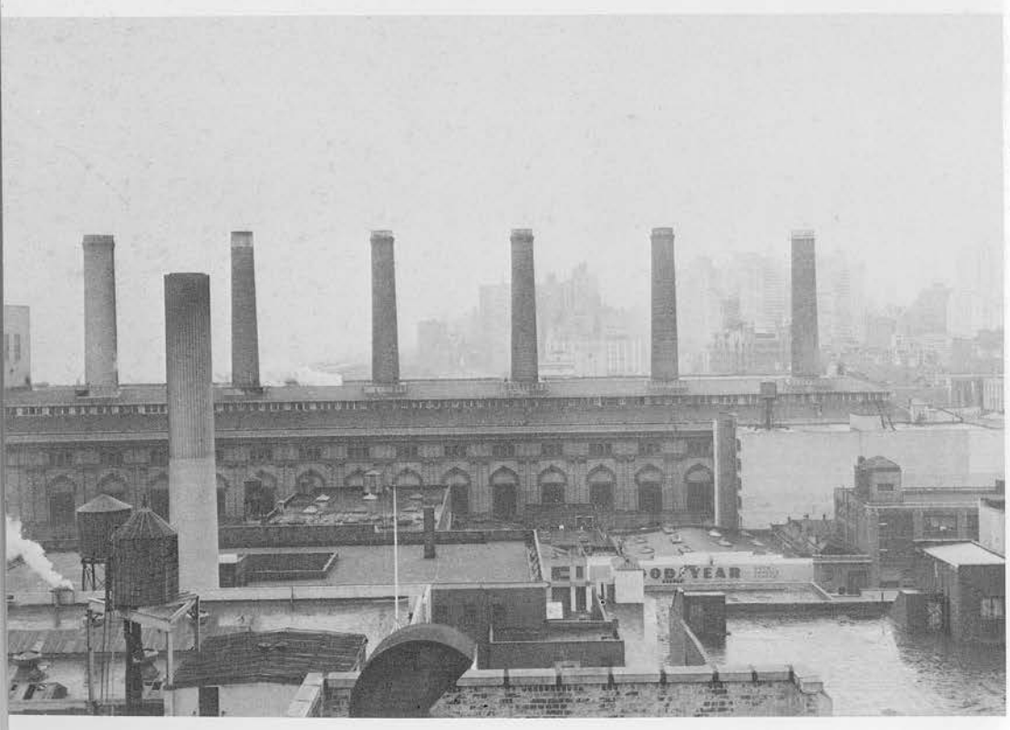
**WASTE MANAGEMENT SYSTEM**






This aerator in Ulster County, New York, improves water quality by exposing the water to air and sunlight. By spraying water into the air, oxygen is added and trapped gases are released.





sures are: releases of stored water to increase a stream's capacity to assimilate organic materials and to dilute nondegradable wastes; aeration devices which add oxygen directly to water courses, such as rivers, estuaries, and lakes; and the use of high stacks to allow the discharge of gaseous wastes at atmospheric levels where the assimilative capacity is greater.

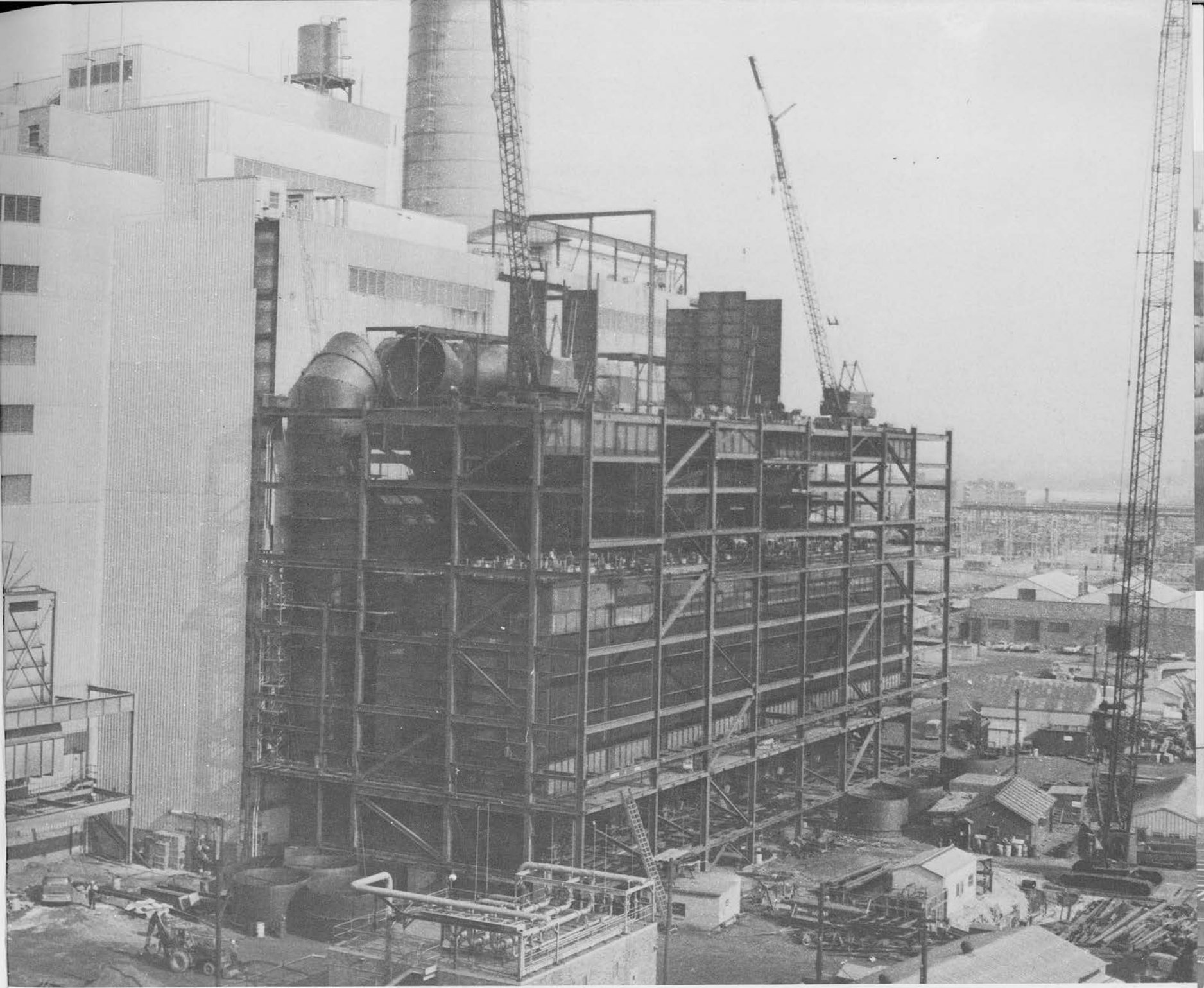
After wastes are generated by a production unit, various types of on-site waste reduction facilities are available for use to reduce the quantity of wastes prior to discharge to the environment or into collective waste handling facilities. On-site waste reduction facilities include liquid waste treatment plants of various types, electrostatic precipitators to reduce the discharge of particulate matter,[1] and facilities for incinerating or compacting solid wastes.

Collective waste reduction may be used after on-site generation of wastes and their reduction at on-site facilities, if any. The wastes discharged from individual generators may be collected and conveyed to central facilities in which wastes from a number of units are handled. For example, liquid wastes from residences, offices, and industries are typically conveyed to municipal sewage treatment plants. Solid wastes from homes and offices are collected and incinerated in municipal plants or disposed of in landfills. There are economies of scale (lower cost per unit of capacity as the size of the facility increases—up to some capacity) for some types of waste handling and reduction facilities. Use of collective facilities, in contrast to facilities at individual sites, therefore, is an important consideration in regional waste management. Economies of scale also exist with respect to some measures for modifying assimilative capacity of the environment.

There are many possible ways of managing the three forms of wastes. In addition to measures for influencing waste generation, various combinations of on-site and collective waste reduction measures are possible. Some of the existing and potential combinations of methods for handling and disposing of solid wastes are shown in Chart 7.

[1] An electrostatic precipitator is a dust and fly ash removal device which is designed to impart an electrical charge to flying particles and to magnetically attract the charged particles to electrically charged collection surfaces.

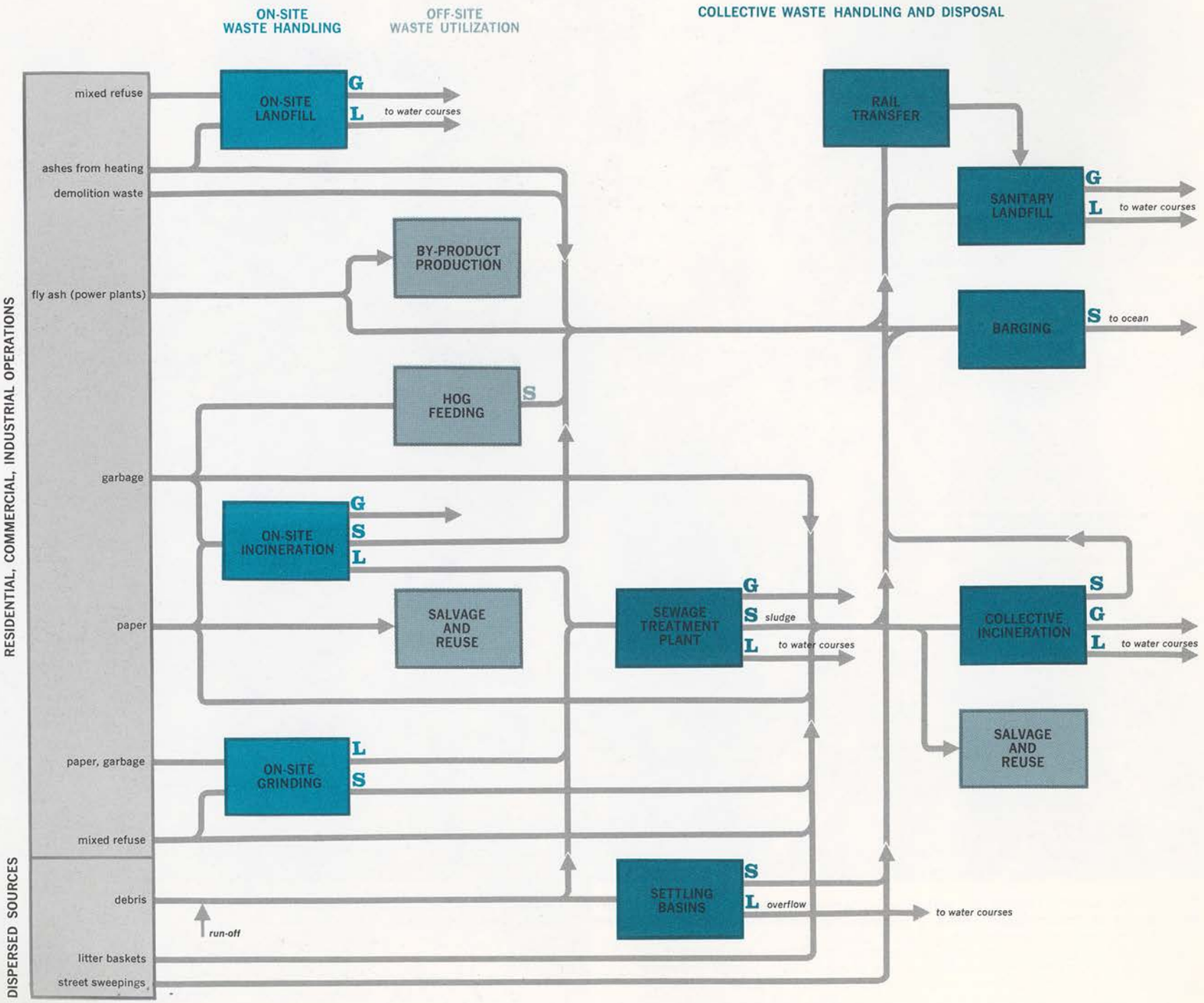
Modernization of Consolidated Edison's 59th Street generating station on Manhattan's West Side included the replacement of four 240-foot-high masonry stacks (left) with a single 500-foot concrete stack (above). Gaseous emissions discharged at higher atmospheric levels disperse more widely and thus make better use of the air's assimilative capacity.



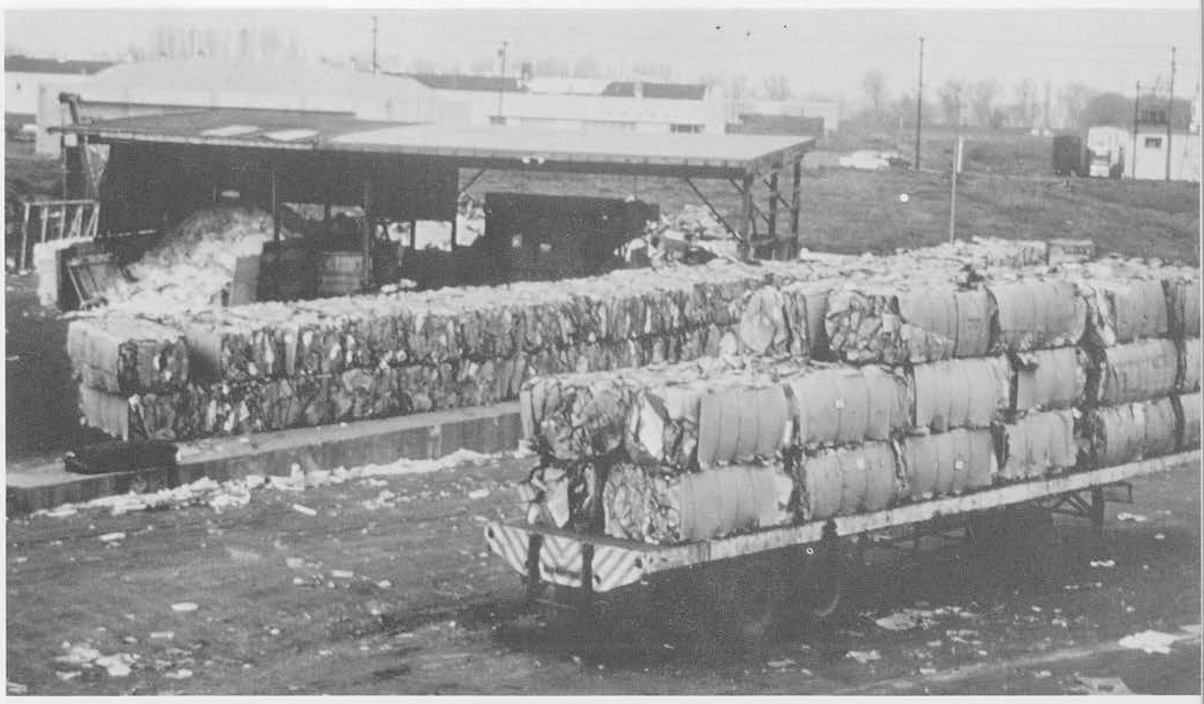
Called "the world's largest air pollution prevention device," this $10 million electrostatic and mechanical precipitator is an on-site waste reduction facility at Consolidated Edison's Ravenswood generating station in Queens. The precipitator is shown under construction.

Chart 7

## COMBINATIONS OF PRESENT AND POTENTIAL METHODS OF HANDLING SOLID WASTES







Above left: **On-site incineration:** Some solid wastes can and should be disposed of where they are generated, but often this is more inefficient, considering overall costs of waste handling and disposal in an area, than collecting them for disposition with solid wastes from other points of generation. Here, for example, trash is burned inefficiently in a backyard. Where this is common in an area, it can be a major source of particulates and other gaseous wastes.

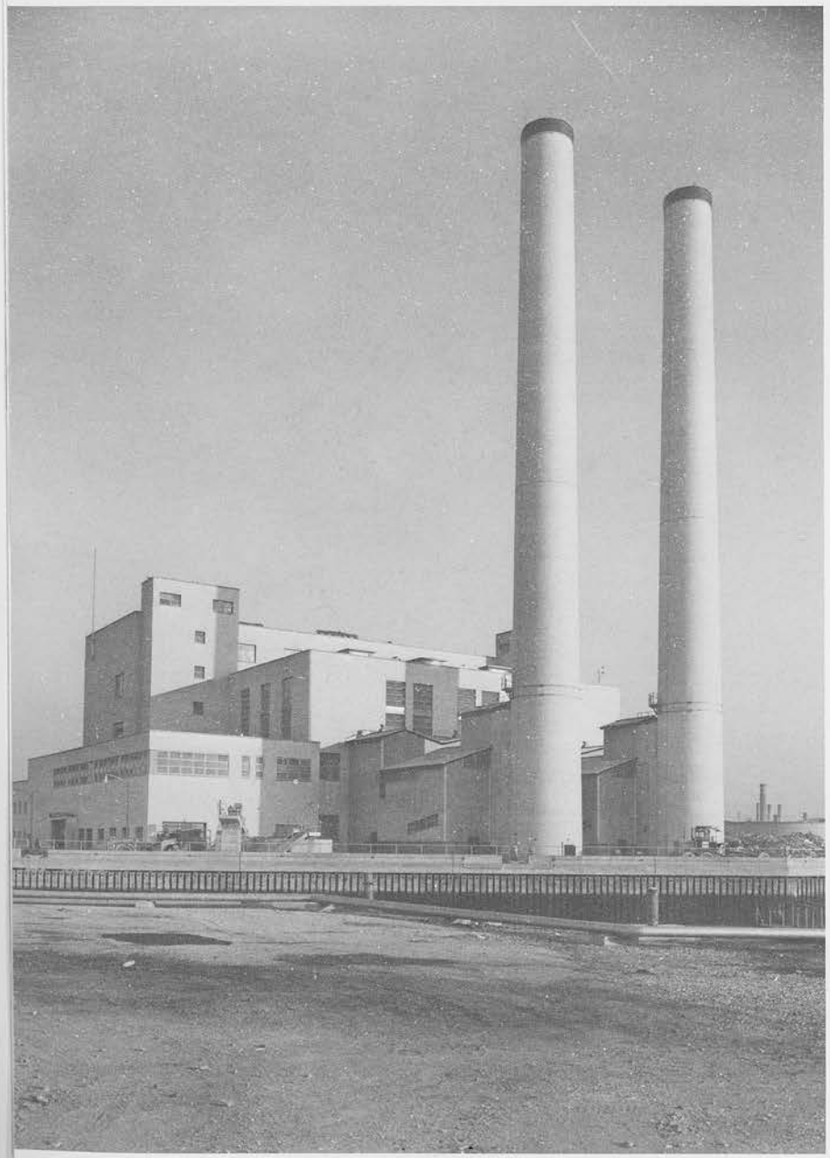
Above right: **Salvage and reuse** often is the most efficient way to handle solid wastes. At this plant, paper is removed from other wastes, and the residue is transferred to incinerators or landfills.

Right: Some solid wastes can be turned into liquid waste by **on-site grinding,** such as kitchen-sink garbage grinders. This adds to the amount of suspended solids discharged to sewerage systems, and ultimately to the sludge that settles to the bottom in the sewage treatment plant settling tanks, like the one pictured here at Hunts Point in the Bronx. On the other hand, it lessens the volume of solid wastes to be collected and disposed of.



**Barges** may be used to carry unreduced solid wastes, incinerator residue, or sewage sludge to disposal areas at sea or to sanitary landfills. The New York City Department of Sanitation transfers wastes from Manhattan (right) to barges which travel to the Fresh Kills landfill site on Staten Island (below right).

**Collective incineration** substantially reduces the volume of collected solid wastes, with the residue usually disposed of in landfills. New York City's Greenpoint Incinerator (below) was opened in 1959 and serves Long Island City, Greenpoint, and adjacent areas in Brooklyn and Queens.








Louis B. Schlivek



**Sanitary landfill** is another way of disposing of solid wastes collected from the site where they were generated. Inert material is used to cover the wastes deposited on land areas. Shown above is one of New York City's large sanitary landfills, in Pelham Bay Park, the Bronx.

## Types of wastes

Within the three general forms of wastes—gaseous, liquid, and solid—there are many types of wastes which may be of concern in particular situations. The impact of these wastes is a function of their concentration and location. For example, household furnishings are damaged by particulate matter, swimmers are bothered by debris in water, and communities are affected by unattractive refuse dumps. Examples of wastes and measures of wastes include the following:

| Gaseous | Liquid | Solid[2] |
|---|---|---|
| Suspended dust | Biochemical oxygen demand (BOD) | Paper and paper products |
| Settleable solids (dustfall or particulates) | Suspended solids | Garbage and other organic materials |
| Sulphur dioxide | Total dissolved solids (TDS) | Demolition materials |
| Oxides of nitrogen | Phenols | Other non-combustibles—cans, bottles, discarded furniture |
| Carbon monoxide | Hardness | Debris from dispersed sources, such as street sweepings and materials conveyed in storm runoff |
| Hydrocarbons | Color | Abandoned vehicles |
| Sulphuric acid mist | pH | |
| Organic aerosols | | |
| Fluorides | | |
| Hydrogen sulphide | | |

Some wastes have greater impact on human beings, plants, and wildlife than other wastes. Since this study is illustrative and procedural, and because the nature of and methods for analyzing the waste management problem can be illustrated without discussing all wastes, only a few types were selected for consideration in this report. These are:

**Gaseous.** Sulphur dioxide ($SO_2$), particulate matter, hydrocarbons.

**Liquid.** Biochemical oxygen demand (BOD).

**Solid.** Paper and paper products, mixed wastes.

[2] "Refuse" is a term typically used as a synonym for solid wastes. For a detailed classification of solid wastes see American Public Works Association, Committee on Solid Wastes, **Refuse Collection Practice** (3rd ed., 1966), p. 15, Table 2-1.

## The effects of wastes discharged to the environment

The heart of the waste management problem involves (1) determining the impact of waste discharges on quality of the environment, with impact measured by the time pattern of concentrations of wastes; and (2) determining the effects of time patterns of waste concentrations on users of water, air, and land. Human beings and their activities may be affected, along with plant and animal life. Determining the impact on environmental quality and determining the effect of quality on users are complicated by interaction among wastes, which affects the resulting time pattern of concentration. That is, the degradation of one type of waste after discharge into the environment may be inhibited or increased by the presence of other wastes. The response of humans or animals to a particular waste may be attenuated or markedly increased by the presence of other wastes as, for example, the response of fish to low levels of dissolved oxygen in the presence of toxic materials. A brief discussion of problems in determining impacts and effects follows, primarily using gaseous wastes for illustration.

The dispersion of a gaseous waste from a single point or from multiple points by air motion is a continuous process, but the rate of dispersal can have great variations. The horizontal and vertical movements of the atmosphere in the local area are primary factors determining the rate of dispersion and, hence, the resulting concentrations at various distances from points of discharge.

The degree of horizontal dispersion from a waste source depends upon the horizontal speed of the waste, which is a function of air velocity. Turbulence in air motion affects the shape of the gas stream. Consequently, dilution of the waste usually takes place in both vertical and horizontal directions. In most areas, the velocity of horizontal air movement increases with elevation above ground level. The horizontal dispersion of wastes can be significantly constrained by topography, as in the case of the Los Angeles basin.

In the course of dispersion, another process may occur, that of degradation or change in the chemical composition of the wastes. For example, sulphur dioxide and nitric oxide may be converted into sulphuric acid and into nitric acid, respectively.

Vertical dispersion of wastes can be retarded by abnormal vertical temperature distribution in the atmosphere. Normally, temperature decreases at about one degree centigrade per hundred meters above the

ground. Under this normal condition any vertical motion stimulated by the wind can occur without too much resistance. But when there is an increase in temperature with height, known as a temperature inversion, vertical motion is suppressed. An inversion usually occurs when there is practically no wind. Prolonged inversion conditions, combined with a lack of horizontal movement, permit accumulations of gaseous wastes within a given air mass.

The West Coast of the United States is subject to continuous periods of inversion conditions during the summer and fall. As a result, concentrations of gaseous wastes build up daily during these periods when the air is incapable of dispersing the wastes; i.e., the assimilative capacity of the air mass is low. Deep, narrow valleys also provide particularly favorable locations for the accumulation of cold air at low elevations. Such accumulation can create strong temperature inversions. Thus, the impact of various patterns of gaseous waste discharges on air quality, and programs developed to modify the discharges in order to improve quality, are affected to a large degree by the weather phenomena characteristic of the local area.

Similar problems of dispersion and degradation occur in water. Discharge of a waste, such as organic material, into a stream, estuary, or groundwater aquifer may result in significant changes in water quality over time and space. As in the case of air quality, estimating the impact on water quality is usually a complex problem, particularly in estuary and groundwater areas. The factors which affect the quality of water in an estuarine area include the magnitude, location, and nature of waste discharges, and the physical and hydraulic characteristics of the estuary, including tidal phenomena and wind patterns. In order to develop a rational water quality management program, it is necessary to devise models by which estimates can be made of the time pattern of water quality resulting from various time and spatial patterns of liquid waste discharges.[3]

The discharge of solid wastes on the land affects environmental quality in several ways. Unless properly performed, landfill operations can cause odors, stimulate breeding of insects and rodents, produce smoke from combustion, lower water quality, and be very ugly. Their impact on the appearance of the land can be likened to the impact of obnoxious floating debris on a stream.





The New York area experienced a severe temperature inversion on November 24, 1966. From the Empire State Building on that date, the view south to the Battery was filled with gaseous emissions trapped by warm, stagnant air. During normal atmospheric conditions, the same gases are emitted, but they are readily dispersed.

[3]The Delaware Estuary Comprehensive Study is an example of the necessary procedural approach. U.S. Department of the Interior, Water Pollution Control Administration, **Delaware Estuary Comprehensive Study** (Philadelphia, 1966).

Unlike gaseous and liquid wastes, which are regularly degraded by natural forces and/or assimilated by the natural environment,[4] solid wastes degrade and compact only to a minor degree. Consequently, solid wastes accumulate. Since the land available for disposing of solid wastes within any given region is essentially fixed, there is an approximate limit to the capacity of the land to receive solid wastes. However, the amount of solid wastes which may be disposed of within the limited space available can be significantly altered in two ways: (1) by the methods used in the disposal system, i.e., incineration, compaction, recycling; and (2) by modifying the depth and height of the filling operation, i.e., contouring of final grade. Nevertheless, because of continuous accumulation, the most important consideration in the disposal of solid wastes is the amount of space available on and/or adjacent to the land in a region.

After determining the impact of a waste discharge on the time pattern of quality at different locations, the second problem is to determine the effects of that time pattern on people, plants, and animals. The effects of gaseous or liquid wastes are a function of the concentration, the duration of the concentration, and the sequence of occurrence of different concentrations. Thus, a short period of high concentration may have effects different from a long exposure to a much lower concentration. Repeated exposures, each of several days duration, to a concentration of a particular waste may be more or less damaging than a continuous exposure for the same total amount of time.

The relationship between quality and impact on users must be specified in terms of damage functions. The general nature of such functions is illustrated in Charts 8 and 9. Chart 8 suggests the relationship between concentration of $SO_2$ and crop yield, as measured by the decrease in bushels per acre. The decreased yield may be converted into dollars. Note that the damage is related to both concentration and duration. Chart 9 suggests the relationship between chloride concentration in the intake water and dollar damages caused in a paper mill producing bleached paper products. Here, also, the amount of damage is a function of both concentration and duration. The damage function for a landfill operation might indicate the reduction in value of adjacent land or the reduction in recreation use of adjacent land according to how well the operation is performed.

Chart 8
**DAMAGE FUNCTION: $SO_2$ VS. CROP YIELD**

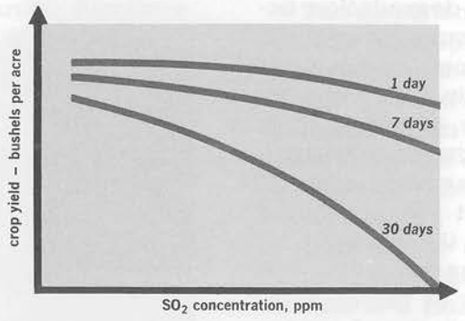
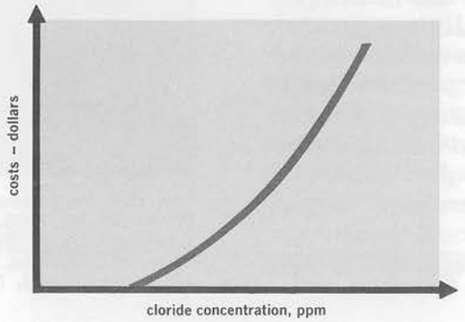



Chart 9
**DAMAGE FUNCTION: CHLORIDE VS. COSTS**




In general, up to some waste concentration level there is no detectable damage to a crop or an individual or increased costs to the production unit. Above some level of concentration, damages begin to occur—physiological damage to human beings, dollar cost to industry, and reduction in crop yield.

Unfortunately, damage functions are poorly defined for all three forms of wastes. The effects of various gaseous wastes on human beings, for example, are still basically undetermined. It has been suggested that people suffering from bronchitis and asthma are seriously affected by some level of exposure to gaseous wastes. It has also been suggested that the increase in lung cancer in the United States may in part be attributed to gaseous wastes as well as to cigarette smoking. During the past decade or so, a great many statistical and laboratory studies have been undertaken in an effort to find a direct relationship between air quality and chronic diseases. None of these projects has produced conclusive evidence which suggests that any gaseous waste must be controlled to a specified level of concentration in order to safeguard public health. With respect to vegetation, some experiments and field studies have shown adverse effects of various gaseous wastes on plant life. Most of the studies have been done on crops. However, few of these studies have resulted in developing specific relationships between the duration and level of concentration and the decrease in crop yield.

[4] In the short run, i.e., 50-100 years, the air and water masses can be considered infinite sinks as far as accumulation is concerned.

The same problems exist with respect to liquid wastes. For instance, although water quality standards for bathing have been established in relation to coliform count, no scientific studies have demonstrated a definitive relationship between water quality, as measured by this parameter, and the incidence of disease.[5] It is interesting to note that raw milk is considered to be of acceptable quality for sale "as long as the bacterial count by the same test is less than 100,000."[6] With respect to irrigation, general limits on the "allowable" concentration of total dissolved solids (TDS) in water to be used for crop irrigation have been suggested. However, concentrations several times these amounts have been used in many areas with no adverse effects on crop yields. This is possible because, in addition to type of crop and water quality, a number of factors influence crop yields, such as soil type, drainage facilities, and tillage practices. Further, the response of crops to TDS is significantly affected by the presence of particular constituents, such as boron, in the water.

## Controls on waste discharges

Waste management involves the regulation of discharges from points of waste generation and from collective waste handling facilities. Various forms of regulation are possible—standards (see below), fees on the waste discharger related to the quantity and character of the discharge (known as effluent charges),[7] or combinations of these.

Three types of standards can be applied: raw material standards, discharge standards (related to emissions and/or facility performance), and ambient standards. The first type is imposed upon the raw material inputs to a production process, such as specification of the maximum sulphur content in fuels used for power generation. Discharge standards are imposed on the magnitude (tons per day) and/or concentration (parts per million [ppm]) of wastes at the point of discharge from the production unit, in terms of performance of a waste reduction facility, or on the way in which the discharge is performed. For example, a sewage treatment plant may be required to achieve 80 percent reduction in BOD, a dust collector may be required to have a collection efficiency of 90 percent, and covering procedures may be specified for landfill

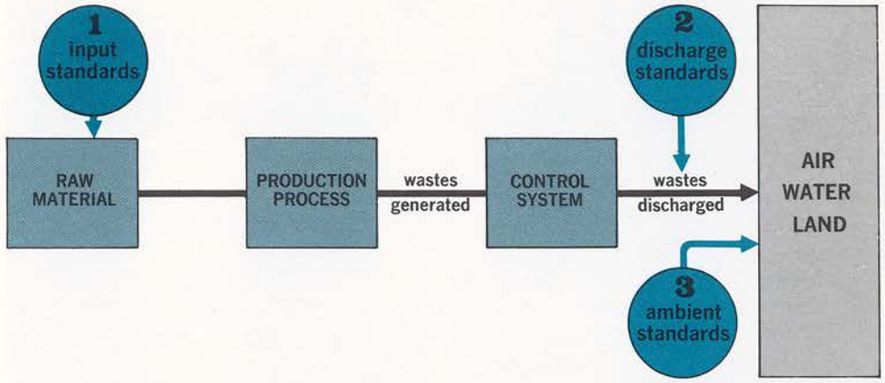
[5]See the excellent discussion in J. E. McKee and H. W. Wolf, **Water Quality Criteria** (Sacramento: California State Water Quality Control Board, Publication No. 3-A, 1963), pp. 118-121.

[6]J. E. Kinney, "Water Quality: Mirages and Myths," **Industrial Water Engineering**, III, No. 8 (1966), p. 28.

[7]Effluent charges are discussed in Allen V. Kneese, **The Economics of Regional Water Quality Management** (Baltimore: Johns Hopkins Press, 1964), Chapter 4.

Chart 10

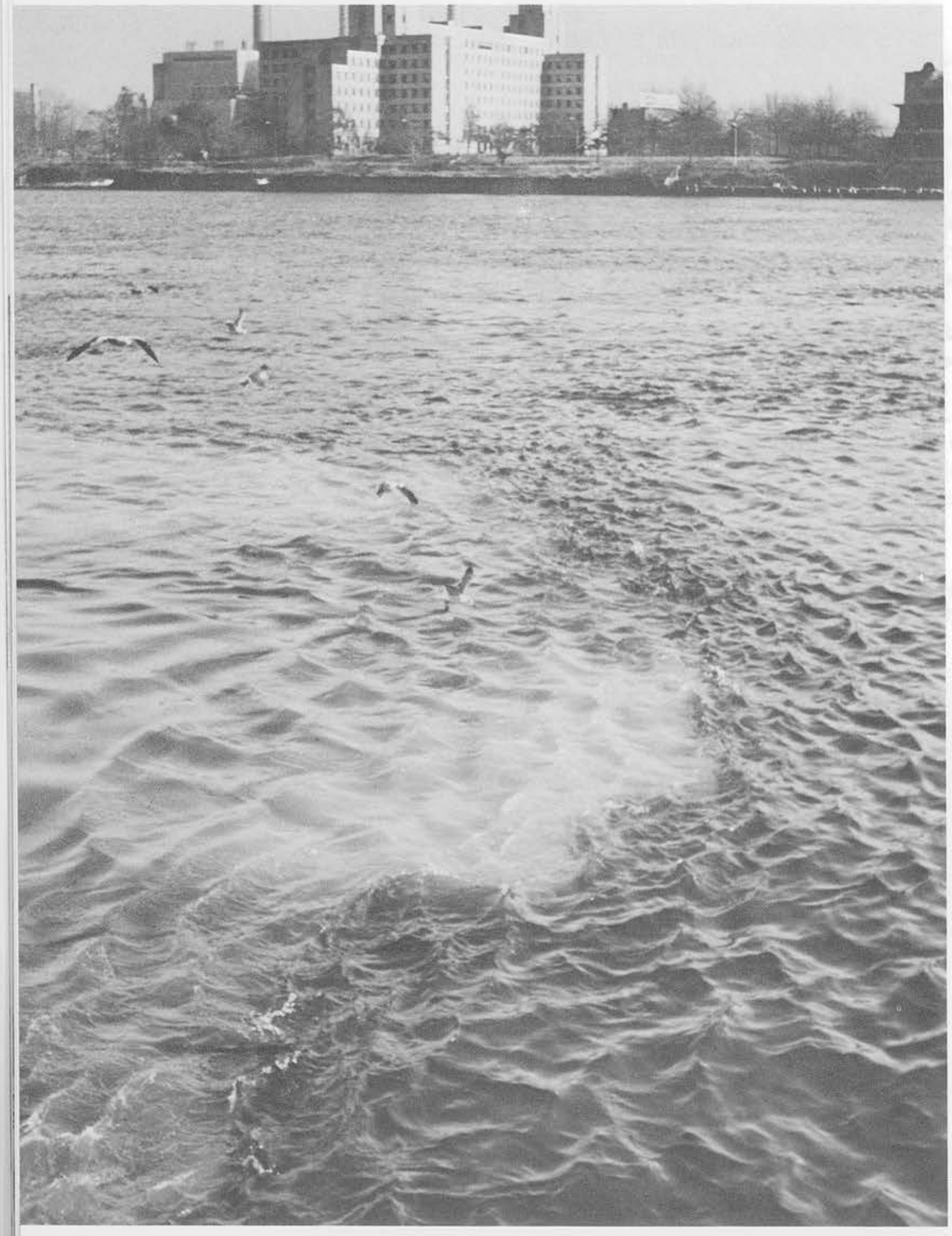
**TYPES OF CONTROLS FOR ENVIRONMENTAL QUALITY MANAGEMENT**






Although damages caused by exposure to various concentrations of wastes over time are not fully known, particularly effects on human health, the effect of gaseous wastes to buildings is readily seen on the Paramount Building on Times Square, and the cost of cleaning it can be attributed to inadequate waste management.

Richard T. Anderson



Many waterways in the Region still receive large volumes of untreated sewage. Discharge standards set by the Interstate Sanitation Commission, which covers New Jersey, New York, and Connecticut, require termination of many of these raw waste discharges in the near future. This photograph shows untreated effluent emptying into the East River at 60th Street, Manhattan. This will end—except during periods of heavy storm runoff—with completion of New York City's North River Pollution Control Plant in 1972.

operations. Ambient standards are applied to the receiving body, whether a water course or air mass, in terms of level and duration of concentration of wastes. The foci of the three types of standards are illustrated in Chart 10.

Standards and/or effluent charges can be applied in several ways. They may be applied uniformly to all waste dischargers or selectively to specific dischargers. The selective procedure takes into consideration that (1) the location of a discharge may significantly affect its impact on quality of the receiving body and hence the effects on other users; and (2) far fewer resources may be required to achieve a specified level of quality because waste load reduction can be achieved more efficiently at some points than at others.

Therefore, standards and/or charges can be applied —uniformly or selectively—either continuously or only during periods of adverse environmental conditions, such as temperature inversions or low streamflows. The noncontinuous approach makes use of the widely varying assimilative capacity of the environment. Table 2 illustrates the various alternatives.

Table 2

**TYPES OF CONTROLS AND METHODS OF APPLICATION**

| Method of Application | TYPES OF CONTROLS | | | |
|---|---|---|---|---|
| | Input | Discharge | | Ambient |
| | Specifications | standards | effluent charges | Standards[a] |
| Uniform, continuous | X | X | X | X |
| Uniform, noncontinuous | X | X | X | X |
| Selective, continuous | X | X | X | X |
| Selective, noncontinuous | X | X | X | X |

[a]In relation to ambient standards, "selective" means that different quality standards may be applied to different sub-areas within a region; "noncontinuous" means that the quality standards may be varied by time of year. With respect to the latter, for example, the dissolved oxygen standard in a stream may be higher in the spring and fall during anadromous fish runs than during the rest of the year.

It should be emphasized that application of noncontinuous controls, standards or charges or both, is related to variation in the environment's assimilative capacity. Such variation is a function of hydrologic and atmospheric conditions, which are stochastic variables; i.e., they can be predicted only in terms of probability distributions. Thus, during periods when the assimilative capacity of the atmosphere or a water body is large, the same quantity of wastes discharged will have relatively less impact on quality than when the assimilative capacity is small.

Because some methods for reducing wastes prior to discharge and some methods for increasing assimilative capacity involve high operating costs but low capital costs, the most efficient waste management system may be one in which certain types of facilities are

operated only during relatively infrequent adverse periods. For example, higher levels of liquid waste reduction can be achieved by addition of chemicals to wastes during particularly severe low-flow periods. This will decrease the wastes discharged in accord with available assimilative capacity. During normal and high-flow periods, the addition of such chemicals is not necessary to achieve desired levels of water quality.

Recognition of time variation in assimilative capacity of the environment, whether diurnally, seasonally, or year to year, emphasizes the fact that any desired quality level cannot be achieved with 100 percent certainty, except under rare conditions or at very large cost. In general, the costs involved increase rapidly as 100 percent certainty is approached.

Levels of quality, including, for example, sulphur dioxide concentration in the atmosphere or dissolved oxygen concentration in a stream, are a function of three major factors: (1) hydrologic or atmospheric conditions, (2) demands on air or water, and (3) probability of breakdown of waste reduction or modification equipment. If a severe inversion condition were to occur during a period of peak power generation and, coincidentally, a major emission control device were to break down, regardless of what standards had been established, the desired level of quality would not likely be met. At the same time, the probability of the coincident occurrence of such events is very low. To provide 100 percent certainty would require the installation of significant quantities of equipment which would be used very infrequently. An important aspect of waste management is to determine what short-run losses occur during periods of deficient air and water quality. Little work has been done to date on such loss functions.

## Reducing wastes and modifying assimilative capacity

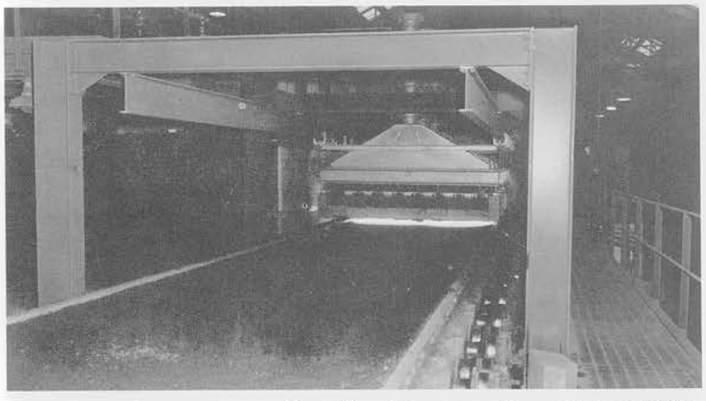
The quality of air, water, and land, when affected by the discharge of wastes, can be modified or improved in three ways: (1) by reducing the generation of wastes; (2) by reducing, in on-site and/or collective facilities, the quantity of wastes discharged after generation; and (3) by modifying the assimilative capacity of the environment or making better use of the existing assimilative capacity. Table 3 illustrates some of the various possibilities.

The quantity and type of wastes generated in the production process can be changed by modification of raw materials, modification of production processes, and change in product mix. This is true for all three forms of wastes. After the wastes are generated, their reduction before discharge can be accomplished, for example, by materials recovery and production of by-products, and/or by waste treatment. After discharge from the production unit, the remaining quantity can be further reduced by collective waste reduction measures. In the case of liquid wastes, the assimilative capacity of receiving waters can be improved by releasing stored water to increase dilution capacity of streams and estuaries and by artificial aeration. For both liquid and gaseous wastes, better use of existing assimilative capacity can be accomplished by redistributing the effluent. Methods include modifying the height of chimney stacks and changing the locations and/or types of liquid effluent discharge pipes.

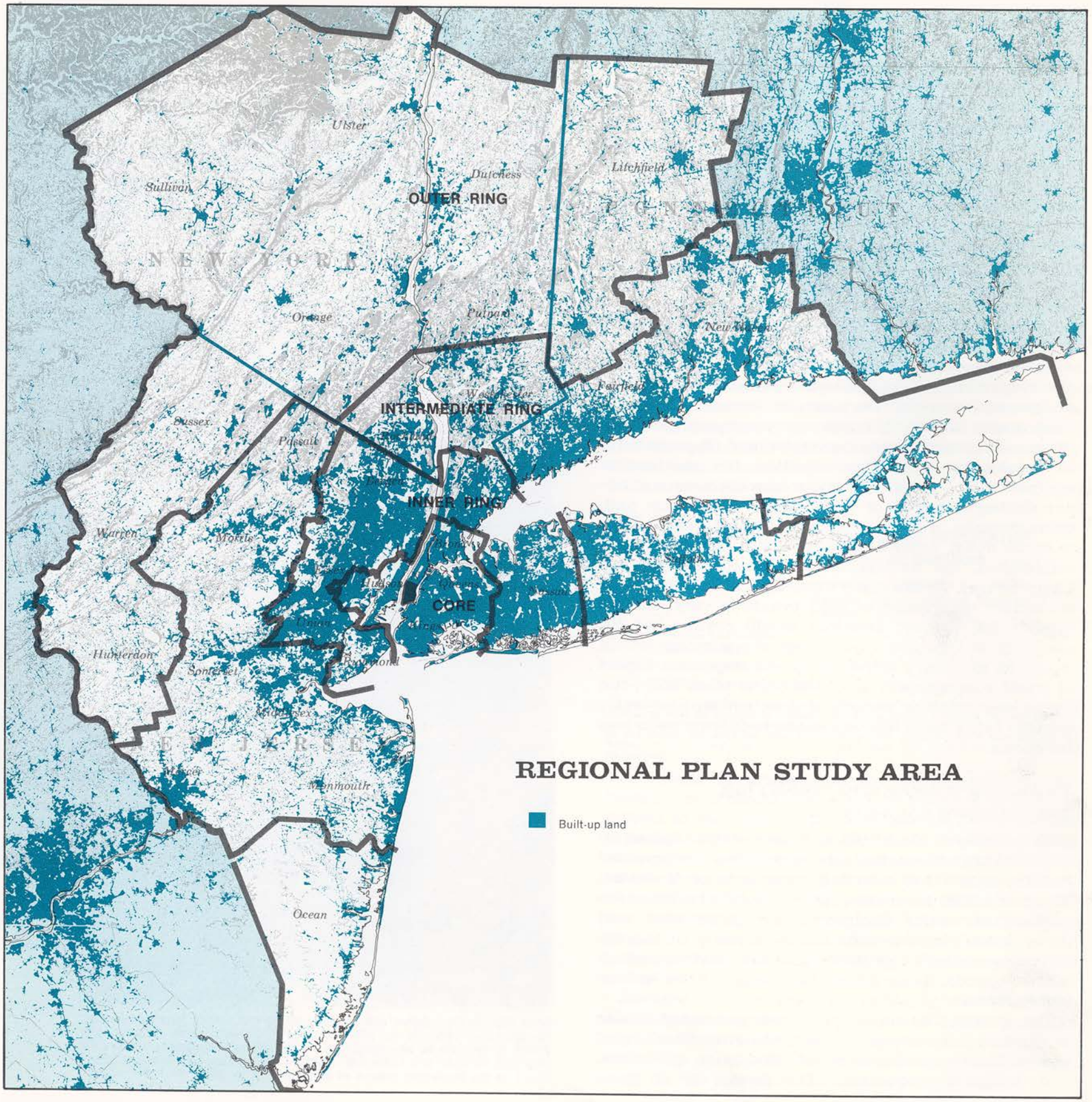
The particular methods for handling and disposing of the wastes chosen for analysis in this report are described in the latter portion of the next chapter.

Table 3
**METHODS FOR IMPROVING ENVIRONMENTAL QUALITY**

| | FORM OF WASTE | | |
|---|---|---|---|
| | Liquid | Gaseous | Solid |
| **Methods for reducing waste generation** | | | |
| Change in raw material inputs | X | X | X |
| Change in production process | X | X | X |
| Change in product outputs | X | X | X |
| **Methods for reducing wastes after generation** | | | |
| Materials recovery and salvage | X | X | X |
| By-product production | X | X | X |
| Treatment (i.e., incineration, sewage treatment) | X | X | X |
| **Methods for making better use of existing assimilative capacity** | | | |
| Effluent redistribution | X | X | X |
| Change in location of generation | X | X | X |



After generation, wastes can be reduced by recovering useful materials. Consolidated Edison's fly ash sintering plant in Astoria, Queens, produces a lightweight aggregate, used in building construction, from incinerator fly ash. If a sufficient market is developed for this product, it could be the least-cost means of disposing of fly ash.


Ulster
Sullivan
Dutchess
Litchfield
OUTER RING
Orange
Putnam
Fairfield
INTERMEDIATE RING
Sussex
Passaic
INNER RING
Warren
Morris
CORE
Union
Hunterdon
Somerset
Middlesex
Monmouth
Ocean
REGIONAL PLAN STUDY AREA
Built-up land

**Map I**

# 3. PROCEDURES FOR ANALYSIS OF WASTE MANAGEMENT

How can estimates be made of the magnitude and time pattern of generated wastes and residual wastes discharged, as well as the costs of waste management in a region? In this chapter we describe procedures and assumptions used in outlining an approach to the analysis of waste management in the New York Region. Further details on both procedures and assumptions, and the actual figures used, are included in the Appendix.

Consideration is first given to the basic economic data necessary. This is followed by discussions of (1) major sources of wastes in the Region and related factors; (2) bases for the estimates of quantities of wastes generated and discharged; (3) bases for estimating waste management costs; (4) problems of assessing the impact of waste discharges on environmental quality; and (5) some policy problems with respect to waste management and environmental quality.

## Basic projections

The basic economic data for this study consist of Regional Plan Association projections to the year 2000 for population and employment by two-digit Standard Industrial Classification (SIC) categories of the U.S. Bureau of the Census. These projections were made for sub-areas of the Region, either counties or portions of counties.[1] The year 2000 is specified only to provide a basis for the estimates, but the single year can be used in assessing the waste problem, realizing that first, the estimates may be reached in 2000 plus or minus 5 or 10 years and, second, that the assessment of the problem in the Region should be continuous (see Chapter 6).

Although it is likely that there would have been significant differences in the estimates of population, employment, and their distribution within the Study Area if other assumptions had been made about such phenomena or factors as birth rates, net migration, labor force participation, governmental policies, and technology, only one estimate was made for total population and employment in 2000. Given the population and employment for the Study Area as a whole, alternative spatial arrangements of population and economic activities within the Region are possible. In order to examine relationships between spatial arrangement and waste generation, waste management costs, and environmental quality, three distributions of population and employment, called variants, were devised with the help of the Regional Plan staff. The three variants consist of two relatively polar distributions—a more dispersed region and a more compact region—and one in between. The in-between pattern is designated Variant I, the dispersed pattern Variant II, and the compact pattern Variant III.[2]

Data on population and on employment by two-digit SIC categories provide only the starting points for developing estimates of wastes generated and discharged. Because generation of energy, for example, represents a major source of gaseous wastes, population data must be translated into energy demand, and this in turn into the types of generating facilities and the quantities of different types of fuel used to meet the energy demand. Since the internal combustion engine is a major source of gaseous wastes, the volume of vehicular travel is important, and estimates of population and employment by sub-area must be transformed into estimates of vehicle-miles traveled. Both of these transformations are complex and require lengthy and detailed investigation.

Employment by two-digit SIC categories is an inadequate basis for estimating wastes generated in industrial operations. First, not all industries in one two-digit SIC category are major waste producers. Second, relating wastes to employment as, for instance, pounds of BOD per employee, ignores problems relating to industrial productivity. Two plants in the same industry producing essentially the same product may generate significantly different amounts of wastes per employee, depending upon productivity. Third, data for some wastes, particularly gaseous wastes, are available only in relation to the physical product produced, per ton of castings or unit of raw material processed.

[1] Map 1 shows the 31 counties and rings of development for the Study Area.

[2] The variants are described in greater detail in the Appendix, Section 2, p. 86.

The procedure followed for liquid and gaseous wastes from major industries was to apply the National Planning Association's estimated changes in productivity to the RPA employment estimates. The NPA's estimates were checked against projected changes in productivity made by the Office of Business Economics of the U.S. Department of Commerce. Data on solid wastes generated by specific industries were not available. Therefore, to obtain a basis for estimating future quantities of solid wastes, available data on solid waste generation were divided into two categories, residential and business, and reduced to per capita and per employee generation.

Implicit in almost all estimates of economic variables and related production quantities is the generally logical assumption that the availability of water and the cost of measures to meet regulations concerning environmental quality are not sufficient to modify the estimates of future economic activity in the area. In only a few areas is such an assumption likely to be incorrect, and the New York Region is not one of them. Thus, the procedure was to translate the estimates of economic variables into, for example, quantities of fuel, vehicle-miles traveled by internal combustion engines, and tons of products produced.

## Major sources of wastes

Wastes are generated in essentially two types of situations. The first is in connection with economic activities, including households. The second is in connection with the handling of generated wastes. For example, households and industrial plants produce solid wastes. These may be collected and incinerated in municipal facilities, which in turn produce gaseous wastes and solid residue. Similarly, organic materials discharged from households, office buildings, and industrial activities may be treated in sewage treatment plants which themselves generate gaseous and solid wastes, in the form of sludge, which must be disposed of in some manner.

Some waste handling facilities, such as incinerators, yield a net reduction of wastes. That is, the total quantity of solid material discharged from an incinerator is less than the total input. The function of a waste handling facility is to transform one type of waste into other types, or into a modified form and/or quantity of the same type of waste, in order to achieve a material which can be disposed of more readily. Since these facilities end their process with wastes, they must be considered waste generators, though not in the same sense as a paper mill, power plant, or office building.

Table 4 shows the major waste generators in the New York Region. These do not necessarily represent the major causes of air, land, and water quality deterioration in the Region. In terms of proportion of total residual wastes discharged into the environment, some of these generators are relatively insignificant, in that their wastes cannot be "found" in the environment in relation to all other wastes discharged.

**Table 4**

**MAJOR WASTE GENERATORS IN THE NEW YORK REGION**

| WASTE GENERATOR | FORM OF WASTE | | |
|---|---|---|---|
| | Gaseous[a] | Liquid[b] | Solid[c] |
| **Individual** | | | |
| Power plants, fossil fuel | X | | X |
| Space heating: residential, commercial, industrial | X | | X |
| Residential (other than heating) | | X | X |
| Commercial (other than heating) | | X | X |
| Industrial processes | X | X | X |
| Transportation, internal combustion | X | | |
| On-site incineration | X | | X |
| **Collective** | | | |
| Incineration | X | X | X |
| Liquid waste treatment plants | X | X | X |

[a] $SO_2$, dust, and/or hydrocarbons
[b] BOD
[c] Mixed solid wastes

A major waste generator is defined as an activity which normally generates large quantities of wastes per unit of product, per unit of raw material processed, or per person. In a given area, at a given time, the quantity of one type of waste from all industrial operations in the area may be very small in relation to the quantity of the same waste from generation of electric energy, or in relation to the same waste from space heating. Further, the major generators of one type of waste are not necessarily major generators of other types of wastes. For example, steam electric plants using coal may contribute greatly to the $SO_2$ in the atmosphere but make little contribution to the hydrocarbon content. The internal combustion engine, on the other hand, is the primary generator of hydrocarbons but adds relatively little to the quantity of $SO_2$ in the atmosphere.

Two other wastes merit special mention, although the available evidence suggests that they are either not likely to become problems or will become lesser problems in the future. One of these is the abandoned or junked vehicle. Abandoned vehicles are stockpiled

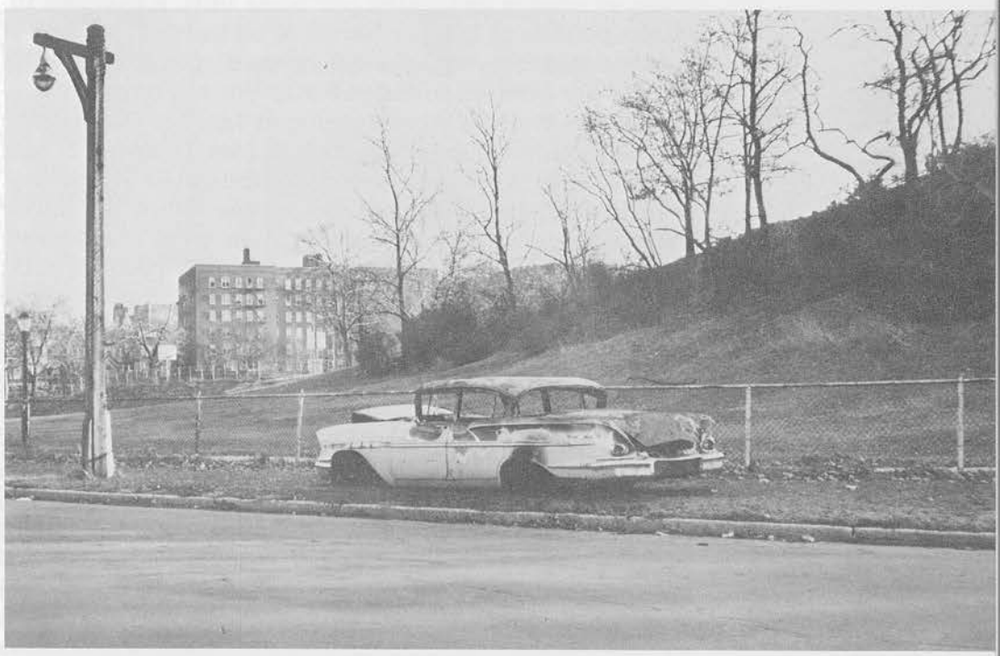
in numerous ugly wrecker yards, processor yards, and "graveyards." These may provide habitat for rodents and insects and in many instances occupy land which could be used for industrial, recreational, or residential purposes. A recent nationwide Bureau of Mines study revealed that only 3 percent of abandoned automobiles were found in "graveyards."[3] The remaining 97 percent were distributed in the areas studied as follows: 73 percent in wreckers' yards, 18 percent on public and private property, and 6 percent in scrap processors' yards. The abandoned vehicle problem has grown rapidly for many reasons, of which over 80 are listed in the Bureau of Mines report.

However, at this time in the New York Region, abandoned vehicles are considered a source of scrap metal to be reclaimed and reused rather than as an item of solid waste to be disposed of. Recent developments in the processing of vehicles, particularly the scrap shredding plant, appear to improve significantly the quality of scrap obtainable, thereby increasing the demand for this "product" and reducing the actual stockpile of abandoned vehicles. It seems likely that the trend toward increased recycling will continue in the future, particularly in metropolitan areas which comprise concentrated sources of abandoned vehicles as well as markets for the output of the reclamation process. If the market is inadequate to achieve the level of recycling which would preclude the abandoned vehicle becoming a solid waste problem, then incentives, such as an automobile disposal tax, could be used to stimulate "clearing the market." This study does not consider the abandoned vehicle as a solid waste, and the quantities and disposal practices considered herein do not include such vehicles.

Radioactive wastes also merit consideration. All projections of the role of nuclear power in the generation of energy in the future foresee a vastly expanded, and eventually predominant, role for nuclear power. In making such projections, the basic assumption has been that the technology will be such that there will be no limit to the location of nuclear plants within or near major metropolitan areas. For the present study, it was assumed that nuclear plants will be located in the metropolitan area. This is not meant to imply that there are no further questions concerning such location, but that this is the most reasonable assumption that can be made at the present time. In the course of the next decade or so, the evidence will begin to ac-

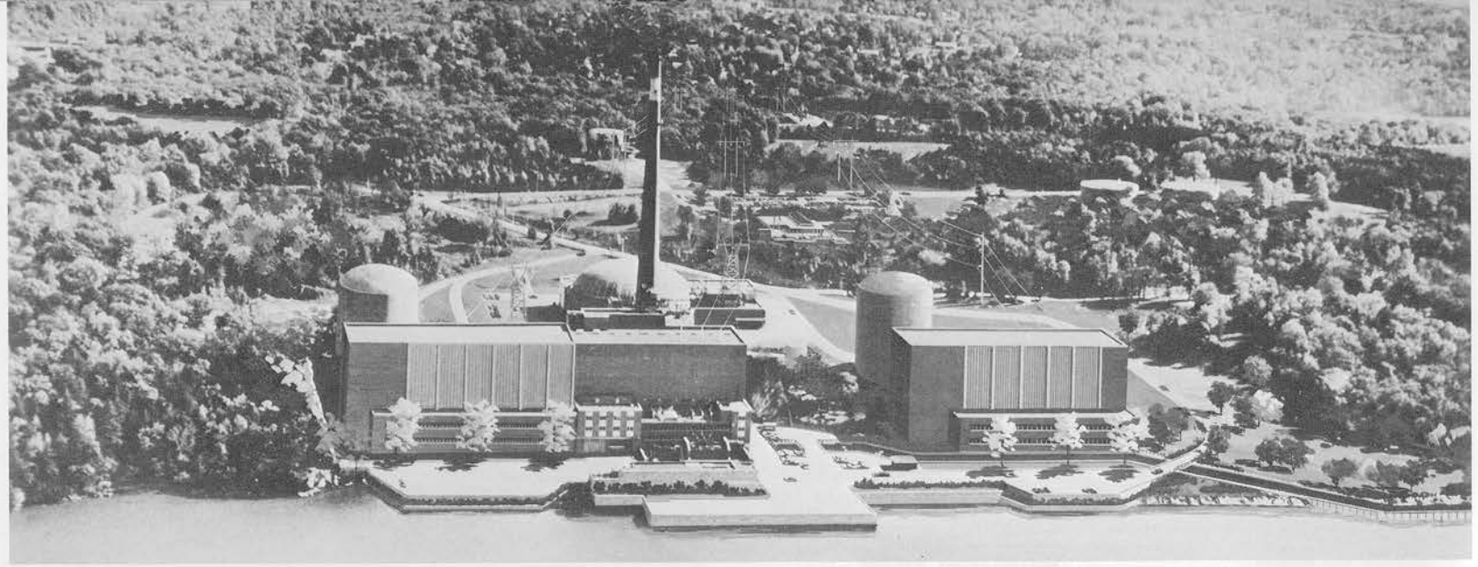


Vehicles are abandoned at a rapid rate throughout the Region, but new methods are encouraging greater salvage. Nevertheless, they often are piled in ugly yards and sometimes are burned to eliminate nonmetal parts—changing some of the wastes from solid to gaseous.



About 25,000 vehicles presently are abandoned on New York City streets each year, like this one on the Shore Parkway, Brooklyn, adjacent to Owls Head Park. However, private salvage contracts may substantially reduce the city's removal cost, perhaps even producing a profit to the city.

[3] U.S. Department of the Interior, Bureau of Mines, **Automobile Disposal: A National Problem** (Washington: GPO, 1967).



By the year 2000, nuclear power is expected to be the predominant source of electric energy in the Region. This does not produce gaseous wastes, though possible problems of disposing of radioactive wastes have not been entirely explored. This artist's rendering on a photograph shows Consolidated Edison's nuclear power complex at Indian Point, Buchanan, New York, as it will look in 1971. Indian Point No. 1 is in the center (with stack), Indian Point No. 2 (under construction) is on the left, and the proposed Indian Point No. 3 is on the right.

cumulate which will result in either acceptance or modification of this assumption.

## Estimating wastes generated and discharged

After transforming the population and employment data into physical quantities where necessary, the next step was to develop "waste coefficients," i.e., the quantities of wastes generated per some unit. Examples include: pounds of $SO_2$ per barrel of oil burned, pounds of particulates per ton of coal burned, pounds of solid wastes per person, pounds of BOD per ton of paper produced. Coefficients were developed only for the specific wastes selected for consideration (see Chapter 2) and for the major waste generators, as indicated previously.

In developing the coefficients, the following major factors influencing waste generation were considered: (1) technology of production process; (2) product mix; (3) type of raw material inputs; and (4) controls on waste discharges, whether direct or indirect. To illustrate, in the production of pulp there has been a major shift from the sulphite to the sulphate process of production in the last two decades, with a consequent reduction in BOD wastes generated per ton, all other factors remaining the same. On the other hand, there has been a significant increase in the last five to ten years in the production of colored paper products and in the use of various paper coatings and sizings. These tend to increase the BOD load per ton. Depending on the nature and stringency of controls on discharges, there is greater or lesser stimulus to adopt production processes which minimize or reduce the wastes generated per unit.

The waste generation coefficients used for the major categories of waste generators and for specific four-digit SIC industries are listed and their development described in detail in the Appendix (see Section 3). The coefficients are based on available data, knowledge of trends in various industries, and judgment about alternative possibilities. The accuracy of the coefficients varies widely, both for a given waste from generator to generator and among the various wastes. For some wastes, existing data are based on extensive sampling under a wide range of conditions; for others, especially gaseous and solid wastes, basic data are very sparse.

The quantities of wastes discharged reflect waste generation and on-site and collective waste reduction activities. Waste reduction coefficients used in this study are based on foreseeable technology of waste treatment and on alternative assumptions about levels of waste load reduction to be achieved in on-site and/or collective facilities. They are applied to generated wastes. For example, good incinerator practice should result in waste generation of about 50 pounds of particulate matter per ton of solid waste input. This is the waste generation coefficient. After the waste stream passes through a well-operated wet scrubber system, the final gaseous waste discharge for good incineration will be about 10 pounds of particulates per ton of solid waste input, or a reduction of 40 pounds (80 percent) by the scrubber system. The 80 percent is the waste reduction coefficient for this treatment process.

For some production processes, it is impossible to separate the production process equipment from the waste reduction process or emission control equipment. This is true, for example, of a dust collector on an open hearth furnace. The collector is designed as an integral part of the installed plant. This is in contrast to a stabilization lagoon used to treat wastes from a cannery; the lagoon is not an integral part of the production process. The distinction has important policy implications, as will be indicated later in this chapter.

## Estimating waste management costs

The costs of waste management include such items as annual charges on the investment in on-site and collective waste reduction facilities, operation and maintenance (O&M) costs for these facilities, cost of land for landfill, effluent charges paid, capital and O&M costs of quality monitoring networks (air and water), and costs of performance checking. The capital and O&M cost of facilities for improving the assimilative capacity of water bodies, which make possible a higher level of final waste discharge into the environment, should be included where utilized, but such facilities were not considered in this study. Costs of collecting and transporting wastes to facilities for further treatment and/or disposal are also relevant waste management costs. Although these collection-conveying costs represent a very substantial portion of total waste management costs, the amount of time available for the study precluded their consideration. Finally, no attempt was made to estimate the costs of waste reduction by in-plant process changes. That such changes are often the least-cost way of reducing wastes discharged to the environment has been clearly demonstrated.[4] Again, this fact has important implications for waste management policies.

Two points with respect to waste collection costs should be noted. First, the level of reduction in wastes discharged can vary widely with the same collection system. Thus, a municipal treatment plant can be built to provide primary or secondary treatment to the same incoming waste load. A municipal incinerator can be designed and operated to discharge five pounds of particulate matter per ton of solid wastes incinerated or 30 pounds per ton with the same input.

Second, the geographic arrangement of economic activities in an area has an impact on waste collection costs. For example, costs of solid waste collection are a function of "solid waste density," that is, the quantity of solid wastes generated per acre. This is illustrated in Chart 11. The point of inflection on the curve is dependent on traffic congestion in the area and actual transport distances involved.

Waste management costs are directly dependent on the assumptions made with respect to methods for handling and disposing of wastes, degree of recycling of generated wastes, and the technology of waste handling, reduction, and disposal, both on-site and collective. Of the various sets of assumptions about policies, technology, etc. that could be made for the year 2000, a number were selected and analyzed. Some of these are discussed in the following two chapters; details on both assumptions and bases for the cost estimates are in the Appendix.

Whatever the assumptions, the procedure requires determining functional relationships between capacity of facilities—incinerator, electrostatic precipitator, trickling filter—and the costs (capital and O&M) of the facilities, and between costs and degree of waste removal. Examples are shown in Charts 12, 13, and 14. Charts 12 and 13 illustrate a very important aspect of waste management, namely, the existence of scale economies. The cost of municipal incineration varies from $4.00 to $7.00 per ton incinerated,[5] depending on discharge standards. The lower unit cost is for larger plants. Operating cost of sanitary landfill varies from $0.75 to $2.50 per ton, depending on the scale of the operation.

Chart 11
DENSITY OF SOLID WASTE GENERATION VS. COLLECTION COSTS

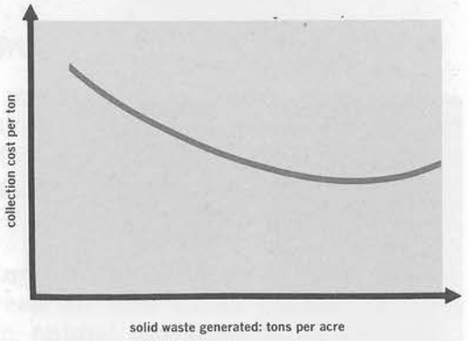



Chart 12
INCINERATOR CAPACITY VS. CAPITAL COSTS

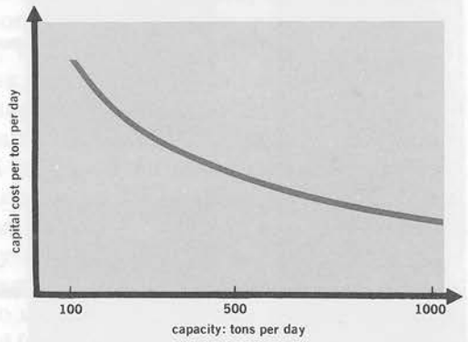



Chart 13
ACTIVATED SLUDGE TREATMENT PLANTS: DEGREE OF BOD REMOVAL VS. COSTS

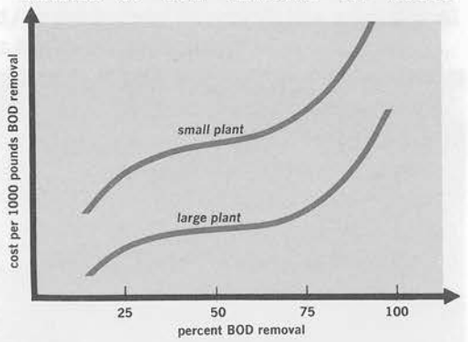
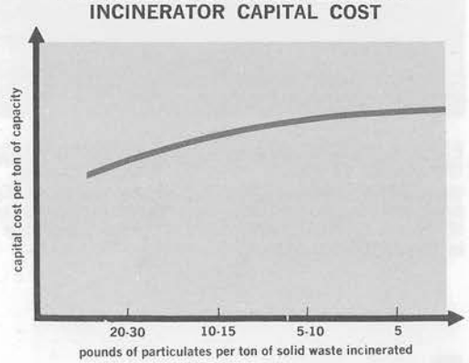



Chart 14
PARTICULATE EMISSION LEVEL VS. INCINERATOR CAPITAL COST

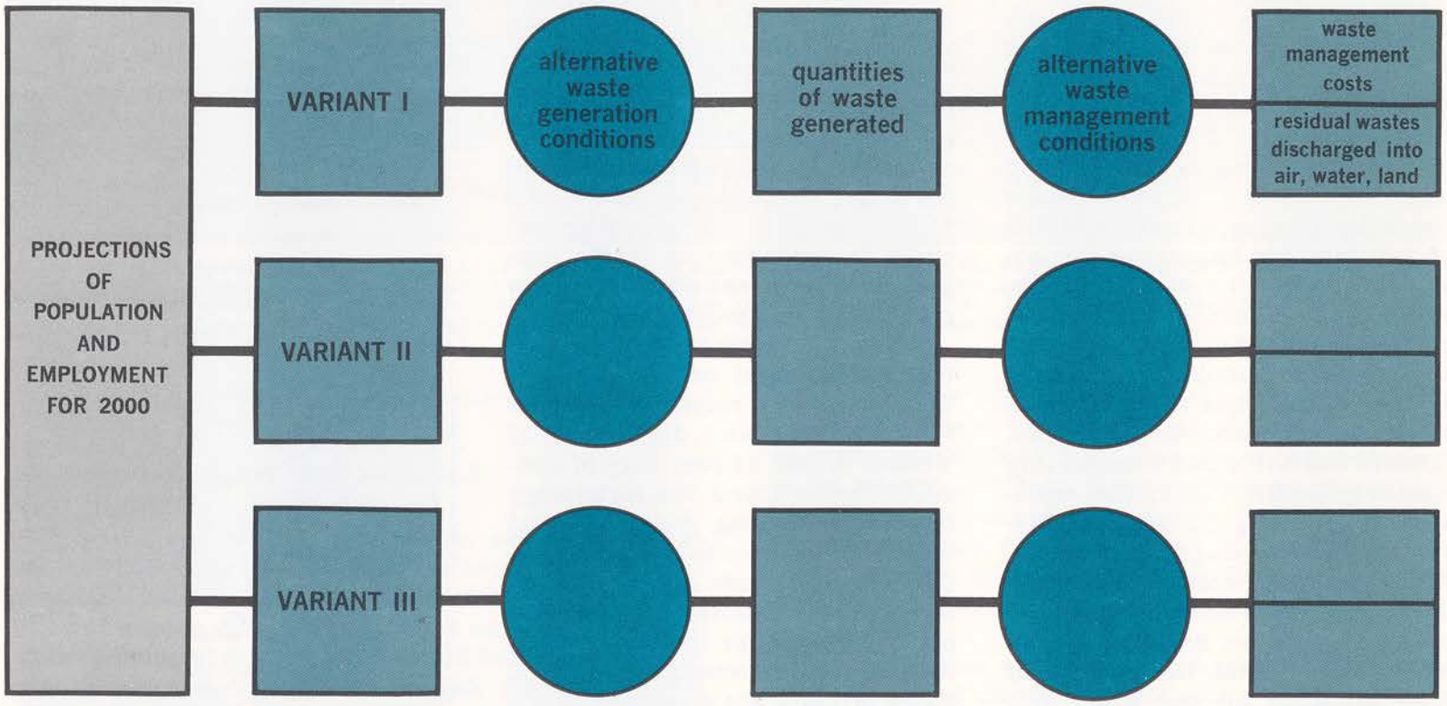


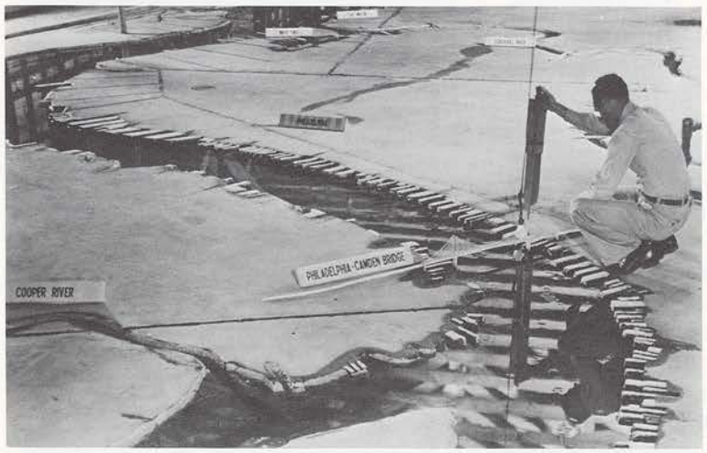

[4]See G. O. G. Löf and A. V. Kneese, **The Economics of Water Utilization in the Sugar Beet Industry** (Washington: Resources for the Future, in press).

[5]Annual charge on capital investment plus O&M costs.

Chart 15

**PROCEDURE FOR WASTE MANAGEMENT ANALYSIS**




Physical as well as mathematical models are useful in understanding the impact of wastes on environmental quality. This model of the Delaware River Basin, at the U.S. Army Corps of Engineers' Waterways Experiment Station, Vicksburg, Mississippi, has been used in developing solutions to waste disposal and other problems related to water quality in the Delaware Estuary.

Other relationships are important. For instance, the "quality" of a landfill, which depends on drainage, covering procedures, and insect and rodent control, has an impact on environmental quality. These relationships and others—between quantity of wastes discharged and resulting quality, and between quality and damages—are essential to studies of waste management and environmental quality. A simplified diagram of the analysis described in this chapter is shown in Chart 15.

## Assessing the impact of waste discharges

As noted previously, the ideal measure of the impact of specified time patterns of discharges of a particular waste is the resulting time pattern of concentrations at various points in the area of concern. This requires the development of mathematical models which interrelate the variables. An example is a gaseous diffusion model involving: distribution of wind speed and tem-

perature by elevation; degradation pattern of the waste in the atmosphere, if any; and the location, magnitude, and time pattern of gaseous waste discharges.[6] Similar models are required for various water bodies in the Region. The model developed for the Delaware Estuary represents the type needed[7]. In the New York Region, such models and the sampling networks necessary for their development are nonexistent for most water bodies or are in an early stage of development.

The development of such models is time-consuming, difficult, and expensive. Thus, the critical sub-areas of the Region, in terms of air and water quality, and the critical wastes in terms of actual damages, should be identified and models developed only for them. If, for example, the discharge of fluoride gas is likely to remain at a level such that impact on concentration of fluoride in the area is not measurably affected, and hence the damages are insignificant, it does not make sense to allocate scarce manpower to the development of a diffusion model for fluorides.

Lacking such models for the New York Region, several alternative indirect ways of illustrating the impact of waste discharges on the environment were used in this study. First, the quantities of residual wastes discharged to the environment were computed for the year 2000 and contrasted with the gross quantities discharged at present. This was done for both the Study Area as a whole and for sub-areas. Second, the concentration of hydrocarbons and $SO_2$ in peak periods of waste generation were estimated. Finally, the residual gaseous wastes discharged per acre were compared to residual discharges per acre in Los Angeles for 1940 conditions, when no adverse effects on air quality apparently existed.

## Policy problems

What levels of air and water quality are "desirable" in a region? If all the consequences (damages) of different levels of air, water, and land quality, in the form of relationships as defined earlier in this chapter, and the relationships between costs and modification of quality by various methods, were known, then the optimal level of quality could be determined by comparing costs and benefits (benefits measured in terms of damages reduced). The optimal level is actually a time pattern of levels, for the reasons noted in previous discussion.

At the present time we do not know all the physical relationships between air and water quality and the responses of human, animal, and plant life, nor has the difficulty of relating physical responses to dollar damages been resolved.[8] As a result, policy decisions must be based on economics and known physical effects. The known effects, which can be described in qualitative, physical terms, are such things as degree of eye irritation from smog, number of shad surviving upstream migration, and appearance of landfill areas. The economic criterion is based on costs defined in terms of the resources necessary to achieve different levels of quality. This was done in the study of the Delaware Estuary, previously referred to. Thus, what can be established is the magnitude of additional resources society would have to allocate to achieve each additional level of quality and/or the additional resources necessary to achieve a higher degree of certainty of any specified level of quality. Whether the additional increment of quality and/or certainty is worth the additional increment in cost is a political decision.

It is important to emphasize that the cost of achieving a specified quality can vary widely depending on the alternative methods of waste handling and reduction adopted.[9] These in turn depend on policy decisions, primarily by governmental agencies. For example, all incineration could be prohibited in the New York Region, or only in the Core and Inner Ring. This decision would significantly affect disposal space needs and waste management costs (see Chapter 5).

The effluent control policies adopted by the relevant governmental agencies are part of the waste management system and hence influence waste management costs. Much of the current discussion of air and water "pollution" problems is oriented toward "end of the pipe" methods for reducing waste discharges—waste

[6]For a discussion of some of the problems inherent in developing physical models of diffusion phenomena, see T. L. Montgomery and M. Corn, "Adherence of Sulfur Dioxide Concentrations in the Vicinity of a Steam Plant to Plume Dispersion Models," **Journal of the Air Pollution Control Association,** XVII, No. 8 (1967), pp. 512-517.

[7]U.S. Department of the Interior, Water Pollution Control Administration, **Delaware Estuary Comprehensive Study** (Philadelphia, 1966).

[8]For a discussion of some of the evaluation problems, see the articles by Allen V. Kneese and Ronald G. Ridker in **The Economics of Air Pollution,** ed. Harold Wolozin (New York: W. W. Norton, 1966).

[9]This is well illustrated in a case study of the Potomac Estuary. See R. K. Davis, "Planning a Water Quality Management System: The Case of the Potomac Estuary," in Kneese and Smith (eds.), **Water Resources Research,** (Baltimore: Johns Hopkins Press, 1966).

treatment or emission control facilities. Controls on the quality of fuel are an exception. Little or no consideration has been, or is being, given to means for influencing the generation of wastes. Grants for construction and operation, tax incentives of various types, and depreciation allowances are all oriented to waste treatment. This approach to air, water, and land quality management is not likely to be the most efficient for society. As has been demonstrated for both liquid and gaseous wastes, in numerous instances modification of production processes is a far less expensive way of reducing residual wastes discharged to the environment than is treatment. Policies which stimulate consideration of such modifications are essential components of an efficient waste management system. Just as the concern with the impact of detergents on water quality stimulated research and product development which eventually resulted in a change in the product, so consideration of the external costs imposed on society by the use of nonreturnable bottles and nondegradable containers could lead to a change in product and process which would decrease overall costs.

Even where controls on discharges are effected through regulation of raw material, such as type of fuel, the net effect on resource use may be positive; that is, fewer resources may be required than under previous conditions. For example, it is possible that the net cost of energy generation in fossil fuel plants with low sulphur fuels may be less than with high sulphur fuels, if the increased fuel costs are more than offset by lower O&M costs stemming from reduced corrosion. At the least, the net increase will be less than if there were no savings from reduced corrosion. Thus, in determining possible least-cost waste management systems from society's point of view, the effects on production processes and the possible responses which can be stimulated by effluent charges, standards, and other incentives must be taken into consideration.

Up to this point we have described the nature of environmental quality problems; the generation of wastes in society; what is meant by the assimilative capacity of air, water, and land; the interrelationships between location of economic activities and waste generation and management; and the interrelationships among the different forms of wastes. We have also indicated the specific wastes to be considered in this analysis of waste management and the procedures to be used. We now turn to these analyses, present our findings, and interpret their implications.

# 4. WASTE GENERATION: PRESENT AND FUTURE

This chapter includes estimates of the quantities of various wastes generated in the present—defined as conditions in 1964—and in the future, under various sets of assumptions concerning waste generation. Since the quantities of residual wastes discharged into the environment are a function of the methods of handling wastes after generation, both on-site and in collective facilities, estimates of residual wastes discharged are presented in the next chapter.

Details concerning the bases used to develop the waste generation coefficients for the present and future under alternative assumptions are given in the Appendix. However, some general comments on the coefficients and the background data are relevant at this point. There are few data available on various types of solid wastes expressed as units generated per capita, per office employee, or per amount of product. Other complications with respect to solid wastes stem from variations in the rate of building demolition and generation of agricultural wastes within a region. The best source of information on solid wastes in the New York Region is the New York City Department of Sanitation. Unit generation coefficients for the present were developed on the basis of data from that and other sources and were modified as described below for the year 2000.

The primary sources of data for unit generation coefficients for gaseous wastes are the studies of the Los Angeles County Air Pollution Control District and the U.S. Public Health Service.[1] These data were supplemented by unpublished material.

Certain generators of gaseous wastes, such as aircraft flying and chemical process industries other than petroleum refining, have been excluded from this study because they generate a relatively small proportion of the total gaseous wastes in the Study Area.[2] Wastes generated from the use of fuels have been divided between power generation and other uses, such as fuel for heating residences, commercial, and industrial buildings, and fuel used in industrial processes.

The term "particulates" is used interchangeably in this report with the term "dust," referring to settleable solid particles. These terms include smoke and fly ash from combustion, metal fume from all metal processors, and dust produced by grinding, milling, and processing of earthen materials. As will be evident, the contribution from all industrial sources is very small in relation to the total quantity of dust generated in the Region.

"Hydrocarbons," as used herein, are related to gasoline. The manufacture, storage, and marketing of gasoline result in generation of hydrocarbon compounds which may be discharged to the atmosphere through evaporation. Incomplete combustion of gasoline in internal combustion engines generates the rest of this type of waste.

Oxides of nitrogen ($NO_x$) were not included in the estimates of gaseous wastes. Generation of this gaseous waste stems about equally from industrial operations and the use of internal combustion engines. The quantity generated is roughly proportionate to the magnitude of hydrocarbons.

Unit generation coefficients for liquid wastes were derived from a variety of sources. The work at, and sponsored by, Resources for the Future was particularly helpful. The data on liquid waste coefficients, while leaving much to be desired, are on the whole much better than the data on solid and gaseous waste coefficients.

## Present waste generation

The basic economic data for estimating waste generation in the present are shown in Tables 5, 6, and 7, which include population and employment, vehicle-miles traveled, and fossil fuel use. Based on these data and the coefficients given in the Appendix (see Section 3), estimates of wastes generated in the present are shown in Table 8. Because of treatment or other waste reduction methods, the quantities generated are not

[1] G. Ozolins and R. Smith, **A Rapid Survey Technique for Estimating Community Air Pollution Emissions** (Public Health Service Publication No. 999-AP-29; Washington: GPO, 1966).

[2] It should be emphasized that a type of activity which may not be a major waste generator and discharger from the "macro" view, i.e., the Study Area as a whole, may be a major contributor to quality deterioration from the "micro" view, i.e., in a local area. Statements in this report concerning the relative unimportance of certain waste generators and waste discharges should not be taken to mean that such activities result in no problems. Assessing impacts on the micro level requires the existence of the types of physical models mentioned in the previous chapters.

Table 5

**POPULATION AND EMPLOYMENT BY RING, 1964**

all values in millions

| Ring | Population | Office Employment | Total Employment |
|---|---|---|---|
| Manhattan CBD | 0.51 | 0.80 | 2.10 |
| Rest of Core | 8.25 | 0.34 | 2.38 |
| Inner Ring | 4.65 | 0.17 | 1.47 |
| Intermediate Ring | 4.28 | 0.16 | 1.28 |
| Outer Ring | 1.29 | 0.05 | 0.38 |
| **Total** | **18.97** | **1.52** | **7.61** |

Table 6

**VEHICLE-MILES PER BUSINESS DAY BY RING, 1964 AND PROJECTED FOR VARIANTS I, II, AND III IN 2000**

all values in millions

| Ring | Present | Variant I | Variant II | Variant III |
|---|---|---|---|---|
| Manhattan CBD | 1.6 | 3 | 3 | 3 |
| Rest of Core | 37.9 | 44 | 36 | 50 |
| Inner Ring | 46.6 | 70 | 57 | 84 |
| Intermediate Ring | 57.3 | 110 | 136 | 82 |
| Outer Ring | 17.7 | 62 | 76 | 31 |
| **Total** | **161.1** | **289** | **308** | **250** |

Table 7

**ESTIMATED FOSSIL FUEL USE FOR ENERGY GENERATION IN THE STUDY AREA, 1964 and 2000**

| | 1964[a] | 2000[b] |
|---|---|---|
| Coal, million tons | 13 | 2 |
| Oil, million barrels | 26 | 50 |
| Gas, billion cubic feet | 101 | 300 |

[a]Based on actual data compiled in Federal Power Commission, **Steam Electric plant Construction Cost and Annual Production Expenses,** (Report S-171). Seventeenth Annual Supplement—1964 (Wash., D.C.: Federal Power Commission, 1966).
[b]Estimated

Table 8

**WASTE GENERATION IN THE STUDY AREA, 1964**

| Waste | million tons |
|---|---|
| Solid Wastes | 17.4 |
| BOD | 0.72 |
| $SO_2$ | 2.00 |
| Dust | 0.48 |
| Hydrocarbons | 1.47 |

the same as the quantities discharged into the environment. These quantities of wastes generated relate to the Study Area as a whole. Details on generation by source and/or sub-area within the Region are presented in the Appendix.

## Future waste generation

Estimating future waste generation coefficients is difficult because of the many variables which influence the coefficients.[3] There is a large range of uncertainty attached to any coefficient estimated for a time almost 35 years in the future. Some of the considerations involved are illustrated by the following discussion of solid wastes.

The most significant factors affecting the magnitude and characteristics of generated solid wastes probably have been changes in packaging practices and in household heating fuels. Packaging changes have increased significantly the amount of paper and paper products, have decreased food wastes, and have introduced plastic as a small but potentially important component. Noncombustible solid wastes have increased significantly as a proportion of the total, as a result of the popularity of nonreturnable bottles and cans. On the other hand, the amount of household ashes has diminished and will probably continue to diminish to a point of virtual disappearance as a result of the increasing use of gas, oil, and, to a lesser extent, electric power for home heating.

A report by the National Academy of Sciences—National Research Council indicates that per capita generation of solid wastes grew from about 2.75 pounds per day in 1920 to about 4.5 pounds per day in 1965, and anticipates a future increase by some 2 percent annually.[4] Nationwide, gross solid waste production is believed to be increasing at about 4 percent per year. Records of the Department of Sanitation of New York City indicate that gross solid wastes from households in its service area have increased at an average rate of slightly over 2.5 percent per year since 1960. Other cities, including Philadelphia, Buffalo, Los Angeles, and Milwaukee, report that residential per capita solid waste generation has increased at an average of 2 percent per year in recent years.

[3]For a discussion of factors affecting industrial water utilization, see Blair T. Bower, "The Economics of Industrial Water Utilization," in Kneese and Smith (eds.), **Water Resources Research** (Baltimore: Johns Hopkins Press, 1966).

[4]National Academy of Sciences—National Research Council, **Waste Management and Control: A Report to the Federal Council for Science and Technology** (Publication 1400; Washington, 1966).




Coal trucks are now a rare sight in the Region, as coal is replaced by oil and gas for heating. Such changes in fuel type have important effects on the type and quantity of wastes generated and discharged.

Paper is the largest component of residential, commercial, and retail solid wastes. Studies at Purdue University in the early 1960's showed that average municipal solid wastes were 42 percent paper by weight. This percentage has increased since the time of the study and is currently estimated to be between 45 percent and 55 percent. In recent years, disposable paper clothing and disposable bed linens have been introduced. Future per capita paper consumption may be significantly increased by further development of disposable clothing, linens, and other items. Estimates of paper and paperboard use in 1963 and 1980 are shown in Table 9.

Table 9

**PAPER AND PAPERBOARD CONSUMPTION IN THE U.S., 1963 and 1980**

| | 1963 | 1980[a] |
|---|---|---|
| Total United States consumption, tons | 43 | 76 |
| Consumption, lb/capita/year | 460 | 640 |
| Waste paper reused, lb/capita/year | 96 | 130 |
| Paper in buildings and to storage, lb/capita/year | 54 | 75 |
| Balance to disposal, lb/capita/year | 310 | 435 |
| Increase in quantity for disposal per capita 1963-1980 | 40 percent | |

[a]Estimated

Disposable containers for liquids and foods have virtually eliminated the returnable, reusable bottle. Perhaps the first major shift was from milk bottles to coated paper cartons. The steel, aluminum, glass, paper, and plastics industries are all currently competing for the disposable container market. The "mix" of container types which develops will affect the quantity and characteristics of solid wastes and the problems of their disposal. For example, aluminum and plastics are lighter in weight than the other materials and are virtually nondegradable. Aluminum may be incinerated at high temperatures, but this results in gaseous wastes which could lower air quality. Plastics generally have very high heat values and may cause gaseous waste problems if they are incinerated. Glass is heavy, will melt but seldom burn at normal incineration temperatures, and is nondegradable in landfills. A paper container may be plastic-lined and/or have various kinds of coatings and sizings; these affect its biodegradability and increase its heat value if incinerated.

These are examples of potential changes in solid waste quantities and characteristics which may result from developments that can be foreseen or that are

currently known and underway. But new developments are likely to take place by the year 2000. These may profoundly affect solid waste generation coefficients. The development of containers which can be used by the consumer would have such an effect. The classic example of this is the ice cream cone. Physical changes in the structure of urban communities could result in purchasing and delivery systems which would reduce packaging needs.

Many sets of assumptions could be made about the factors which will affect solid waste generation in the future; each set would result in a generation coefficient representing both quantity and characteristics per unit. Obviously, all possible sets could not be analyzed. Since the main objective of this study is to develop a procedure, and since this objective can be achieved without analyzing all possibilities, only two coefficients of "mixed" solid waste generation were selected for analysis. These represent two possible, but significantly different, "waste generation conditions."

Generation Condition X assumes that the present trend of increase in solid waste generation per capita will continue, so that by the year 2000 per capita generation will have increased by 100 percent. In contrast, Generation Condition Y assumes that policies, regulations, and/or incentives will be established so that the per capita generation of solid wastes in the year 2000 will be the same as at present.

Many factors affect unit generation of liquid and gaseous wastes. The major factors have been mentioned previously: technology of production, product mix, nature of raw materials, and controls on waste discharges (applied to the discharge or to the quality of the receiving body). Two types of generation conditions were also posited for both liquid and gaseous wastes. Generation Condition X assumes that waste generation coefficients in 2000 will be affected primarily by the foreseeable changes in production technology, such as the shift from fossil fuel to nuclear power, and the shift to use of the basic oxygen furnace in the production of steel; and changes in product mix, such as the increasing proportion of colored and coated paper products. It is assumed that no external stimuli, such as effluent charges, will be imposed to induce production process changes that would reduce wastes generated.[5] Generation Condition Y assumes that there will be external stimuli to induce shifts to currently known processes that generate less wastes, adoption of better "housekeeping" practices within industry, and use of "best" available practices for reducing waste generation, and that new production processes will evolve that will generate fewer wastes per unit of product output or per unit of raw material processed.

Assumptions comprising the two waste generation conditions are summarized in relation to the various waste generators in Table 10.

Table 10

**WASTE GENERATION CONDITIONS, 2000**

| TYPE OF WASTE AND SOURCE | GENERATION CONDITION X | GENERATION CONDITION Y |
|---|---|---|
| Mixed solid wastes | 100 percent increase in per capita generation | Present per capita generation |
| Internal combustion vehicles | Present pattern of vehicle utilization, types of vehicles, average vehicle-miles per gallon of gasoline, wastes generation per gallon | Same as for Condition X |
| Energy generation | Generation "mix" and fuel use shown in Table 7 | Same as for Condition X |
| Gaseous wastes, heavy industry (except from space heating) | Present per unit quantities in absence of more stringent external stimuli than exist at present, considering changes in production technology and product mix which are likely to occur | Per unit quantities reflecting best practices under imposition of external stimuli, changes in product mix, and positive changes in production technology |
| Liquid wastes, heavy industry | Per unit generation without external stimuli, i.e., in response to changing production technology and product mix | Per unit generation reflecting best practices under external stimuli, positive changes in production technology |
| Liquid wastes, residential | Small increase in per capita BOD generation reflecting increased affluence, larger increase in volume generated reflecting present practices relating to water intake (See Management Condition 1, Liquid wastes [Lr], Table 14) | Small increase in per capita BOD generation reflecting increased affluence, no increase in volume generated reflecting changes in practices relating to water intake (See Management Condition 2, Liquid wastes [Lr], Table 14) |
| Space heating, residential | Decrease in oil use by ⅓ by shift to gas and electric heating, increase in efficiency of heating | Same as for Condition X |
| Space heating, commercial and industrial | No change in use of oil | Same as for Condition X |

[5]The importance of this assumption is clarified in the next section of this chapter.

## Impact of effluent charges and water intake prices

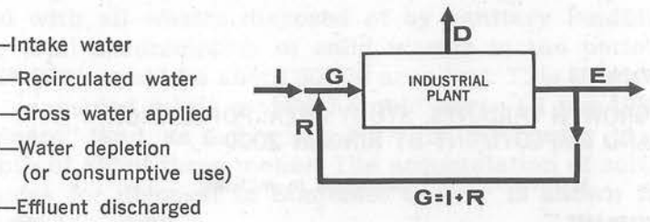
As already noted, effluent charges comprise one potential component of a waste management system. Further discussion of effluent charges and related water intake charges is therefore necessary.[6]

An important question in water quality management is whether institutional mechanisms can be found to reduce wastes discharged to streams, estuaries, lakes, groundwater basins, and oceans. Effluent charges may be such a mechanism.[7] An effluent charge is imposed on anyone discharging wastes to a water body; the amount of the charge depends upon the amount of wastes discharged. As an illustration, manufacturers might be charged $1.00 for each 5,000 pounds of BOD discharged to water bodies. Such charges would encourage those discharging wastes to seek ways of discharging fewer wastes in order to lower the monthly charge imposed upon them.

This might be done in several ways.[8] The production process and/or raw materials might be altered in order to generate fewer wastes and thus lower the effluent charge. There might be materials recovery and/or production of by-products; that is, there might be attempts to recover wastes for recycling within the production process or for production of by-products. Finally, there could be additional waste treatment.

As an example of reducing residual discharges, consider a petroleum refinery. We have estimated that about 100 pounds of BOD are generated per 1,000 barrels of crude oil processed at present; in a large plant processing 200,000 barrels of crude oil per day, about 20,000 pounds of BOD would be generated per day. This is a rather large waste load if discharged without any reduction. However, if the firm installed a secondary treatment plant which would remove, say, 90 percent of the BOD, only 2,000 rather than 20,000 pounds of BOD would be discharged. But secondary treatment plants are costly and the firm would probably need some incentive to install such a plant; this incentive would be given to the firm by placing a fee on its waste discharge. Of course, rather than installing a treatment plant, the firm might choose to reduce its discharge by materials recovery, by-product production, or alteration of the production process. The firm would continue to make changes until the costs of modifications become greater than the reduction in charges.

Another question often raised is whether water intake can be decreased. Before discussing this question, terms relating to industrial water use need to be defined, as illustrated by the following diagram:




Intake water (I) is the actual amount obtained from sources external to the plant. (G) is the gross water applied, i.e., the total quantity of water necessary to produce a unit of product or process a unit of raw material. It is obtained from a combination of intake water and recirculated water (R). An example of (R) is water used for cooling which is then conveyed through a cooling tower and reused. Part of the water used will be "lost" through evaporation or incorporation into products. This is water depletion (U). The quantity finally discharged is the effluent (E), which is the difference between intake water (I) and water depletion (U).

There are a number of possibilities for decreasing water intake. It can be achieved through greater recirculation of water. The degree of recirculation, expressed as a ratio of recirculated water to gross water applied (R/G), can approach 98 percent, which represents almost complete recirculation of water. In the U.S. in 1964, R/G in petroleum refining was less than 80 percent, in paper mills less than 70 percent, and in food processing less than 40 percent.[9] Thus, significant potential exists for reducing water intake by increasing recirculation.

Whether the practice of recirculating water will increase is an economic question. Equipment for recirculation requires a capital outlay followed by operating expenses. Firms are unwilling to undertake such outlays unless there is an economic reason to do so. If intake water is costly, firms may find it cheaper to install recirculation systems. Higher water charges will

[6]The material in this section was prepared by Mr. Gilbert W. Bonem of the Department of Economics, The University of New Mexico. Mr. Bonem also helped in the development of the liquid waste coefficients.

[7]See Allen V. Kneese, **The Economics of Regional Water Quality Management** (Baltimore: Johns Hopkins Press, 1964).

[8]For a more complete discussion of the technology for reducing liquid waste discharges, see the forthcoming book by Allen V. Kneese and Blair T. Bower, **Managing Water Quality,** to be published by Resources for the Future.

[9]U. S. Department of Commerce, Bureau of the Census, **Water Use in Manufacturing** (Washington, D.C.: U.S. Government Printing Office, 1964).

generally result in more recirculation and reduce the amount of water withdrawn from water sources.

In summary, imposing higher effluent charges and water charges will give plants incentives to find ways to discharge less wastes and to reduce water intake, both of which will improve water quality.

Table 11

GROWTH VARIANTS, STUDY AREA: POPULATION AND EMPLOYMENT BY RING IN 2000

all values in millions

| VARIANT | RING | Population | Office Employment | Total Employment |
|---|---|---|---|---|
| I | MANHATTAN CBD | 0.5 | 1.30 | 2.40 |
| | REST OF CORE | 8.6 | 0.56 | 2.88 |
| | INNER RING | 7.3 | 0.45 | 2.65 |
| | INTERMEDIATE RING | 9.4 | 0.52 | 3.83 |
| | OUTER RING | 4.4 | 0.17 | 1.41 |
| | **TOTAL** | **30.2** | **3.00** | **13.17** |
| II | MANHATTAN CBD | 0.5 | 1.10 | 2.11 |
| | REST OF CORE | 7.0 | 0.52 | 2.56 |
| | INNER RING | 6.0 | 0.38 | 2.25 |
| | INTERMEDIATE RING | 11.5 | 0.75 | 4.53 |
| | OUTER RING | 5.2 | 0.25 | 1.72 |
| | **TOTAL** | **30.2** | **3.00** | **13.17** |
| III | MANHATTAN CBD | 0.7 | 1.50 | 2.72 |
| | REST OF CORE | 10.0 | 0.70 | 3.50 |
| | INNER RING | 11.0 | 0.50 | 3.54 |
| | INTERMEDIATE RING | 6.5 | 0.20 | 2.53 |
| | OUTER RING | 2.0 | 0.10 | 0.88 |
| | **TOTAL** | **30.2** | **3.00** | **13.17** |

Table 12

WASTE GENERATION IN THE STUDY AREA, 2000

Quantity generated in year—millions of tons

| | VARIANT I | | VARIANT II | | VARIANT III | |
|---|---|---|---|---|---|---|
| | GC/X[a] | GC/Y | GC/X | GC/Y | GC/X | GC/Y |
| Solid wastes[b] | 56.7 | 28.4 | 56.8 | 28.0 | 57.4 | 28.7 |
| BOD | 1.60 | 1.33 | 1.60 | 1.33 | 1.60 | 1.33 |
| $SO_2$ | 1.43 | 1.43 | 1.41 | 1.41 | 1.48 | 1.48 |
| Dust | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 |
| Hydro-carbons | 2.9 | 2.9 | 3.0 | 3.0 | 2.6 | 2.6 |

[a]GC = Generation Condition.
[b]Excludes wastes produced in handling, i.e., in incineration. See Table 15.

## Waste generation in the year 2000

Data on population and employment by Ring for the three variants are shown in Table 11. Basic data on vehicle-miles traveled and fossil fuel use for 2000 are in Tables 6 and 7. Based on these data, and the coefficients developed as described above, quantities of the various wastes generated in 2000 were estimated for Generation Conditions X and Y. These estimates are shown in Table 12. They are total quantities in tons generated (not discharged) in the single year for the entire Study Area.

## Impact of waste discharges on environmental quality

We have emphasized the current difficulty of estimating the impact of various waste discharges on air, water, and land quality in the Study Area. For example, little is now known about the time pattern of atmospheric concentrations of various wastes throughout the area. The concentrations of dust, sulphur dioxide, and hydrocarbons have been sampled at a limited number of stations in New York City and in northern New Jersey, and are currently being monitored at three stations in these areas. In addition, some data are being accumulated from rural areas of New York and New Jersey. Measurements of this type must be continued over a number of years to determine average concentrations, hourly variations, and peak concentrations during periods of adverse weather conditions before waste discharges can be related to quality. Thus, in terms of air quality, the tons of sulphur dioxide discharged from various locations in and around Manhattan, and the results of reducing or increasing these amounts, cannot at present be related to time patterns of concentrations of sulphur dioxide at various points in the area. Similar problems of relating liquid waste discharges to water quality exist.

Before proceeding to the analysis of various waste management alternatives, i.e., how these generated wastes might be handled after generation, which we present in the next chapter, it may be helpful to illustrate the significance of the estimated quantities of generated waste.

Some quantity of solid wastes is generated each year. Unlike liquid and gaseous wastes, solid wastes accumulate over time. The figures presented in Tables 8

and 12 show waste generation in two specific years—1964 and 2000. They do not show accumulation. The problem can be illustrated by consideration of solid waste accumulation (requiring disposal) in the period from 1965 to 2000 for the five boroughs of New York City for Variant I. For Generation Condition X, assuming no reclamation or salvage of the generated solid wastes, with about 28 percent and 12 percent of the generated wastes handled in municipal and on-site incineration respectively, and with the remainder of the generated wastes plus the incinerator residue going directly to landfill, the total volume of compacted solid wastes to be disposed of over that period would be about 500,000 acre-feet. If this volume were disposed of in Central Park, it would cover the total area of the park to a depth of about 600 feet (assuming vertical sides). The accumulation for the five boroughs is shown in Chart 16.

This is contrasted with Somerset County, New Jersey, one of the most rapidly growing counties in the Region. With the same Variant I assumptions about waste generation, reclamation, and salvage, as above, and with all wastes disposed of by sanitary landfill, the total accumulation of solid wastes in the period 1965-2000 would be about 30,000 acre-feet. This volume of compacted waste material would cover all the 1965 "vacant" land, as defined by RPA, in the county to a depth of about three inches. The accumulation of solid wastes for disposal in Somerset County is shown in Chart 17.

Chart 16

**ACCUMULATION OF SOLID WASTES FOR DISPOSAL, NEW YORK CITY, 1965-2000**

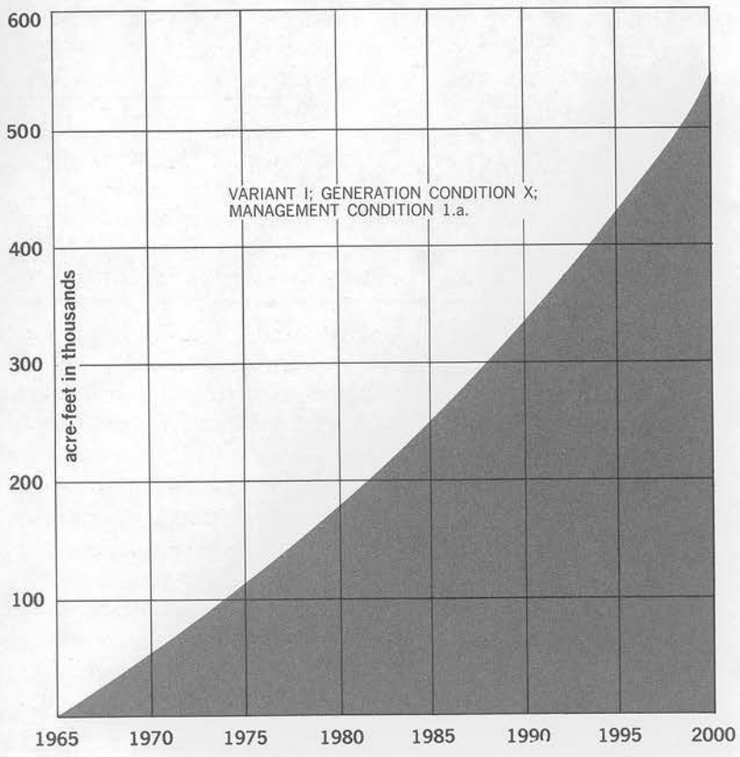
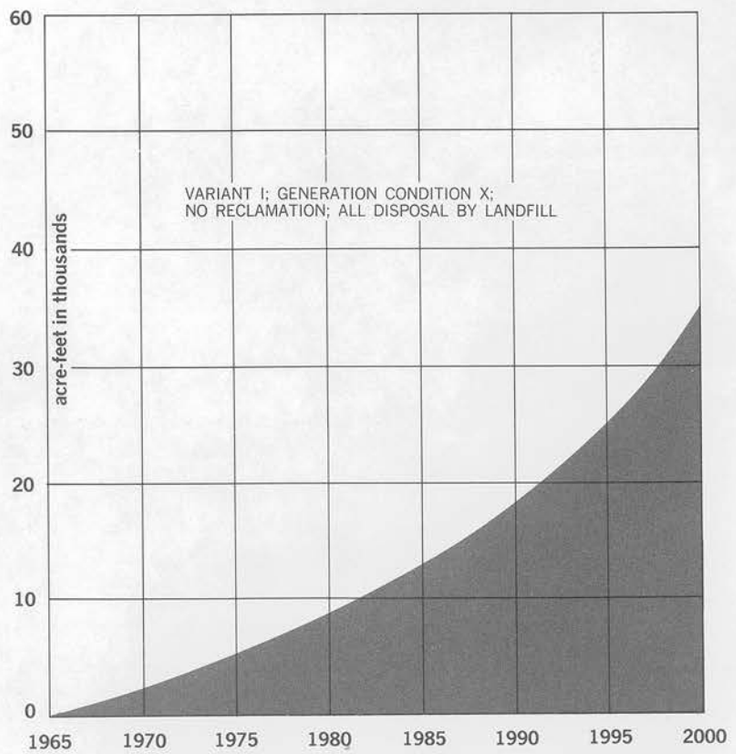
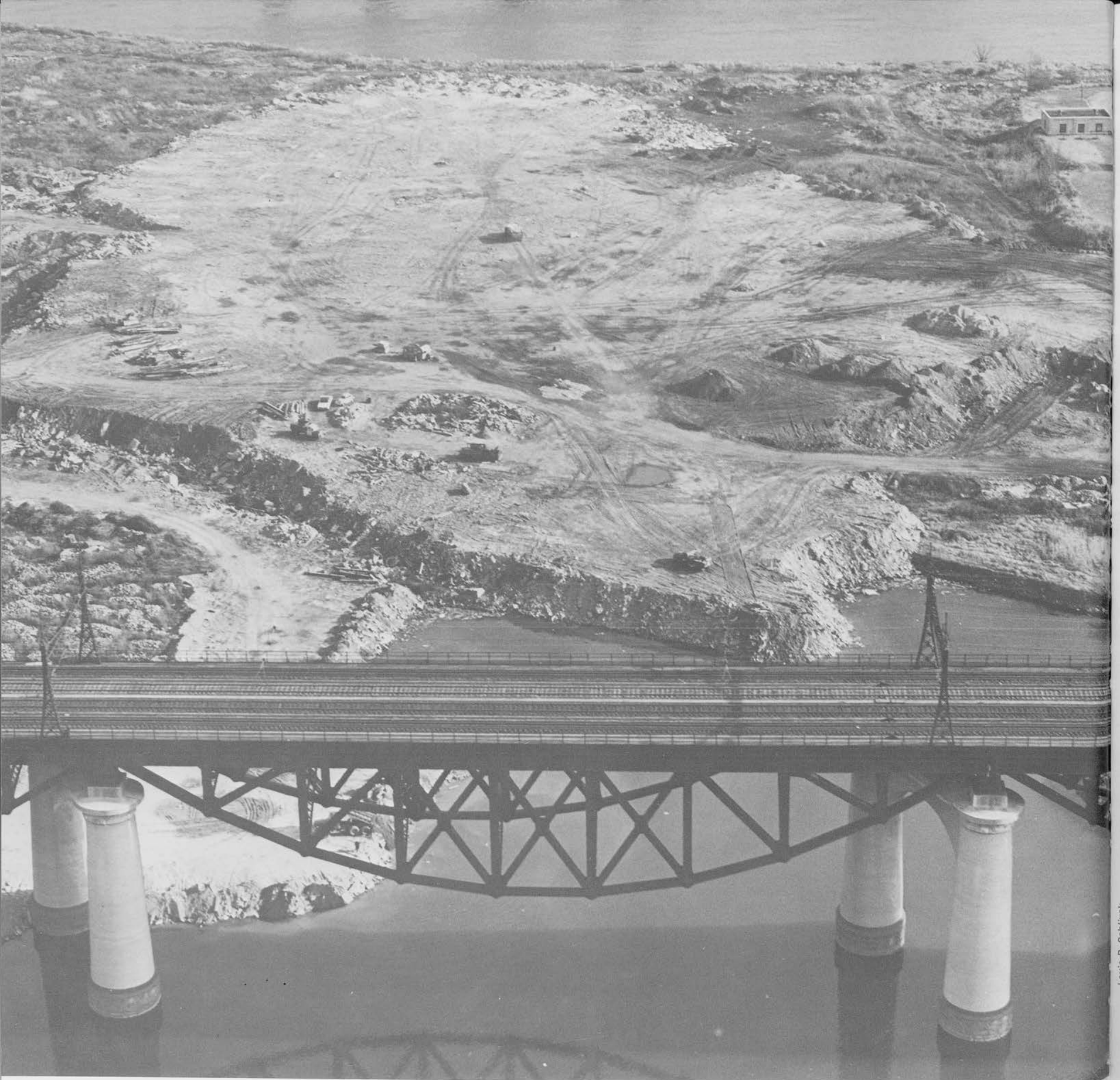



Chart 17

**ACCUMULATION OF SOLID WASTES FOR DISPOSAL, SOMERSET COUNTY, NEW JERSEY, 1965-2000**





Louis B. Schlivek

Many years of landfilling have joined Randall's and Ward's Islands in the East River. In the spring of 1968, a forty-five acre park built mainly on fill will be opened at Sunken Meadow, the northeastern corner of Randall's Island, by the Triborough Bridge and Tunnel Authority.

# 5. WASTE MANAGEMENT METHODS AND RESIDUAL WASTES DISCHARGED: PRESENT AND FUTURE

In this chapter, we describe present and alternative future waste management methods and related estimates of residual wastes discharged to the environment. The two are interrelated; the quantity of residual wastes discharged is a function of the methods for handling and disposing of the wastes after they are generated. The quantity, as well as the form, of a waste can be altered by the method of handling. The costs of waste management are in turn a function of the methods for handling and disposing of the wastes after generation.

There are two general methods for handling and disposing of wastes: on-site and collective. Examples of on-site methods are apartment house incinerators, power plant electrostatic precipitators, and liquid waste treatment plants on industrial sites. Collective facilities include municipal incinerators, sewage treatment plants, and sanitary landfills.

## Present residual waste discharges and handling methods

The estimates of residual wastes discharged in 1964 are given in Table 13. Present methods used in the Region for handling BOD, hydrocarbons, $SO_2$, particulates, and solid wastes are discussed here.

1. **Biochemical Oxygen Demand.** There is a wide range in the degree of BOD removal achieved in on-site and collective waste load reduction facilities in the Region. The degree of removal ranges from 0 to 70 or 80 percent. Although in the minority, there are still municipalities and industrial plants which provide no waste load removal and discharge the total BOD generated into the Region's water bodies.[1] In general, the average degree of BOD removal ranges from about 30 percent to 70 percent.

2. **Hydrocarbons.** To date, devices to control emissions from the vehicles used in the Region are not required. The production and marketing of petroleum products is the other major source of hydrocarbons. Probably about 30 percent to 50 percent removal is achieved on-site in refining, none in marketing.

3. **Sulphur dioxide.** There are as yet no feasible methods for on-site reduction in the quantity of $SO_2$, except where the production of sulphur pays for itself. Consequently, almost all of the $SO_2$ generated, except that in the petroleum refining industry, is discharged into the air.

4. **Particulates.** Four aspects are important. First, a considerable portion of the dust generated in industrial production is currently removed by on-site facilities. Second, a considerable portion of particulates generated in power production also are removed on-site. Third, in contrast, dust generated in residential, commercial, and industrial oil heating is not reduced—the quantity discharged equals the quantity generated. Similarly, the dust generated by the incomplete combustion of gasoline in vehicles is discharged in the same quantity as generated. Finally, the other, in fact predominant, source of particulates in the atmosphere at present stems from the handling of solid wastes in such operations as apartment house and municipal incinerators and open burning on landfills. Apparently, few of the on-site apartment house and industrial incinerators operate within reasonable emission standards. Few of the dozens of municipal incinerators in the Region operate within the generous emission limits set forth in the American Society of Mechanical Engineers **Power Plant Code.**[2] Except for an occasional municipal incinerator test, generally for new facilities, incinerator stack emissions are seldom tested. Nevertheless, the evidence to date substantiates the general conclusion that current incinerator operations are not within reasonable emission standards.

Considerable quantities of particulates are discharged into the atmosphere from open burning on landfills. Such open burning, either deliberate or through negligence, is commonplace. Based on records obtained from the state health departments in the Region, which in turn are based on periodic inspections of public and private landfills, many of the solid wastes disposed of by landfill are burned in the open. Small amounts of particulates also result from burning of solid wastes in backyard burners and truncated cone "teepee" burners.

5. **Solid Wastes.** The principal method currently used for disposal of solid wastes is landfill without burning. According to records of the state health departments, however, very few of the hundreds of landfills in the

[1] This does not imply that such discharges inevitably have an adverse effect on water quality.

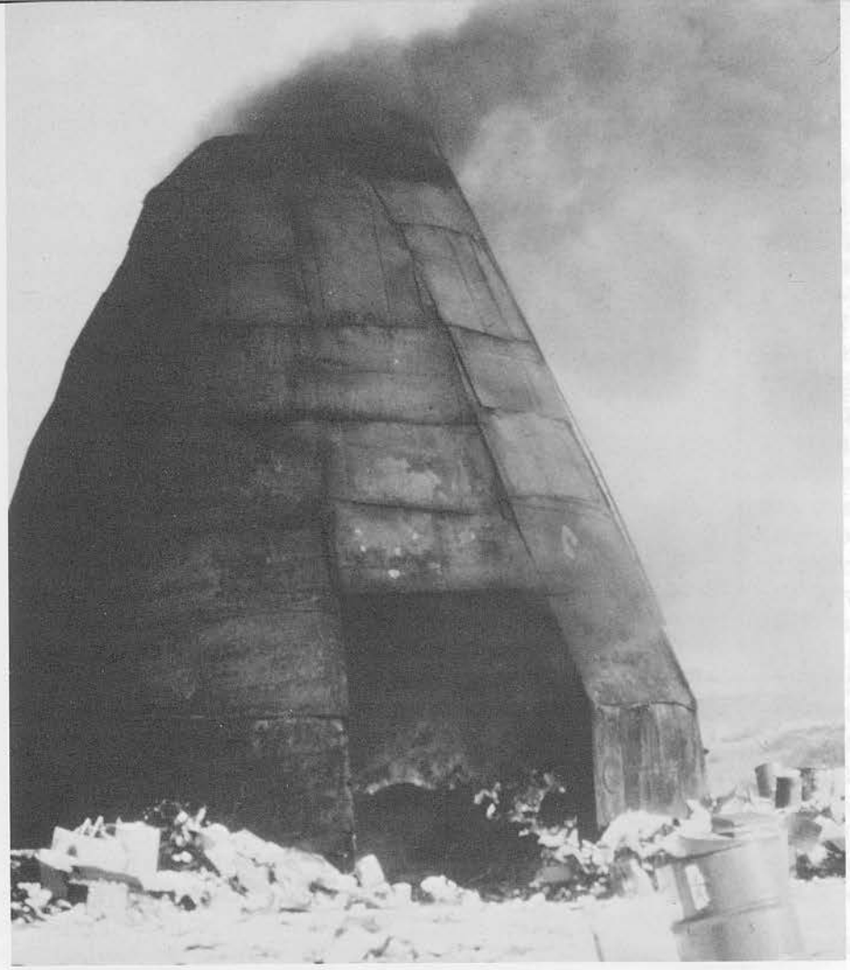
[2] This limit is 0.85 pounds of particulates per 1,000 pounds of gas corrected to 12 percent $CO_2$.



Louis B. Schlivek







**Characteristics of Landfill Operations**

Far left, above: **Open dumps** are the principal method of solid waste disposal in the Region. Few filling operations are conducted according to standards prescribed for sanitary landfills, and thus lead to rodent and insect breeding, odors, and an ugly landscape.

Far left, below: **Open burning** is still common in filling operations, even though it is prohibited by most state and local authorities in the Region. Open burning produces noxious odors and generates large quantities of particulates in the air.

Left: **Conical (teepee) burners** are used at many landfill sites to reduce the volume of solid wastes. Although combustion is aided by these burners, without wet scrubbers or other emission control devices they produce large quantities of particulates per ton of refuse burned.

Below: **Sanitary landfill** is the only satisfactory method of landfilling. Solid wastes are deposited in trenches or shallow surfaces, compacted, and covered with clean earth frequently enough to prevent nuisances.



Pix Inc.

Region are operated as sanitary landfills in accord with established regulations.[3]

Other methods for handling solid wastes after generation are garbage grinding, hog feeding, and salvage. Food wastes represent 10 percent to 12 percent by weight of residential solid wastes and have a 70 percent moisture content as compared to 20 percent moisture content for mixed solid wastes. At the present time, only a very small portion of the garbage generated in the Region is disposed of by grinding, with subsequent water carriage through sewage systems.

Hog feeding is still used to dispose of restaurant and hotel food wastes and bakery wastes. These solid wastes are generally picked up by the hog farmer or private garbage collector and conveyed directly to the hog farm. Hog feeding will probably be eliminated as a significant method of disposal in the future, as hog farmers in the Region are forced by spreading urban development to move farther away from the Core, which is the concentrated source of these wastes.

Salvage is another method of solid waste disposal. Waste paper is the primary component salvaged and recycled, particularly from solid wastes generated in office and retail establishments. This salvage operation is conducted as a business venture by private operators who also collect and dispose of general solid wastes from commercial establishments. As recently as 15 years ago, 60 percent to 70 percent of the paper wastes collected by members of the Greater New York Wastepaper Association was salvaged and reused, in contrast to between 10 percent and 20 percent at present. The economics of paper and paper goods production indicate that the trend away from waste paper recycling will continue.

Table 13 shows quantities of wastes originally generated and, based on the present methods of handling wastes described above, estimates of residual wastes discharged to water, air, and land.

Table 13

**RESIDUAL WASTES DISCHARGED TO THE ENVIRONMENT IN THE STUDY AREA, 1964**

all values in millions of tons

| Waste | Wastes Generated | Wastes Discharged to: Air | Water | Land |
|---|---|---|---|---|
| Solid wastes | 17.4 | | | 12.0 |
| BOD | 0.72 | | 0.46 | |
| $SO_2$ | 2.00 | 1.94 | | |
| Dust | 0.48 | 0.29 | | |
| Hydrocarbons | 1.47 | 1.38 | | |

[3]Sanitary landfill is a disposal method in which refuse is deposited on a surface or in a trench, compacted, and covered with inert material at a frequency and to a depth which will result in the prevention of nuisances, e.g., open burning, rodent and insect breeding.

## Future residual waste discharges and handling methods

Since the quantities of residual wastes discharged into the environment are a function of the methods for handling the generated wastes, various assumptions can be made about future waste handling and disposal methods. In a manner similar to the development of "generation conditions," sets of assumptions about waste management can be posited. These are termed "management conditions."

Many possible alternatives are available for handling wastes. Principally, these incorporate different combinations of on-site and collective methods, and different combinations of "sinks" for final disposal. These management conditions also involve different types of policy decisions; for example, regulations concerning exhaust controls on vehicles, on-site incineration, dumping wastes at sea, and types of fuel used in combustion. The various management conditions relating to different types and sources of wastes are shown in Table 14. These possible management conditions can be combined in many ways, some of which are shown in Table 15. For example, the Management Combination designated IX includes the following: Management Condition 1 for Gaseous wastes, space heating; Management Condition 2 for Gaseous wastes, vehicular transportation (90 percent reduction in emissions); Management Condition 3b for Solid wastes (all solid wastes incinerated in central incinerators, no paper recycled, residue barged to sea); and so on.

Estimates of residual wastes are derived by associating a waste management combination with a waste generation condition (Table 10). The results for several of these "packages" are shown in Table 16. Not all of the combinations analyzed are included in the table, and many other possible groupings could have been analyzed.

## Some implications of the results

1. The factors which affect waste generation have a major impact on the quantity of residual wastes discharged and on waste management costs. The impact on residual wastes discharged is shown by contrasting the results for the different generation management combinations in Table 16.

2. The quantity of residual wastes discharged is responsive to policy decisions made by governmental agencies. This is exemplified by residual discharges of hydrocarbons. Table 17 shows rough estimates of peak hydrocarbon concentrations for the year 2000 in four boroughs of New York City. Note that for Variant II,

Table 14

## WASTE MANAGEMENT CONDITIONS, 2000

| Waste Category | Management Conditions |
|---|---|
| Gaseous wastes, energy generation (E) | 1. Mean annual efficiency of particulate removal devices, 95 percent; mean annual reduction of $SO_2$ (fuel + emission control), 50 percent |
| Gaseous wastes, space heating (H) | 1. None, except for fuel shift (See Table 10) |
| Gaseous wastes, vehicular transportation (T) | 1. 1968 federal standards for vehicle emissions, i.e., 50 percent reduction; no change in governmental policies concerning modal split<br>2. 90 percent reduction in vehicle emissions; no change in governmental policies concerning modal split |
| Solid wastes (S) | 1. Continuation of present distribution of disposal practices, except no hog feeding, no open burning, and all incinerator emissions to meet NYC Local Law 14 dust limitations<br>a. 0 percent of paper recycled<br>b. 20 percent of paper recycled<br>c. 80 percent of paper recycled<br>2. All solid wastes incinerated in central or municipal incinerators, with recommended federal emission rates, i.e., 0.2 lb. per 1,000 lbs. of air at 50 percent excess air (approximately 4 lbs. of particulates per ton of refuse incinerated); 0 percent of paper recycled; residue to landfill<br>3. All solid wastes incinerated in central or municipal incinerators, with recommended federal emission rates; 0 percent of paper recycled<br>a. Residue by rail to landfill out of Region<br>b. Residue by barge to sea<br>4. All incineration prohibited; 0 percent of paper recycled<br>a. Disposal of all wastes by rail to landfill out of Region<br>b. Disposal of all wastes by barging to sea |
| Gaseous wastes, heavy industry (except heating) (G) | 1. Levels of emission control as currently proposed<br>2. 90 percent reduction of wastes generated in on-site facilities |
| Liquid wastes, heavy industry (Li) | 1. 35 percent average reduction of wastes generated in on-site facilities<br>2. 85 percent average reduction of wastes generated in on-site facilities |
| Liquid wastes, residential, commercial, light industry (Lr) | 1. Continuation of present pattern of jurisdictions for water supply and liquid waste disposal; continuation of present practices in NYC system, i.e., no additional metering, flat rate charges when assessed, no use of reclaimed waste water except on Long Island, no tightening up of distribution system; 35 percent BOD reduction in collective facilities<br>2. Efficient sub-regional systems for waste water handling; 100 percent metering, charges by volume, tightening of system, maximum utilization of groundwater and reclaimed waste water; 35 percent BOD reduction in collective facilities<br>3. Same as condition 2, except with 85 percent BOD reduction in collective facilities |

Table 15

## COMBINATIONS OF MANAGEMENT CONDITIONS

| Combination Designation | Waste Category and Management Condition | | | | | | |
|---|---|---|---|---|---|---|---|
| | E | H | T | S | G | Li | Lr |
| Ia | 1 | 1 | 1 | 1a | 1 | 1 | 1 |
| Ib | 1 | 1 | 1 | 1b | 1 | 1 | 1 |
| Ic | 1 | 1 | 1 | 1c | 1 | 1 | 1 |
| II | 1 | 1 | 1 | 2 | 1 | 1 | 1 |
| IIIa | 1 | 1 | 1 | 3a | 1 | 1 | 1 |
| IIIb | 1 | 1 | 1 | 3b | 1 | 1 | 1 |
| IVa | 1 | 1 | 1 | 4a | 1 | 1 | 1 |
| IVb | 1 | 1 | 1 | 4b | 1 | 1 | 1 |
| V | 1 | 1 | 2 | 2 | 2 | 1 | 1 |
| VI | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
| VII | 1 | 1 | 2 | 3a | 2 | 1 | 1 |
| VIII | 1 | 1 | 2 | 3a | 2 | 2 | 2 |
| IX | 1 | 1 | 2 | 3b | 2 | 1 | 1 |
| X | 1 | 1 | 2 | 3b | 2 | 2 | 2 |
| XI | 1 | 1 | 2 | 4a | 2 | 1 | 1 |
| XII | 1 | 1 | 2 | 4a | 2 | 2 | 2 |
| XIII | 1 | 1 | 2 | 4b | 2 | 1 | 1 |
| XIV | 1 | 1 | 2 | 4b | 2 | 2 | 2 |
| XV | 1 | 1 | 1 | 2 | 1 | 2 | 2 |
| XVI | 1 | 1 | 2 | 2 | 2 | 2 | 3 |
| XVII | 1 | 1 | 2 | 3a | 2 | 2 | 3 |
| XVIII | 1 | 1 | 2 | 3b | 2 | 2 | 3 |
| XIX | 1 | 1 | 2 | 4a | 2 | 2 | 3 |
| XX | 1 | 1 | 2 | 4b | 2 | 2 | 3 |

Table 16

## RESIDUAL WASTES DISCHARGED TO THE ENVIRONMENT IN THE STUDY AREA, 2000

all values in millions of tons

| | Generation/ Management Combinations | Solid Wastes to Land | BOD to Water | $SO_2$ to Air | Dust to Air | Hydro-carbons to Air |
|---|---|---|---|---|---|---|
| A | GC/X - MC/Ia | | | | | |
| | Variant I | 37.4 | 1.04 | 1.34 | 0.16 | 1.55 |
| | Variant II | 37.4 | 1.04 | 1.32 | 0.16 | 1.65 |
| | Variant III | 37.4 | 1.04 | 1.39 | 0.16 | 1.40 |
| B | GC/Y - MC/Ic | | | | | |
| | Variant I | 11.2 | 0.86 | 1.34 | 0.14 | 1.55 |
| | Variant II | 11.2 | 0.86 | 1.32 | 0.14 | 1.65 |
| | Variant III | 11.4 | 0.86 | 1.39 | 0.14 | 1.40 |
| C | GC/Y - MC/VI | | | | | |
| | Variant I | 7.1 | 0.75 | 1.21 | 0.15 | 0.29 |
| | Variant II | 7.1 | 0.75 | 1.19 | 0.15 | 0.30 |
| | Variant III | 7.2 | 0.75 | 1.26 | 0.15 | 0.26 |
| D | GC/X - MC/VIII | | | | | |
| | Variant I | 0 | 0.79 | 1.21 | 0.23 | 0.29 |
| | Variant II | 0 | 0.79 | 1.19 | 0.21 | 0.30 |
| | Variant III | 0 | 0.79 | 1.26 | 0.21 | 0.26 |
| E | GC/X - MC/XII | | | | | |
| | Variant I | 0 | 0.79 | 1.21 | 0.10 | 0.29 |
| | Variant II | 0 | 0.79 | 1.19 | 0.10 | 0.30 |
| | Variant III | 0 | 0.79 | 1.26 | 0.10 | 0.26 |
| F | GC/X - MC/XVI | | | | | |
| | Variant I | 16.2 | 0.20 | 1.21 | 0.21 | 0.29 |
| | Variant II | 16.2 | 0.20 | 1.19 | 0.21 | 0.30 |
| | Variant III | 16.2 | 0.20 | 1.26 | 0.21 | 0.26 |
| G | GC/Y - MC/XVI | | | | | |
| | Variant I | 7.1 | 0.20 | 1.21 | 0.15 | 0.29 |
| | Variant II | 7.1 | 0.20 | 1.19 | 0.15 | 0.30 |
| | Variant III | 7.2 | 0.20 | 1.26 | 0.15 | 0.26 |

Table 17

ESTIMATED PEAK HYDROCARBON CONCENTRATION[a]

| | Present (1964) | Variant I (2000) | Variant II (2000) | Variant III (2000) |
|---|---|---|---|---|
| Vehicle-miles in peak 3-hour morning period (millions)[b] | 6.5 | 7.7 | 6.4 | 8.7 |
| Gasoline consumed, gallons (thousands)[c] | 0.65 | 0.77 | 0.64 | 0.87 |
| Hydrocarbon emissions, no exhaust controls, pounds (millions)[d] | 0.32 | 0.38 | 0.31 | 0.43 |
| Hydrocarbon concentration, no exhaust controls (ppm)[e] | 0.6 | 0.7 | 0.6 | 0.8 |

[a]Based on area of Manhattan + Brooklyn + Queens + Bronx.
[b]Based on 20 percent of 24-hour traffic in peak morning period.
[c]Based on 10 vehicle-miles per gallon.
[d]Based on 0.5 pounds per gallon consumed.
[e]Based on 1,000 foot ceiling.

the peak concentration with no exhaust controls would be about the same as at present. This result occurs because Variant II represents a widely dispersed distribution of population and economic activities in the Region. Assuming that the required 50 percent reduction in emissions is effective, then the peak concentration would be about 50 percent, 60 percent, and 70 percent of that at present for Variant II, Variant I, and Variant III, respectively.

These estimates of peak concentration are based on estimates of vehicle-miles and related assumptions concerning the factors affecting them. Suppose, however, that vehicle-miles were grossly underestimated. With 50 percent emission control, the hydrocarbon concentration in the year 2000 would still be less than at present.

There are other ramifications relating to policies with respect to hydrocarbon emissions. For example, it appears likely that maintenance will be difficult for the types of facilities proposed to achieve a 50 percent reduction in hydrocarbon emissions. If the average performance of these devices were only 25 percent, then there might be little improvement in the peak hydrocarbon concentration in the Core by the year 2000.

Controlling vehicle exhausts is not the only way of reducing peak hydrocarbon concentrations in Manhattan. Rather than imposing controls on the waste discharges, it is possible to impose controls on the waste generators themselves. For example, charges could be imposed, on the order of $3.00 or $4.00 per vehicle, on all vehicles entering Manhattan between 7 a.m. and 7 p.m. If the first level of charge were insufficient to reduce traffic enough to achieve the desired hydrocarbon concentration level, the charges could be imposed during all business days in the year.

Alternatively, if there were an adequate air quality monitoring system, so that periods of adverse weather conditions could be predicted at least shortly beforehand, the charges could be levied only during the most adverse conditions, and/or in proportion to the severity of the condition. This procedure would tend to eliminate vehicle trips with marginal social benefits. A basic assumption implicit in this approach is that alternative forms of transportation would be available.

Assuming that vehicle-miles were grossly underestimated, and that the management alternative of imposing significant charges on vehicles entering Manhattan were not adopted, an alternative way of achieving the desired hydrocarbon concentration would be to impose a 90 percent reduction level on individual vehicle exhausts. Assuming that 90 percent reduction would cost about $0.002 per vehicle-mile, the total cost for the Region would be between $150 and $200 million annually. (Theoretically, only those vehicles coming into, going out of, and moving in Manhattan would have to have the exhaust controls. Administration of such a procedure would be difficult.)

An alternative consisting of a combination of a lower level of emission control plus selective charges on those vehicles entering Manhattan would involve much lower net costs to society. These kinds of alternatives are mentioned to show the impact of different waste management policies.

3. Given the shift to nuclear power to meet energy demands in the New York Region, the contribution of energy generation to sulphur dioxide concentrations in the air will decrease very significantly by the end of the century. The relative contribution of fossil fuel plants could be so small that they would not have to use desulphurized fuel to maintain the desired levels of $SO_2$ concentration. By the year 2000, the major source of $SO_2$ will be space heating in residences, and commercial and industrial operations.

This emphasizes the need to maintain flexibility in waste management policies. However, because of increased heating needs, it would appear that in the year 2000, even if no power were generated from fossil fuel and no $SO_2$-generating industries existed in the area,

the total discharge of sulphur dioxide would still be significant, relative to that at present.

4. The spatial distribution of economic activities significantly affects waste management costs. For example, looking at the two alternatives of hauling all solid wastes by rail outside of the Region and barging all solid wastes to sea, the most efficient development pattern for the rail alternative would be Variant I, while the most efficient distribution for barging would be Variant III. In Variant III, population and economic activities are concentrated near the core of the Study Area.

5. The total water intake for incineration in the management condition with maximum incineration represents a negligible portion of total water intake for all uses in the Region. Even if once-through water utilization, which approximately triples water intake, were practiced, the quantity of water required for incineration would not be important unless the incinerators were located in local areas of limited water supply. Since brackish water and/or reclaimed sewage effluent can be used, even local situations should not result in water problems.

6. The management condition which assumes that all incineration in the Region is prohibited, and that all solid wastes are disposed of in landfill, would obviously result in the largest space requirements and in the largest quantity of residual discharges to the land. Since the least available land is generally located where the most wastes are generated, this management condition would result in the most expensive waste transport. Thus, solid waste disposal predominantly by landfill would be least expensive for Variant II, which has the greatest activity dispersion.

The impact of disposing of solid wastes on land is reflected in Maps 2 and 3, which show "madeland" in 1900 and 1966. Not all madeland can be attributed to solid waste disposal, since other materials have been used for fill, but its contribution is certainly significant. Map 3 suggests that a considerable portion of the areas readily accessible for filling operations with minimum costs and closest to the major sources of solid wastes have already been used.

Not all the possible implications which might be drawn from the data have been suggested here, nor have all the possible or even likely alternative combinations of management conditions been analyzed. Other alternatives need to be assessed. But those presented illustrate how to approach the problem.



Flushing Meadow Park in New York City was "made" from wetlands by landfilling. It comprises 1,250 acres and has been the site of two world's fairs.



The lower half of Governor's Island in Upper New York Bay was manufactured from landfill, most of which was obtained from subway excavations during the early part of this century. The Island houses the largest U.S. Coast Guard base in the world.

Louis B. Schlivek



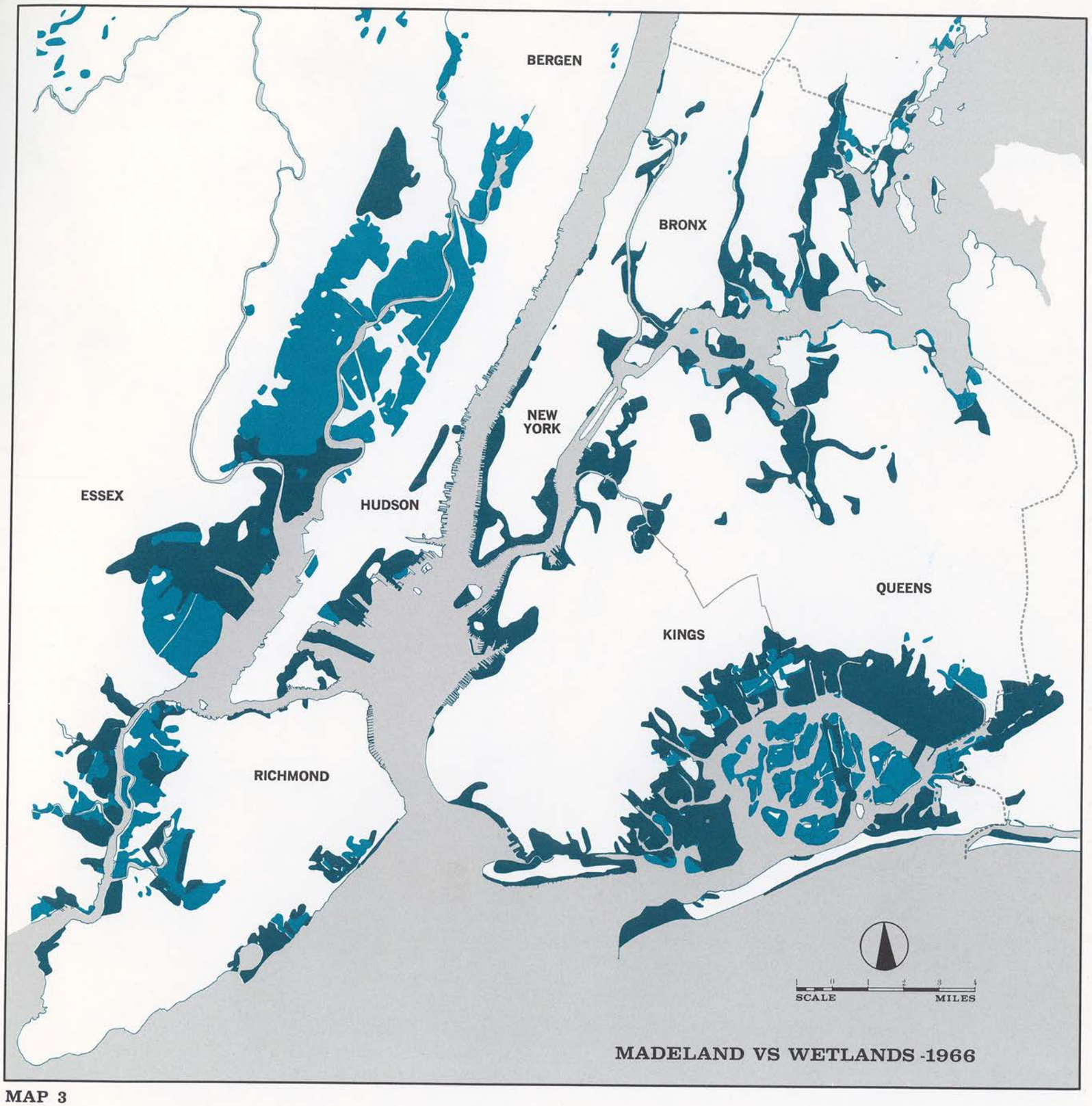
Between 1944 and 1948, over 15 million cubic yards of solid wastes were used to fill Great Kills Park on Staten Island. Today the 1,450-acre park is one of New York City's major recreation areas.




**MAP 2**

SOURCE: New York City Department of City Planning; U.S.G.S. **Folio 83,** 1901

■ MADELAND ■ WETLANDS

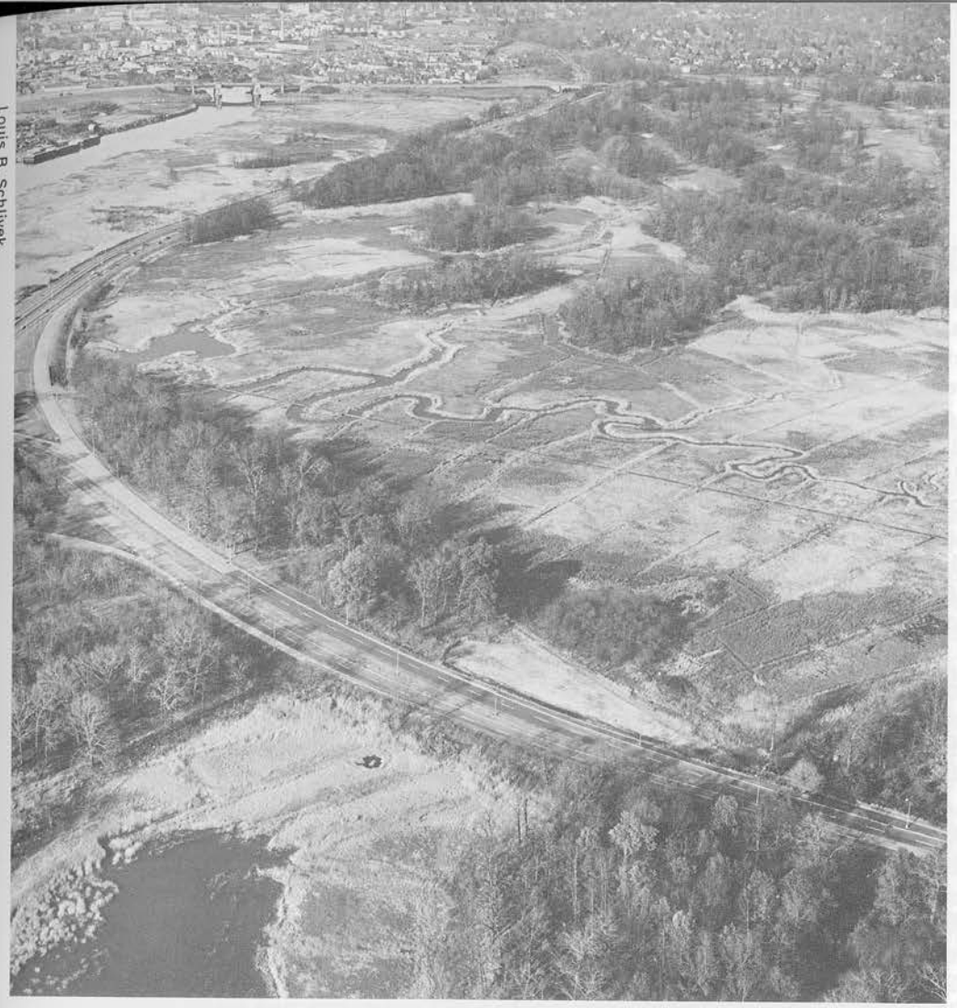



**MAP 3**

SOURCE: New York City Department of City Planning, U.S.G.S. 1957; aerial photographs, 1966

■ MADELAND ■ WETLANDS

LOUIS B. SCHIVER



Louis B. Schlivek

Wetlands are important as habitat for local and migratory wildlife and often for natural regulation of storm runoff, but they also offer potential sites for sanitary landfill, particularly when located near urban centers where land is valuable for development. The Hackensack Meadows in New Jersey (left) are only a short distance from Manhattan and Newark, yet they include more than 13,000 acres, or 20 square miles, which are untouched by development. Many wetlands in New York City already have been filled, as Maps 2 and 3 show. Pelham Bay Park (above) and Jamaica Bay (below), already filled in part, are sought for additional landfill sites. Conservationists, however, deplore any further intrusion on the few remaining wetlands in the city. This conflict can be expected to intensify.



Louis B. Schlivek

## Comments on waste management costs

First, total annual costs of waste management in the year 2000 were computed on the basis of a 10 percent annual charge on the capital investment plus the operation and maintenance costs. It should be emphasized that these are the costs in a single year and represent the generation and management conditions assumed for that time. They are not the present value of a future time stream of waste management costs which would be incurred from the present until the year 2000. Ideally, the analysis should be in terms of time streams of costs.

Second, the costs computed represent roughly the incremental costs over and above the costs of (1) existing facilities for handling wastes and (2) facilities which will be installed to meet standards and regulations, such as the 1968 federal standards on vehicle hydrocarbon emissions, state standards for degree of removal in municipal treatment plants, and limits on sulphur content of fuels. That is, if a currently existing on-site or collective plant reduces BOD by 35 percent, corresponding to Management Condition 1 (Liquid wastes [Li], Table 14), the cost of that degree of reduction is not included. Only the difference between the cost of removing 35 percent and the cost of removing the higher percentage assumed in this report is included in these calculations. For example, the following are not included: costs of facilities necessary to achieve 50 percent reduction in hydrocarbon emissions from vehicles, costs of changing to different types of fuel, and costs of upgrading incinerators to meet the specified standards.

Third, the management approach assumed in all of the management conditions is that of uniform, continuous operation of the waste reduction facilities. (See Chapter 2 for alternative approaches.) This does not take into consideration variations in the assimilative capacity of the environment and, hence, it results in maximum waste management costs.

Fourth, certain on-site costs relating to industrial users are not included in the calculations. Data are very sparse on the costs of gaseous waste reduction in various types of industrial operations. However, the residual wastes discharged, with or without on-site reduction, represent a very small portion of total residual wastes discharged. The total cost to the firms is likely to represent a similarly small portion of total regional waste management costs, even though the cost of achieving higher levels of waste reduction on-site in such operations may be significant to the individual operations. Therefore, the on-site costs of gaseous waste load reduction in the industrial sector were ignored. Similarly, the on-site costs of industrial landfill operations were neglected.

Fifth, the cost of liquid waste handling (BOD removal) is significantly affected by the volume of waste water. To put it simply, sewage treatment costs can be thought of as the cost of handling the volume of liquid used in the plant and the cost of reducing BOD. The same quantity of BOD can be transported in widely varying volumes of liquid. Since the cost of BOD removal in the context of waste management will then be dependent not only on the quantity of BOD but also on the volume or quantity of liquid involved, the policies adopted which affect water intake will significantly affect the discharge volume and, hence, the volume of liquid to be handled at the sewage treatment plant.[4]

Thus, if we assume no metering on water intake, no charges or flat-rate charges for water, no incentives for water recirculation, and no leakage and waste prevention surveys within municipal water systems, then the quantity of liquid wastes to be handled would be significantly larger than if the opposite management policies were adopted. The difference would be reflected in the difference in waste management costs (as well as in the cost of water supply).[5]

Sixth, waste collection costs, i.e., costs of conveyance from generation site to collective facilities, for both liquid and solid wastes, are not included. Although such costs comprise a significant portion of overall waste management costs, it is the costs of final methods of disposal in relation to the level of waste reduction, final discharge, and environmental quality which are of concern in this study. Thus, since the same waste collection system can be used with a variety of ways of handling or disposing of wastes after collection, the omission of collection costs does not negate the validity of the comparisons. As noted previously, the same quantity of BOD can be conveyed in a sewer system, regardless of the degree of removal achieved at the treatment plant. Of course, waste collection costs are intimately related to the distribution of population and economic activities. This is perhaps the most important reason why subsequent analyses of waste management in the New York Region should explicitly consider these costs.

Seventh, the cost of land for landfill operations is not included. Since the value of the land is often enhanced by these operations, there may be a net gain, rather than a cost. Thus, the costs estimated relate only to the operations themselves.

Eighth, economies of scale are important in the methods for handling and disposing of wastes. In fact, economies of scale with respect to certain types of facilities contribute significantly to the differences in total annual costs among the management alternatives investigated. For the same method of waste reduction in secondary sewage treatment plants, for example, and for the same quantity of BOD to be removed, a multiplicity of small plants will require more expenditures than a few large plants. Consequently, fragmented political jurisdictions can increase waste management costs.

Finally, there is an important assumption relating to all of the management conditions specified. If the assumed degrees of waste removal in on-site and collective facilities are to be realized, high levels of operating performance and maintenance are required. As noted in the previous section concerning present waste handling and disposal methods in the Region, such high-level performance is not characteristic of the operation of existing facilities. Nevertheless, to assume that the specified levels of performance would not be achieved in the future would be unjustified. It should be emphasized, however, that waste management will only achieve the desired levels of air, land, and water quality through constant attention to facility maintenance, which requires adequate financing and well-trained personnel.

[4]Amplification of this point was made in Chapter 4 (see p. 49).

[5]The implication for the New York Region is obvious, and the point merits emphasis. As controls on the quality of liquid waste discharges become more stringent, not only will waste treatment costs increase but so will the quality of the final effluent. The additional cost to reclaim the effluent for potable supply is likely to be less than most, if not all, alternative sources of water intake. See U.S. Public Health Service, Division of Water Supply and Pollution Control, **Proposal for Augmenting New York City Water Supply through Waste Water Purification and Reuse** (August, 1965).

# 6. IMPLICATIONS FOR GOVERNMENTAL ORGANIZATION

It is not within the purview of this report to make specific recommendations regarding the structure and functions of public or private agencies for waste management in the New York Region, but it is necessary to point out that governmental organization, policies, and programs will be crucial determinants of (1) how decisions concerning waste management and environmental quality in the Region will be made, and (2) how efficiently the resources allocated to waste management and to improving environmental quality will be used. It might also be useful to indicate the types of public and private activities which are necessary for effective and efficient waste management.

Basic changes in American life have combined to accentuate the problem of waste generation and disposal and to make it one of the most intricate and technically difficult problems of metropolitan areas. New factors have profoundly affected the problem in recent decades. Among them are population movement from farm to city, extensive spreading out of urban areas, a shift from rail transportation to motor vehicles driven by internal combustion engines, steadily increasing demand for electric power, expanding use of easily disposable but nondegradable materials, and greatly increased industrial production. These changes have combined to increase vastly the volume of wastes generated and discarded, and have tended to concentrate them within the relatively small areas of urban cores. This has strained assimilative capacity of the environment and accented the significance of waste accumulation.

As this report indicates, regional planning will need to give considerable attention to waste generation and waste management in the years ahead. Certain questions must be faced. The importance of assessing the relationship between the distribution of regional activities and waste generation quantities and waste management costs has already been mentioned. Other more specific questions include: How can data on waste generation best be maintained? How can regional and subregional standards of environmental quality best be established and enforced? How can optimum benefits be achieved for money spent? How can advanced technology for dealing with wastes be most fully and efficiently applied? How can economies of scale be achieved? How can infringements on the rights and properties of citizens be kept to a minimum?

Waste management is ultimately the responsibility of government; there is no doubt that technologically it is possible to prevent deterioration of environmental quality below whatever standards the public is willing to finance. The uncertain factor is adequacy of government. The ability of government to cope with the wastes of society is the key factor which will determine environmental quality.

We have gathered no data on, and have made no analysis of, governmental organization for waste management in the New York Region, nor have we directly examined the efficiency of present procedures. This was not within the scope of our assignment. However, it is common knowledge that various waste handling and disposal activities are spread among many different units and levels of government. When all three forms of wastes are considered as a single problem, the relevant governmental institutions and activities appear highly fragmented.

The question of how government might best be organized for waste management requires that we consider the characteristics which make the waste disposal and environmental quality problem unique in relation to other human activities. Table 18 summarizes some of these characteristics.

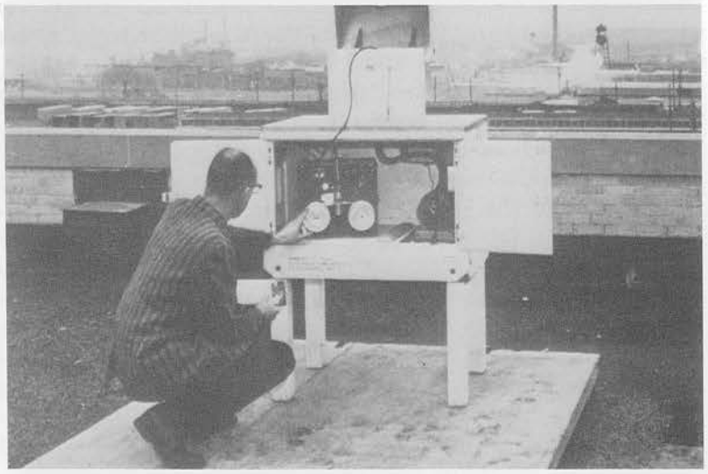
Presently, all levels of government are engaged in activities relating to waste management. At each level, the handling and disposal of wastes have, by historical development, been allocated to different departments according to the form of waste—solid, liquid, or gaseous. This is because many of the physical tasks of coping with each of the three forms are different, despite similarities of other problems. The objective has been simply to dispose of wastes in what was for the particular agency the quickest and cheapest way. Prevention of damage to water, air, and land quality has become a motivation for greater control of waste discharges and improved performance of waste disposal services by various public agencies.

Only in recent years, however, has the concept of comprehensive waste management systems evolved.

Table 18

## CHARACTERISTICS OF WASTES AND ENVIRONMENTAL QUALITY

1. **Personal.** Everyone generates wastes, directly or indirectly, and virtually everyone must endure environmental quality deterioration to a greater or lesser degree.
2. **Interchangeable.** Wastes can be transformed back and forth among solid, gaseous, and liquid forms.
3. **Non-coterminous.** Physical boundaries of watersheds, airsheds, and solid waste disposal areas are not likely to coincide.
4. **Ubiquitous.** Wastes in some form and to some degree are almost everywhere—in the air, in the water, and on the land.
5. **Technical.** Advanced science and technology encompassing a wide range of professions are involved in handling and disposing of wastes—most notably chemistry, biology, public health, ecology, geology, limnology, meteorology, economics, and engineering.
6. **Diffuse.** Many wastes dissolve or are carried in suspension in water or air, degrade, and/or are diluted.
7. **Cumulative.** Assimilation by air, water, and particularly land has limits. When the rate of wastes discharged exceeds assimilative capacity, accumulation occurs.
8. **Combinable.** Although most wastes as they are transported in the air and water simply mix and do not combine chemically, some do combine to produce a different waste, most notably hydrocarbons reacting under the effect of sunlight. Further, the effect of a given waste may be increased or diminished by the presence of other wastes.
9. **Damaging.** Externalities generally accompany the discharge of wastes; that is, subsequent users are disadvantaged and extra costs accrue to these users and to society in general.
10. **Permanently injurious.** Irreversibilities may occur from the discharge of waste, such as permanent contamination of groundwater basins and destruction of marshes and similar areas of wildlife habitat.
11. **Interjurisdictional.** Governmental boundaries are not respected by the movement of wastes and their effects on environmental quality. This is so not only with respect to wastes carried by air and water, but with respect to land as well, since the capacity of disposal sites for solid refuse is reached most quickly in the densely populated areas where the most wastes are generated.



Environmental quality management requires continuous monitoring of air, water, and land conditions. This continuous tape sampler records particulates in the atmosphere.

This concept, which to our knowledge has not yet been applied anywhere in the U.S., embraces such related public policies and functions as:

Reducing the generation of wastes in all forms;

Monitoring environmental quality on a continuous basis, and measuring damages from waste discharges on a region-wide basis;

Devising least-cost methods of handling wastes from the standpoints of both the waste producer and of those adversely affected by the discharges of wastes.

We recommend a thorough study of governmental and private organization for waste management in the New York Region. The central focus of the study should be to examine the adequacy of the decision-making process for policy formulation, planning, and program development within the Region for the total waste problem.

In such a study, it will be important to distinguish between regional and sub-regional functions in waste management and to do so for each form of waste. Both regional and sub-regional organizations have their special advantages, and there are important roles for each. Sub-regional agencies are close to local problems. They can tailor solutions to local conditions and respond quickly and effectively to such problems and conditions. A regional organization is more efficient for such activities as research, data compilation, data storage and retrieval, use of computers, systems analysis, and the installation and operation of facilities affecting region-wide environmental quality. Also at the regional level, it is likely to be easier to attract and hold highly competent professional people in the relevant fields, people who are in great demand. A regional unit is the logical center from which to integrate quality monitoring activities carried out by a wide range of agencies, both public and private.

Differentiation of functions between regional and sub-regional levels may not be the same for all forms of wastes, and very few of the functions are likely to be exercised exclusively at either level. A study of governmental organization will have to assess the possible roles of the state and federal governments with respect to regional waste management agencies and how interrelationships among them can be delineated.

The list of activities relating to waste management in Table 19 indicates the range of functions which should be studied to ascertain the adequacy of present performance in the New York Region and whether

Table 19

## WASTE MANAGEMENT FUNCTIONS IN NEED OF STUDY AND ANALYSIS IN RELATION TO GOVERNMENTAL ORGANIZATION FOR THE NEW YORK REGION

**I. Data collection, analysis, monitoring, and forecasting for all three forms of wastes**

- **A.** Assembly and continuous maintenance of data on the generation of wastes and the factors affecting generation
- **B.** Cost analyses of externalities, control measures, product and processing changes, and management systems
- **C.** A monitoring system covering air quality, water quality, and landfill operations
- **D.** Projections of waste generation and discharge for specific periods of time

**II. Topical research**

**A. Solid wastes**

1. Ecological and limnological effects of fill operations on land, in tidal areas, and in the ocean
2. Technology of incineration: handling—containers, shredding, compaction, grinding, baling; and transportation equipment—rail cars, loading and unloading devices, barges, sewer systems
3. Development of substitute and/or reusable materials for containers
4. Development of disposal areas, through methods such as land contouring, island making, and filling strip mines
5. Use of wastes as fuel for energy generation and heating

**B. Liquid wastes**

1. Effects of waste discharges on quality of various types of water bodies, i.e., development of diffusion models
2. Techniques and economics of materials recovery and by-product production
3. Evaluation of process changes which reduce waste generation
4. Evaluation of economies of joint collection and disposal facilities in sub-areas of the Region
5. Evaluation of effects of regulated discharges into water courses on water quality

**C. Gaseous wastes**

1. Effects of gaseous waste discharges on air quality, i.e., development of diffusion models
2. Effects of time patterns of concentrations of gaseous wastes on human, animal, and plant life
3. Evaluation of process changes which reduce waste generation
4. Techniques and economics of materials recovery and by-product production
5. Assessment of availability and impact of substitute fuels
6. Technology and economics of emission control devices

**D. Economics relating to all forms of wastes**

1. Economic consequences of different levels and time patterns of environmental quality
2. Studies of benefits from, and costs of, modifying environmental quality
3. The costs of alternative waste management systems
4. Impact of possible relocation of activities on the regional economy
5. New uses for waste products
6. Secondary effects on the community and on industry of regulations imposed on waste discharges
7. Administrative costs of alternative waste management systems and their variation with alternative spatial arrangement of economic activities
8. Costs and consequences of alternative forms of regulation devices—charges, standards, and combinations of both
9. Determining the extent to which economies of scale exist for materials recovery, waste reduction facilities, and waste disposal methods—treatment plants, dust collectors, landfill operations, rail transportation of solid wastes
10. Evaluation of alternative ways of financing waste management in the Region, i.e., who pays what portion of the costs

**E. Operating activities relating to all forms of wastes**

1. Evaluation of various monitoring and reporting methods
2. Evaluation of alternative enforcement procedures for political, administrative, and equity problems

**III. Continuous comprehensive planning for waste management**

- **A.** Application of systems analysis to waste management
- **B.** Locating appropriate places for solid waste disposal
- **C.** Specification of sub-areas of the Region having air movements most suited and most adverse to assimilation and dispersion of gaseous wastes
- **D.** Specification of bodies of water most suitable and most adverse for municipal, industrial, and agricultural wastes assimilation
- **E.** Review of land use plans and regulations throughout the Region to determine their potential effects on environmental quality and on the costs of waste management
- **F.** Review of environmental quality standards set by other agencies and, where necessary, establishment of governing standards for the Region

**IV. Advice and services—technical and administrative—to local and sub-regional governmental agencies, perhaps to state agencies, and to private parties on measures to avoid or cope with waste problems throughout the Region**

**V. Implementation of a comprehensive waste management plan and incorporation in the plans of other planning bodies at the municipal, county, and regional level; programming by operating agencies performing waste management functions; and performance by such agencies consistent with the comprehensive planning**

**VI. Exercise of legal authority by appropriate governmental bodies to require public and private actions to be consistent with the comprehensive waste management plan**

**VII. Legislative authorization to appropriate governmental bodies to implement programs of waste management—indirectly, through financial devices, such as effluent charges, subsidies to waste generators, and grants; or, if necessary, directly, wherever such programs are found to be essential and not otherwise initiated or not adequately performed**

governmental restructuring is needed. Some of these activities are already being carried out to some degree by various agencies at the different levels of government—federal, state, interstate, county, local.

Two major questions to be investigated in the study are (1) the extent to which the various relevant activities should be performed by a single overall regional agency, and (2) the extent to which activities relating to all three forms of wastes should be organizationally combined. Several reasons for allocation of activities to regional and sub-regional levels have already been suggested. With respect to the second question, there are advantages and disadvantages in combining management of all three forms of wastes in a single organization. Among the advantages would be the efficiency of continuous planning for integrated waste management systems, and the efficiency in use of resources required for management. Further, the agency would be of sufficient importance to obtain high-level executive participation from the state governments involved. If there were three separate regional agencies, one for each form of waste, high-level participation would be less likely. If all three forms of wastes were under the jurisdiction of one regional policy-making agency, it would probably function more efficiently if not encumbered with day-to-day administrative responsibilities. However, excessive centralization of administrative functions might make for more problems than it would solve.

There is at least one more important problem to be considered. Water quality management is but one component of overall water resources management.[1] Efficient water quality management cannot be achieved without consideration of the other products and services resulting from the management of water resources —water supply, hydroelectric power, water-based recreation, and so on. As noted in the previous chapters, policies which affect water intake have significant effects on waste discharges. Similarly, regulations imposed on liquid waste discharges have important effects on water intake. The direct and obvious interrelationships between intake water and liquid wastes appear to be much stronger than the relationships between liquid and solid wastes or liquid and gaseous wastes. If all three forms of wastes were under the jurisdiction of a single agency, how would that agency relate to the overall water resources agency? Questions of this sort need careful and explicit consideration in a study of governmental organization.

There are many policy decisions and value judgments involved in waste management and environmental quality which require political determination. But much of the information on which such decisions are made should come from highly professional, scientific, and technical studies. Regardless of how qualified the personnel of a waste management agency may be, the agency still must be subject directly or indirectly to the wishes of the electorate and to judicial review for the protection of individual rights. This means that, for administrative purposes, it must be responsible to the elected chief executive; for major fiscal, budgetary, and policy determinations, it must be under the control of the legislative arm; and for the protection of human and property rights through due process of law, it must be subject to judicial review. These considerations further emphasize the need for a wide-ranging study of governmental organization for waste management. The profusion and overlapping of governmental bodies and levels in the New York Region will make analysis of political structure quite difficult.

The evolution of the Delaware River Basin Commission illustrates at least two of the problems in rationalizing governmental organization. The first relates to the scope of management responsibility; the second to the area of jurisdiction.

Traditionally, governmental agencies dealing with environmental problems were established in response to particular problems of importance at a given point in time, such as mosquito abatement districts and land drainage districts. Although water quantity and quality are physically inseparable, it is not likely that the entire range of water problems—water quality, drought, flood damage, etc.—will impinge simultaneously on the public consciousness. Given the basic interrelationships among various water problems, the political issue is to design an agency which can "handle" evolving interrelated problems. This was done in the case of the Delaware River Basin Commission.

The second problem—areal jurisdiction—was also of major importance in the case of the Delaware Commission. For years, almost as a legend, the river basin or watershed has been tacitly accepted as a "logical" area for water resources management. Yet the watershed may not have any fixed relationship to the areas

[1]This point is explored in Allen V. Kneese and Blair T. Bower, **Managing Water Quality,** to be published by Resources for the Future.

in which demands will arise for the outputs of water and water-related products and services, e.g., water-based recreation opportunities and electric energy. In the Delaware Basin there are major extra-basin demands for water for municipal and industrial use, both in New York City and northeastern New Jersey. It is not logical to make all of these demands "internal" to the management system. Similarly, on the supply side, there are potentially important relationships between water in the Basin and groundwater in the coastal plain of New Jersey. Here again, compromise is appropriate with respect to the extent to which all potential sources of water are under the jurisdiction of a single agency.

The problem of areal jurisdiction becomes far more complicated when dealing with the three forms of wastes. The drainage basin is the typical, but not necessarily the only, unit for handling liquid wastes. But the boundaries of an "airshed" seldom, if ever, coincide with the boundaries of a drainage basin. The boundaries of a solid waste handling system might be defined in terms of the economically feasible transport distance, just as the power market areas of electric utility systems were defined by the economic transmission distance. Of course, both economic solid waste transport and economic transmission distances will change with changing technology.[2] It may be that the costs and administrative problems of collection, not the economic transport distance, will determine the logical areal scope of agency jurisdiction. In either case, the boundaries are not likely to coincide with the watershed or the airshed boundaries.

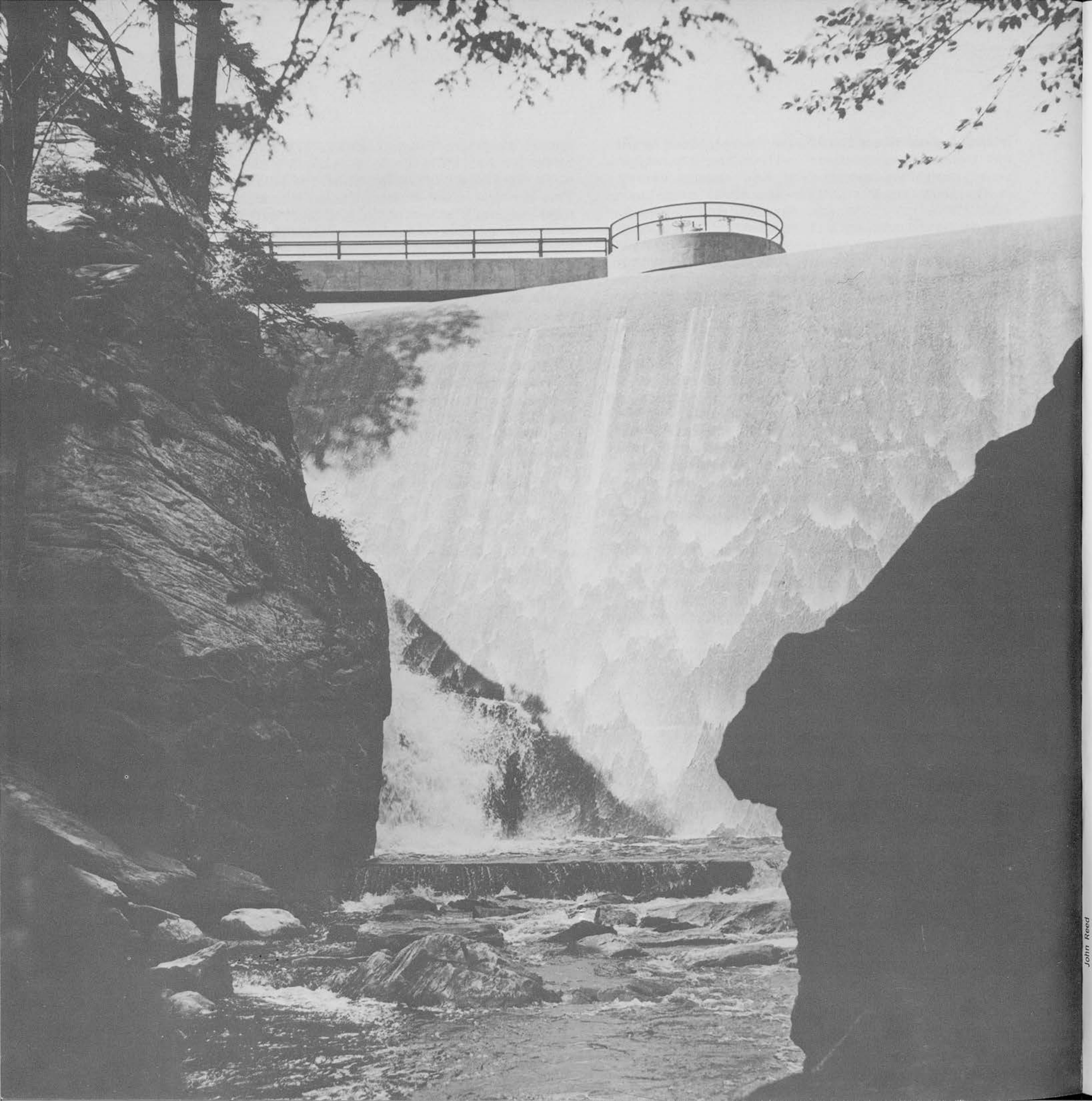
The enactment of the Mid-Atlantic States Air Pollution Control Compact reflects a recognition of the territorial and intergovernmental character of the air quality problem. The compact bestows considerable powers with respect to air quality control on the Commission provided for in the compact. It represents a significant improvement in governmental organization at the regional level. However, it does not allocate to the Commission any functions in regard to the other two forms of wastes. Inclusion of those two forms should be preceded by the study recommended here. This will provide criteria and a rationale for governmental restructuring, if needed. In contrast to the Mid-Atlantic Compact, Mayor Lindsay's new Environmental Protection Administration, recently approved by the New York City Council, does place the handling of all three forms of wastes under one administration. This includes solid waste disposal (including street cleaning), maintenance of the quality of water supplies and water courses (along with actual water supply and distribution), and the management of air quality.

Even without the extensive analysis contemplated in the proposed study of governmental organization for waste management in the Region, these two steps appear to be in the right direction. They are not, however, answers to how the functions and powers listed in Table 19 should be organized and allocated among different agencies and levels of government. Nor do these new measures provide for means of dealing directly with the generation of wastes, which is the primary cause of environmental quality deterioration. Rather, they are geared to the handling of wastes after they are generated.



Water from this stream in Ulster County, near Sundown, New York, flows to New York City via Rondout Reservoir and the Delaware Aqueduct. This use of Delaware Basin water by New York City illustrates the complex relationships in water resources management, particularly with respect to the Delaware River Basin.

[2]Generally, the boundaries will expand with time; that is, improved technology will reduce costs of transportation. On the other hand, it is conceivable that technological developments with respect to on-site, self-contained waste handling systems could result in contraction of the relevant management area.



John Reed

# 7. SUMMARY AND SUGGESTIONS

We have discussed waste generation and waste management in relation to environmental quality and how they may be analyzed within the context of regional planning. The procedure begins with basic economic data developed in the planning process. These data include alternative assumptions about the future level and distribution of population and economic activities. These estimates, along with sets of assumptions that we have called "waste generation conditions," are then translated into quantities of wastes generated. The waste generation conditions reflect such factors as alternative policy decisions by governmental agencies, technological changes, and consumer behavior as reflected in product mixes. The residual wastes discharged to the air, water, and land are then estimated, based on sets of assumptions about "waste management conditions." Governmental policy decisions are important components of both the generation conditions and management conditions. Since the residual wastes discharged depend on the management conditions assumed, the costs of waste management are determined at the same time as waste quantities.

Given the location, magnitude, and time patterns of residual wastes discharged, the impact of such discharges on the time and spatial patterns of air, land, and water quality can be determined, provided that the necessary relationships between discharges and quality have been developed. Models of these relationships for air and water are not now available for the New York Region or its sub-areas. If the time and spatial patterns of concentrations of wastes in the environment are known, then effects on human beings and on plant and animal life can theoretically be determined. But the lack of definitive knowledge about the relationships between quality and effects prevents determination of all the possible ramifications, particularly the economic ones.

This lack of knowledge precludes comparison of damages from quality deterioration with costs of quality improvement in order to determine the economically efficient allocation of resources for waste management. Because some of the benefits associated with environmental quality are as yet undefinable in economic terms, decisions concerning the degree of quality to be achieved, which are political decisions, can be made only by deciding whether additional improvements of quality are worth the additional costs necessary to achieve them.

Several sets of waste generation and waste management conditions were analyzed. Some of the important general conclusions derived from these analyses are as follows: First, the contrasting quantities of wastes generated under the different generation conditions emphasize the crucial nature of the assumptions made about factors influencing waste generation. Second, the magnitude and distribution of residual waste discharges are primarily affected by the waste management conditions and secondarily by the pattern of economic activities. Third, waste management costs are sensitive to the combination of activity location and assumptions made concerning the methods of waste handling and disposal. Fourth, waste management policies adopted at one point in time, oriented toward what is a major contributor to the total residual discharge of a particular waste, may become economically irrational with expansion and change of the economy. Fifth, in general, waste management costs are affected more by assumptions about waste generation than by assumptions about methods of waste handling and the location of economic activities.

## What next?

A part of our assignment was to point out areas of data deficiency relating to waste generation, waste management, and environmental quality in the New York Region. But this did not require a systematic assessment of these deficiencies or detailed definitions of studies necessary to provide adequate data for decisions on efficient waste management vis-a-vis environmental quality, or the establishment of priorities among them. However, as indicated in Chapter 6, we think that high priority should be attached to a study of governmental organization for waste management in the Region.

The remainder of this chapter consists of some observations and suggestions relevant to the continuous appraisal of environmental quality and waste management in the Region. We divide these comments and suggestions roughly into two categories—short-run and long-run. This categorization does not necessarily reflect a time factor, since some of the studies to be dis-

John Reed

cussed as long-run are already underway or should be started immediately. The orientation of this report is that those items included as short-run could be thought of as building directly on, or as extensions of, the analyses included herein. The long-run suggestions are conceived of in terms of developing data needed for rational decision-making with respect to waste management and environmental quality, and/or reflect possible developments of potential relevance to the overall waste problem. Some of the activities discussed below were included in Table 19.

## Short-run suggestions

1. Refine the analyses of waste management costs. This has at least several facets.

a. Analyze various waste generation-waste management conditions in terms of time streams of costs, rather than for a single year. Costs for waste handling and disposal are likely to be affected significantly in considering the dynamic case instead of the static case; for example, the mix of capital intensive and operating intensive facilities. Analyzing a period of 30 or 40 years would permit an assessment of the impact of varying assimilative capacity on waste management costs. In addition, the solid waste accumulation problem would be set in a more realistic context.

b. Include waste collection costs as components of waste management systems. These costs are sensitive to population and activity distributions and to the methods and locations of waste disposal. The costs of collecting solid wastes represent from 50 percent to 90 percent of the total costs of solid waste handling and disposal in a community. The unit cost of conveying sewage for a two-million gallons per day system is less than 50 percent of the unit cost for a one-million gallons per day system.[1]

The universal use of garbage grinders should be considered. Although garbage is only about 10 percent of residential solid wastes, by weight, it is the portion most attractive to insects and rodents. The elimination of garbage to be collected would reduce solid waste handling and disposal costs in more than direct proportion to its dry weight. Disposal of 100 percent of garbage from residential solid wastes by grinding, with subsequent carriage in sewer systems, would permit changes in practices of on-site storage of solid wastes and permit less frequent waste collection. This could significantly affect the costs of solid waste handling. For example, a reduction from twice- to once-a-week solid waste collection in an urban area like Philadelphia would decrease collection costs by between 25 percent and 35 percent.

Of course, such a change in collection practices would have other impacts, primarily on liquid waste collection and handling. Even assuming that the capacity of the existing sewer system were sufficient to handle the increased volume of discharge, the BOD and suspended solids received at the waste treatment facilities would be increased significantly. Decreased costs of solid waste collection must be compared with increased costs of liquid waste handling.[2] Included in the cost of the "liquid" system is the additional water intake necessary to flush the ground garbage through the sewer system. If garbage grinding were universally adopted, it would emphasize the need for developing water reclamation and renovation systems in order to minimize overall water supply-liquid waste handling and disposal costs.

c. Analyze additional waste management conditions, particularly with respect to disposal methods. For each waste management condition specified in this report, it was assumed that the same methods would be applied throughout the Study Area. Actually, this is unlikely. There will be different methods and combinations of methods in different sub-areas of the Region. For example, the Core and Inner Ring might incinerate combustible solid wastes and dispose of the residue by landfill within the Inner Ring, or out of the Inner Ring but in the Region, or out of the Region altogether; meanwhile, the rest of the Region might use sanitary landfill. Another combination would involve transporting all solid wastes, unmodified, out of the Core, while incinerating combustible wastes in the Inner and Intermediate Rings, with the residue going to landfills, and operating sanitary landfills in the Outer Ring.

2. Inventory the areas and spaces available for land disposal of solid wastes within the Region. This inventory should include not only details on the quantity of space available at each location, but also details on the amenability of the specific areas to contouring

[1] D. A. Okun, "Tomorrow's Methods To Provide Tomorrow's Service," **Journal of the American Water Works Association,** LVIII, No. 8 (1966), p. 943.

[2] For an example of such a comparison see C. M. Clark **et al.,** "Home Disposers versus Surface Collection—Comparative Cost Analysis," **Water and Wastes Engineering,** III, No. 9 (1966), pp. 78-80.

and the costs necessary to prevent decline in water quality. The inventory should be made in relation to the generation of solid wastes by sub-areas and should include any legal restrictions which may exist on the use of sites. Data are currently available with respect to a number of presently used disposal sites, such as the Hackensack Meadows, Fresh Kills on Staten Island, other sites in New York City, and Croton Point in Westchester County. Some additional data are available from local health department reports on sanitary landfill inspections which occasionally indicate space available at the sites. However, a more systematic inventory is needed before detailed solid waste management systems can be proposed and evaluated.[3]

3. Delineate the functional relationships required for, and the policy issues involved in, the application of the analysis of waste generation, waste management, and environmental quality outlined in this report. Data necessary for the analysis have been mentioned; e.g., relationships between unit capital cost and incinerator capacity, between unit operating cost of landfills and size of landfill (scale of operation), and between degree of particulate removal achieved and cost of wet scrubbers. A systematic listing of these relationships would expose the data gaps and provide a basis for determining study priorities. Similarly, indication of where policy decisions are involved in the analysis of waste generation, waste management, and environmental quality would make it possible for subsequent efforts to provide information which would illuminate these policy issues.

4. Show how studies by other agencies can be incorporated in subsequent analyses of waste generation, waste management, and environmental quality in the Region. Although we did not attempt to survey the many studies under way by such agencies as the Hudson River Valley Commission, the U.S. Army Corps of Engineers, the Federal Water Pollution Control Administration, the National Center for Air Pollution, and various state and local agencies, we are cognizant of the considerable work in progress. There should be a systematic categorization and evaluation of these studies' findings and how they would fit into the approach suggested here.

5. Assess administrative costs of waste management in relation to (a) quality monitoring systems for air, water, and land; and (b) the methods used for waste handling and disposal. These are interrelated, since the administrative costs of a waste management system vary depending upon the methods used for disposal and on the type(s) of controls imposed on waste discharges. For example, less frequent inspections are needed for landfills which are used for incinerator residue disposal than for those which are used for untreated solid wastes. Or, if all solid wastes were handled at large central incinerators, the inspection needs would be considerably less than for a system which permitted the use of many small, on-site incinerators. Similarly, frequency of inspections of gaseous waste emissions would depend on the concentration of the generating activities.

Administrative costs also vary with the type of waste control system used. For example, uniform controls could be applied on every waste generator throughout the area. These could be applied with little or no data on ambient air quality. On the other hand, utilization of selective, noncontinuous controls and/or effluent charges would perhaps require more extensive air quality monitoring and forecasting. At the same time, however, the investment costs required to achieve desired air quality levels would be considerably less than with the uniform, continuous controls. Thus, the assessment of administrative costs of quality monitoring is necessary to make possible the comparative analyses which are essential to rational decision-making for waste management.

## Long-run suggestions

1. Collect data for waste generation coefficients, especially for solid and gaseous wastes. These coefficients should incorporate both quantity and quality and be based on information about the factors which influence the coefficients.

The most serious data deficiency is for solid waste coefficients, although the data for gaseous wastes are little better. The only reasonably accurate information on solid waste generation was provided by the New York City Sanitation Department, and that only for residential solid wastes. No specific information could be obtained from industry sources on solid waste generation. Although New York, New Jersey, and Connecticut are currently conducting solid waste surveys

[3]The importance of a systematic inventory is pointed up by the reported comment of the Suffolk County Executive concerning the plan to dump New York City garbage in Suffolk County, as follows: "Over my . . . dead body." See **Water Newsletter**, IX, No. 15 (1967), p. 2.

under programs financed by the U.S. Public Health Service, these state studies are unlikely to provide data on the magnitude and characteristics of solid waste generation by major industries. Hence, data collection should be undertaken to determine solid waste generation coefficients for at least the following major industries in the Region: (a) petrochemical; (b) plastics, rubber, synthetics, and similar materials; (c) apparel; (d) printing and publishing; (e) pharmaceutical; and (f) aircraft parts. Similar generation coefficients should be obtained for office, retail, and commercial establishments.

A similar data collection effort should be undertaken with respect to gaseous waste generation coefficients for the major generators in the area.

Currently, more information is available for liquid wastes than for solid and gaseous wastes, and more detailed analysis of the factors influencing liquid wastes has been done. Nevertheless, data collection for liquid waste coefficients is still necessary.

Data collection will not be very useful unless it includes information on more than gross quantities of wastes which can be divided by some total numbers—people or production—to derive unit coefficients. It is essential that data collection produce information on the factors which influence waste generation and are the determinants of the coefficients. Only if these factors have been delineated in a reasonably adequate fashion will there be a basis for estimates of future coefficients.

2. Develop models of the impact of waste discharges on air, water, and land quality. Some work on such models is already underway through local, state, and federal auspices. But the major gap in data necessary for analysis of the waste management-environmental quality problem is the lack of models simulating the relationships between discharge quantities and environmental quality. Relationships between environmental quality and effects on people, plants, and animals also must be developed. These effects should be in terms of damage functions which relate the frequency, duration, and sequence of concentrations of various wastes in the environment to economic, physiological, and aesthetic damages. It is of particular importance to determine short-run loss functions, i.e., the damages during short-time periods of adverse conditions.

3. Determine if there are specific areas within the Region where it would be desirable to modify the topography in relation to proposed, potential, and desired land uses by landfill with solid wastes, either treated or untreated. Topographic modification reflects a more positive approach to landfilling than has been traditional in the past. For example, a hill is being constructed out of solid wastes by the city of Virginia Beach, Virginia. Upon completion, the 60-foot hill will be used as an amphitheater and as a coasting ramp. The result will be an attractive hill in a predominantly flat area.[4] Building islands for recreation, bird habitat, navigational aids, and so on, should be considered. A systematic assessment of the possibilities in the Region is desirable.

4. Investigate the applicability of effluent charges for encouraging reductions in waste generation and wastes discharged. Although effluent charges in the form of sewer surcharges have been applied to industrial wastes discharged to municipal sewer systems for about 50 years in the United States, only recently has attention been given to this device as a potential component of water quality management on a region-wide basis. Virtually no consideration has as yet been given to effluent charges as part of air quality management and solid waste management. It would be useful to study the imposition of a charge system in the Region as a whole, or in different sub-regions for all three forms of wastes.

5. Investigate the feasibility, costs, method of operation, and gains from selective, noncontinuous controls (of whatever type) on one or more forms of wastes, as opposed to uniform, continuous controls. The investment and operating costs for on-site and collective waste reduction facilities used with selective, noncontinuous controls, should be compared with the capital and operating costs with uniform, continuous controls. Differences in extent and cost of administration of the quality monitoring system also should be included.

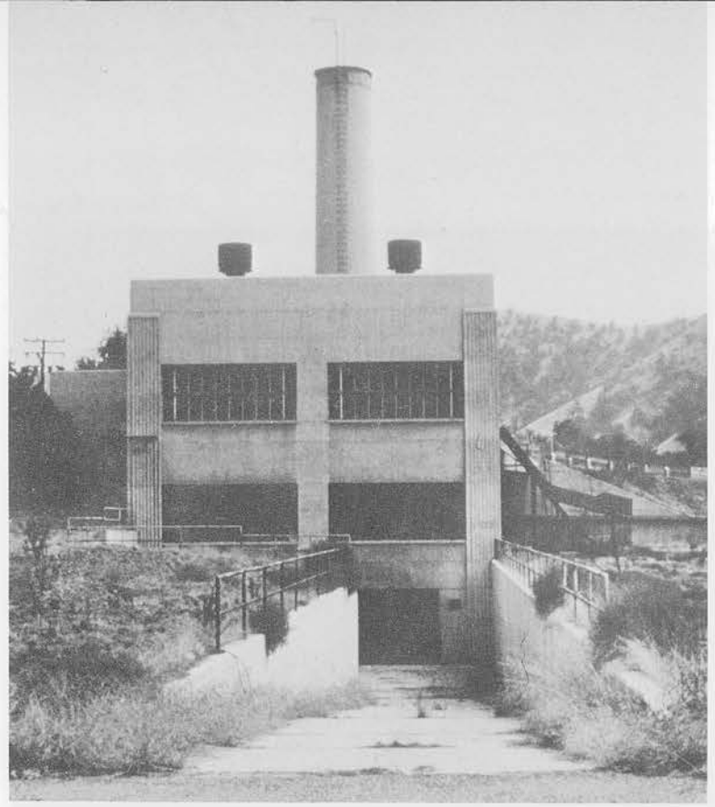
6. Investigate alternative methods of incineration. Because incineration is an important component of waste management, and because it may become even more important in the future since it functions to reduce the quantity of residual wastes for discharge or disposal, considerable effort could be spent on analyzing particular incineration procedures. At least, the results of current studies should be assessed for incorporation into any analyses of the future Regional

4See R. P. Lonergan and E. M. Herson, "Solid Waste . . . Natural Resource?" presented at Western Resources Conference, Boulder, Colorado (1967); and R. Stone, "Planning for Multi-Purpose Parks," **Public Works,** XCVIII, No. 5 (1967), pp. 78-80.

Louis B. Schlivek



Joining Swinburne Island (foreground) with Hoffman Island in Lower New York Bay by filling with treated and compacted solid wastes is under study by the New York City Sanitation Department. This is only one possible method of topographic modification.



This abandoned incinerator symbolizes many that were built throughout the U.S. during a period of enthusiasm for incineration in the 1930's. They are no longer in use because they are considered relatively inefficient—higher in cost than landfills and too productive of particulate matter. In all of New Jersey, of 38 incinerators in existence, only seven were operating at the end of 1967.

waste problem. Examples of incineration subjects for study, some of which are currently under investigation but perhaps will merit further work, are as follows:

a. Incineration at extremely high temperatures (over 3000°F) to reduce noncombustible wastes to a dense slag which could be used as construction material or as a better quality, less space-occupying fill than the residue from present incinerator operations.

b. Development and use of sophisticated dust collection equipment for incinerators, such as electrostatic precipitators, bag filters, and high draft-loss wet scrubbers.

c. Production of dry incinerator residue to reduce the weight of the material which must be transported to the final disposal area. Incinerator residue at the present time is almost universally quenched, which results in a moisture content of the residue of between 15 percent and 30 percent.

Two alternatives exist: (1) drying the incinerator residue before final transport; (2) handling the incinerator residue hot. Both are technically feasible. The latter requires special rail or barge equipment, which probably would have to be covered to limit absorption of moisture from the atmosphere and from precipitation during transit. The increased cost of equipment would be compared with the reduction in costs for transporting the residue.

d. Evaluation of incinerator residues to determine their potentially salvageable components, if any.

e. Assessment of the possibility of using solid wastes as fuel for the generation of energy or heat or both. Although solid wastes have a lower heat value than fuels now used, they contain less than one pound of sulphur per ton.

7. Investigate devices for stimulating increased recycling of wastes and the development of processes and product mixes which will result in fewer wastes. For example, more standardization of containers would reduce the variety of solid wastes, increase possibilities for reuse or recovery of materials, and simplify handling. Water soluble packaging materials which could be flushed into the sewer system would reduce the solid wastes to be handled. To date, the packaging industry has evinced little interest in this approach.

8. Investigate further the feasibility of disposal of wastes to the ocean. Dumping solid wastes at sea has a long history. However, in 1933 the United States Supreme Court upheld a ruling requiring that New York City cease the practice of dumping general solid wastes at sea.[5] This ruling, although it stopped the dumping of municipal wastes, did not stop the dumping of other solid wastes at sea. Currently, such different solid or liquid wastes as sewage sludge, chemicals, fly ash from power plants, and atomic wastes are being dumped into designated ocean areas under controlled conditions. This is occurring without any apparent detrimental effects.

Because of its virtually unlimited capacity and its proximity to the Region, the ocean should be considered for the disposal of at least some portion of the solid wastes of the area. More intensive investigation of the possible effects and problems connected with such a practice should be undertaken. Particularly important is assessment of various "pretreatment" practices, such as incineration, compaction, baling, and containerization.

9. Assess the feasibility and economics of new waste collection systems. The importance of waste collection costs in the total waste management picture has been emphasized at various points herein. Alternative methods which need to be assessed include on-site handling of all types of generated wastes, not merely a particular component such as garbage. Thus, solid

[5]New Jersey v. City of New York, 290 U.S. 237 (1933).

wastes generated on-site might be processed through grinders or hoggers to develop uniformity of material size which would improve the efficiency of handling and disposal. On-site refuse balers and shredders might be developed. All of these pre-transport treatments could be used with either water or pneumatic carriage. The latter may be too costly for consideration in congested areas, but it may be economically feasible for new developments and/or for large redevelopment sites. Two pneumatic installations already exist in Sweden and another is being considered for the Borough of Westminster in London.

10. Delineate the specific interrelationships among the various types of wastes in more detail and in a more quantitative fashion than was done in this report. Some of these interrelationships have been suggested; for instance, the relationships among the degree of particulate removal achieved, the quantity of water required for that removal, and the quantity of residual materials to be disposed of as solid wastes. Another type of interrelationship is that in which one type of waste is used to modify or help dispose of another type of waste. An example is the use of fly ash in disposal of sludge from liquid waste treatment.[6]

11. Finally, the ultimate solution of the waste problem would be the development of an on-site system which would handle all types of wastes, maximize recycling, minimize residue, and dispose of the residue on-site. This would be the equivalent of the astronaut in his capsule. It is conceivable that this could be approached or achieved at some time in the future, if it were considered in conjunction with changes in production processes and with products and their containers.

In no sense should the foregoing list of relevant topics be considered inclusive. The objective of making the list is to indicate the kinds of problems and considerations which are relevant to an analysis of waste management and environmental quality in the context of regional planning.

[6]F. W. Moehle, "Fly Ash Aids in Sludge Disposal," **Environmental Science and Technology,** I, No. 5 (1967), pp. 374-379.

Sludge from sewage plants has been dumped into the Atlantic Ocean by New York City for many years by vessels such as the Tallman's Island sludge boat with no deleterious consequences for flora or fauna. The possibility of disposing of other solid wastes at sea is worth further study.



New York City Department of Public Works

# APPENDIX

## 1. WASTE MANAGEMENT COSTS

As indicated in the body of the report, waste management costs are sensitive to assumptions and policy decisions with respect to (1) waste generation, as reflected in unit generation coefficients; (2) spatial distribution of population and economic activities; and (3) methods of waste handling and disposal. The quantities and locations of residual wastes discharged into the environment are a function of the same factors. The following analyses of management alternatives for solid wastes were selected to illustrate the interrelationships involved.

Liquid and gaseous wastes could just as well have been used for illustration. However, the differences in costs may not be as great as for solid wastes. This is because the difference between handling all solid wastes by incineration and by barging to sea is probably greater than, for example, the difference between handling liquid wastes in trickling filter plants and in activated sludge plants.

1. The effects of recycling waste paper are shown in Table A-1. Costs are 50 percent higher and particulate emissions 67 percent higher when no waste paper is recycled than when 80 percent is recycled.

2. The effects of alternative spatial patterns of economic activities on management costs, particulate emissions, and space requirements within the Region are shown in Table A-2. Costs of solid waste disposal for the Region as a whole are about the same for all three variants, as are total emissions and total space requirements. However, all three vary significantly within the Region. (An implicit assumption is that the solid wastes are disposed of within the Ring where they are generated. In this respect, Manhattan CBD and Rest of Core are considered together.)

3. Waste management costs and residual discharges are sensitive to policy decisions regarding methods of waste handling. For example, for Variant I, the least-cost system results from Management Condition 1a, in which no waste paper is recycled under all management systems. MC/1a, however, assumes that space for disposal will be available within the Region by sub-area, roughly in proportion to the wastes generated by sub-area. It is unlikely that such a distribution of space will be available in 2000, considering accumulation over the time period involved. Of course, space could be "manufactured" by topographic modification, but this would add significantly to the costs.

TABLE A-1

**EFFECT OF RECYCLING ON WASTE MANAGEMENT (Generation Condition X — Variant I)**

| Management Condition 1a — Solid Wastes | Costs million dollars | Particulate Emissions thousand tons | Space Required thousand acre-feet | Water Intake billion gallons |
|---|---|---|---|---|
| Manhattan CBD | 15.0 | 2.9 | 7.0 | 1.8 |
| Rest of Core | 42.5 | 8.1 | 19.9 | 5.1 |
| Inner Ring | 36.1 | 6.9 | 16.9 | 4.3 |
| Intermediate Ring | 47.3 | 9.0 | 22.1 | 5.7 |
| Outer Ring | 20.3 | 3.9 | 9.5 | 2.4 |
| **Totals** (rounded) | **160** | **31** | **75** | **19** |
| **Management Condition 1c — Solid Wastes** | | | | |
| Manhattan CBD | 9.9 | 1.7 | 4.4 | 0.7 |
| Rest of Core | 28.1 | 4.9 | 12.5 | 1.9 |
| Inner Ring | 23.8 | 4.1 | 10.6 | 1.6 |
| Intermediate Ring | 31.2 | 5.4 | 13.9 | 2.0 |
| Outer Ring | 13.4 | 2.3 | 6.0 | 0.9 |
| **Totals** (rounded) | **105** | **18** | **47** | **7** |

**Note:** For Tables A-1 through A-5, the figures shown are totals for the year 2000; e.g. total particulate emissions for the year. The generation conditions are defined in Chapter 4, and the management conditions in Chapter 5 (See, in particular, Table 14). The variants are discussed in Chapter 3 and defined in greater detail in Section 2 of the Appendix, beginning on page 86.

TABLE A-2

**EFFECT OF SPATIAL ARRANGEMENT ON WASTE MANAGEMENT (Generation Condition X — Management Condition 1b) — Solid Wastes**

| VARIANT I | Costs million dollars | Particulate Emissions thousand tons | Space Required thousand acre-feet | Water Intake billion gallons |
|---|---|---|---|---|
| Manhattan CBD | 13.6 | 2.6 | 6.4 | 1.5 |
| Rest of Core | 38.7 | 7.3 | 18.1 | 4.1 |
| Inner Ring | 32.8 | 6.2 | 15.4 | 3.5 |
| Intermediate Ring | 42.9 | 8.1 | 20.0 | 4.6 |
| Outer Ring | 18.4 | 3.5 | 8.6 | 2.0 |
| **Totals** (rounded) | **145** | **28** | **68** | **16** |
| **VARIANT II** | | | | |
| Manhattan CBD | 12.2 | 2.3 | 5.7 | 1.3 |
| Rest of Core | 33.2 | 6.3 | 15.5 | 3.6 |
| Inner Ring | 27.2 | 5.2 | 12.7 | 2.9 |
| Intermediate Ring | 52.3 | 9.9 | 22.4 | 5.6 |
| Outer Ring | 21.5 | 4.1 | 10.1 | 2.3 |
| **Totals** (rounded) | **145** | **28** | **66** | **16** |
| **VARIANT III** | | | | |
| Manhattan CBD | 15.9 | 3.0 | 7.4 | 1.7 |
| Rest of Core | 46.5 | 8.8 | 21.6 | 5.0 |
| Inner Ring | 47.5 | 9.0 | 22.2 | 5.1 |
| Intermediate Ring | 28.2 | 5.5 | 13.7 | 3.1 |
| Outer Ring | 9.3 | 1.8 | 4.4 | 1.0 |
| **Totals** (rounded) | **145** | **28** | **69** | **16** |

TABLE A-3

EFFECT OF MANAGEMENT POLICIES ON WASTE MANAGEMENT
(Generation Condition X — Variant I)

| Management Condition 1a — Solid Wastes | Costs million dollars | Particulate Emissions thousand tons | Space Required thousand acre-feet | Water Intake billion gallons |
|---|---|---|---|---|
| Manhattan CBD | 15.0 | 2.9 | 7.0 | 1.8 |
| Rest of Core | 42.5 | 8.1 | 19.9 | 5.1 |
| Inner Ring | 36.1 | 6.9 | 16.9 | 4.3 |
| Intermediate Ring | 47.3 | 9.0 | 22.1 | 5.7 |
| Outer Ring | 20.3 | 3.9 | 9.5 | 2.4 |
| **Totals** (rounded) | **160** | **31** | **75** | **19** |
| **Management Condition 3 — Solid Wastes** | | | | |
| Manhattan CBD | 45.7 | 10.6 | 0 | 5.3 |
| Rest of Core | 130.0 | 30.0 | 0 | 15.0 |
| Inner Ring | 110.2 | 25.4 | 0 | 12.7 |
| Intermediate Ring | 144.1 | 33.2 | 0 | 16.6 |
| Outer Ring | 62.0 | 14.3 | 0 | 7.2 |
| **Totals** (rounded) | **490** | **114** | **0** | **57** |
| **Management Condition 4 — Solid Wastes** | | | | |
| Manhattan CBD | 27.2 | 0 | 0 | 0 |
| Rest of Core | 77.5 | 0 | 0 | 0 |
| Inner Ring | 65.6 | 0 | 0 | 0 |
| Intermediate Ring | 85.9 | 0 | 0 | 0 |
| Outer Ring | 36.9 | 0 | 0 | 0 |
| **Totals** (rounded) | **295** | **0** | **0** | **0** |

TABLE A-4

EFFECT OF SPATIAL ARRANGEMENT ON COSTS[1]
(Generation Condition X)

| Management Condition 4 — Solid Wastes Variant I | Costs million dollars | Particulate Emissions thousand tons | Space Required thousand acre-feet | Water Intake billion gallons |
|---|---|---|---|---|
| Manhattan CBD | 27.2 | 0 | 0 | 0 |
| Rest of Core | 77.5 | 0 | 0 | 0 |
| Inner Ring | 65.6 | 0 | 0 | 0 |
| Intermediate Ring | 85.9 | 0 | 0 | 0 |
| Outer Ring | 36.9 | 0 | 0 | 0 |
| **Totals** (rounded) | **295** | **0** | **0** | **0** |
| **Management Condition 3 —Solid Wastes Variant III** | | | | |
| Manhattan CBD | 32.0 | 0 | 0 | 0 |
| Rest of Core | 93.6 | 0 | 0 | 0 |
| Inner Ring | 95.7 | 0 | 0 | 0 |
| Intermediate Ring | 59.0 | 0 | 0 | 0 |
| Outer Ring | 18.9 | 0 | 0 | 0 |
| **Totals** (rounded) | **300** | **0** | **0** | **0** |

[1]Using disposal outside the Region.

Table A-3 shows the costs, emissions, and space requirements under three alternative management systems.

Not only is MC/1a the least costly, it also results in fewer emissions than MC/3, in which all wastes are incinerated before disposal. On the other hand, no space is required within the Region for MC/3. But this in turn presents political problems. Political jurisdictions outside the Region may be unwilling to permit disposal of the Region's solid wastes within their jurisdictions.

4. The spatial pattern of population and economic activities affects the cost of handling and disposing of solid wastes. Suppose, for the dual objectives of minimizing residual particulates discharged to the air and minimizing space required for disposal within the Region, the decision was made to prohibit all incineration within the Region and to dispose of all solid wastes either by rail transfer to landfill outside the Region or by barging to disposal areas at sea. Despite the sketchy nature of cost data for these methods it is obvious that, for each method, a different spatial pattern will result in the least cost to the Region. This is shown in Table A-4, where Variant I yields the minimum cost for rail transfer and Variant III for barging to sea, the latter because of the concentration of population and economic activities in and near the Core.

5. Suppose the objective is to minimize the space required for disposal of solid wastes within the Region, with neither transfer out of the Region nor dumping at sea permitted. To minimize residual discharge to the land, all wastes should first be incinerated. Variant II will result in minimum space requirements and minimum costs, the latter because of reduced hauling costs stemming from the dispersion of population and economic activities. In addition, costs, residual gaseous wastes (particulates) discharged to the air, and space requirements would be cut approximately in half if incentives, regulations, controls, and technological changes resulted in maintenance of the present per capita level of solid waste generation, i.e., Generation Condition Y instead of Generation Condition X. Table A-5 shows these results.

TABLE A-5

EFFECT OF GENERATION CONDITIONS ON WASTE MANAGEMENT
(Management Condition 2 — Solid Wastes — Variant II)

| Generation Condition X | Costs million dollars | Particulate Emissions thousand tons | Space Required thousand acre-feet | Water Intake billion gallons |
|---|---|---|---|---|
| Manhattan CBD | 34.3 | 9.4 | 1.5 | 4.7 |
| Rest of Core | 93.8 | 25.8 | 4.0 | 12.9 |
| Inner Ring | 77.0 | 21.1 | 3.3 | 10.6 |
| Intermediate Ring | 147.6 | 40.5 | 6.3 | 20.2 |
| Outer Ring | 60.7 | 16.7 | 2.6 | 8.3 |
| **Totals** (rounded) | **415** | **114** | **18** | **57** |
| **Generation Condition Y** | | | | |
| Manhattan CBD | 17.2 | 4.7 | 0.7 | 2.4 |
| Rest of Core | 46.9 | 12.9 | 2.0 | 6.5 |
| Inner Ring | 38.5 | 10.5 | 1.6 | 5.3 |
| Intermediate Ring | 73.8 | 20.2 | 3.1 | 10.1 |
| Outer Ring | 30.4 | 8.3 | 1.3 | 4.2 |
| **Totals** (rounded) | **205** | **57** | **9** | **28** |

**Note:** Details on the computations for the above analyses are contained in the following tables and accompanying discussion.

## Management Condition 1—Solid Wastes: Explanations and Supporting Data

1. MC/1a assumes that 0 percent of all paper in solid wastes is reclaimed.

2. MC/1b assumes that 20 percent of all paper is reclaimed. Based upon current estimates that 45 percent to 55 percent of collected refuse is paper, it is assumed that 50 percent of refuse is paper. Therefore, 10 percent of all refuse would be reclaimed in MC/1b.

3. MC/1c assumes that 80 percent is reclaimed and, consequently, that 40 percent of all refuse is reclaimed.

4. Of the 17.4 million tons of solid wastes per year currently generated in the Region, disposal is apportioned approximately as follows: central or municipal incineration—26 percent; landfilling (including open burning)—62 percent; on-site incineration—6 percent; backyard burning—1 percent; paper salvage—2 percent; hog feeding—2 percent; teepee burning—1 percent. To meet the requirements of MC/1, it is assumed that all solid wastes are disposed of by central incineration, sanitary landfilling, and on-site incineration. The same relationship currently prevailing will be assumed, which results in the following apportionment: central incineration—28 percent; sanitary landfilling—66 percent; and on-site incineration—6 percent.

5. The total cost of incineration in large municipal incinerators varies from $4.00 to $10.00/ton. New York City reported a cost of $5.41/ton for 1965, including the cost of hauling residue to landfills or barges, but excluding the cost of plant amortization. Approximately $0.50/ton of this cost is attributable to residue handling. The operating costs for the City's newer plants are much lower than the average; however, amortization is higher. The present City installations do not meet the emission standards set by Local Law No. 14, passed in 1966. The cost of upgrading the plants to meet this code is estimated at 10 percent of total cost, or about $0.60/ton.

For MC/1a, it is estimated, therefore, that the total cost of municipal incineration capable of meeting the new standards would be $6.60/ton + $0.60/ton for hauling and disposal of residue. For MC/1b, it is assumed that the incineration cost would remain about the same, but more residue would be produced, increasing the costs of residue handling and disposal. The residue cost would be equal to the MC/1a residue cost, since there will be no change in the quantity of noncombustibles. For MC/1c, the cost of incineration will increase approximately 10 percent ton because of the decrease in combustibles, and the residue disposal

TABLE A-6

COMPUTATIONS OF SOLID WASTE COMPONENTS FOR MANAGEMENT CONDITION 1[1]
all values are quantities for the year 2000

| | | Total Solid Wastes thousand tons | Solid Wastes Reclaimed thousand tons | Solid Wastes Disposed thousand tons | Central Incineration thousand tons | Incineration Cost million dollars | Sanitary Landfill thousand tons | Sanitary Land Cost million dollars | On-site Incinerator thousand tons | On-site Incinerator Cost million dollars | Total Cost million dollars | Particulate Emissions thousand tons | Space Required million cubic yards | Water Required billion gallons | Space Required thousand acre-feet |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GC/X | MC/1a | 56,700 | – | 56,700 | 15,900 | 114.5 | 37,400 | 46.7 | 3,400 | 0.068 | 161.3 | 30.6 | 121.9 | 19.3 | 75.5 |
| VARIANT I | MC/1b | 56,700 | 5,700[2] | 51,000 | 14,300 | 104.0 | 33,600 | 42.0 | 3,100 | 0.062 | 146.1 | 27.7 | 110.5 | 15.7 | 68.5 |
| | MC/1c | 56,700 | 22,700[3] | 34,000 | 9,600 | 79.4 | 22,400 | 27.0 | 2,000 | 0.040 | 106.4 | 18.4 | 76.8 | 7.0 | 47.5 |
| GC/Y | MC/1a | 28,400 | – | 28,400 | 8,000 | 57.5 | 18,700 | 23.4 | 1,700 | 0.034 | 80.9 | 15.4 | 60.9 | 9.7 | 37.7 |
| VARIANT I | MC/1b | 28,400 | 2,800 | 25,600 | 7,200 | 52.4 | 16,900 | 21.1 | 1,500 | 0.030 | 73.5 | 13.8 | 55.3 | 7.8 | 34.2 |
| | MC/1c | 28,400 | 11,400 | 17,000 | 4,800 | 39.6 | 11,200 | 14.0 | 1,000 | 0.020 | 53.6 | 9.2 | 38.4 | 3.5 | 23.8 |
| GC/X | MC/1a | 56,800 | – | 56,800 | 15,900 | 114.5 | 37,500 | 46.9 | 3,400 | 0.068 | 161.5 | 30.6 | 122.0 | 19.3 | 75.5 |
| VARIANT II | MC/1b | 56,800 | 5,700 | 51,100 | 14,300 | 104.0 | 33,700 | 42.1 | 3,100 | 0.062 | 146.2 | 27.7 | 111.0 | 15.7 | 68.5 |
| | MC/1c | 56,800 | 22,700 | 34,100 | 9,600 | 79.4 | 22,500 | 27.1 | 2,000 | 0.040 | 106.5 | 18.4 | 77.0 | 7.0 | 47.5 |
| GC/Y | MC/1a | 28,400 | – | 28,400 | 8,000 | 57.5 | 18,700 | 23.4 | 1,700 | 0.034 | 80.9 | 15.4 | 60.9 | 9.7 | 37.7 |
| VARIANT II | MC/1b | 28,400 | 2,800 | 25,600 | 7,200 | 52.4 | 16,900 | 21.4 | 1,500 | 0.030 | 73.8 | 13.8 | 55.3 | 7.8 | 34.2 |
| | MC/1c | 28,400 | 11,400 | 17,000 | 4,800 | 39.6 | 11,200 | 14.0 | 1,000 | 0.020 | 53.6 | 9.2 | 38.4 | 3.5 | 23.8 |
| GC/X | MC/1a | 57,400 | – | 57,400 | 16,200 | 116.8 | 37,800 | 47.3 | 3,400 | 0.068 | 164.2 | 31.0 | 123.0 | 19.6 | 76.3 |
| VARIANT III | MC/1b | 57,400 | 5,700 | 51,700 | 14,500 | 105.4 | 34,100 | 47.6 | 3,100 | 0.062 | 148.1 | 28.0 | 112.1 | 15.8 | 69.5 |
| | MC/1c | 57,400 | 23,000 | 34,400 | 9,600 | 79.4 | 22,700 | 28.4 | 2,100 | 0.042 | 107.8 | 18.6 | 77.9 | 7.0 | 48.1 |
| GC/Y | MC/1a | 28,700 | – | 28,700 | 8,000 | 57.5 | 18,900 | 23.6 | 1,700 | 0.034 | 81.1 | 15.4 | 61.5 | 9.7 | 38.1 |
| VARIANT III | MC/1b | 28,700 | 2,900 | 25,800 | 7,300 | 53.0 | 17,000 | 21.2 | 1,500 | 0.030 | 74.2 | 14.0 | 55.9 | 7.9 | 34.6 |
| | MC/1c | 28,700 | 11,500 | 17,200 | 4,800 | 39.6 | 11,400 | 14.0 | 1,000 | 0.020 | 53.6 | 9.2 | 39.1 | 3.5 | 24.2 |

NOTE: 1a: 0 percent paper recycled
1b: 20 percent paper recycled
1c: 80 percent paper recycled

[1]Present disposal practices, except dust limitations, according to New York City Local Law No. 14; all landfilling in accord with good practices, no open burning; no hog feeding.
[2]See Management Condition 1, No. 2 p. 83.
[3]See Management Condition 1, No. 3 p. 83.

cost will be equal to the residue cost of MC/1a.

Therefore, incineration costs are as follows:

$$MC/1a = \$7.20/ton$$

$$MC/1b = \$6.60/ton + \frac{0.60}{0.9} = \$7.27/ton$$

$$MC/1c = \frac{\$6.60 \times 1.10}{ton} + \frac{.60}{0.6} = \$8.26/ton$$

6. Properly operated landfills vary in cost from $0.75/ton to $2.50/ton, depending upon such factors as the size of operation, availability of cover material, type of terrain, etc. An average operating cost, $1.25/ton, will be used in this evaluation. However, if expensive site preparation is required, as would be the case with waterfront property, the cost would be considerably higher. When comparing costs of sanitary landfilling and other disposal methods, the cost of hauling, whether by truck, trailer, barge, or rail, must be added to the landfill operating cost.

7. On-site incineration (apartment house and industrial) varies considerably in initial installation (capital) and operating costs. The costs of recent upgrading of NYC on-site installations averaged over $15,000 per apartment house plus anticipated auxiliary fuel costs. These data indicate on-site incineration costs of approximately $20.00/ton.

8. For purposes of computing particulate emissions, it is assumed that municipal incinerator furnace capacities are either 300 tons/day (TPD) or 12.5 tons/hr (TPH), and on-site furnaces are 500 lb/hr. Under NYC regulations, the permissable municipal incinerator emission rate is 38 lb/hr or 3 lb/ton of refuse incinerated. The permissable on-site rate is 1 lb/hr or 4 lb/ton of refuse.

9. Space requirements for sanitary landfill are based upon a compaction rate of 3 cu. yd/ton and a residue compaction factor of ½ cu. yd/ton of original refuse. However, residue contains essentially noncombustible refuse, and removal of paper in the salvage process will not reduce the amount of incinerator residue. Therefore, space requirements for MC/1b and MC/1c are computed as follows:

$$MC/1b, \text{ space} = \frac{0.5 \text{ cu. yd.}}{0.9} = 0.56 \text{ cu. yd/ton}$$

$$MC/1c, \text{ space} = \frac{0.5 \text{ cu. yd.}}{0.6} = 0.83 \text{ cu. yd/ton}$$

10. It is assumed that wet scrubbing devices will be used to control gaseous emissions and that 1,000 gal. of intake water will be needed for each ton of refuse burned under MC/1. Water intake for MC/1b and MC/1c will be less than for MC/1a because of the reduction in heat value in the refuse. Consequently, water intake for MC/1b will be 900 gal/ton, and for MC/1c 600 gal/ton.

TABLE A-7

**COMPUTATIONS OF SOLID WASTE COMPONENTS FOR MANAGEMENT CONDITION 2**
**all values are quantities for the year 2000**

| | | Total Solid Wastes thousand tons | Space Required million cubic yards | Incineration Cost million dollars | Landfill Cost million dollars | Total Cost million dollars | Particulate Emissions thousand tons | Space Required thousand acre-feet | Water Required billion gallons |
|---|---|---|---|---|---|---|---|---|---|
| Variant I | GC/X | 56,700 | 28.4 | 408 | 5.67 | 414 | 113.4 | 17.6 | 56.7 |
| Variant I | GC/Y | 28,400 | 14.2 | 204 | 2.84 | 207 | 56.7 | 8.8 | 28.4 |
| Variant II | GC/X | 56,800 | 28.4 | 408 | 5.68 | 414 | 113.4 | 17.6 | 56.8 |
| Variant II | GC/Y | 28,400 | 14.2 | 204 | 2.84 | 207 | 56.7 | 8.8 | 28.4 |
| Variant III | GC/X | 57,400 | 28.7 | 413 | 5.74 | 419 | 114.8 | 17.8 | 57.4 |
| Variant III | GC/Y | 28,700 | 14.4 | 207 | 2.87 | 210 | 57.4 | 8.9 | 28.7 |

## Management Condition 2—Solid Wastes: Explanations and Supporting Data

1. Residue from incineration of typical municipal refuse occupies ½ cu. yd. of space/ton of refuse incinerated after compaction and settlement in a landfill. The space occupied by the fly ash collected is not significant, even if all fly ash is included.

2. Incineration costs, including operation, maintenance, amortization, administration, and hauling of residue is estimated at $7.20/ton (See Management Condition 1, no. 5, p. 83).

3. Incinerator residue from a properly operated plant requires spreading and compaction at a landfill site, but other sanitary landfill activities, such as cover, litter control, etc. are not required. The cost of disposing of residue is approximately $0.10/ton of original refuse, based upon operating experience in Philadelphia.

4. Water intake is estimated at 1,000 gal/ton of refuse (See Management Condition 1, no. 10, p. 84).

## Management Condition 3—Solid Wastes: Explanation and Supporting Data

1. The ratio of refuse weight to uncompacted residue volume as reported by the cities of Hartford, Chicago, and Philadelphia is ¾ to 1 cu. yd. of residue for each ton of refuse incinerated. For this study, an average of ⅞ cu. yd. of residue/ton is assumed.

2. New York City reports a dry weight reduction of refuse incinerated of 26.6 percent. Other cities report wet residue weights of 1,100 to 1,200 lb/cu. yd., or, using the ⅞ cu. yd/ton relationship noted in No. 1 above, 1,000 lb. of wet residue/ton of refuse burned. However, residue would probably be drained before hauling by rail or barge and would weigh between 540 lb. (dry) and 1,000 lb. (wet)/ton of refuse. A reasonable average would be 750 lb. of residue/ton of refuse, which is used herein.

3. See Management Condition 2, No. 3, p. 84.

4. It is assumed that residue will be hauled by rail a one-way distance of 125 miles to a sanitary landfill. The New York Central Railroad has prepared a proposal for hauling refuse from Westchester County to landfill sites approximately 75 miles from the County. The unit haul cost for this operation, including the rail transfer station amortization and operating costs, averages $2.70/ton. To this should be added the cost of carrying the residue an additional 50 miles, which is estimated at $0.005/ton-mile. The haul cost is estimated at $2.95/ton of residue. Adding administrative charges estimated at 25 percent, the total cost is $3.68/ton.

5. The concept of barging and dumping incinerator residue at sea has not yet been accepted. However, studies at Harvard University indicate that this may be feasible, and the New York City barging operation is used as a basis for estimating the costs of this type of operation. New York currently barges refuse and residue from several barge transfer stations 20 to 30 miles to Staten Island. It is assumed that a trip of 75 miles will be required to barge residue to acceptable disposal areas at sea. The present NYC barging and landfilling operating cost is $3.10/ton, of which 28 percent or $0.87/ton is attributable to the transfer operation. Hauling costs average $45.43/1,000 ton-miles. For a 75-mile haul, this would be $3.40/ton. The total unit cost for barging 75 miles and dumping at sea would be $4.27/ton. It is conceivable that larger, less costly operations could be developed, or dump sites could be located closer to the shore, which could lower this cost significantly.

TABLE A-8

**COMPUTATIONS FOR SOLID WASTE COMPONENT FOR MANAGEMENT CONDITION 3**
all values are quantities for the year 2000

| | | Total Solid Waste thousand tons | Incineration Cost million dollars | Residue Volume thousand cubic yards | Residue Weight thousand tons | Landfill Cost million dollars | Rail Transfer Cost million dollars | Barging Cost to Sea million dollars | Total Cost Rail Trans. million dollars | Total Cost Barging million dollars | Particulate Emissions thousand tons | Space Required in Region thousand acre-feet | Water Required billion gallons |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variant I | GC/X | 56,700 | 408 | 49,600 | 21,200 | 5.67 | 78.0 | 90.6 | 492 | 499 | 113.4 | 0 | 56.7 |
| Variant I | GC/Y | 28,400 | 204 | 24,800 | 10,600 | 2.84 | 39.0 | 45.3 | 246 | 249 | 56.7 | 0 | 28.4 |
| Variant II | GC/X | 56,800 | 408 | 49,600 | 21,200 | 5.68 | 78.0 | 90.6 | 492 | 499 | 113.4 | 0 | 56.8 |
| Variant II | GC/Y | 28,400 | 204 | 24,800 | 10,600 | 2.84 | 39.0 | 45.6 | 246 | 249 | 56.7 | 0 | 28.4 |
| Variant III | GC/X | 57,400 | 413 | 50,200 | 21,600 | 5.74 | 79.5 | 92.3 | 499 | 505 | 114.8 | 0 | 57.4 |
| Variant III | GC/Y | 28,700 | 207 | 25,100 | 10,800 | 2.87 | 39.8 | 46.1 | 250 | 253 | 57.8 | 0 | 28.7 |

## Management Condition 4—Solid Wastes: Explanation and Supporting Data

1. Landfill cost is estimated at $1.50/ton, which is the estimate contained in the New York Central Railroad proposal to Westchester County.

2. See Management Condition 3, no. 4, above.

3. Solid wastes which are to be disposed of at sea (without prior incineration) will require "pretreatment" to prevent flotation. Although a suitable process for this method of disposal has not been developed, it is assumed for this study that the transfer and hauling operations will still represent the major components of cost, and the pretreatment operation will add $1.00/ton to the cost of this method of disposal. Therefore, the cost of barging to sea is estimated at $4.27/ton (See Management Condition 3, no. 5, above), plus $1.00/ton, or $5.27 ton.

TABLE A-9

**COMPUTATIONS OF SOLID WASTE COMPONENTS FOR MANAGEMENT CONDITION 4**
all values are quantities for the year 2000

| | | Total Solid Waste thousand tons | Landfill Cost million dollars | Rail Trans. Cost million dollars | Total Cost Rail Trans. million dollars | Total Cost of Barging to Sea million dollars | Particulate Emissions thousand tons | Space Required in Region thousand acre-feet | Water Required billion gallons |
|---|---|---|---|---|---|---|---|---|---|
| Variant I | GC/X | 56,700 | 85.0 | 208 | 293 | 299 | 0 | 0 | 0 |
| Variant I | GC/Y | 28,400 | 42.5 | 104 | 147 | 150 | 0 | 0 | 0 |
| Variant II | GC/X | 56,800 | 85.0 | 208 | 293 | 299 | 0 | 0 | 0 |
| Variant II | GC/Y | 28,400 | 42.5 | 104 | 147 | 150 | 0 | 0 | 0 |
| Variant III | GC/X | 57,400 | 86.0 | 211 | 297 | 302 | 0 | 0 | 0 |
| Variant III | GC/Y | 28,700 | 43.0 | 106 | 149 | 151 | 0 | 0 | 0 |

## 2. ASSUMPTIONS USED IN DEVELOPING VARIANTS FOR 2000

### Characterization of variants

Variant I "Moderately centralized" growth: medium CBD, major growth close in.

Variant II "Dispersed" growth: medium CBD, reduced Core, more uniform growth throughout remainder of Area, particularly in Intermediate and Outer Rings.

Variant III "Centralized" growth: large Core and Inner Ring, dispersed growth elsewhere.

### Assumptions

1. Total population and total employment in the Study Area are the same for all variants.

2. Distribution of population and employment among Rings changes with each variant. Distribution of population by sub-area within each Ring corresponds to that of Variant I.

3. Office employment by sub-area for each variant is as projected by RPA.

4. Retail service employment as a percentage of resident population increases by 1 to 3 percent over 1964, depending on sub-area. The sub-areas having the largest percentage of such employment in 1964 are assumed to have the largest percentage increases.

5. Institutional employment as percent of resident population doubles in Manhattan CBD and Manhattan Remainder and triples in all other counties.

6. Location and magnitude of employment in 2-digit manufacturing industries remain the same in all variants, as projected for Variant I, except for split counties. The following table indicates the percentage of manufacturing employment estimated for divided counties.

| | VARIANTS I, III | VARIANT II |
|---|---|---|
| Manhattan CBD | 0.95 | 0.9 |
| Manhattan Remainder | 0.05 | 0.1 |
| Essex East (Newark) | 0.6 | 0.5 |
| Essex West | 0.4 | 0.5 |
| Westchester South | 0.8 | 0.65 |
| Westchester North | 0.2 | 0.35 |
| Passaic South | 0.95 | 0.9 |
| Passaic North | 0.05 | 0.1 |
| Suffolk West | 0.9 | 0.8 |
| Suffolk East | 0.1 | 0.2 |
| Fairfield South | 0.8 | 0.7 |
| Fairfield North | 0.2 | 0.3 |

7. Location and magnitude of employment in principal waste generating industries are the same for all variants.

The increase or decrease in employment in the major waste generating industries by 4-digit SIC category by sub-area will be the same as projected for the corresponding 2-digit categories; that is, industry mix within 2-digit categories remains the same.

8. For Variant III (centralized growth), as shown in Table A-13, the following is assumed for residual employment (other than retail service, manufacturing, or institutional employment):

a. In the Manhattan CBD it remains the same as in Variant I.

b. Of the residual employment in all other sub-areas, 35 percent is related to manufacturing employment, and hence is located in the same sub-areas. Thus, 65 percent of the residual employment is related to the location of population and other economic activities.

c. 50 percent of the remaining residual employment in each sub-area of the Outer and Intermediate Rings is allocated to the Inner Ring and Rest of Core.

d. 60 percent of this total is allocated to the Inner Ring and 40 percent to the Rest of Core (based on the relative increases in total population in the two Rings between Variants I and III). This is distributed among sub-areas of Inner Ring and Rest of Core in proportion to total employment by sub-area in Variant I.

9. For Variant II (dispersed growth), as shown in Table A-13, the following is assumed for residual employment:

a. In Manhattan CBD and Manhattan Remainder it remains the same as in Variant I.

b. Of residual employment in all other sub-areas, 35 percent is related to manufacturing employment, and hence is located in same sub-areas; that is, 65 percent of the residual employment in all other sub-areas is related to the location of population and other economic activities.

c. 30 percent of the remaining residual employment in the Rest of Core and Inner Rings is allocated to the Intermediate and Outer Rings.

d. 70 percent of this total is allocated to the Intermediate Ring and 30 percent to the Outer Ring (based on the relative increases in total population in the two Rings between Variants I and II). This is distributed among sub-areas of the Intermediate Ring and Outer Ring in proportion to total employment by sub-areas in Variant I.

10. Location of power plants will not be affected by variations in distribution of population and employment.

The resulting characteristics of the variants are indicated in Tables A-10, A-11, A-12, and A-13, showing population and population density, by sub-area; and population and employment by major category, by sub-area.

For comparison, present population, population density, and employment by major category, by sub-area, are shown in Table A-14.

TABLE A-10

## POPULATION AND POPULATION DENSITY IN 2000 FOR VARIANTS I, II, AND III

| County | VARIANT I | | VARIANT II | | VARIANT III | |
|---|---|---|---|---|---|---|
| | Population thousands | Density thousand/ sq. mile | Population thousands | Density thousand/ sq. mile | Population thousands | Density thousand/ sq. mile |
| Manhattan CBD | 526 | 60.9 | 500 | 57.9 | 700 | 81.1 |
| Manhattan Rmndr. | 1,052 | 78.7 | 875 | 65.4 | 1,250 | 93.5 |
| Brooklyn | 2,685 | 38.7 | 2,240 | 32.3 | 3,200 | 46.2 |
| Queens | 2,123 | 19.5 | 1,771 | 16.3 | 2,530 | 23.3 |
| The Bronx | 1,440 | 34.3 | 1,197 | 28.5 | 1,710 | 40.7 |
| Hudson | 602 | 13.3 | 504 | 11.2 | 720 | 15.9 |
| Essex (Newark) | 500 | 21.2 | 413 | 17.5 | 590 | 25.0 |
| Richmond | 475 | 8.23 | 390 | 6.76 | 715 | 12.4 |
| Nassau | 2,080 | 6.97 | 1,704 | 5.71 | 3,124 | 10.5 |
| Westchester (So.) | 1,155 | 9.03 | 948 | 7.41 | 1,738 | 13.6 |
| Bergen | 1,430 | 6.13 | 1,176 | 5.04 | 2,156 | 9.24 |
| Passaic (So.) | 555 | 8.12 | 456 | 6.67 | 836 | 12.2 |
| Essex (West) | 864 | 8.28 | 708 | 6.79 | 1,298 | 12.4 |
| Union | 755 | 7.33 | 618 | 6.00 | 1,133 | 11.0 |
| Suffolk (West) | 1,405 | 2.54 | 1,714 | 3.10 | 968 | 1.75 |
| Westchester (No.) | 544 | 1.77 | 667 | 2.17 | 377 | 1.23 |
| Rockland | 320 | 1.79 | 391 | 2.19 | 221 | 1.24 |
| Passaic (No.) | 40 | 0.34 | 46 | 0.39 | 26 | 0.22 |
| Morris | 912 | 1.95 | 1,115 | 2.38 | 631 | 1.35 |
| Somerset | 690 | 2.25 | 840 | 2.73 | 474 | 1.54 |
| Middlesex | 1,425 | 4.56 | 1,748 | 5.59 | 988 | 3.16 |
| Mercer | 710 | 3.12 | 874 | 3.84 | 494 | 2.17 |
| Monmouth | 980 | 2.06 | 1,196 | 2.51 | 676 | 1.42 |
| Fairfield (So.) | 1,001 | 2.64 | 1,230 | 3.24 | 696 | 1.83 |
| New Haven | 1,372 | 2.25 | 1,679 | 2.76 | 949 | 1.56 |
| Suffolk (East) | 380 | 1.11 | 452 | 1.31 | 174 | 0.51 |
| Putnam | 190 | 0.81 | 229 | 0.97 | 88 | 0.37 |
| Dutchess | 750 | 0.92 | 900 | 1.10 | 346 | 0.42 |
| Orange | 765 | 0.92 | 915 | 1.10 | 352 | 0.42 |
| Ulster | 390 | 0.34 | 468 | 0.41 | 180 | 0.16 |
| Sullivan | 125 | 0.13 | 151 | 0.15 | 58 | 0.06 |
| Sussex | 140 | 0.27 | 166 | 0.31 | 64 | 0.12 |
| Warren | 240 | 0.66 | 286 | 0.79 | 110 | 0.30 |
| Hunterdon | 345 | 0.79 | 411 | 0.95 | 158 | 0.36 |
| Ocean | 350 | 0.55 | 416 | 0.65 | 160 | 0.25 |
| Fairfield (No.) | 325 | 1.28 | 390 | 1.54 | 150 | 0.59 |
| Litchfield | 345 | 0.37 | 416 | 0.44 | 160 | 0.17 |

TABLE A-11

## POPULATION AND EMPLOYMENT DISTRIBUTION IN 2000: VARIANT I

all values in thousands

| County | Population | Office Employment | Retail Service Employment | Institutional Employment | Manufacturing Employment | Residual Employment | Total Employment |
|---|---|---|---|---|---|---|---|
| Manhattan CBD | 526 | 1,300 | 477 | 126 | 129 | 368 | 2,400 |
| Manhattan Rmndr. | 1,052 | 54 | 180 | 100 | 7 | 31 | 372 |
| Brooklyn | 2,685 | 149 | 242 | 99 | 148 | 143 | 781 |
| Queens | 2,123 | 111 | 180 | 64 | 90 | 157 | 602 |
| The Bronx | 1,440 | 66 | 101 | 53 | 42 | 80 | 342 |
| Hudson | 602 | 71 | 60 | 22 | 84 | 150 | 387 |
| Essex (Newark) | 500 | 108 | 100 | 18 | 59 | 116 | 401 |
| Richmond | 475 | 27 | 31 | 25 | 24 | 29 | 136 |
| Nassau | 2,080 | 90 | 260 | 46 | 92 | 174 | 662 |
| Westchester (So.) | 1,155 | 80 | 167 | 40 | 45 | 144 | 485 |
| Bergen | 1,430 | 86 | 150 | 31 | 106 | 151 | 524 |
| Passaic (So.) | 555 | 41 | 67 | 19 | 62 | 54 | 243 |
| Essex (West) | 864 | 50 | 73 | 24 | 39 | 67 | 253 |
| Union | 755 | 62 | 94 | 25 | 72 | 94 | 347 |
| Suffolk (West) | 1,405 | 70 | 98 | 27 | 63 | 176 | 434 |
| Westchester (No.) | 544 | 38 | 59 | 16 | 11 | 102 | 226 |
| Rockland | 320 | 21 | 22 | 10 | 24 | 52 | 129 |
| Passaic (No.) | 40 | 2 | 2 | 1 | 3 | 2 | 10 |
| Morris | 912 | 58 | 91 | 34 | 38 | 156 | 377 |
| Somerset | 690 | 23 | 48 | 48 | 35 | 55 | 209 |
| Middlesex | 1,425 | 67 | 107 | 56 | 94 | 199 | 523 |
| Mercer | 710 | 54 | 99 | 43 | 47 | 155 | 398 |
| Monmouth | 980 | 60 | 108 | 25 | 34 | 143 | 370 |
| Fairfield (So.) | 1,001 | 53 | 125 | 45 | 100 | 168 | 491 |
| New Haven | 1,372 | 77 | 165 | 73 | 121 | 226 | 662 |
| Suffolk (East) | 380 | 17 | 57 | 10 | 7 | 63 | 154 |
| Putnam | 190 | 9 | 11 | 3 | 3 | 16 | 42 |
| Dutchess | 750 | 35 | 75 | 20 | 29 | 105 | 264 |
| Orange | 765 | 19 | 76 | 37 | 25 | 82 | 239 |
| Ulster | 390 | 9 | 43 | 12 | 19 | 32 | 115 |
| Sullivan | 125 | 3 | 25 | 6 | 3 | 18 | 55 |
| Sussex | 140 | 7 | 10 | 3 | 9 | 17 | 46 |
| Warren | 240 | 3 | 22 | 8 | 22 | 20 | 75 |
| Hunterdon | 345 | 4 | 21 | 12 | 15 | 43 | 95 |
| Ocean | 350 | 19 | 35 | 6 | 11 | 33 | 104 |
| Fairfield (No.) | 325 | 40 | 29 | 10 | 25 | 8 | 112 |
| Litchfield | 345 | 8 | 34 | 6 | 33 | 30 | 111 |
| **Totals** | **29,866** | **3,000** | **3,544** | **1,203** | **1,770** | **3,659** | **13,176** |

TABLE A-12

**POPULATION AND EMPLOYMENT DISTRIBUTION IN 2000: VARIANT II**
all values in thousands

| County | Population | Office Employment | Retail Service Employment | Institutional Employment | Manufacturing Employment | Residual Employment | Total Employment |
|---|---|---|---|---|---|---|---|
| Manhattan CBD | 500 | 1,100 | 425 | 95 | 122 | 368 | 2,110 |
| Manhattan Rmndr. | 875 | 50 | 175 | 105 | 14 | 31 | 375 |
| Brooklyn | 2,240 | 140 | 202 | 83 | 148 | 115 | 688 |
| Queens | 1,771 | 103 | 151 | 53 | 90 | 126 | 523 |
| The Bronx | 1,197 | 61 | 84 | 44 | 42 | 64 | 295 |
| Hudson | 504 | 66 | 50 | 18 | 84 | 121 | 339 |
| Essex (Newark) | 413 | 100 | 83 | 15 | 49 | 93 | 340 |
| Richmond | 390 | 23 | 25 | 21 | 24 | 23 | 116 |
| Nassau | 1,704 | 77 | 213 | 37 | 92 | 140 | 559 |
| Westchester (So.) | 948 | 86 | 137 | 33 | 36 | 116 | 408 |
| Bergen | 1,176 | 73 | 123 | 26 | 106 | 122 | 450 |
| Passaic (So.) | 456 | 25 | 55 | 16 | 58 | 43 | 197 |
| Essex (West) | 708 | 43 | 60 | 20 | 49 | 54 | 226 |
| Union | 618 | 53 | 77 | 20 | 72 | 76 | 298 |
| Suffolk (West) | 1,714 | 101 | 120 | 33 | 56 | 199 | 509 |
| Westchester (No.) | 667 | 39 | 73 | 20 | 20 | 114 | 266 |
| Rockland | 391 | 30 | 27 | 13 | 24 | 59 | 153 |
| Passaic (No.) | 46 | 19 | 2 | 1 | 7 | 3 | 32 |
| Morris | 1,115 | 83 | 112 | 41 | 38 | 175 | 449 |
| Somerset | 840 | 33 | 59 | 59 | 35 | 66 | 252 |
| Middlesex | 1,748 | 96 | 131 | 68 | 94 | 225 | 614 |
| Mercer | 874 | 77 | 113 | 52 | 47 | 175 | 464 |
| Monmouth | 1,196 | 86 | 132 | 31 | 34 | 162 | 445 |
| Fairfield (So.) | 1,230 | 76 | 154 | 55 | 87 | 194 | 566 |
| New Haven | 1,679 | 110 | 201 | 89 | 121 | 260 | 781 |
| Suffolk (East) | 452 | 24 | 68 | 12 | 14 | 74 | 192 |
| Putnam | 229 | 13 | 14 | 3 | 3 | 20 | 53 |
| Dutchess | 900 | 50 | 90 | 24 | 29 | 123 | 316 |
| Orange | 915 | 28 | 92 | 44 | 25 | 98 | 287 |
| Ulster | 468 | 13 | 51 | 15 | 19 | 40 | 138 |
| Sullivan | 151 | 4 | 30 | 7 | 3 | 22 | 66 |
| Sussex | 166 | 10 | 12 | 4 | 9 | 21 | 56 |
| Warren | 286 | 4 | 26 | 10 | 22 | 25 | 87 |
| Hunterdon | 411 | 6 | 25 | 14 | 15 | 49 | 109 |
| Ocean | 416 | 28 | 42 | 7 | 11 | 40 | 128 |
| Fairfield (No.) | 390 | 58 | 35 | 12 | 38 | 15 | 158 |
| Litchfield | 416 | 12 | 42 | 7 | 33 | 37 | 131 |
| **Totals** | **30,200** | **3,000** | **3,511** | **1,207** | **1,770** | **3,688** | **13,176** |

TABLE A-13

**POPULATION AND EMPLOYMENT DISTRIBUTION IN 2000: VARIANT III**
all values in thousands

| County | Population | Office Employment | Retail Service Employment | Institutional Employment | Manufacturing Employment | Residual Employment | Total Employment |
|---|---|---|---|---|---|---|---|
| Manhattan CBD | 700 | 1,500 | 595 | 133 | 129 | 368 | 2,725 |
| Manhattan Rmndr. | 1,250 | 89 | 250 | 150 | 7 | 63 | 559 |
| Brooklyn | 3,200 | 176 | 288 | 118 | 148 | 195 | 925 |
| Queens | 2,530 | 147 | 215 | 76 | 90 | 194 | 722 |
| The Bronx | 1,710 | 93 | 120 | 63 | 42 | 95 | 413 |
| Hudson | 720 | 67 | 72 | 26 | 84 | 168 | 417 |
| Essex (Newark) | 590 | 128 | 118 | 21 | 59 | 136 | 462 |
| Richmond | 715 | 16 | 46 | 38 | 24 | 48 | 172 |
| Nassau | 3,124 | 173 | 390 | 69 | 92 | 252 | 976 |
| Westchester (So.) | 1,738 | 57 | 252 | 61 | 45 | 197 | 612 |
| Bergen | 2,156 | 89 | 226 | 47 | 106 | 209 | 677 |
| Passaic (So.) | 836 | 29 | 100 | 29 | 62 | 81 | 301 |
| Essex (West) | 1,298 | 78 | 110 | 36 | 39 | 102 | 365 |
| Union | 1,133 | 58 | 142 | 37 | 72 | 128 | 437 |
| Suffolk (West) | 968 | 14 | 68 | 18 | 63 | 103 | 266 |
| Westchester (No.) | 377 | 35 | 41 | 11 | 11 | 62 | 160 |
| Rockland | 221 | 10 | 15 | 7 | 24 | 35 | 91 |
| Passaic (No.) | 26 | 2 | 2 | 1 | 3 | 1 | 9 |
| Morris | 631 | 29 | 63 | 23 | 38 | 90 | 243 |
| Somerset | 474 | 4 | 33 | 33 | 35 | 37 | 142 |
| Middlesex | 988 | 16 | 74 | 38 | 94 | 119 | 341 |
| Mercer | 494 | 29 | 69 | 30 | 47 | 90 | 265 |
| Monmouth | 676 | 13 | 74 | 18 | 34 | 90 | 229 |
| Fairfield (So.) | 696 | 17 | 87 | 31 | 100 | 98 | 333 |
| New Haven | 949 | 31 | 114 | 51 | 121 | 138 | 455 |
| Suffolk (East) | 174 | 20 | 26 | 5 | 7 | 43 | 101 |
| Putnam | 88 | 2 | 5 | 1 | 3 | 11 | 22 |
| Dutchess | 346 | 14 | 35 | 9 | 29 | 71 | 158 |
| Orange | 352 | 10 | 35 | 17 | 25 | 55 | 142 |
| Ulster | 180 | 5 | 20 | 6 | 19 | 22 | 72 |
| Sullivan | 58 | 2 | 12 | 3 | 3 | 12 | 32 |
| Sussex | 64 | 4 | 5 | 2 | 9 | 11 | 31 |
| Warren | 110 | 3 | 10 | 4 | 22 | 13 | 52 |
| Hunterdon | 158 | 2 | 9 | 5 | 15 | 29 | 60 |
| Ocean | 160 | 8 | 16 | 3 | 11 | 22 | 60 |
| Fairfield (No.) | 150 | 26 | 13 | 4 | 25 | 5 | 73 |
| Litchfield | 160 | 4 | 16 | 3 | 33 | 20 | 76 |
| **Totals** | **30,200** | **3,000** | **3,766** | **1,227** | **1,770** | **3,413** | **13,176** |

TABLE A-14

**POPULATION, POPULATION DENSITY, AND EMPLOYMENT BY MAJOR CATEGORIES, 1964**
all values in thousands except density

| County | Population | Population Density 1,000/sq. mi. | Office Employment | Retail Service Employment | Institutional Employment | Residual Employment | Total Employment |
|---|---|---|---|---|---|---|---|
| Manhattan CBD | 513.5 | 59.5 | 804.4 | 425.5 | 50.2 | 817.5 | 2,097.6 |
| Manhattan Rmndr. | 1,052.3 | 78.7 | 29.8 | 181.9 | 60.1 | 52.8 | 324.6 |
| Brooklyn | 2,698.2 | 38.9 | 103.5 | 206.2 | 33.6 | 388.3 | 731.6 |
| Queens | 1,941.7 | 17.9 | 68.1 | 137.8 | 19.8 | 258.0 | 483.7 |
| The Bronx | 1,527.4 | 36.4 | 43.5 | 85.7 | 19.1 | 149.0 | 297.3 |
| Hudson | 613.2 | 13.6 | 39.7 | 51.3 | 7.5 | 170.9 | 269.4 |
| Essex (Newark) | 410.9 | 17.4 | 59.1 | 72.6 | 5.0 | 131.9 | 268.6 |
| Richmond | 258.5 | 4.48 | 12.3 | 15.3 | 4.6 | 21.8 | 54.0 |
| Nassau | 1,396.3 | 4.68 | 50.9 | 141.8 | 10.6 | 195.4 | 398.7 |
| Westchester (So.) | 654.9 | 5.12 | 35.1 | 81.5 | 7.6 | 98.3 | 222.5 |
| Bergen | 849.0 | 3.64 | 31.9 | 74.7 | 6.3 | 149.0 | 261.9 |
| Passaic (So.) | 402.5 | 5.89 | 18.5 | 40.4 | 4.7 | 102.1 | 165.7 |
| Essex (West) | 553.0 | 5.30 | 26.7 | 43.8 | 5.3 | 81.2 | 157.0 |
| Union | 539.5 | 5.24 | 29.1 | 57.4 | 5.9 | 118.5 | 210.9 |
| Suffolk (West) | 838.9 | 1.52 | 17.5 | 47.3 | 5.3 | 86.5 | 156.6 |
| Westchester (No.) | 198.1 | 0.65 | 11.2 | 18.0 | 2.0 | 23.2 | 54.4 |
| Rockland | 186.9 | 1.05 | 5.2 | 11.6 | 2.0 | 23.9 | 42.4 |
| Passaic (No.) | 31.9 | 0.27 | 0.4 | 0.7 | 0.1 | 1.8 | 3.0 |
| Morris | 319.1 | 0.68 | 11.4 | 27.7 | 4.0 | 69.3 | 112.4 |
| Somerset | 174.9 | 0.57 | 4.9 | 9.8 | 4.1 | 25.8 | 44.6 |
| Middlesex | 492.4 | 1.57 | 16.5 | 30.9 | 6.5 | 95.7 | 149.6 |
| Mercer | 294.6 | 1.29 | 27.2 | 35.6 | 5.9 | 51.5 | 120.2 |
| Monmouth | 399.0 | 0.84 | 11.4 | 36.5 | 3.5 | 45.2 | 96.6 |
| Fairfield (So.) | 626.2 | 1.65 | 26.2 | 65.4 | 9.2 | 134.8 | 235.6 |
| New Haven | 717.0 | 1.18 | 29.2 | 71.5 | 12.7 | 154.7 | 268.1 |
| Suffolk (East) | 88.1 | 0.26 | 4.2 | 11.5 | 0.8 | 12.6 | 29.1 |
| Putnam | 41.8 | 0.18 | 0.9 | 2.2 | 0.2 | 3.2 | 6.5 |
| Dutchess | 208.5 | 0.26 | 10.4 | 17.7 | 1.9 | 39.1 | 69.1 |
| Orange | 205.8 | 0.25 | 6.9 | 17.7 | 3.3 | 33.7 | 61.6 |
| Ulster | 131.1 | 0.11 | 4.1 | 11.9 | 1.4 | 23.4 | 40.8 |
| Sullivan | 46.3 | 0.05 | 1.4 | 8.3 | 0.7 | 7.1 | 17.5 |
| Sussex | 59.9 | 0.11 | 1.8 | 3.8 | 0.5 | 7.7 | 13.8 |
| Warren | 69.6 | 0.19 | 1.5 | 5.2 | 0.8 | 15.1 | 22.6 |
| Hunterdon | 60.8 | 0.14 | 1.4 | 3.8 | 0.7 | 9.8 | 15.7 |
| Ocean | 148.0 | 0.23 | 8.4 | 12.7 | 0.8 | 13.8 | 35.7 |
| Fairfield (No.) | 98.0 | 0.39 | 3.9 | 7.6 | 1.0 | 19.2 | 31.7 |
| Litchfield | 130.6 | 0.14 | 2.9 | 11.1 | 0.8 | 25.6 | 40.4 |
| **Totals** | **18,978.4** | | **1,561.5** | **2,084.4** | **308.5** | **3,657.4** | **7,611.5** |

# 3. BACKGROUND DATA: GENERATION AND HANDLING OF WASTES

## Solid waste quantities — 1965: sources of data

Data on solid waste quantities and methods of handling were obtained from the New York City Departments of Sanitation, City Planning, and Licenses (information on the number and sizes of privately-owned vehicles licensed to haul refuse); the Greater New York Wastepaper Association; various agencies working for the counties of Westchester, Rockland, Morris, Somerset, and Monmouth; Region II of the U.S. Public Health Service (the Hackensack River Basin Study Report); and the three State Health Departments, which submitted the limited data available to them.

The only source which provided data based upon accurate weight records was the New York City Department of Sanitation. However, the data from this source were limited to refuse collected and disposed of by the City and did not include data on refuse collected privately for disposal outside the City or disposed of on-site by incineration or other means. All other data for New York City were determined by evaluating estimates from the several agencies concerned and the Wastepaper Association. The estimated New York City quantity information on solid wastes is separated into the two following categories: residential, including public buildings and on-site incineration; and business, including office, retail and services, demolition, industrial, etc. All attempts to obtain detailed solid waste quantity information from industry failed.

The New York City solid waste quantity estimates compiled from the available sources made it possible to develop unit solid waste generation figures for residential and other governmental activities, and for business activities (commercial and industrial). Recognizing that solid waste produced by demolition activities, although at times significant, is dependent upon activities such as highway construction, redevelopment, etc. which fluctuate considerably, this quantity is recorded separately. Although there may be variations in residential solid waste generation for different population densities and socio-economic levels, surveys reported by the American Public Works Association indicate that these variations are not significant.[1]

Residential solid waste generation for the five New York City boroughs ranges from 0.46 tons/capita/year to 0.68 tons/capita/year with an average of 0.58 tons/capita/year. Studies of residential solid waste generation in three other counties in the Region show quantities of 0.51 tons/capita/year, 0.59 tons/capita/year, and 0.62 tons/capita/year. Solid wastes generated by commerce and industry were determined on the basis of number of employees in each county. For New York City, this ranged from 0.46 tons/employee/year for Richmond to 0.95 tons/employee/year for Manhattan. The extremely high proportion of employees to total resident population in Manhattan makes this a special condition. The average figure for the other four boroughs is approximately 0.75 tons/employee/year. Although it is recognized that future studies may reveal a considerable variation in solid waste generation/employee from the 0.75 ton average, particularly for manufacturing industries, this average is used as an estimate for the entire Region.

Estimates of solid waste generation in 1965 for the remaining counties in the Region are based upon the data developed above, namely (1) residential solid waste generation averages of 0.58 tons/resident/year; and (2) industrial and commercial solid waste generation averages of 0.75 tons/employee/year. Since no meaningful information on demolition wastes was available outside of New York City, estimates of solid waste quantities for the remainder of the Region do not include demolition wastes. Other important omissions, which significantly affect the availability of space for the disposal of solid wastes, include agricultural wastes and self-disposed, noncombustible, industrial wastes, including fly ash from power plants.

The resulting estimates of solid wastes generated and the methods for disposal for 1965 are shown in Tables A-15 and A-16, respectively.

Unit generation coefficients were then developed for the year 2000 for Generation Conditions X and Y. These coefficients, and their use in developing estimates of solid wastes generated by sub-area and the total Region, are shown in Table A-17.

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[1] American Public Works Association, Committee on Solid Wastes, *Refuse Collection Practice* (3rd ed.; Chicago, 1966).

TABLE A-15

SOLID WASTE GENERATION IN THE STUDY AREA, 1965

| County | Residential Solid Wastes TPC[1] | Residential Solid Wastes TPY[2] thousand tons | Business Solid Wastes TPE[3] | Business Solid Wastes TPY[2] thousand tons | Total Solid Wastes TPC[1] | Total Solid Wastes TPY[2] thousand tons |
|---|---|---|---|---|---|---|
| Manhattan | 0.68 | 1,080 | 0.95 | 2,280 | 2.08 | 3,250 |
| Brooklyn | 0.46 | 1,240 | 0.65 | 470 | 0.63 | 1,710 |
| Queens | 0.66 | 1,110 | 1.29 | 640 | 0.90 | 1,750 |
| The Bronx | 0.53 | 800 | 1.46 | 440 | 0.81 | 1,240 |
| Hudson | 0.58 | 356 | 0.75 | 195 | 0.90 | 551 |
| Richmond | 0.50 | 150 | 1.45 | 80 | 0.89 | 230 |
| Nassau | 0.58 | 810 | 0.75 | 325 | 0.81 | 1,135 |
| Westchester | 0.62 | 525 | 0.75 | 225 | 0.88 | 750 |
| Bergen | 0.58 | 491 | 0.75 | 207 | 0.82 | 698 |
| Passaic | 0.58 | 252 | 0.75 | 133 | 0.89 | 385 |
| Essex | 0.58 | 559 | 0.75 | 321 | 0.91 | 880 |
| Union | 0.58 | 313 | 0.75 | 172 | 0.90 | 485 |
| Suffolk | 0.58 | 537 | 0.75 | 150 | 0.74 | 687 |
| Rockland | 0.51 | 95 | 0.75 | 36 | 0.70 | 131 |
| Morris | 0.59 | 189 | 0.75 | 74 | 0.82 | 263 |
| Somerset | 0.58 | 102 | 0.75 | 38 | 0.80 | 140 |
| Middlesex | 0.58 | 285 | 0.75 | 122 | 0.83 | 407 |
| Mercer | 0.58 | 171 | 0.75 | 97 | 0.91 | 268 |
| Monmouth | 0.58 | 232 | 0.75 | 16 | 0.77 | 308 |
| Fairfield | 0.58 | 420 | 0.75 | 204 | 0.86 | 624 |
| New Haven | 0.58 | 417 | 0.75 | 208 | 0.87 | 625 |
| Putnam | 0.58 | 24 | 0.75 | 6 | 0.72 | 30 |
| Dutchess | 0.58 | 121 | 0.75 | 58 | 0.86 | 179 |
| Orange | 0.58 | 120 | 0.75 | 50 | 0.83 | 170 |
| Ulster | 0.58 | 71 | 0.75 | 31 | 0.78 | 102 |
| Sullivan | 0.58 | 27 | 0.75 | 14 | 0.89 | 41 |
| Sussex | 0.58 | 35 | 0.75 | 11 | 0.77 | 46 |
| Warren | 0.58 | 41 | 0.75 | 18 | 0.84 | 59 |
| Hunterdon | 0.58 | 35 | 0.75 | 13 | 0.79 | 48 |
| Ocean | 0.58 | 86 | 0.75 | 26 | 0.76 | 112 |
| Litchfield | 0.58 | 71 | 0.75 | 32 | 0.79 | 103 |
| **Totals** | | **10,765** | | **6,557** | | **17,394** |

[1]TPC = tons/capita/year
[2]TPY = tons/year
[3]TPE = tons/employee/year

TABLE A-16

DISPOSAL OF SOLID WASTES IN THE STUDY AREA, 1965
all values in thousands of tons

| County | Incineration | Landfill (excluding residue) | Landfill (including residue) | On-site Burning incin. | On-site Burning backyard | Salvage and Reclamation | Open Burning Teepee | Grinding |
|---|---|---|---|---|---|---|---|---|
| Manhattan | 743 | 1,000[1] | | 350 | | 200[2]<br>400[3] | | |
| Brooklyn | 1,032 | | 76 | 240 | | 80[2] | | |
| Queens | 308 | 944 | 947 | 190 | | 80[2] | | |
| The Bronx | 150 | 713 | 777 | 130 | | 40[2] | | |
| Hudson | 130 | 411 | 446 | 10 | | | | |
| Richmond | | 1,681 | 2,539 | | | | | |
| Nassau | 520 | 595 | 730 | 20 | | | | |
| Westchester | 250 | 500 | 562 | | | | | |
| Bergen | 81 | 620[1] | 640 | 10 | 60 | | | 2 |
| Passaic | | 285[1] | 285 | | 10 | | | |
| Essex | | 800[1] | 820 | 25 | 25 | | 30 | |
| Union | | 457 | 457 | 3 | 25 | | | |
| Suffolk | 250 | 437 | 500 | | | | | |
| Rockland | 50 | 81 | 94 | | | | | |
| Morris | | 250 | 253 | | 10 | | 3 | |
| Somerset | | 124 | 128 | | 10 | | 6 | |
| Middlesex | 10 | 377 | 385 | | 20 | | | |
| Mercer | 35 | 223 | 235 | | 10 | | | |
| Monmouth | 15 | 268 | 278 | | 25 | | | |
| Fairfield | 375 | 225 | 335 | | | | 25 | |
| New Haven | 375 | 225 | 335 | | | | 25 | |
| Putnam | 10 | 20 | 22 | | | | | |
| Dutchess | 50 | 129 | 142 | | | | | |
| Orange | 60 | 110 | 125 | | | | | |
| Ulster | | 102 | 102 | | | | | |
| Sullivan | 6 | 35 | 37 | | | | | |
| Sussex | | 38 | 40 | | 5 | | 3 | |
| Warren | | 54 | 55 | | 5 | | | |
| Hunterdon | | 43 | 44 | | 5 | | | |
| Ocean | | 102 | 105 | | 10 | | | |
| Litchfield | | 78 | 90 | | | | 25 | |
| **Totals** | **4,450** | **10,849** | **11,584** | **978** | **220** | **800** | **117** | **2** |

[1]To New Jersey landfill — Hackensack Meadows
[2]Garbage to hogs in New Jersey
[3]Paper salvage

## TABLE A-17
## SOLID WASTES GENERATED IN 2000: VARIANT I

| County | Population | Employment | Generation Condition X: Residential TPC[1] | Residential thousand tons | Business TPE[2] | Business thousand tons | Total thousand tons | Generation Condition Y: Population | Employment | Residential TPC[1] | Residential thousand tons | Business TPE[2] | Business thousand tons | Total thousand tons |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Manhattan CBD | 526 | 2,400 | 1.36 | 715 | 1.90 | 4,550 | 5,265 | 526 | 2,400 | 0.68 | 358 | 0.95 | 2,280 | 2,638 |
| Manhattan Rmndr. | 1,052 | 372 | 1.36 | 1,430 | 1.90 | 706 | 2,136 | 1,052 | 372 | 0.68 | 716 | 0.95 | 353 | 1,069 |
| Brooklyn | 2,685 | 781 | 0.92 | 2,480 | 1.30 | 1,015 | 3,495 | 2,685 | 781 | 0.46 | 1,240 | 0.65 | 508 | 1,748 |
| Queens | 2,123 | 602 | 1.32 | 2,800 | 2.58 | 1,550 | 4,350 | 2,123 | 602 | 0.66 | 1,400 | 1.29 | 776 | 2,176 |
| The Bronx | 1,440 | 342 | 1.06 | 1,530 | 2.92 | 1,000 | 2,530 | 1,440 | 342 | 0.53 | 763 | 1.46 | 500 | 1,263 |
| Hudson | 602 | 387 | 1.16 | 700 | 1.50 | 580 | 1,280 | 602 | 387 | 0.58 | 350 | 0.75 | 290 | 640 |
| Essex (Newark) | 500 | 401 | 1.16 | 580 | 1.50 | 600 | 1,180 | 500 | 401 | 0.58 | 290 | 0.75 | 300 | 590 |
| Richmond | 475 | 136 | 1.00 | 475 | 2.90 | 394 | 869 | 475 | 136 | 0.58 | 238 | 1.45 | 197 | 435 |
| Nassau | 2,080 | 662 | 1.16 | 2,420 | 1.50 | 993 | 3,413 | 2,080 | 662 | 0.50 | 1,210 | 0.75 | 496 | 1,706 |
| Westchester (So.) | 1,155 | 485 | 1.24 | 1,430 | 1.50 | 723 | 2,153 | 1,155 | 485 | 0.58 | 716 | 0.75 | 364 | 1,080 |
| Bergen | 1,430 | 524 | 1.16 | 1,660 | 1.50 | 785 | 2,445 | 1,430 | 524 | 0.62 | 830 | 0.75 | 392 | 1,222 |
| Passaic (So.) | 555 | 243 | 1.16 | 645 | 1.50 | 364 | 1,009 | 555 | 243 | 0.58 | 322 | 0.75 | 182 | 504 |
| Essex (West) | 864 | 253 | 1.16 | 1,000 | 1.50 | 380 | 1,380 | 864 | 253 | 0.58 | 500 | 0.75 | 190 | 690 |
| Union | 755 | 347 | 1.16 | 875 | 1.50 | 520 | 1,395 | 755 | 347 | 0.58 | 438 | 0.75 | 260 | 698 |
| Suffolk (West) | 1,405 | 434 | 1.16 | 1,630 | 1.50 | 650 | 2,280 | 1,405 | 434 | 0.58 | 830 | 0.75 | 325 | 1,155 |
| Westchester (No.) | 544 | 226 | 1.21 | 674 | 1.50 | 340 | 1,014 | 544 | 226 | 0.58 | 337 | 0.75 | 169 | 506 |
| Rockland | 320 | 129 | 1.02 | 326 | 1.50 | 194 | 520 | 320 | 129 | 0.62 | 163 | 0.75 | 97 | 260 |
| Passaic (No.) | 40 | 10 | 1.16 | 46 | 1.50 | 15 | 61 | 40 | 10 | 0.51 | 23 | 0.75 | 8 | 31 |
| Morris | 912 | 377 | 1.18 | 1,080 | 1.50 | 565 | 1,645 | 912 | 377 | 0.58 | 538 | 0.75 | 282 | 820 |
| Somerset | 690 | 209 | 1.16 | 800 | 1.50 | 310 | 1,110 | 690 | 209 | 0.59 | 400 | 0.75 | 155 | 555 |
| Middlesex | 1,425 | 523 | 1.16 | 1,650 | 1.50 | 785 | 2,435 | 1,425 | 523 | 0.58 | 826 | 0.75 | 392 | 1,218 |
| Mercer | 710 | 398 | 1.16 | 823 | 1.50 | 597 | 1,420 | 710 | 398 | 0.58 | 411 | 0.75 | 298 | 709 |
| Monmouth | 980 | 370 | 1.16 | 1,140 | 1.50 | 555 | 1,695 | 980 | 370 | 0.58 | 568 | 0.75 | 278 | 846 |
| Fairfield (So.) | 1,001 | 491 | 1.16 | 1,160 | 1.50 | 737 | 1,897 | 1,001 | 491 | 0.58 | 580 | 0.75 | 368 | 948 |
| New Haven | 1,372 | 662 | 1.16 | 1,590 | 1.50 | 994 | 2,584 | 1,372 | 662 | 0.58 | 796 | 0.75 | 496 | 1,292 |
| Suffolk (East) | 380 | 154 | 1.16 | 440 | 1.50 | 231 | 671 | 380 | 154 | 0.58 | 220 | 0.75 | 115 | 335 |
| Putnam | 190 | 42 | 1.16 | 220 | 1.50 | 63 | 283 | 190 | 42 | 0.58 | 110 | 0.75 | 31 | 141 |
| Dutchess | 750 | 264 | 1.16 | 870 | 1.50 | 396 | 1,266 | 750 | 264 | 0.58 | 435 | 0.75 | 198 | 633 |
| Orange | 765 | 239 | 1.16 | 887 | 1.50 | 358 | 1,245 | 765 | 239 | 0.58 | 445 | 0.75 | 179 | 624 |
| Ulster | 390 | 115 | 1.16 | 452 | 1.50 | 173 | 625 | 390 | 115 | 0.58 | 226 | 0.75 | 86 | 312 |
| Sullivan | 125 | 55 | 1.16 | 145 | 1.50 | 83 | 228 | 125 | 55 | 0.58 | 73 | 0.75 | 41 | 114 |
| Sussex | 140 | 46 | 1.16 | 162 | 1.50 | 69 | 231 | 140 | 46 | 0.58 | 81 | 0.75 | 35 | 116 |
| Warren | 240 | 75 | 1.16 | 278 | 1.50 | 112 | 390 | 240 | 75 | 0.58 | 139 | 0.75 | 56 | 195 |
| Hunterdon | 345 | 95 | 1.16 | 400 | 1.50 | 142 | 542 | 345 | 95 | 0.58 | 200 | 0.75 | 71 | 271 |
| Ocean | 350 | 104 | 1.16 | 405 | 1.50 | 156 | 561 | 350 | 104 | 0.58 | 203 | 0.75 | 78 | 281 |
| Fairfield (No.) | 325 | 112 | 1.16 | 377 | 1.50 | 168 | 545 | 325 | 112 | 0.58 | 189 | 0.75 | 84 | 273 |
| Litchfield | 345 | 111 | 1.16 | 400 | 1.50 | 167 | 567 | 345 | 111 | 0.58 | 200 | 0.75 | 83 | 283 |
| **Totals** | **29,986** | **13,176** | | **34,695** | | **22,020** | **56,715** | **29,986** | **13,176** | | **17,364** | | **11,013** | **28,377** |

[1]TPC = tons/capita/year
[2]TPE = tons/employee/year

## Solid wastes: methods for handling and disposal

Landfilling, either with or without prior incineration, and incineration are the two major methods for handling and disposing of solid wastes. Since a residue remains after incineration, the "ultimate" disposal method is landfill, or the related procedure of dumping at sea. Both methods have impacts on environmental quality and on the generation and handling of other types of wastes.

Little is known about the qualitative effects of landfill operations on surface and groundwaters in the New York Region, except from tests conducted several years ago by New York City on filling operations in tidal waters. (Studies of this type have been done elsewhere, however [e.g., in California], so that the general nature of the relationships between landfill operations and water quality is known.) These tests indicated that landfilling did lower water quality, but other sources of contaminants resulted in considerably greater quality deterioration than landfilling. The organic fraction of solid wastes decomposes biologically under proper conditions of moisture, temperature, and air. The process will be aerobic or anaerobic, depending on the amount of oxygen present and the temperature attained during decomposition. If water passes through the refuse during the process, oxygen will be removed from the water, which results in a reduction of dissolved oxygen in the water. Solid wastes contain bacteria and water-soluble chemicals, which also may affect water quality. If the landfilled refuse is a good-quality incinerator residue rather than untreated solid wastes, changes in the quality of water draining through the landfill are limited to the addition of water-soluble chemicals. However, a filling operation on land can be conducted without causing any lowering of ground or surface water quality, provided the operation is designed and conducted in a manner which will prevent leaching into underground waters and prevent surface runoff from passing through the solid wastes in the fill.

If landfilling takes place in water, some deterioration of water quality will take place. If filling is conducted behind a bulkhead, the lowering of receiving water quality can be reduced, if not eliminated entirely.

The burning of typical municipal (as contrasted with industrial) solid wastes results in the generation of various gases and particulate matter. The principal gases which may be produced are hydrocarbons, oxides of sulphur and nitrogen, and chlorine. Hydrocarbons are eliminated when incinerator operating temperatures above 1200°F are maintained. The sulphur content of municipal solid wastes is generally on the order of 1 lb/ton of solid wastes, and only a small fraction of this is oxidized in the combustion process. Also, only a very small fraction of the nitrogen content oxidizes in the incineration process at normal temperatures of 1500°F to 2000°F. The principal source of chlorine from incineration is polyvinyl plastic, which is a small part of the less than 2 percent plastic content currently found in refuse. Consequently, normal good incineration at temperatures between 1200°F and 2000°F generates gaseous wastes containing only traces of harmful gases. Thus, the effect on air quality of gases from incineration of solid wastes at proper temperatures is minimal.

In contrast, incineration of solid wastes can result in the generation (and discharge) of significant quantities of particulates. The following are ranges of particulate generation in several refuse burning processes:

| Generation of Particulates in Burning Solid Wastes | |
|---|---|
| Open burning | 50 to 100 lb/ton |
| Poor apartment house incineration | about 50 lb/ton |
| Good apartment house incineration | 10 to 20 lb/ton |
| Average municipal incineration | 20 to 30 lb/ton |
| Good municipal incineration | 10 to 20 lb/ton |

In estimating gaseous wastes generated at present, the following coefficients were used: open burning—75 lb/ton; apartment house incineration—50 lb/ton; and municipal incineration—25 lb/ton. In the future, the proposed federal standard for particulates discharged from incinerators is 3 lb. to 5 lb/ton. This level can be achieved for both on-site and central (collective) incineration with present technology. It can be done through both incinerator design and operation (which affect the generation of particulates), and the use of particulate removal devices, such as wet scrubbers and electrostatic precipitators.

Recently, a new municipal incinerator in the Region, designed with existing equipment, has been tested and found capable of meeting the federal standards. Tests of electrostatic precipitators and wet scrubbers are to be made in the near future to determine the ability of these devices to remove particulates from incinerators. Using strategically located auxiliary fuel, adequate combustion space, and spray chambers, apartment house and industrial incinerators can also be designed and operated to meet the proposed federal emission limits.

In order to evaluate space needs for the final disposal of solid wastes, relationships between solid waste characteristics and disposal methods must be established. Some of these relationships are as follows:

1. Normal residential and commercial solid wastes occupy about 3 cu. yd. of landfill space/ton, after placement, compaction, and settlement. If cover material is brought to a landfill site, an additional ¼—½ cu. yd. of space would be occupied by the cover material for each ton of solid wastes.

2. Incinerated solid wastes occupy ½ cu. yd. of landfill space for each ton of refuse burned, after placement, compaction, and settlement. The question of cover material requirements for incinerator residue has not been resolved. However, present practice permits the deposit of good quality residue without cover material.

3. Noncombustible, industrial solid wastes, which consist essentially of cinders, slag, waste chemicals, demolition debris, and similar materials, occupy approximately 1 cu. yd/ton.

4. Oversized, burnable wastes are estimated to occupy twice the space/unit weight of normal refuse, or about 6 cu. yd/ton. If the wastes were hogged, the space requirement would probably be the same as normal refuse, or about 3 cu. yd/ton.

One alternative for handling the garbage component of solid wastes is on-site grinding, followed by discharge to the sewer system. This procedure adds 0.1 to 0.2 lb/capita/day (dry weight of solids) to the liquid waste discharge from residences. The additional water required is 1 to 2 gal/capita/day. Total grinding of garbage with water disposal would have the following results on the input to the sewage treatment plants:[2]

(a) Average increase in suspended solids of 50 percent.
(b) Average increase in BOD of 30 percent.
(c) Average increase in grit of 40 percent.
(d) An increase of up to 100 percent of scum and sludge in primary sedimentation.
(e) An increase of 5 percent to 10 percent of suspended solids and 15 percent to 30 percent of BOD in the effluent from primary sedimentation. The additional cost of operation of collective sewage treatment plants, because of complete grinding and water disposal of residential garbage, was estimated in 1960 to range from $0.50 to $1.50/capita/year.

The on-site costs of garbage grinding have been estimated as follows:

Capital cost: new home—$100
old home—$150-$200
Operation cost: $1.50/year for water and power
Maintenance cost: $7.00/year

Assuming $100 capital cost and a 20-year life, or $7.50/year, plus $8.50/year for operation and maintenance, the annual on-site costs would be about $16.00/year. Assuming a family of four, and $2.00/capita incremental cost for sewage treatment plant operation, the result is a total annual cost of $24.00, or $6.00/capita. Whether or not this incremental increase in costs would be more or less offset by the reduction in solid waste collection costs is a question requiring detailed investigation and analysis. It should be emphasized, however, that the cost estimates given above are based on very meager data.

[2] *Ibid.*

Garbage grinders are also available for on-site, commercial use; for example, in restaurants, food processing plants, hospitals, and hotels, or at central stations to serve garbage collection vehicles. We know of no central garbage grinders in this Region at the present time. Since the use of such grinders requires separation of garbage at the source, it would appear unlikely that this method would be used or would be efficient for garbage alone. However, on-site commercial grinders could be efficient, as well as desirable for public health reasons, provided the capacities of sewer systems and sewage treatment facilities are adequate. Commercial grinders cost from $1,000 for a 1½ horsepower (hp.) unit to $2,000 for a 5 hp. unit, installed. An operation handling up to ½ ton of garbage/day would generally use the 1½ hp. unit; where 2 to 3 tons/day of garbage is to be ground, the 5 hp. unit would be used. Average installed hp. would be approximately 2 hp/ton of garbage ground/day, at an average cost of $1,000 to $1,500/ton. Power cost would be approximately $0.10/ton of garbage. Gross water requirements vary from 5 gpm. for a 1½ hp. unit to about 20 gpm. for a 10 hp. unit. Assuming 2 hours per day of operation for the average 2 hp. unit for 1 ton of disposal capacity, the approximate gross water requirement would be 900 gal/ton, or roughly 1,000 gal/ton of garbage ground. The on-site costs of commercial garbage grinding would then be about $0.50/ton, as follows: capitalization at $10.00/yr/ton—$0.033; power—$0.08; water—$0.30; and maintenance—$0.10.

## Liquid waste quantities, present and future: sources of data

Liquid waste generation coefficients for biochemical oxygen demand (BOD) were developed for two broad categories: industrial, and all other. The "industrial" category consists of the major liquid waste generating industries. Coefficients for the present, and for the future under two alternative generation conditions, are based on data from various sources.[3]

Factors affecting the coefficients include (1) technology of the production process, including the nature of the raw materials; (2) product mix; and (3) the level of effluent controls which presently exists, or is likely to exist in the future.

The technology of the production process, as it affects liquid wastes generated (as well as water intake and water depletion), will vary from industry to industry. For some industries, such as

[3] W. W. Eckenfelder, *Industrial Water Pollution Control* (New York: McGraw-Hill, 1966). C. F. Gurnham, *Industrial Wastewater Control* (New York: Academic Press, 1965). D. H. Stormont, "Refineries Make Good Use of Fresh-water Supplies," *Oil and Gas Journal*, Vol. 61, No. 8 (1963), p. 90. Blair T. Bower, "The Economics of Industrial Water Utilization," Kneese and Smith (eds.), *Water Research* (Baltimore: Johns Hopkins Press, 1966), pp. 143-173. Several detailed studies of industrial water utilization have been made under the auspices of Resources for the Future, including studies of beet sugar, steam power, and fruit and vegetable canning, with less detailed studies of petroleum refining and pulp and paper.

fluid milk and perhaps the manufacture of soap and detergents, there appears to be relatively little likelihood of changes in the production process that would have a significant impact on BOD generated/unit of product output or per unit of raw product processed. Nor, in those two cases specified, does there seem to be a great likelihood of product output proliferation which would complicate the production process, thereby resulting in higher waste generation (as well as more gross water applied) unit.

On the other hand, there are industries in which it appears that there will be a continuing proliferation of product output, e.g., petroleum refining and pulp and paper, with related changes in production technology and possibilities for increases in BOD generation per unit. These are also industries, however, that may well be able to develop new production tchnology which, in spite of proliferation of product output, would result in reduced waste generation per unit.

The final factor affecting the generation and discharge of liquid wastes is the level and type of effluent controls specified. These controls can be imposed in various ways; e.g., with respect to the quantity of waste discharged, with respect to the resulting quality of the receiving water, and/or with respect to effluent or water utilization charges.

The coefficients finally selected were based on extrapolation of present data; these data are of varying quality among the relevant industry categories. They are based on different degrees of knowledge about the production technology and the water utilization practices in the given industries and on different degrees of knowledge about changing products in the various industries. The coefficients used are listed in Table A-18.[4]

Because the economic projections for the year 2000 were made only in terms of employees, the liquid waste (BOD) generation coefficients had to be transformed, for use in making estimates of wastes generated, into coefficients in terms of lb. of BOD/employee, for each of the relevant industries. This transformation had to take into consideration changes in productivity, in terms of physical output/employee over the time period. (This same transformation was necessary for application of the gaseous waste coefficients.) Tables A-19 and A-20 give the physical output/employee and liquid wastes generated/employee, respectively, for the relevant SIC industries.

[4]See Table A-24, p. 100, for definition of SIC industry categories.

**TABLE A-18**

**COEFFICIENTS OF LIQUID WASTES GENERATED, BY SIC INDUSTRY CATEGORY**

| SIC Industry Category | Present Waste Load Generated Lb. of BOD | Future With No External Stimulus | | Future With External Stimulus | | Original Sources[1] |
|---|---|---|---|---|---|---|
| | | Lb. of BOD | Assumptions | Lb. of BOD | Assumptions | |
| 2011, 2013, 2015 | 12/1,000 lb. of live weight | 12 | No reason to increase; product mix not adverse | 10 | Better utilization of raw product likely | Eckenfelder |
| 2026 | 1.2/1,000 lb. intake | 1.2 | No apparent reasons for change | 1.0 | Better housekeeping possible | Eckenfelder |
| 2033, 2037 | 30/ton of raw product processed | 30 | Predominance of vegetable production in area; product mix not adverse | 20 | Improved raw materials; increased efficiency of processing equipment | Bower |
| 2062 | 2/ton of product | 2 | Relatively straightforward production process with essentially one product | 1 | Changes possible, as in beet sugar industry | Gurnham |
| 2085 | 0.5/bushel of grain processed | 0.5 | No change foreseeable | 0.5 | No change foreseeable | Gurnham |
| 2261 | 50/1000 linear yards | 70 | Product proliferation i.e., coatings, etc. | 30 | Process modification possible | Gurnham, Bonem |
| 2262 | 20/1000 linear yards | 25 | Product proliferation | 10 | Process modification possible | Gurnham, Bower |
| 2621 | 80/ton of product | 100 | More emphasis on fine and specialty papers | 40 | Process modification; materials recovery; by-product production | Gurnham, Bower |
| 2631 | 50/ton of product | 60 | Proliferation of coated, colored products | 25 | Process modification; materials recovery; by-product production | Gurnham, Bower |
| 2641 | 30/ton processed | 50 | Product proliferation | 20 | Process modification | Gurnham, Bower |
| 2654 | 30/ton processed | 50 | Product proliferation, coatings | 20 | Process modification | Gurnham, Bower |
| 2911 | 100/bbl of crude processed | 110 | More jet fuel, gasoline per barrel of crude; increase in average complexity of refineries | 75 | Process modification; better housekeeping | Stormont |

[1]For complete sources, see footnote 3, p. 94. Mentions of Bonem and Bower refer to unpublished data.

TABLE A-19

PHYSICAL OUTPUT PER EMPLOYEE

| Industry | Unit | 1964 Output/Employee | 2000 Output/Employee |
|---|---|---|---|
| 2011 — Meat packing | 1,000 lb. of live weight processed | 225 | 383 |
| 2013 — Meat processing | 1,000 lb. of fresh and frozen meat processed | 64 | 109 |
| 2026 — Fluid milk | 1,000 lb. of intake | 364 | 1,475 |
| 2031 — Canned and cured seafood | 1,000 lb. canned | 54 | 317 |
| 2033 — Canned fruits and vegetables | Tons of fruits and vegetables canned | 92 | 540 |
| 2037 — Frozen fruits and vegetables | Tons of fruits and vegetables frozen | 139 | 815 |
| 2042 — Prepared animal feed | 1,000 tons of feed, output | 688 | 1,211 |
| 2051, 2052 — Bread, biscuits, crackers | 1,000 lb. of flour processed | 46 | 73 |
| 2061 — Raw cane sugar | Short tons of raw cane sugar | 306 | 834 |
| 2062 — Cane sugar refining | Short tons of refined cane sugar | 633 | 1,710 |
| 2086 — Bottled and canned soft drinks | 1,000 cases | 18 | 35 |
| 2085 — Distilled liquors | 1,000 bushels of grain processed | 3 | 6 |
| 2261 — Finishing plants, cotton | 1,000 linear yards | 186 | 664 |
| 2262 — Finishing plants, synthetic | 1,000 linear yards | 162 | 579 |
| 2621 — Paper, except building | Short tons | 127 | 362 |
| 2631 — Paperboard mills | Short tons | 317 | 904 |
| 2641 — Paper coating and glazing | Short tons of paper and board processed | 49 | 142 |
| 2654 — Sanitary food containers | Short tons of paper and board processed | 53 | 150 |
| 2841 — Soap and detergents | 1,000 lb. produced | 380 | 858 |
| 2851 — Paints and allied products | 1,000 gal. produced | 13 | 27 |
| 2871, 2872 — Fertilizers | Short tons produced | 621 | 1,525 |
| 2891 — Glue and gelatin | 1,000 lb. produced | 305 | 943 |
| 2892 — Explosives | 1,000 lb. produced | 64 | 198 |
| 2911 — Petroleum refining | 1,000 barrels of crude processed | 29 | 84 |
| 2951 — Paving mixtures and blocks | Short tons of asphalt processed | 409 | 1,187 |
| 2952 — Asphalt felts and coatings | Short tons of asphalt processed | 324 | 939 |
| 3111 — Tanning | 1,000 sq. ft. of leather tanned | 44 | 98 |
| 3273 — Ready-mixed concrete | Cu. yd. produced | 1,697 | 5,613 |
| 3275 — Gypsum products | 1,000 tons produced | 1 | 3 |
| 3312 — Blast furnaces | Tons of steel ingots | 167 | 449 |
| 3315 — Steel wire drawing | Tons of wire and wire products | 217 | 584 |
| 3321, 3323 — Iron and steel foundries | Tons of castings produced | 66 | 129 |
| 3331 — Primary copper | Tons of refined copper | 204 | 521 |
| 3334 — Primary aluminum | Tons of refined aluminum | 117 | 299 |
| 3361, 3362, 3369 — Nonferrous castings | Tons of castings | 13 | 36 |
| 3411 — Metal cans | 1,000 tons of cans produced | .12 | .40 |

TABLE A-20

LIQUID WASTE COEFFICIENTS: POUNDS OF BOD PER EMPLOYEE[1]

| Industry | Present (1964) | Future (2000)[2] no change[3] | increase[4] | decrease[5] |
|---|---|---|---|---|
| 2011 — Meat packing | 2,700 | 4,596 | — | 3,830 |
| 2026 — Fluid milk | 437 | 1,770 | — | — |
| 2033 — Canned fruits and vegetables | 2,760 | 16,200 | — | 10,800 |
| 2037 — Frozen fruits and vegetables | 4,170 | 24,450 | — | 16,300 |
| 2061 — Raw cane sugar | 1,224 | 3,336 | — | 1,668 |
| 2062 — Cane sugar refining | 1,266 | 3,420 | — | 1,710 |
| 2085 — Distilled liquor | 1,500 | 3,000 | — | — |
| 2261 — Finishing plants, cotton | 9,300 | 33,200 | 46,480 | 19,920 |
| 2262 — Finishing plants, synthetic | 3,240 | 11,580 | 14,475 | 5,790 |
| 2621 — Paper mills | 10,160 | 28,960 | 36,200 | 14,480 |
| 2631 — Paperboard mills | 15,850 | 45,200 | 54,240 | 22,600 |
| 2641 — Paper coating and glazing | 1,470 | 4,260 | 7,100 | 2,130 |
| 2654 — Sanitary food containers | 1,590 | 4,500 | 7,500 | 2,250 |
| 2911 — Petroleum refining | 2,900 | 8,400 | 9,240 | 6,300 |
| 3111 — Leather tanning | 6,600 | 14,700 | — | 9,800 |

[1] Lb. of BOD/employee = lb. of BOD/unit times the unit of output/employee.

[2] Based on coefficients in Table A-18 and productivity estimates in Table A-19.

[3] By the year 2000 there may be no change in the liquid waste coefficient/unit, i.e. lb. of BOD/ton; but, for a given industry, the lb. of BOD/employee would increase because of increased productivity/employee.

[4] Based on possible increase in liquid waste coefficients, with no external stimuli.

[5] Based on possible decreases in liquid waste coefficients, with external stimuli.

For the "all other" category, the coefficient for BOD generation was assumed to be 0.17 lb/capita for both the present and the future under Generation Condition X (no changes), and 0.20 lb/capita for the future under Generation Condition Y (changes stemming from increased affluence). A recent detailed study of per capita BOD generation showed that 78 percent of sewage treatment plants had inflows reflecting per capita BOD generation of less than 0.17 pounds, and 84 percent less than 0.20 pounds.[5]

Table A-21 shows estimates of BOD generated in 1964 by sub-area within the Region.

One other aspect of the analysis of liquid waste generation should be mentioned. For some industries, the degree to which water is recirculated within the plant affects the BOD generated/unit. Thus, this factor must be considered in developing future unit generation coefficients. The present extent of recirculation, as measured by the proportion of gross water applied coming from recirculated water (R/G x 100 percent) in the major industry groups of interest is shown in Table A-22.

With respect to the handling of liquid wastes after generation, the major industrial generators have three alternatives: on-site handling and disposal, discharge to collective systems, and some combination of these. The present extent to which various industry groups discharge to public sewer systems in the Delaware and Hudson region, which overlaps the RPA Study Area, is indicated in Table A-22, i.e. D/E x 100 percent.

The analysis of liquid waste generation and management costs cannot be divorced from analysis of industrial and municipal water utilization patterns as a whole, from intake to outlet. The same types of analyses as for BOD generation are necessary to develop unit coefficients for water intake and water depletion. This is illustrated in Table A-22, in which water intake/employee and water depletion/employee coefficients are shown.

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[5] N. W. Classen, "Per Capita Wastewater Contributions," *Public Works*, XCVIII (1967), No. 5, pp. 81-83.

## Water utilization for fly ash control in incinerators

Because incineration is such an important method for handling solid wastes in the Region, and because incineration is also a major contributor of residual gaseous wastes (primarily particulates) discharged to the atmosphere, some discussion of the interrelationship between reduction of particulate discharges and water utilization is warranted.

Theoretically, about 350 gallons of water at 70°F are required to reduce gas temperatures 1000°F for typical solid wastes of between 4,000 and 4,500 btu. heat value using 130 percent excess air. This would be an average condition for a wet impingement baffle installation in which gas temperatures leaving the combustion chamber are approximately 1600°F and are reduced to 600°F in the cooling and gas treatment process.[6] Actually, the water requirement is considerably higher than 350 gal/ton. It varies from 50 percent to 200 percent higher depending upon water loss, evaporation during treatment, etc.

For a wet baffle system, from two to five times the evaporated quantity of water is used in the fly ash handling system itself. If the water used for this purpose is plentiful and inexpensive, total water intake could easily be as much as 3,000 gal/ton of solid wastes incinerated. However, where the water is reused, evaporation in the treatment system and from the elevated temperatures of the reused water will result in a water intake of about 50 percent to 100 percent above the theoretical rate of 350 gal/ton.

Two other major factors influencing the quantity of water intake and the gross water used are the excess air usage and the heat value of the solid wastes. Although the use of larger quantities of excess air will reduce gas temperatures leaving the combustion chamber, they will also increase significantly the volume of gas that must be cooled, and invariably result in an increase in the amount of water required for cooling purposes. With respect to the heat value of the solid wastes, the quantity of water required is directly proportional to the heat value of the solid wastes.

For the more sophisticated high draft-loss, low-temperature, wet scrubbers, such as the Peabody Scrubber, water requirements are higher, since the operating temperature of the scrubber is usually around 150° to 200°F. Consequently, water use for such a system will be approximately 40 percent to 50 percent higher than the impingement baffle type installation.

To illustrate, the Whitemarsh, Pennsylvania Incinerator, a 10 ton/hour plant using a Peabody Scrubber discharging at 170°F, has a water treatment and recirculation system. We estimate that water evaporation will average between 250 gal. and 300 gal/minute, representing an evaporation rate of 1,500 gal. to 1,800 gal/ton of solid wastes incinerated. The Philadelphia Northwest Incinerator, which has mechanical cyclones for fly ash collection and uses water to reduce temperatures from approximately 1600°F to 600°F, results in water evaporation of 85 percent to 95 percent of the approximately 300 gal/minute used, for a 600 ton/day installation. This amounts to 600 gal/ton, or about one-third of the evaporation at the Whitemarsh plant. The heat value of the refuse at the Northwest plant exceeds 5,000 btu/lb.

[6] A wet impingement baffle is a type of wet scrubble which consists of a series of baffles with wetted surfaces. Dust and fly ash impinge on the baffle surface and are washed away as water is added to the surface.

TABLE A-21

LIQUID WASTE GENERATION (BOD) IN THE STUDY AREA, 1964

| County | All Other tons | Industrial tons | Total tons |
|---|---|---|---|
| Manhattan CBD | 15,900 | 6,900 | 22,800 |
| Manhattan Rmndr. | 32,600 | 100 | 32,700 |
| Brooklyn | 83,600 | 8,200 | 91,800 |
| Queens | 60,200 | 2,100 | 62,300 |
| The Bronx | 47,300 | 1,000 | 48,300 |
| Hudson | 19,000 | 10,100 | 29,100 |
| Essex (Newark) | 12,700 | 7,300 | 20,000 |
| Richmond | 8,000 | neg. | 8,000 |
| Nassau | 43,300 | 600 | 43,900 |
| Westchester (So.) | 20,300 | 1,000 | 21,300 |
| Bergen | 26,300 | 24,400 | 50,700 |
| Passaic (So.) | 12,500 | 27,000 | 39,500 |
| Essex (West) | 17,100 | 2,700 | 19,800 |
| Union | 16,700 | 5,900 | 22,600 |
| Suffolk (West) | 26,000 | 100 | 26,100 |
| Westchester (No.) | 6,100 | 400 | 6,500 |
| Rockland | 5,800 | 100 | 5,900 |
| Passaic (No.) | 1,000 | neg. | 1,000 |
| Morris | 9,900 | 4,800 | 14,700 |
| Somerset | 5,400 | 1,300 | 6,700 |
| Middlesex | 15,300 | 5,300 | 20,600 |
| Mercer | 9,100 | 2,900 | 12,000 |
| Monmouth | 12,400 | 400 | 12,800 |
| Fairfield (So.) | 19,400 | 200 | 19,600 |
| New Haven | 22,200 | 9,500 | 31,700 |
| Suffolk (East) | 2,700 | 0 | 2,700 |
| Putnam | 1,300 | 0 | 1,300 |
| Dutchess | 6,500 | 1,700 | 8,200 |
| Orange | 6,400 | 1,300 | 7,700 |
| Ulster | 4,100 | 600 | 4,700 |
| Sullivan | 1,400 | neg. | 1,400 |
| Sussex | 1,900 | neg. | 1,900 |
| Warren | 2,200 | 500 | 2,700 |
| Hunterdon | 1,900 | neg. | 1,900 |
| Ocean | 4,600 | 0 | 4,600 |
| Fairfield (No.) | 3,000 | neg. | 3,000 |
| Litchfield | 4,100 | neg. | 4,100 |
| **Totals (rounded)** | **588,200** | **126,400** | **714,600** |

**Note:** neg. = negligible.

Philadelphia incinerators which use wet impingement baffles for fly ash control and which do not recirculate water have a water intake of between 1,000 and 2,000 gal/ton of refuse burned. Between one-fourth and one-third of the water is evaporated, the rest being used for conveying fly ash to a settling chamber, after which the water is either returned to the river or empties into the Philadelphia sanitary sewer system.

## Gaseous waste quantities, present: sources of data

The activities of society generate vapors, gases, and dusts. Although these gases, vapors, and dusts can be characterized by their chemical properties, the large number of chemical reactions which take place in the atmosphere and the large number of chemical compounds which have insignificant impacts and effects on air quality and air "users" leads to assessing the air quality problem by analyzing the physical properties of these wastes.

TABLE A-22

WATER COEFFICIENTS, DELAWARE & HUDSON REGION, 1964

| SIC Category | Water Intake per Dollar of Gross Output | Water Depletion per Dollar of Gross Output | Water Intake per Employee | Water Depletion per Employee | S/G x 100 percent | R/G x 100 percent | C/G x 100 percent | D/E x 100 percent | IP/I x 100 percent |
|---|---|---|---|---|---|---|---|---|---|
| | thousand gal/dollar | thousand gal/dollar | thousand gal/ employee | thousand gal/ employee | | | | | |
| 20 | 18 | 1 | 765 | 53 | 21.1 | 31.7 | 36.5 | 29.6 | 32.7 |
| 22 | 41 | 3 | 794 | 57 | 0 | 77.4 | 3.2 | 61.5 | 35.7 |
| 26 | 168 | 4 | 5,527 | 137 | 0.3 | 60.5 | 1.6 | 10.1 | 2.5 |
| 2621 | 331 | 3 | 10,551 | 106 | 0 | 32.1 | 2.0 | 9.1 | 1.0 |
| 28 | 62 | 3 | 2,680 | 122 | 24.8 | 35.1 | 47.9 | 7.5 | 16.3 |
| 2815 + 2816 + 2818 + 2819 | 138 | 8 | 5,648 | 312 | 33.3 | 30.6 | 56.7 | 2.9 | 8.2 |
| 2821 | 60 | – | 2,160 | – | 1.6 | 50.0 | 36.7 | 11.7 | 10.0 |
| 2834 | 7 | 1.5 | 355 | 79 | 0 | 65.3 | 7.7 | – | 44.4 |
| 2911 | 162 | 3.5 | 22,900 | 512 | 27.7 | 57.2 | 33.9 | 0.1 | 1.7 |
| 30 | 17 | – | 401 | – | 0 | 47.0 | 35.3 | 22.2 | 33.3 |
| 32 | 67 | 3.5 | 1,438 | 74 | 23.5 | 23.5 | 13.7 | 2.7 | 5.1 |
| 33 | 124 | 9 | 3,954 | 290 | 5.9 | 21.8 | 51.3 | 3.2 | 5.0 |

G = Gross water applied
S = Brackish water
R = Recirculated water
C = Cooling and condensing water, other than steam electric generation
E = Final effluent
D = Discharge to public sewer
IP = Intake from public water systems

**Source:** *Water Use in Manufacturing*, 1963 Census of Manufacturers, MC63 (1)-10, 1966.

Combustion of fuel at present produces the largest quantity of gaseous wastes. The burning of oil, coal, a number of other minor fuels, and solid wastes produces smoke, oxides of nitrogen, sulphur dioxide, and dust. Consideration of gaseous wastes can usefully begin with smoke. Smoke is commonly understood to be burnable carbon particles. Where the design of a combustion system is correct and the installation properly operated, no visible smoke should be generated (and discharged to the atmosphere). On the other hand, inherent in any fuel is a small percentage of ash which cannot be burned.[7] A portion of this ash will remain in the combustion zone and the balance may be discharged in the gas stream to the atmosphere as fly ash. Both smoke and fly ash can accumulate under adverse weather conditions.

Sulphur dioxide, an invisible gas, is generated in the combustion process because of the inherent sulphur content of fuel. The amount of sulphur in fuels ranges from a fraction of a percent to as high as 10 percent. This substance, when reacted at high temperatures, produces sulphur dioxide and small amounts of sulphuric acid. In all high temperature combustion processes, the nitrogen in the atmosphere will combine with oxygen to produce oxides of nitrogen. These gases are not known to be directly objectionable, except under certain adverse weather conditions when they are activated by sunlight to produce ozone which, in sufficiently high concentrations, may have adverse effects on people, plants, or animals. This condition can only prevail when (1) the oxides of nitrogen are exposed for a few hours to sunlight; and (2) wind conditions are such that the oxides of nitrogen are not diluted more rapidly than ozone is formed.

All manufacturing processes which handle earthen materials produce small quantities of dust from grinding, milling, and similar operations. The industries involved are ceramics, primary smelters, stone, gravel, and asphalt preparation. All of these generate from ½ percent to 2 percent of the total raw material input as a gaseous waste. This dust is not particularly harmful, but it reduces visibility and may be deposited in large quantities on adjoining neighborhoods.

The use of gasoline-driven automobiles results in the generation of large quantities of gasoline vapor. This invisible material reaches the air from evaporation in the automobile carburetor and gas tank and through the operation of the engine, in which from 3 percent to 5 percent of the gasoline entering the cylinders is discharged through the exhaust only partially burned or, under some operating conditions, untouched by the high temperature in the engine. It has been clearly established that gasoline vapor, essentially consisting of hydrocarbons, will react in the atmosphere to form other gaseous materials. This phenomenon is known as photochemical smog. This photochemical reaction takes place under weather conditions which provide time for the reactions to take place between the hydrocarbons and ozone or oxides of nitrogen. There are many descriptions of this reaction, none of which are completely definitive, since the products of the reaction between hydrocarbons and ozone or oxides of nitrogen have never been completely identified.

[7] Some of the coal used in the Region's steam power plants has an ash content of almost 12 percent.

The chemical industry is another generator of gaseous wastes. In this industry, a great variety of compounds are manufactured. The gaseous wastes generated in production usually consist of invisible gases, or droplets of liquid materials. In general, these do not amount to large quantities, but they may be important contributors of odors which affect local areas. Each process must be individually assessed in terms of the wastes generated and their impact on air quality. Unlike combustion, which involves a basic process and a reasonably well-known range of fuels, the vast chemical industry has a wide range of production processes, making the development of waste generation coefficients difficult.

Basic data on the generation of gaseous wastes in various production processes and activities from which unit generation coefficients can be developed are very scarce. In addition to the preliminary work of the Public Health Service,[8] a major source is the work done by the Los Angeles County Air Pollution Control District. This work was extensively used in developing the coefficients used in this report. The coefficients for the most relevant industries are given in Table A-23; other coefficients and their applications are discussed in subsequent parts of this section. Table A-24 defines the SIC numbers and gives the physical units used.

Because there can be rapid variations in the assimilative capacity of the air, time variation in generation of gaseous wastes is of particular importance. So far as the authors are aware, virtually no data have been collected on this aspect of the problem, despite its important implications for policy decisions with respect to air quality management. What needs to be developed for the major gaseous waste generators are relationships of the types shown in Charts A-1 and A-2; that is, between operating rate of production and waste generation, and between the percent of time and waste generation, respectively. The importance of the variability in waste generation is illustrated by the following discussion of a specific case.

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[8] G. Ozolins and R. Smith, *A Rapid Survey Technique for Estimating Community Air Pollution Emissions* (U.S. Public Health Service Publication No. 999-AP-29; Washington: U.S. Government Printing Office, 1966).

TABLE A-23

**COEFFICIENTS OF GASEOUS WASTES GENERATED, BY SIC INDUSTRY CATEGORY**

| SIC Industry Category | Gaseous Waste | Gaseous Waste Generated | | |
|---|---|---|---|---|
| | | present | future | assumptions |
| 2911 | $SO_2$ | 45 tons/year /1,000 bbls. of crude processed | 22 tons/year | Cheaper source of fuel for refinery power; extraction of sulphur from crude oil input |
| | Hydrocarbons | 570 tons/year /1,000 bbls. of crude processed | 570 tons/year | No change |
| | Dust | 6 tons/year /1,000 bbls. of crude processed | 3 tons/year | Cheaper source fuel for refinery power |
| 2951, 2952 | Dust | 2.5 lb/ton processed | 2.5 lb/ton | No change |
| 3275 | Dust | 0.5 lb/ton produced | 0.5 lb/ton | No change |
| 3312 | Dust | 200 lb/ton produced | 20 lb/ton | Improved technology |
| 3321, 22, 23 | Dust | 10 lb/ton produced | 10 lb/ton | No change |
| 3361, 62, 69 | Dust | 15 lb/ton produced | 15 lb/ton | No change |

Chart A-1

**FREQUENCY DISTRIBUTION OF GASEOUS WASTES GENERATED**

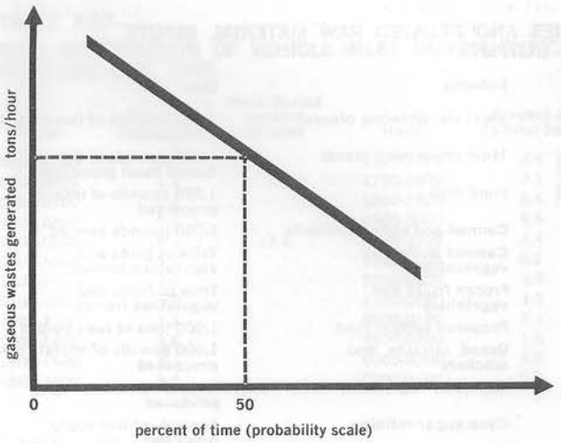



Chart A-2

**RELATIONSHIP BETWEEN OPERATING RATE AND GASEOUS WASTES GENERATED**

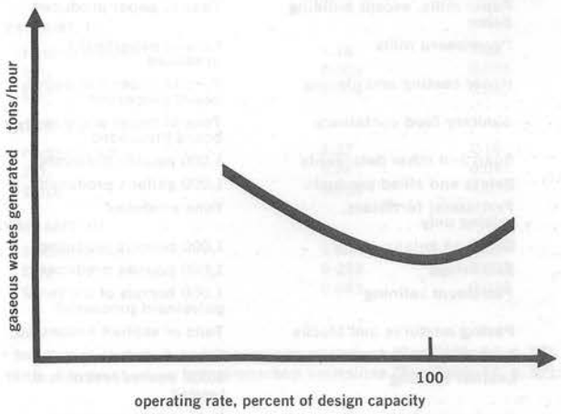


TABLE A-24

SIC CATEGORIES AND RELATED RAW MATERIAL INPUTS OR PRODUCT OUTPUTS

| SIC Code | Industry | Unit |
|---|---|---|
| 2011 | Meat slaughtering plants | 1,000 pounds of live weight processed |
| 2013 | Meat processing plants | 1,000 pounds of fish and frozen meat processed |
| 2026 | Fluid milk | 1,000 pounds of intake processed |
| 2031 | Canned and cured seafoods | 1,000 pounds canned |
| 2033 | Canned fruits and vegetables | Tons of fruits and vegetables canned |
| 2037 | Frozen fruits and vegetables | Tons of fruits and vegetables frozen |
| 2042 | Prepared animal feed | 1,000 tons of feed output |
| 2051, 2052 | Bread, biscuits, and crackers | 1,000 pounds of wheat flour processed |
| 2061 | Raw cane sugar | Tons of raw cane sugar produced |
| 2062 | Cane sugar refining | Tons of refined sugar produced |
| 2086 | Bottled and canned soft drinks | 1,000 cases (24 bottles or cans per case) |
| 2261 | Finishing plants, cotton | 1,000 linear yards |
| 2262 | Finishing plants, synthetic | 1,000 linear yards |
| 2085 | Distilled liquor | 1,000 bushels of grain processed |
| 2621 | Paper mills, except building paper | Tons of paper produced |
| 2631 | Paperboard mills | Tons of paperboard produced |
| 2641 | Paper coating and glazing | Tons of paper and paperboard processed |
| 2654 | Sanitary food containers | Tons of paper and paperboard processed |
| 2841 | Soap and other detergents | 1,000 pounds produced |
| 2851 | Paints and allied products | 1,000 gallons produced |
| 2871, 2872 | Fertilizers; fertilizers, mixing only | Tons produced |
| 2891 | Glue and gelatin | 1,000 pounds produced |
| 2892 | Exlposives | 1,000 pounds produced |
| 2911 | Petroleum refining | 1,000 barrels of crude petroleum processed |
| 2951 | Paving mixtures and blocks | Tons of asphalt processed |
| 2952 | Asphalt felts and coatings | Tons of asphalt processed |
| 3111 | Leather tanning | 1,000 square feet of leather tanned |
| 3273 | Ready-mixed concrete | Cubic yards produced |
| 3275 | Gypsum products | 1,000 tons produced |
| 3312 | Blast furnaces | Tons of steel ingots produced |
| 3315 | Steel wire drawing | Tons of wire and wire products |
| 3321, 3322, 3323 | Gray iron, malleable iron and steel foundries | Tons of castings produced |
| 3331 | Primary copper | Tons of refined copper produced |
| 3334 | Primary aluminum | Tons of refined aluminum produced |
| 3361, 3362, 3369 | Nonferrous castings | Tons of castings produced |
| 3411 | Metal cans | Tons of cans produced |

## Geographical and weather factors affecting air quality in Monroe County, New York.

Monroe County is located at approximately the midpoint of the southern shore of Lake Ontario. The present concentration of population and industry is in and about the City of Rochester, located six miles upstream from the mouth of the Genesee River. The terrain is moderately undulating and inclines toward the lake, which has an elevation of 246 feet. Five miles south of Rochester the elevation is approximately 600 feet, and along an east-west line 15 miles south of the City the elevation is about 1,000 feet. The valley of the Genesee River is not deep, so that gaseous wastes do not tend to accumulate therein.

The climate is generally moderate and is influenced both summer and winter by the temperature conditions of Lake Ontario.

The location and weather conditions make the area not subject to prolonged temperature inversion conditions. However, warm layers of air 500 feet above the ground level occur during the summer and fall months, and occasionally during the winter. This condition, which tends to prevent the escape of gaseous wastes discharged to the air, occurs only for short periods of time.

The frequency of low wind speeds is another factor in the accumulation of gaseous wastes. When wind speed is less than 5 mph., gaseous discharges to the atmosphere from various sources may accumulate over certain areas and, at best, will not disperse in such a manner as to reduce concentrations rapidly. Table A-25 shows the percentage of time for each month of the year when wind conditions are equal to or less than 7 mph. as compiled at the U.S. Weather Bureau station at the Rochester Airport.

TABLE A-25

WIND SPEEDS AT ROCHESTER AIRPORT

| Month | Percent of Time Wind Speed 0-3 mph. | Percent of Time Wind Speed 4-7 mph. |
|---|---|---|
| January | 5.5 | 18.3 |
| February | 5.9 | 15.3 |
| March | 5.3 | 16.3 |
| April | 6.8 | 19.2 |
| May | 8.7 | 22.9 |
| June | 8.9 | 24.5 |
| July | 9.8 | 27.5 |
| August | 13.1 | 28.7 |
| September | 9.12 | 25.9 |
| October | 10.3 | 34.4 |
| November | 6.7 | 19. |
| December | 4.8 | 17.5 |

TABLE A-26

**VEHICLE-MILES PER BUSINESS DAY FOR 1964 AND FOR VARIANTS I, II, AND III FOR 2000**
all values in thousands

| County | Present | VARIANT I | VARIANT II | VARIANT III |
|---|---|---|---|---|
| Manhattan CBD | 1,600 | 2,600 | 2,500 | 3,000 |
| Manhattan Rmndr. | 3,500 | 4,200 | 3,300 | 5,800 |
| Brooklyn | 8,800 | 9,000 | 7,600 | 10,400 |
| Queens | 13,600 | 16,500 | 13,500 | 17,700 |
| The Bronx | 5,000 | 5,900 | 4,500 | 6,400 |
| Hudson | 4,200 | 5,800 | 4,600 | 6,300 |
| Essex (Newark) | 2,800 | 2,900 | 2,500 | 3,200 |
| Richmond | 2,600 | 4,800 | 3,700 | 6,900 |
| Nassau | 14,000 | 20,500 | 16,800 | 22,800 |
| Westchester (So.) | 6,600 | 10,200 | 8,600 | 12,000 |
| Bergen | 8,500 | 14,000 | 11,200 | 16,400 |
| Passaic (So.) | 4,000 | 4,900 | 4,100 | 6,300 |
| Essex (West) | 5,500 | 8,100 | 6,500 | 10,100 |
| Union | 5,400 | 7,800 | 6,200 | 9,000 |
| Suffolk (West) | 11,400 | 18,000 | 23,200 | 12,600 |
| Westchester (No.) | 2,700 | 7,200 | 8,200 | 5,100 |
| Rockland | 2,500 | 4,400 | 5,300 | 3,000 |
| Passaic (No.) | 300 | 900 | 1,400 | 700 |
| Morris | 4,400 | 10,500 | 13,200 | 8,700 |
| Somerset | 2,300 | 8,800 | 10,600 | 6,400 |
| Middlesex | 6,500 | 14,200 | 17,400 | 10,900 |
| Mercer | 3,900 | 7,900 | 9,500 | 6,000 |
| Monmouth | 5,300 | 12,000 | 14,800 | 9,000 |
| Fairfield (So.) | 8,400 | 10,800 | 13,700 | 8,700 |
| New Haven | 9,600 | 15,000 | 18,800 | 11,000 |
| Suffolk (East) | 1,200 | 5,200 | 6,400 | 2,900 |
| Putnam | 500 | 2,800 | 3,400 | 1,300 |
| Dutchess | 2,800 | 9,300 | 11,700 | 4,900 |
| Orange | 2,800 | 10,200 | 12,100 | 5,300 |
| Ulster | 1,600 | 5,200 | 6,300 | 2,800 |
| Sullivan | 600 | 2,000 | 2,600 | 800 |
| Sussex | 700 | 2,500 | 3,100 | 1,200 |
| Warren | 900 | 3,800 | 4,600 | 1,700 |
| Hunterdon | 700 | 5,000 | 6,100 | 2,400 |
| Ocean | 2,000 | 6,000 | 7,300 | 3,000 |
| Fairfield (No.) | 1,300 | 4,600 | 5,700 | 2,100 |
| Litchfield | 2,600 | 5,400 | 6,500 | 2,600 |
| **Totals (rounded)** | **161,000** | **289,000** | **307,000** | **249,000** |

**Assumptions:** 1. Per capita vehicle ownership will remain the same
2. Per vehicle use will remain the same
3. Present travel patterns and transportation policies will remain the same
4. Time pattern within day will remain the same

**Note:** Based on Tri-State Transportation Commission data and RPA projections.

TABLE A-27

**TIME DISTRIBUTION OF VEHICLE-MILES DURING TYPICAL BUSINESS DAY, 1965**

| Hour | Percent of 24-hour total | Peak Period percent of total | Hour | Percent of 24-hour total | Peak Period percent of total |
|---|---|---|---|---|---|
| 0400-0500 | 0.9 | | 1600-1700 | 6.6 | |
| 0500-0600 | 1.2 | | 1700-1800 | 7.1 | 20.2 |
| 0600-0700 | 3.0 | | 1800-1900 | 6.5 | |
| 0700-0800 | 5.6 | | 1900-2000 | 5.5 | |
| 0800-0900 | 6.3 | 17.6 | 2000-2100 | 4.4 | |
| 0900-1000 | 5.7 | | 2100-2200 | 3.7 | |
| 1000-1100 | 5.0 | | 2200-2300 | 3.7 | |
| 1100-1200 | 4.9 | | 2300-2400 | 3.5 | |
| 1200-1300 | 4.7 | | 0000-0100 | 2.4 | |
| 1300-1400 | 4.8 | | 0100-0200 | 1.5 | |
| 1400-1500 | 5.2 | | 0200-0300 | 1.0 | |
| 1500-1600 | 5.9 | | 0300-0400 | 0.8 | |

TABLE A-28

**GASEOUS WASTES GENERATED AND DISCHARGED, MOTOR VEHICLES, STUDY AREA, 2000**

| | Wastes Generated million tons | Wastes Discharged, million tons: Management Condition T1[1] | Management Condition T2[2] |
|---|---|---|---|
| **VARIANT I** | | | |
| Hydrocarbons | 2.18 | 1.09 | 0.22 |
| $SO_2$ | 0.039 | 0.039 | 0.039 |
| Dust | 0.050 | 0.050 | 0.050 |
| **VARIANT II** | | | |
| Hydrocarbons | 2.32 | 1.16 | 0.23 |
| $SO_2$ | 0.041 | 0.041 | 0.041 |
| Dust | 0.054 | 0.054 | 0.054 |
| **VARIANT III** | | | |
| Hydrocarbons | 1.88 | 0.94 | 0.19 |
| $SO_2$ | 0.033 | 0.033 | 0.033 |
| Dust | 0.043 | 0.043 | 0.043 |

[1]50 percent reduction in hydrocarbon emissions (See Table 14, p. 57).
[2]90 percent reduction in hydrocarbon emissions (See Table 14, p. 57).

TABLE A-29

**COEFFICIENTS OF GASEOUS WASTES GENERATED, ENERGY PRODUCTION**

| Type of Fuel | Gaseous Waste: $SO_2$ present | $SO_2$ future | Particulates present | Particulates future |
|---|---|---|---|---|
| Coal | 75 lb/ton[1] | 37.5 lb/ton[2] | 16 lb/ton[3] | 16 lb/ton[3] |
| Oil | 0.3 lb/gal[2] | 0.15 lb/gal[2] | 0.008 lb/gal | 0.008 lb/gal |
| Gas | — | — | 15 lb/million cu. feet | 15 lb/million cu. feet |

[1]Based on average sulphur content of 2 percent
[2]Based on average sulphur content of 1 percent
[3]Based on average ash content of 5 percent

From Table 29 it can be estimated that from 15 percent to 25 percent of the time winds are less than 5 mph. These calm and low wind periods are expected to occur during evening and early morning hours and under conditions when the airflow will be from high land south of the lake toward the lake shore. The period of the year from May through October shows the greatest frequency of calm and low wind speed conditions. Thus, while certain influences of terrain and weather conditions will serve to create periods when residual gaseous wastes discharged will not move rapidly away from their sources, these conditions will not occur more than 25 percent of the time in any one month, and usually less. The balance of the time, the area will experience favorable weather conditions, which will serve to dilute all the discharges of gaseous wastes and thus avoid high ground level concentrations.

The above analysis of climate must be combined with data on the time pattern of gaseous waste generation to provide the basis for an air quality management program which can utilize measures to preclude high concentrations of gaseous wastes during periods of adverse weather conditions, i.e., low wind speeds and temporary inversion conditions.

## Transportation

Estimates of vehicle-miles were made on the basis of a continuation of present trends. The estimates were based on population density and vehicle-miles by sub-area for 1963. Regression lines were fitted relating population to vehicle-miles for counties with similar population densities. The same regression lines were used to estimate vehicle-miles by sub-area for 2000 for each variant. The results are shown in Table A-26. In estimating total gaseous wastes generated by vehicles in a year, it was assumed that on 250 and 115 days of the year the number of vehicle-miles would be 100 percent and 50 percent of those shown in the table. An average of 10 vehicle-miles/gallon of gasoline was assumed.

The time pattern of vehicle movements during a typical business day was based on a count of vehicles crossing the Manhattan CBD cordon in 1965. Internal vehicle movements were assumed to follow the same time pattern. The concentration of vehicle-miles in peak periods was assumed to remain essentially the same for the year 2000, and is shown in Table A-27.

Unit waste generation coefficients were based on Los Angeles County data; i.e., the use of 7.6 million gallons of gasoline in a day resulted in the generation of 1,862 tons of hydrocarbons, 33 tons of $SO^2$, and 43 tons of dust. The possible effects of other factors, such as vehicle mix (age and type) and average vehicle speed, were ignored. The resulting coefficients are:

| Gaseous Waste | Lb/gallon used |
|---|---|
| Hydrocarbons | 0.49 |
| $SO^2$ | 0.0087 |
| Dust | 0.011 |

These generation coefficients were assumed to be the same in 2000 as at present. Gaseous wastes generated and discharged by internal combustion vehicles in 2000 are shown in Table A-28.

## Energy generation

There are two principal utilities serving the Study Area: Consolidated Edison Company of New York, Inc., and Public Service Electric and Gas Company. Data provided by these two companies plus data from the Federal Power Commission[9] comprised the basis for estimates of the quantities of fossil fuels used to generate energy in the Study Area in 1964 and in 2000.

The following assumptions were made in arriving at estimated fuel use in 2000:

1. Con Edison and Public Service will produce about 70 percent of the energy generated in the Study Area. Total generation will be about 300 billion kwh.

2. The estimated mix of energy generation by source in the Region will be:

| | Percent of total |
|---|---|
| Nuclear | 70.0 |
| Pumped storage | 3.5 |
| Gas turbines | 3.5 |
| Other fossil fuel units | 23.0 |
| | 100.0 |

3. Most of the "other" fossil fuel units will use oil and gas.

4. For gas turbines, 50 kwh is generated/1,000 cu. feet of gas used; for large gas-fired units, 75 kwh/1,000 cu. feet; and for oil-fired units, 750 kwh/barrel of oil.

5. The results of these assumptions yield the following pattern of fuel use in 2000:

| | |
|---|---|
| Coal, thousand tons | 2,000 |
| Oil, thousand barrels | 50,000 |
| Gas, million cubic feet | 300,000 |

Obviously, the availability of natural gas is crucial to the foregoing estimates.

6. In addition to energy generated by the utilities serving the area, there will be an additional amount generated at various industrial locations.

7. With a load factor of 0.6 for both the present and future, a crude estimate of the energy generated on the peak day in the year can be made. Assuming a direct proportion between annual and maximum day energy generation and fuel use, the quantity of fuel used on the peak day can be estimated. Thus, total annual generation in 2000 is 300 billion kwh., or an average of about 0.82 kwh/day. With the load factor of 0.6, about 1.37 billion kwh. would be generated on the maximum day, or about 0.5 percent of the total annual generation. Thus, it is assumed that 0.5 percent of the annual fuel consumption was used on the maximum day; i.e., 10,000 tons of coal, 250,000 barrels of oil, and 1.5 billion cu. feet of gas.

In estimating gaseous wastes generated in energy production, it was assumed that the energy load and method of generation would remain essentially the same for all variants. The unit coefficients used are given in Table A-29.

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[9]Federal Power Commission, *Steam-Electric Plant Construction Cost and Annual Production Expenses*, Report S-171, Seventeenth Annual Supplement-1964 (Wash., D.C.: Federal Power Commission, 1966).

TABLE A-30

AGGREGATE REFINERY PROCESS MIX: NEW YORK REGION AND LOS ANGELES AREA

| Process | Ratio to Crude Charge Capacity[1] | |
|---|---|---|
| | New York Region | Los Angeles Area |
| Crude capacity, BPSD[2] | 348,500 | 849,500 |
| Vacuum distillation | 0.51 | 0.49 |
| Thermal operations | 0.036 | 0.35 |
| Catalytic cracking (fresh feed and recycle) | 0.63 | 0.38 |
| Catalytic reforming | 0.11 | 0.23 |
| Hydrogen treating | 0.32 | 0.34 |
| Alkylation | 0.046 | 0.042 |
| Polymerization | 0.014 | 0.004 |
| Lubes | 0.001 | 0.002 |
| Asphalt | 0.136 | 0.054 |

[1]Ratios are based on charge capacities for vacuum distillation through hydrogen treating, on production capacities for the remainder. Capacities are in barrels/day.
[2]BPSD = Barrels/stream day.

**Source:** "Refinery Capacities and Construction," *Oil and Gas Journal*, Vol. 65 (April 3, 1967), No. 14.

TABLE A-31

GASEOUS WASTE COEFFICIENTS, SPACE HEATING

| Gaseous Waste | Type of Area | |
|---|---|---|
| | Industrialized Counties | Other Counties |
| $SO_2$, tons/capita/year | | |
| present | 0.10 | 0.05 |
| future | 0.05 | 0.033 |
| Dust, lb/capita/year | | |
| present | 6 | 3 |
| future | 6 | 3 |

## Space heating

Oil is the predominant fuel used for space heating in residences, commercial establishments, and industrial operations.[10] Based on average fuel used in heavy industrialized counties, as in northeastern New Jersey, and in relatively nonindustrialized counties, coefficients were developed for $SO_2$ and dust produced in the two types of areas. For the year 2000, the trend toward increased use of gas and electricity for residential heating was assumed to continue. No change in fuel for space heating was assumed for industrial uses; however, the coefficient was modified to account for reduced sulphur content of the fuel. The coefficients are shown in Table A-31.

Present gaseous wastes generated and discharged in the Study Area in the present are shown in Table A-32. The figures are totals for 1964.

[10]The primary source of data on quantities of oil used and gaseous wastes generated in the New York Region is R. S. Yunghaus, "Metropolitan New Jersey's Air Quality — Approaches for Present & Future Control" (Paper presented at the Workshop for Air Pollution Control, MCA & Chemical Industrial Council of Eastern Pennsylvania; Philadelphia, March 16, 1967).

## Petroleum refining

The coefficients of gaseous wastes generated in petroleum refining were based on data from Los Angeles County. In that area, at the time of measurement, 722,000 barrels of crude throughput resulted in the following wastes generated: 1,550 tons of hydrocarbons, 1,060 tons of $SO_2$, and 10 tons of dust. The resulting unit coefficients are:

| | lb/barrel |
|---|---|
| Hydrocarbons | 4.30 |
| $SO_2$ | 2.94 |
| Dust | 0.028 |

Since products and processes vary from refinery to refinery, detailed analyses of gaseous wastes generated are necessary in each area. Lacking such data for the New York Region, the above generation coefficients were used for both the present and the future.

Some indication of the possible validity of this assumption can be obtained by comparing the mix of processes in the New York and Los Angeles areas. This comparison is shown in Table A-30 in terms of the ratio of aggregate capacity for specified processes to aggregate crude capacity. Thermal operations and catalytic cracking are the most important processes with respect to the generation of gaseous wastes. Thermal operations are virtually nil in the New York Region but are sizeable in the Los Angeles area. On the other hand, catalytic cracking operations in the New York Region comprise about a 65 percent greater proportion of crude capacity than in the Los Angeles area. Whether these differences balance out in terms of gaseous waste generation is not known.

TABLE A-32

GASEOUS WASTES GENERATED AND DISCHARGED, STUDY AREA, 1964

| Source | Wastes Generated, thousand tons | | | Wastes Discharged, thousand tons | | |
|---|---|---|---|---|---|---|
| | $SO_2$ | Dust | Hydrocarbons | $SO_2$ | Dust | Hydrocarbons |
| Space heating with oil: residential, commercial, industrial | 1,150 | 25 | | 1,150 | 25 | |
| Incineration: apartment (on-site) | | 15 | | | 15 | |
| municipal | | 110 | | | 55 | |
| open burning | | 120 | | | 120 | |
| total | 5 | | | 5 | | |
| Transportation: gasoline-driven vehicles | 20 | 30 | 1,215 | 20 | 30 | 1,215 |
| Petroleum refining and marketing | 175 | <5 | 255 | 115 | <5 | 165 |
| Industrial processes other than petroleum refining | | 70 | | | 10 | |
| Power generation: coal[1] | 485 | 105 | | 485 | 25 | |
| oil[2] | 165 | <5 | | 165 | 5 | |
| gas | | 5 | | | <5 | |
| **Totals** | **2,000** | **480** | **1,470** | **1,940** | **285** | **1,380** |

[1]Average sulphur content, 2 percent; average ash content, 5 percent
[2]Average sulphur content, 2 percent.

# 4. UNCERTAINTY IN ENVIRONMENTAL QUALITY MANAGEMENT

Because the environments, especially water and air, into which residual wastes are discharged vary with time and are predictable only in terms of probabilities, the management of wastes and of environmental quality must be considered within the context of uncertainty. Because the assimilative capacities of water and air vary within periods as short as a single day, from season to season, and from year to year, levels of water and air quality resulting from a specified time pattern of residual waste discharges can only be defined in terms of expectation. Further, the assumption that the time pattern of residual waste discharges is fixed is itself an oversimplification. There are probably factors which result in significant random variation in the generation and discharge of liquid, gaseous, and solid wastes from industrial operations, and liquid and solid wastes from residences.

A major problem, with profound policy implications, is that of determining the value of "certainty" of environmental quality, i.e., of having a specified dissolved oxygen or $SO_2$ concentration a specified percentage of the time; or conversely, the losses associated with periods of "deficient" air, water, and land quality, i.e., loss functions. Thus, how much is it worth to have a given level of air or water quality 100 percent of the time in contrast to, for example, 90 percent of the time? To put it another way, what losses—economic and otherwise—occur during short periods of time when water quality is less than the specified or desired level? What are the economic costs of reducing the frequency and duration of periods of deficient air quality?

An analogous situation exists in the planning of electric power systems. In this case the question involves the extent to which investment should be made in order to achieve a given level of service to the customers, expressed in terms of frequency of outage. In order to reduce outage frequency from one level to a lower level, additional investment costs must be incurred.[11] In order to determine the level of investment which is justified, the value which society places upon the avoidance of interruption of electric service must be determined. This necessitates an analysis of the costs to the power users resulting from interruptions. Relatively little research has been done in this area.

Ideally, continuous relationships between the degree and duration of quality deficiency and costs, and between the degree of deficiency and frequency of occurrence, need to be developed. Such relationships are analogous to those developed in the analysis of flood damage reduction, such as between stream level and flood damage and between stream level and frequency, from which relationships between flood damage and frequency can be developed. Of course, as noted elsewhere, essential components in developing such relationships are models which relate the time pattern of waste discharges to the resulting time pattern of water and air quality.

[11] See C. A. DeSalvo, C. H. Hoffman, and R. G. Hooke, "The Application of Planning Criteria to the Determination of Generator Service Dates by Operational Gaming," *AIEE Transactions*, LXXVIII (1959), Part III, pp. 1752-57. Some references are cited reporting on work on the general problem of service reliability and associated costs in power systems.

The relevant approach to defining loss functions with respect to water and air quality is similar to the approach to defining loss functions relating to water quantity shortages, i.e., periods in which the quantity of water available to one or more users is less than the "target" specified. For example, some analyses have been made of losses relating to shortages of irrigation water.[12] Little has been done to date with respect to loss functions for municipal water supply, industrial water supply, and water-based recreation.[13] In studies of navigation, benefits are ascribed to the short-run provision of navigation water during periods of low flows. These benefits are related to avoidance of delays to navigation and related costs which would occur if the flows were not provided.[14]

One problem in the development of loss functions is determining short-run variations in municipal and industrial water withdrawals and waste discharges. In power system planning, for example, power loads appear to vary randomly in the short run, around a long-term increasing trend line. Thus, according to one authority:

> "It has been pointed out that loads and certain outages are stochastic processes. This means that they are random events and that any one possible sequence of the events is a member of a family of sequences that can be described mathematically."[15]

It would seem that domestic water intake and discharge would also vary randomly. Available data indicate that water intake and discharge vary seasonally for many industrial operations, but that the random component is probably less significant than for municipal water use. However, studies of fruit and vegetable canning operations, petroleum refining, and paper manufacturing indicate sizeable variations in waste discharges even within a single day (both volume and load/unit). This variation stems primarily from variation in the operating level, which in turn is a function of changing availability of raw product and changing product mix.

Water quality loss functions can be developed, and some work has already been done on them.[16] The economic effects of poorer water quality to many users can be specified. For example, increased turbidity in intake water increases treatment costs for municipal water supply systems. Increased chloride content in-

[12] A hypothetical loss function for irrigation is developed and rationalized in A. A. Maass, *et al., Design of Water Resource Systems* (Cambridge, Mass.: Harvard University Press, 1962), pp. 274-278, The source of some empirical data is indicated in the discussion.

[13] A study of losses to municipalities and industries in connection with the recent drought in Massachusetts is currently underway, sponsored by Resources for the Future.

[14] Cf. Mississippi River Commission, *Mississippi River Reservoir Benefit Study, Report and Appendices A through E.* (Vicksburg, Miss.: U.S. Army Corps of Engineers, 1961).

[15] See M. B. Fiering, "The Nature of the Storage-Yield Relationship," *Symposium on Streamflow Regulation for Quality Control* (U.S. Public Health Service Publication 999-WP-30; Washington: U.S. Government Printing Office, 1965), pp. 243-253.

[16] Little work has been done with respect to air quality loss functions.

creases costs for such activities as paper manufacturing. (Of course, water quality is intimately related to water quantity. For many water quality variables, quality changes directly with changes in water quantity.)

Reasoning about losses is exemplified by the following. For domestic and municipal water supply, relatively small water shortages would appear to have little economic effect. The primary result is slight inconvenience to individuals, commercial establishments, and public users stemming from reductions in lawn and park watering, car washing, and so on. Some economic cost might accrue to such temporary inconveniences. For more severe water shortages, economic losses would presumably be greater. For example, inadequate water supply might reduce line pressures, thereby decreasing the amount of fire protection with a consequent increase in fire losses.

Basically, the economic effect of a water shortage on a user is a function of the flexibility of the operation, i.e., the ability to utilize alternative combinations of inputs under conditions of water shortage. With irrigation, for example, this is a function of the difference beween the diversion requirement and the consumptive use, and of the availability of other inputs, such as labor. If the difference between diversion and consumptive use is large, then the actual quantity diverted can be reduced considerably before consumptive use, and hence crop yield and income are affected. Other resources may be employed to counteract the reduction in available water—primarily labor. Water can be used more efficiently in order to achieve the same consumptive use. The degree to which flexibility exists in industrial processes is not well defined in relation to water utilization, although there are obviously some short-run adjustments which are possible, including shifts in product output.

The same approach is relevant to air quality. During periods of low assimilative capacity in the atmosphere, some adjustments are possible, such as a shift to higher cost fuels in power generation.

In environmental quality management, the problem is to determine the degree of certainty which is economically justified. For example, increasing the certainty of availability of some quantity and/or quality of water can be achieved by increasing the amount of reservoir storage, and hence the amount of water available to increase assimilative capacity. Beyond a limited range, each additional increment of certainty requires an increasing increment of storage to augment flows, and hence increasing increments of costs.[17] In water management, the marginal value of the incremental flow must not only be compared with the incremental cost of providing the flow but also with the costs of various alternatives to the provision of such flow as, for example, higher temporary production costs, higher temporary treatment costs, cessation of production, and temporary water recirculation. For a rational allocation of resources, the cost of the last increment of certainty should be no greater than the benefits derived therefrom. As demands on a relatively fixed water supply increase over time, knowledge about loss functions and alternative responses by water users will become increasingly important. Similar considerations are relevant to air quality management. The typical approach of planning for 100 percent certainty, whether for water or air, may well result in significant misallocation of resources.

[17] Fiering, *op. cit.*

## General references


City of New York, Department of Air Pollution Control, Bureau of Engineering, **Criteria Used for Upgrading Existing Apartment House Incinerators in the City of New York,** 1966. (See especially Figure 9, "Allowable Particulate Emission Rate vs. Refuse Charged."

Leo P. Flood, "Air Pollution from Incinerators—Causes and Cures," **Civil Engineering,** Volume 35 (1965), No. 12, pp. 44-48.

Richard J. Frankel, **Cost-Quality Relationships in an Engineering-Economic Model for Municipal Waste Disposal** (Preprint 150; Mobile, Alabama: ASCE Water Resources Engineering Conference, March 8-12, 1965), pp. 3-21.

Richard J. Frankel, **Economics of Artificial Recharge for Municipal Water Supply** (Reprint No. 62; Washington, D. C.: Resources for the Future, 1967), pp. 289-301.

William T. Ingram, Conrad Simon, and James R. McCarroll, "Air Research Monitoring Station System," **Journal of the Sanitary Engineering Division, Proceedings of the American Society of Civil Engineers,** Volume 93 (1967), No. SA 2, pp. 21-31.

Edward W. McHugh, "The Effect of Rapid Transit on San Francisco Bay Air Quality," **Journal of the Air Pollution Control Association,** XVII (1967), No. 5, pp. 277-279.

Ross Nebsoline and Eugene J. Donovan, "Fit Waste Water Treatment to Industrial Process," **Plant Engineering,** Volume 20 (1966), No. 6, pp. 140-145.

Tri-State Transportation Commission, **Electric Power Production and Fuel Consumption, 1965-1985; Interim Technical Report** (New York, 1967).

University of California at Berkeley, College of Engineering and School of Public Health, Sanitary Engineering Research Laboratory, **Economic Evaluation of Water Quality, An Engineering-Economic Model for Water Quality Management** (Report No. 65-3), pp. 1-167.

U. S. Department of Health, Education and Welfare, Public Health Service, Division of Water Supply and Pollution Control, **Modern Sewage Treatment Plants—How Much Do They Cost? A Practical Guide to Estimating Municipal Sewage Plant Construction** (Washington: U. S. Government Printing Office, February, 1965), pp. 1-37.

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# LIST OF TABLES, CHARTS, AND MAPS

## TABLES


1. Example of Effect of Recycling on Waste Management Costs in the New York Region 15
2. Types of Controls and Methods of Application 34
3. Methods for Improving Environmental Quality 35
4. Major Waste Generators in the New York Region 38
5. Population and Employment by Ring, 1964 46
6. Vehicle-Miles per Business Day by Ring, 1964, and Projected for Variants I, II, and III in 2000 46
7. Estimated Fossil Fuel Use for Energy Generation in the Study Area, 1964 and 2000 46
8. Waste Generation in the Study Area, 1964 46
9. Paper and Paperboard Consumption in the U.S., 1963 and 1980 47
10. Waste Generation Conditions, 2000 48
11. Growth Variants, Study Area: Population and Employment by Ring in 2000 50
12. Waste Generation in the Study Area, 2000 50
13. Residual Wastes Discharged to the Environment in the Study Area, 1964 56
14. Waste Management Conditions, 2000 57
15. Combinations of Management Conditions 57
16. Residual Wastes Discharged to the Environment in the Study Area, 2000 57
17. Estimated Peak Hydrocarbon Concentration 58
18. Characteristics of Wastes and Environmental Quality 68
19. Waste Management Functions in Need of Study and Analysis in Relation to Governmental Organization for the New York Region 69


## CHARTS


1. Waste Generation and Disposition 13
2. A Solid Waste Disposal System 15
3. Percent of Paper and Paperboard Production in the United States From Designated Materials 15
4. Relationship Between $SO_2$ Discharged and $SO_2$ Concentration 17
5. Relationship Between $SO_2$ Concentration and Damages 17
6. Waste Management System 23
7. Combinations of Present and Potential Methods of Handling Solid Wastes 26
8. Damage Function: $SO_2$ vs. Crop Yield 32
9. Damage Function: Chloride vs. Costs 32
10. Types of Controls for Environmental Quality Management 33
11. Density of Solid Waste Generation vs. Collection Costs 41
12. Incinerator Capacity vs. Capital Costs 41
13. Activated Sludge Treatment Plants: Degree of BOD Removal vs. Costs 41
14. Particulate Emission Level vs. Incinerator Capital Cost 41
15. Procedure for Waste Management Analysis 42
16. Accumulation of Solid Wastes for Disposal, New York City, 1965-2000 51
17. Accumulation of Solid Wastes for Disposal, Somerset County, New Jersey, 1965-2000 51


## MAPS


1. Regional Plan Study Area 36
2. Madeland vs. Wetlands — 1900 62
3. Madeland vs. Wetlands — 1966 63


## APPENDIX TABLES


A-1. Effect of Recycling on Waste Management 81
A-2. Effect of Spatial Arrangement on Waste Management 81
A-3. Effect of Management Policies on Waste Management 82
A-4. Effect of Spatial Arrangement on Costs 82
A-5. Effect of Generation Conditions on Waste Management 82
A-6. Computations of Solid Waste Components for Management Condition 1 83
A-7. Computations of Solid Waste Components for Management Condition 2 84
A-8. Computations of Solid Waste Components for Management Condition 3 85
A-9. Computations of Solid Waste Components for Management Condition 4 85
A-10. Population and Population Density in 2000 for Variants I, II, and III 87
A-11. Population and Employment Distribution in 2000; Variant I 87
A-12. Population and Employment Distribution in 2000; Variant II 88
A-13. Population and Employment Distribution in 2000; Variant III 88
A-14. Population, Population Density, and Employment by Major Categories, 1964 89
A-15. Solid Waste Generation in the Study Area, 1965 91
A-16. Disposal of Solid Wastes in the Study Area, 1965 91
A-17. Solid Wastes Generated in 2000: Variant I 92
A-18. Coefficients of Liquid Wastes Generated, by SIC Industry Category 95
A-19. Physical Output per Employee 96
A-20. Liquid Waste Coefficients: Pounds of BOD per Employee 96
A-21. Liquid Waste Generation (BOD) in the Study Area, 1964 97
A-22. Water Coefficients, Delaware & Hudson Region, 1964 98
A-23. Coefficients of Gaseous Wastes Generated, by SIC Industry Category 99
A-24. SIC Categories and Related Raw Material Inputs or Product Outputs 100
A-26. Vehicle-Miles per Business Day for 1964 and
A-26. Vehicle-Miles per Business Day for 1964 and for Variants I, II, and III for 2000 101
A-27. Time Distribution of Vehicle-Miles During Typical Business Day, 1965 101
A-28. Gaseous Wastes Generated and Discharged, Motor Vehicles, Study Area, 2000 101
A-29. Coefficients of Gaseous Wastes Generated, Energy Production 101
A-30. Aggregate Refinery Process Mix: New York Region and Los Angeles Area 103
A-31. Gaseous Waste Coefficients, Space Heating 103
A-32. Gaseous Wastes Generated and Discharged, Study Area, 1964 103


## APPENDIX CHARTS


A-1. Frequency Distribution of Gaseous Wastes Generated 99
A-2. Relationship Between Operating Rate and Gaseous Wastes Generated 99