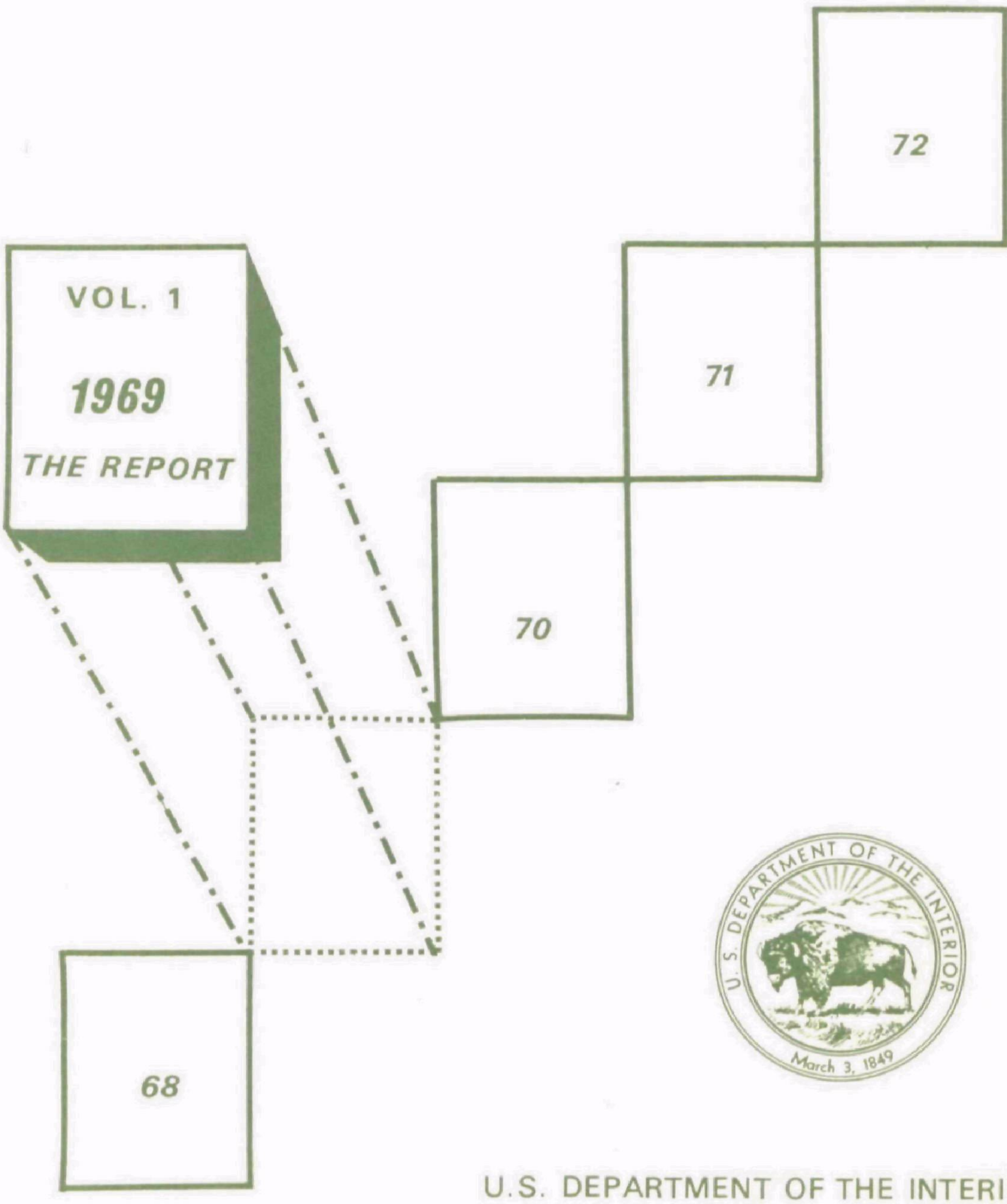
The Cost of Clean Water and its Economic Impact



U.S. DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration

THE COST OF CLEAN WATER AND ITS ECONOMIC IMPACT

Volume I

THE REPORT

U. S. Department of the Interior
Federal Water Pollution Control Administration

January 10, 1969

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UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

APR 2 - 1969

Dear Mr. President:

This transmits our complete 1969 report to the Congress on The Cost of Clean Water and its Economic Impact, pursuant to Section 16(a) of the Federal Water Pollution Control Act, as amended. The Introduction and Summary and Conclusions for this report were transmitted on January 16, 1969, by Secretary Udall.

Volume I, The Report, updates our 1968 analysis of costs contained in the first report, The Cost of Clean Water, submitted to the Congress last year. The 1969 report recognizes the progress made in providing waste treatment for sewered communities while pointing up the need for continuing high levels of investment in upgrading, expanding, and replacing the capital base which has been provided. It concludes that the current and expected short-run rate of investment in municipal waste treatment facilities is inadequate to meet water quality improvement requirements by 1973. Although industrial expenditure data are sketchy, they indicate that, in general, industry has a correspondingly more adequate rate of investment in wastewater treatment facilities.

Volume II, Appendix, provides supporting summary data from the 1962 and 1968 Federal Water Pollution Control Administration Municipal Waste Treatment Inventories, and the State water quality standards implementation plans. In addition, the Appendix contains State and industrial comments on the 1968 report.

Volume III, Sewerage Charges, addresses itself to methods of financing wastewater collection and treatment systems and discusses the considerations pertinent to the selection of a user charge program by local governmental units as a means for raising needed revenues. Based upon a hypothetical model approach, the impact of various user charge methods on each of several classes of users of wastewater systems is analyzed. The findings of this report support the application of user charges to finance a portion of the costs of sewage collection and treatment systems. The choice of the most favorable user charge method should be made on an individual basis by the local governmental unit concerned due to the myriad factors to be considered in such a choice.

A fourth volume is an industrial waste profile of the organic chemicals industry which was prepared by several well-qualified firms in the industrial water pollution control field. The profile includes (1) a five year projected range of cost estimates for attaining various levels of water pollution control by this important industry sector and (2) improved methodology for projecting treatment cost estimates for other industries.

We feel that the work reported on here is a significant step forward in the understanding of the economic aspects of water pollution control.

Sincerely yours,

Assistant Secretary of the Interior

Hon. Spiro T. Agnew
President of the Senate
United States Senate
Washington, D.C. 20510

Enclosure

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

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Sincerely yours,

Carl L. Klein

Assistant Secretary of the Interior

Hon. John W. McCormack
Speaker of the House of
Representatives
Washington, D.C. 20515

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INTRODUCTION

Section 16(a) of the Federal Water Pollution Control Act, as amended, directs the Secretary of the Interior to conduct three studies each year for transmittal to the Congress by January 10th of the following year. One is a study of the cost of carrying out the Act; another, a study of the economic impact on affected units of government due to the cost of installing waste treatment facilities; and the third, a study of the national requirements for and the cost of treating municipal, industrial, and other effluent to attain water quality standards established under the Act or applicable State law. The first series of studies, covering the five-year period beginning July 1, 1968, was submitted in January 1968. Annual updating reports are required each January thereafter. This report comprises a combined updating of the second and third studies -- the economic impact and the national requirements and cost estimate studies.

LAST YEAR'S REPORT

Last year's cost estimate study, The Cost of Clean Water, projected needs over the FY 1969-1973 period at $24 billion to $26 billion, exclusive of the currently completely unpredictable costs of dealing with the combined storm and sanitary sewer problem and the equally uncertain costs of dealing with such "other effluents" as those related to agricultural runoff, mine drainage, animal feedlots, oil pollution, and the like. The $24 billion to $26 billion estimate included projected capital outlays of (1) $8.0 billion for municipal treatment works, (2) $6.2 billion for sanitary sewer construction, (3) $2.6 billion to $4.6 billion for industrial waste treatment, (4) an upper limit estimate of $1.8 billion for industrial cooling treatment, and (5) operation and maintenance costs for municipal and industrial treatment facilities ranging from $5.3 billion to $5.7 billion. The $24 billion to $26 billion estimate is based upon the assumption of unchanging 1968 dollar values. These total estimates would rise to the $26 billion to $29 billion range assuming a continuation of historical increases in construction costs.

Last year's report presented a comprehensive overview of the costs of meeting water quality standards requirements. Allthough comprehensive, the results are considered extremely tentative, necessarily being based upon a series of assumptions. Chief among the assumptions were those relating to levels of cost, population bases for estimating purposes, current plant in place, and the levels of treatment required to achieve water quality standards. In addition, the study represented a first step towards estimating industrial waste control alternatives and costs.

Yet, despite these difficulties, it was apparent that those cost estimates were the most complete and valid estimates yet made on the macro-economic level. It was further apparent that not enough new information could be developed in the ensuing year, nor would the state of the pollution control situation change enough in one year, to warrant a massive attempt to further refine all these estimates. Attempting to concentrate upon all pollution areas would have resulted in no real improvement in the depth of understanding in any particular area and would have resulted in confusing and meaningless changes in the estimates without decreasing their probable error. Therefore, with the exception of changes in tentative cost estimates in the mine drainage, wastes from watercraft, and erosion and sedimentation problem areas, present estimates of cost remain as reported in last year's study.

THE CURRENT STUDY

This year's report includes four volumes. Volume I, The Report, comprises the cost estimate and economic impact studies required by the Congress. Volume II, Appendix, contains much of the detailed raw data upon which the municipal pollution section in Volume I is based as well as the reactions of State water pollution control agencies and key industrial organizations to last year's report, The Cost of Clean Water. Volume III, Sewerage Charges, is a study of local financing of wastewater treatment systems propared at the request of the Senate Committee on Public Works. The last volume is an industrial wastewater profile entitled, Projected Wastewater Treatment Costs in the Organic Chemicals Industry.

It is the intent of FWPCA in updating this report each year to concentrate on particular aspects of the overall problem, proceeding step-by-step to a more refined and sophisticated analysis of overall remedial costs. The aspects to be investigated in depth each year will be selected primarily on their magnitude, priority of importance in implementing the pollution control program, and on the availability of data.

In preparing this year's updated report, emphasis was placed on developing a deeper understanding of municipal pollution problems and their cost aspects. Accordingly, rather than revising the existing estimates of required expenditures presented last year, this year's study attempts to examine the factors that determine investment levels, to establish the current rate of investment, and to express some judgments as to any differences that may exist between existing expenditures and the pursuit of some national goals for municipal waste treatment.

Techniques used in this year's report were possible only because major improvements in information were gained during the course of 1968. The basic sources of data used were the compilation of annual contract awards for waste treatment and collection, the 1968 FWPCA municipal waste inventory, and the pollution control plans of the individual States. Of the three, only reported contract awards were available a year ago. It must be pointed out, however, that there are penalties involved in using very current data. This report was completed at a time when the municipal waste inventories for five of the 50 States remained to be assembled, when the inventorv data for the remaining States were largely preliminary and unverified, and before State program plans were fully analyzed or reduced to a consistent format. As a result, distortions and errors of fact are inevitably associated with portions of this report. In addition, because the data were in rough form, many of the conclusions drawn must be considered as tentative until such data can be verified as to accuracy. It is felt, however, that these shortcomings will be more than compensated for by the greater breadth and currency made possible by the use of the preliminary data.

Two important points should be kept in mind in reading the municipal section of the report. First, the reader should be alerted that the term "new plant" refers to a waste treatment plant providing treatment for the first time to a sewered community and not, for example, to a municipality which modernizes or replaces equipment at an existing plant or adds a new plant as part of an existing overall municipal system. Second, where expenditures in preceding years for waste treatment are discussed, those expenditures refer to current dollars unless otherwise specified as constant dollars. For example, expenditures in 1958 as compared with expenditures in 1964 are not adjusted to any common base insofar as the value of the dollar was concerned unless specifically indicated in the text.

Another area of concern deals with the problems and methods of financing local government investments in wastewater treatment systems. An appraisal of sewerage service charges was

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made, both from historical and theoretical viewpoints, as was an investigation of the potential of such charges for meeting revenue requirements. The dearth of information in many highly important areas of these investigations led to FWPCA'S sponsoring a comprehensive survey of wastewater system financing which is being carried out by the International City Managers' Association. The results of this survey are expected to provide information of considerable value in preparing next year's report.

To a lesser extent, certain aspects of estimating industrial costs have been refined during the past year. The industrial wastewater profile study performed under contract for FWPCA investigated two such aspects. First, it presents a five year projection of estimated costs of controlling pollution from the organic chemical industry, an extremely important sector of the industrial community, which was not included among the industrial profiles (The Cost of Clean Water, Volume III) prepared last year. Second, the profile developed a new and promising technique for approaching the overall problem of estimating industrial costs. The results of the contractors' effort are summarized in the Industrial Pollution section of Volume I and the profile is published in its entirety as another volume of this year's report. Although the profile provides cost estimates for the organic chemical industry and significant help in analyzing industrial treatment costs, it does not provide sufficient new information to warrant changing the industrial estimates presented in last year's report. In future reports, however, the results of this and other analytical efforts will be devoted to reducing the range of cost estimates so far developed.

During the year, a series of invitations were extended and meetings held with industrial organizations to receive comments on last year's industrial estimates. As a result of the comments, additional valuable insights into the problems of estimating industrial costs were gained which will be put to use in future analyses. Comments from several trade organizations are included in Volume II.

Further evaluation of techniques for estimating industrial costs again has emphasized the need for an industrial waste inventory to provide a baseline for analysis of the industrial pollution problem. As estimating techniques become more sophisticated and reliable, the need for such inventory data will be even more severely limiting to the reliability of the final estimates of cost.

The information presented on pollution stemming from "other effluent" sources has merely been updated with current developments. The discussions in last year's report reflected the extreme difficulty of delineating the extent and magnitude of these problems, the unclear understanding of how control may be affected, and the dearth of information on remedial costs. Progress in the last year has added only minimally to knowledge in these areas. The report does, however, describe the general requirements of State water quality standards as they apply to these diffuse "other effluent" sources; information completely unavailable for inclusion in last year's report.

Other Federal agencies also are studying various aspects of the nation's water pollution problem. For example, the U. S. Department of Agriculture's efforts are reflected in its March 1968 publication "Wastes in Relation to Agriculture and Forestry." An Ad Hoc Committee of the Office of Science and Technology also has been working on agricultural subject areas as they relate to the water pollution problem. As cost data from these investigations become available, they will be accommodated in future updatings of these annual reports.

Finally, this report presents a measure of the progress which has been made during the past year. The cost figures developed for last year's report provide estimated rates of investment in municipal and industrial pollution control which must be maintained over the short run if the nation's clean water goals are to be attained within the projected time period. Actual expenditure data compared to these normative rates provide a measure of the progress being achieved. In the final analysis, this measurement of progress in attaining our water quality goals is perhaps the most important contribution which this report can make as it is updated from year to year.

SUMMARY AND CONCLUSIONS

This section presents the summary and conclusions of the second annual report on national requirements and costs and economic impact on local governments in attaining the nation's clean water goals. Volume I, The Report, reaches the following conclusions:

1. Over 90% of the sewered population of the United States is currently connected to waste treatment plants, and about 60% is served by secondary waste treatment. It should be noted that these percentages do not include current data for the States of Pennsylvania, New York, New Jersey, Iowa and Arkansas. Inclusion of such current data would make these percentages even higher. Prevalence of treatment is greatest in States west of the Mississippi River in the coterminous U.S. Untreated sewered population not connected to treatment plants is concentrated in the New England States, New York, Pennsylvania. The southeastern States provide a secondary focus of population without waste treatment, and Alaska and Hawaii have a very low incidence of waste treatment. Deficiencies in providing needed secondary treatment are apparent in the same geographical areas.

2. Since 1952, the nation has invested about $15 billion in municipal and industrial waste-handling facilities. Of the total, 59% has been used to install collecting sewers and interceptors; 30% has been used to construct new municipal plan s and to construct or expand industrial waste treatment plants; and 11% has been expended in connection with municipal facility upgrading, expansion, and replacement needs. After rising at an annual rate in excess of 8.5% between 1952 and 1963, total outlays have been almost unchanged over the last five years (i.e., 1963-1968). Of the increase since 1952, roughly half has been due to price level changes. While investment in new treatment plants has been declining in recent years, and collection sewer investments have experienced a continuous decline in constant dollar value of investment, expenditures for interceptor sewers have been rising; and the portion of the total annual investment devoted to system upgrading, replacement, and expansion has grown almost 50%.

3. On the basis of limited information available in the absence of an industrial waste inventory, largely surveys conducted by McGraw-Hill Inc., and the National Industrial Conference Board, industrial expenditures for waste treatment facilities in the last two years appeared to be very close to target amounts established in the initial report on The Cost of Clean Water. Municipal investment, however, was less than half that proposed under the assumptions underlying that report, with the deficiencies most noticeable in the cases of collection sewers and upgrading, expansion, and replacement of treatment plants. Because a good part of the necessary expansion capital appears to have been available in the form of added capacity to meet future needs in already installed plants, and because need for another portion of the estimated expansion capital was dependent on the rate of collection sewer installation, it is difficult to characterize the significance of the deficiency in municipal investment.

4. Expenditures estimated by 40 of the 50 States in their program plans indicate that municipal waste handling investments over the five year period, 1969 to 1973, will amount to about $6 billion. The level of spending anticipated by these State plans is roughly equal to that spent during the last five years. To some extent, the States' views of their capital needs are independent of the prevalence of treatment achieved to date--while the eight northeastern States that contain over half of the nation's untreated population propose significant increases in expenditures, some States with near-complete installation of secondary waste treatment see no decline in future spending, and others with significant treatment deficiencies (Alaska and Hawaii, for example) indicate no increase in spending. However, experience has indicated that State estimates are constrained by the amount of Federal funds anticipated to be available over the period of estimate.

5. Upgrading, expansion, and replacement needs for plants, interceptors and outfalls account for a steadily increasing portion of total waste-handling investments. Currently, spending for those purposes is about equal to investment for new waste treatment plants. However, because the level of expenditures for expansion

and replacement has been rising by about $40 million a year for the last four years, it is very likely that such outlays will exceed new plant investments during 1969. Replacement costs have been controlled to a very considerable degree by the low average of treatment plants in service; but the average useful life of a waste treatment plant is such that during the next five years the first surge of construction following World War II should be reflected in a sharp rise in replacement needs. There seem to be great expansion and replacement needs in cities of all sizes. Upgrading and expansion investments should also begin in the future to be conditioned by the appearance in some situations of a need for advanced waste treatment.

6. A number of influences are acting to push investment requirements upward in spite of the high prevalence of municipal waste treatment. The average size of plant has increased markedly in recent years, as has the tendency of municipalities to treat industrial wastes. Existing data suggest that about half of the total volume of wastes processed by municipal plants is of industrial origin; and the portion seems to be rising. Costs of interception are rising as municipalities extend the reach of their collection systems. In addition, the degree of treatment required of waste-handling facilities is increasing in many cases and with it the unit cost of treatment.

7. There appear to be very significant differences in construction costs among various regions in the nation. On the whole, a low average cost of construction correlates positively with a high prevalence of treatment. The reasons for apparent cost differences are not understood, but the significance is clear. Those areas in which the most construction will be needed to achieve an adequate level of waste treatment are the very areas in which construction costs appear to be the highest, which should tend to push upward the total national investment for an adequate level of treatment.

8. Operating and maintenance costs associated with municipal waste treatment plants now aggregate $150 million to $200 million a year. Though operating costs have doubled in the last decade, their rise has not been as rapid as the increase in population served by waste

treatment, largely because of a combination of circumstances involving average size of place served by waste treatment, increased use of oxidation ponds, and a high relative use of primary waste treatment in the larger cities of the nation. The force of these influences is lessening, and a growing need for treatment of sewage for phosphorus reduction is being expressed largely as an influence on operating costs. In addition, increased emphasis on upgrading operational efficiency and the need to increase operator wages will tend to further increase total operating and maintenance costs. For these reasons, the costs of operat- and maintaining the nation's municipal waste treatment plants may be expected to rise very sharply in the immediate future.

9. Long-held expectations that the investment requirements associated with municipal waste treatment would be eased when some fixed "backlog" of needed treatment works was worked off do not seem likely to be borne out by events. As treatment deficiencies give way to new plant construction, investment requirements imposed by replacement, upgrading, and treatment of industrial wastes have been taking their place. In addition, it appears that investment in waste treatment thus far has been for those plants with lower unit costs of removal and that the investments remaining to be made will be at increasingly greater marginal costs. This situation will result in pressing capital requirements upward significantly for many years.

   In view of this, it is of particular concern that the levels of investment outlined in the State Program Plans, and strongly conditioned by the availability of Federal grant funds, are roughly equivalent to those of the last six years. These proposed investment levels indicate that unless the rate of capital investment is increased, the nation will fall behind in its goal of providing and maintaining adequate waste treat- treatment for its sewered population.

10. The cost of correcting combined sewer overflows by total separation of stormwater from sewage, including work on private property, was estimated in last year's report at $49 billion. Of this cost $30 billion dollars applied to public sewers. This estimate was based on a survey made by the American Public Works Association. In this survey they reported that alternatives to

separation may reduce costs below this level, perhaps close to $15 billion.

11. Municipalities have exerted only minimal efforts to correct combined sewer overflow problems to date, due largely to the existence of other needs involving higher local priority of funding. Local attitudes in this regard are changing as evidenced by local funding of demonstration projects amounting to nearly $30 million of a total construction cost of $45 million. Other communities are expending undetermined amounts on combined sewer problems, usually involving sewer separation. The level of effort nationally can be expected to expand due to increasing awareness of the pollution significance of combined sewer overflows and as a necessary means of complying with quality objectives established as a part of water quality standards. Interstate enforcement actions have also been an influencing factor in stimulating such efforts.

12. Current information indicates that approximately 85% of the cost for controlling combined sewer overflows will be incurred in 12 States. About 42% of the area and 65% of the projected combined sewer population served by combined sewers in the United States are located in less than four percent of the nation's communities. Since the cost can be estimated on an average per capita basis, approximately 65% of construction expenditures will take place in this relatively small number of communities. Many smaller communities are faced with overflow problems of a like scale when related to local funding resources; therefore, the small urban areas cannot be neglected where alternatives and remedial programs are explored. Also, the impact of combined sewer overflow problems on the immediate receiving body of water must be determined for each location. Small communities could be faced with problems just as serious as the large communities and require immediate corrective actions.

13. Last year's report, based upon several necessarily tentative assumptions, estimated industrial waste treatment costs over the next five years at $2.6 billion to $4.6 billion and cooling requirements at a maximum estimate of $1.8 billion. The reaction of key industrial organizations to these estimates, although useful in providing insights into these problem areas, did not provide a quantitative basis for adjusting this initial range of estimates. Accordingly,

until satisfactory refinements in the original estimating techniques are developed, or new information becomes available, the initial range cannot be more closely defined.

14. An industrial waste profile of the organic chemical industry was prepared during the year. This industry comprises an important portion of the "chemical and allied products" grouping for which cost estimates were presented in last year's report. That report estimated that capital outlays slightly under $400 million would be required over the next five years of the entire chemical industry to attain 85% removal of BOD. The organic chemical profile projects capital requirements of approximately $243 million for that portion of the chemical industry involving organic chemicals to attain comparable (83%) BOD removal over the next five years. The profile also provides estimates of capital outlays required to attain specfied removal levels of chemical exygen demand and suspended solids. In addition to developing cost estimates for the organic chemicals industry, the profile also provides improved methodology for projecting treatment cost estimates for other industries.

15. The necessity for carrying out a survey of industrial waste treatment facilities and requirements was again emphasized by the lack of such data as evidenced by industry comments on the first report and by continuing difficulties in obtaining an accurate appraisal of the industrial situation. It is essential to obtain this information if an adequate projection of industrial waste treatment costs is to be developed.

16. The entire area of "other effluents" remains unclear as to magnitude of the problems, remedial measures, and their costs. New, but limited improvements in knowledge, have been incorporated in this report. In addition, the implementation requirements for compliance with water quality standards have not yet been clearly defined for this class of effluent.

17. It is estimated that over $600 million will be required to minimally equip United States vessels, including pleasure craft, with water pollution control devices. The requirements of the performance standards that will be issued if proposed vessel legislation is

enacted will, of course, determine the actual cost requirements and the validity of this estimate.

18. The costs associated with control of erosion and sedimentation cannot be adequately quantified, especially those dealing with control of erosion from agricultural lands. Costs associated with control of erosion from streambeds, roadways, highway construction, and urban construction sites can only be estimated in very broad ranges. Total initial cost of providing erosion control measures for roadways and streambeds could range from a minimum of $300 million to as much as $10 billion. Annual recurring costs, including urban construction and maintenance of roadway controls, may be expected to range from $140 million to $1.4 billion. It should be recognized that erosion control is practiced for many reasons in addition to controlling pollution, such as preservation of valuable land, and reduction of harbor and reservoir siltation. Therefore, all costs of erosion control are not solely related to controlling pollution.

The initial erosion control costs will likely fall well below the $10 billion figure, depending upon the weighted average cost of providing control. Refinements of this figure can be made only after more extensive surveys are made of the erosion control needs of streambeds and roadways. Also, as more information becomes available as to the amount of erosion from various sources, control methods, and other benefits, agricultural land erosion control costs will be incorporated in the total cost ranges.

19. Studies and results of research contracts available since last year's report indicate that abatement of water pollution from acid mine drainage to meet water quality standards in some cases will require neutralization of acid discharges from active mines and of residual acid discharges from sealed abandoned mines. A summation of the estimated 20 year costs, in constant 1968 dollars, for reducing acid mine drainage ranges from $1.7 billion for a 40% reduction to as much as $6.6 billion for a 95% reduction. Here again the actual costs will depend upon the amount of reduction that is required in specific areas to meet water quality standards.

20. The cost of oil field brine disposal, if it were all required to be disposed of through injection methods,

would fall in an estimated range from $43 million to $758 million. The actual costs would fall somewhere between these two figures depending upon the weighted average costs of the treatments applied and the amount of this cost that can be regained through the beneficial effects of using injection as a secondard recovery method. The cost of chemical brine disposal cannot be estimated until information is available on the volume and character of the brine involved and the probable disposal methods that will be used.

21. Total costs of controlling oil spills cannot be estimated. However, some minimum cleanup costs per unit can be estimated and some examples of total costs of individual cleanup costs can be cited. Using dispersion techniques, and under ideal circumstances which are not possible in many cases, the minimum cost per ton of oil dispersed would run about $250. (These costs are equal to about $450 per gross registered ton.) In at least one case, the costs have been five times this amount. If the oil reaches the beaches or if the spill is in an area where dispersion is not adequate the costs may run substantially higher. Total cost per individual spill varies tremendously, depending on such factors as the amount of pollutant spilled, location of the spill, and the weather. However, experience has shown that total cleanup costs can be very high, even for a single ship disaster. The Torrey Canyon spill, for example, cost an estimated $15 million to clean up and that operation was generally not considered satisfactory.

22. Water pollution from animal wastes, especially from animals in confined feeding situations, is a serious and growing problem. However, lack of data prevent estimation of the total pollution potential from this source as well as either total or unit treatment costs. As on-going and planned future research projects are completed, and site-by-site inventories of animal feedlots are completed, there will be a more adequate basis for estimating the actual scope of the feedlot pollution problem and its remedial costs.

23. Present information on salinity caused by irrigation does not provide a basis for estimating costs of correcting the problem. Current studies in specific areas should provide the groundwork for determining the factors affecting salinity abatement costs.

24. Information that would lead to estimates of the scope of the pesticide water pollution problem and its abatement cost is not available. Last year's report described the problem in general terms and discussed the known relevant factors that affect costs. This year's report adds some discussion of the approaches of the States to the problem. At present, control of the pesticide problem is usually through applicator licensing, pesticide labeling laws, and education of the users. Research is being carried out by other governmental and private agencies in an effort to develop pesticides that will not be sources of water pollution. Other research is aimed at quantifying the problem and determining abatement measures that can be taken until new pesticides are developed. Estimates of future control costs will be largely dependent upon the results of these research efforts.

25. Last year's report estimated the five year costs for control of radioactive wastes from nuclear generating plants at from $60 million to $120 million for capital costs and $42 million for operation and maintenance. It also estimated the five year capital costs for uranium milling treatment at $3 million and operation and maintenance costs at $13 million. No additional cost data have been developed since that report so these estimates have not been revised. However, it is expected that on-going studies such as FWPCA'S Colorado River Basin study will provide additional quantitative information on this problem.

Volume II, Appendix, presents tabular data developed for the analysis in this report, and the comments received on last year's study from various State agencies and industrial organizations.

Volume III, Sewerage Charges, provides an analysis of methods of charging for the provision of sewerage service in a community. The following results summarize the major aspects of this study:

THE CURRENT POSITION OF USER CHARGES

In the first section, the current status of user charges is described. Several of the reports upon which the discussion is based were prepared some time ago and may be outdated. Moreover, the information presented in the reports is not uniform. Accordingly, the description unavoidable reflects these weaknesses in the same material. Nonetheless, the following results are indicated by the data:

1. There are two major types of user charges -- sewer service charges and tap fees. Sewer service charges are monthly or quarterly levies which represent the source of more than 90% of the user charge revenue. Tap fees are levied only when a customer is first connected to the sewer system. Although tap fees account for less than 10% of total user charge revenue they may be important in financing construction of the initial sewerage system and of additions for some municipalities.

2. Approximately 70% of the municipalities over 5,000 in population and a substantial number of municipalities below this size employ sewer service charges of some type. Over three-fourths of these municipalities have adopted such charges in the last 20 years. There also are several sewer and utility districts which levy sewer service charges.

3. There are several reasons for the recent growth in the adoption of user charges, the most important of these being: (1) State and local legal limitations on the amount of general obligation debt; (2) limitations on municipal tax sources and on the taxing power of special districts; and (3) a rapid increase in the demand for public services at the municipal level. When user charges are combined with revenue bonds, State and local debts are not normally increased. The financing of sewerage services through user charges therefore allows a municipality to employ its taxing power in meeting the cost of other public services such as education, roads and urban renewal.

4. The formulas used to determine sewer service charges are varied but they can be placed into five general categories: (a) water use, (b) number and type of plumbing fixtures, (c) uniform flat rate (an identical charge for each customer), (d) modified flat rate (the charge varies by type of customer), (e) size of water meter, and (f) size and number of sewer connections. The most commonly used formula is a uniform or modified flat rate. However, its use is concentrated in the municipalities below 5,000 in population. For municipalities above 5,000 population, approximately 65%

base the charge on water use. The percentage of municipalities employing a water use charge also appears to be increasing. Many municipalities that base the levy on water use exclude water used for lawn sprinkling from the charge. The number of municipalities that base the entire charge on the number and type of plumbing fixtures, size of water meter and size and number of sewer connections is estimated at less than 10%. However, some municipalities levy a minimum charge based on one of these factors and a variable charge on water use.

5. Over 35% of the municipalities provide sewerage service to customers residing outside the municipal boundaries and the percentage is probably increasing. Two-thirds of the municipalities that service outside customers charge them 50 to 100 percent more than the customers residing inside the municipality.

6. Nearly all municipalities have provisions in their ordinances that prohibit the discharge of certain wastes into the sewer system. However, there are variations in restrictions and enforcement severity. Most municipalities do not require pretreatment.

7. Approximately 100 to 200 out of the largest 3,000 municipalities levy a surcharge on industries that discharge effluents of above average pollutant levels. The charge is commonly based on biochemical oxygen demand and suspended solids but oil and chlorine demand are also included in some formulas. Many of the cities which have employed these surcharges indicate that such charges have had some impact on reducing the volume and the strength of effluents discharged by industries.

8. The annual per capita yield from sewer service charges ranges from less than $1 to over $60 but the average yield is estimated at $7, excluding municipalities that levy a uniform flat charge. The annual per capita yield where a uniform flat rate is used is about $5.

9. Statistics relating user charge revenue to sewerage costs are sparse, but it is likely that over two-thirds of the municipalities employing user charges more than meet the operation and maintenance costs of the sewerage system from this revenue source. In Texas, for which the most extensive data were available, user charge revenue exceeds operation and maintenance costs

for more than 90% of the municipalities employing user charges. It is likely, however, that less than one-third of these municipalities obtain enough revenue from user charges to meet both operation and maintenance and debt service costs. The ratio of revenue to costs appears to be the smallest for municipalities below 5,000 and above 500,000 in population.

10. Sewerage charges as a revenue device must be considered within the context of total local government expenditures for all purposes. In spite of increased revenue efforts by State and local governments, revenues have not generally kept pace with expenditures. The income shortage has been covered by larger Federal grants and increases in State and local debts greater than increases in gross national product. The waste treatment cost covered by local governments is usually local cost after deducting State and Federal grants; thus the revenue to cost picture presented is even less clear in this light. The ability to finance all costs in the absence of grants is not known.

DISTRIBUTION OF COST RESPONSIBILITY BETWEEN USERS AND NONUSERS

11. In the second section of Volume III, various formulas for dividing sewerage costs between users, (individuals and businesses who discharge wastes into the system) and nonusers (property owners and Federal, State and municipal governments) are discussed. It should be noted that an individual or business may be assessed costs as a nonuser and also as a user if wastes are discharged. One finding is that no matter what opinion one may have about this division of costs he can find a theory to support it because the formulas vary so widely in terms of where the responsibility for the collection and treatment of wastes is placed. However, this report concludes that there is a strong case for dividing the costs between users and non-users. On this basis, a well-designed user charge system should not cover all of the total construction, operation, and maintenance costs of a sewerage system.

    There are several reasons why users should meet a substantial share of the costs of the sewerage systems. First, users benefit from the collection and treatment of their wastes and it is equitable that they pay for this service. A properly designed user charges system will enhance the equity characteristics by distributing costs in a manner more closely related to service provided than will other ways of raising revenue.

Second, effectively administered user charges can also improve the management of industrial wastes. Charges on volume, and sometimes strength of wastes, can create an incentive for industrial users to pre-treat, change processes and manage wastes more effectively.

Third, user charges provide a relatively stable source of revenue with which to meet sewerage costs which allows for a business-like management of the sewerage system and provides for an orderly expansion and up-grading of the system.

The case for assigning some of the costs to non-users is less obvious but is no less valid. First, property owners gain from having a sewerage system through an appreciation of property values whether or not they discharge wastes. Second, storm water collection in combined systems and the availability of sewerage service both are likely to have a positive influence on property values. Third, the general public benefits from improved water use, disease control, recreational opportunities, and esthetics.

The report suggests that non-users should bear a much greater share of capital costs than operation and maintenance costs. However, no exact division of costs between users and non-users can be specified. Each situation must be examined in terms of the relevant characteristics. For example, property owners should bear a smaller proportion of the costs in areas where storm and infiltration water is unimportant as compared to areas where this water volume is important. Also, policy considerations related to ability to pay and the desired rate of investment for controlling pollution influence the shares borne by higher levels of government. Nor can any universal method of collecting the revenue be specified; there are several types of user charges. On the non-user side, property owners may meet their responsibility through a number of means. Often, these costs will be met through special assessments or through the price of property in cases where developers install the sewer system. Sometimes, non-user costs will be met through general property taxes.

Some of the formulas described in the report do not discuss the role of Federal and State governments in the financing of sewer systems. However, there are several reasons why Federal and State grants should be used in this area. These grants will enable the necessary standard of water quality to be obtained more quickly and will encourage municipalities to plan and construct sewage systems. The grants aid municipalities over the difficult transition period when treatment plants are being constructed, the system is under-utilized, user charges have not or cannot be depended upon to cover the costs, large increases in the property tax are politically unacceptable and debt limits are nearly reached. On balance, Federal and State grants coupled with regulatory action have tended to stimulate investments in waste treatment facilities.

THE DISTRIBUTION OF COST RESPONSIBILITY AMOUNT CATEGORIES OF USERS

12. The third section of the report is devoted to examining various charge formulas in terms of generally accepted tax or charge canons and in terms of the impact on various types of customers and the income distribution. No charge formula is clearly superior to all of the others in terms of equity, economic efficiency, ease of administration, and revenue adequacy. For example, a uniform or modified flat rate charge is the easiest to administer but is deficient in other ways to other types of charges. The so-called Joint Committee Formula (a charge based on the volume and strength of sewage) appears to be a highly equitable system but it is difficult to administer. A charge based on water use scores between the uniform flat rate and the Joint Committee formula when all considerations are taken into account.

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13. A model was constructed to measure the impact of different charge formulas on the various categories of users. Users were classified into residential, commercial, and industrial groups and the charges studied were: (a) a uniform flat charge, (b) a charge proportionate to water volume, and (c) a charge proportionate to biochemical oxygen demand discharged. It is recognized that a uniform flat rate would likely not be used in an actual situation as that modeled; however, it serves to delineate the limits of cost distribution. The amount paid by each user category if sewerage costs were met by the property tax was also computed. Residential users would pay the most under a flat rate and the least under a charge based on biochemical oxygen demand. Industrial users would be in the opposite position. Commercial users would pay the most if costs were covered through a property tax and the least if a flat charge was used.

14. Under any of the charge formulas, the proportion of income paid by an individual in user charges is inversely related to the level of his income. Charges based on water volume and plumbing fixtures are not as likely to widen income differentials as a uniform charge.

15. A municipality, when choosing a charge formula, has to examine the alternatives in the light of its own situation; no general recommendation that can be made at this time would be of much value. In particular, such evaluations must examine the trade-off between administrative simplicity and equity. A water use charge appears to be a good compromise choice if water is already metered; in cases where a variety of industrial wastes form a large part of the sewage brought to a treatment plant, such as may occur in a regional system, a charge based on both volume and strength of waste may be appropriate.

GOALS AND PERFORMANCE
THE BACKGROUND FOR EVALUATION

THE BACKLOG CONCEPT

One of the enduring concepts in the field of water pollution control is a legacy of the Conference of State Sanitary Engineers who at the end of 1960 concluded a survey that indicated a need for 5200 sewage treatment projects having an estimated cost of $2 billion. That expression of need, termed a "backlog" of required works, reflected both the esentially regulatory frame of reference of its compilers and their intimate knowledge of conditions within their respective States.

Eight years later, the nation is in the position of having built almost 4400 new municipal waste treatment plants, having undertaken more than 2000 replacement, upgrading, and miscellaneous projects, of having invested about $1.1 billion in new treatment plants and about $1.3 billion in upgrading, expansion, replacement, and miscellaneous projects; yet concern continues to be expressed about the dimensions of the investment that will be required to eliminate the backlog of needed waste treatment plants.

The most obvious, the clearly minimal, definition of any existing "backlog" would be the need to provide waste treatment to the almost 1600 sewered places in the nation that do not treat their wastes. To accommodate policy-established definitions of baseline treatment adequacy, upgrading the 2100 primary treatment plants in the nation to secondary treatment can be added as an additional component of a backlog. When these 3700 situations are arrayed by size of place, multiplied by appropriate cost functions, multiplied again by a factor to represent the historical relationship between plant costs and costs of interceptors and outfalls in each plant-size category, and summed, the calculation of that "backlog" amounts to less than $2 billion.

That figure, while not highly inconsistent with the 1960 Conference of State Sanitary Engineers' definition of backlog (taking into account price level changes, operational and institutional developments, and increase in sewered population), stands in stark contrast to the $8 billion estimate of need made by FWPCA in 1967 on the basis of an assumption of secondary waste treatment for most of the total urban population of the nation. Both conflict with calculation of the investment consequences of construction needs defined in the water quality standards implementation plans--an amount in the neighborhood of $1.1 billion. No explanation based on inventory inadequacies, unit cost deficiencies, or differences in regional cost can adequately account for estimating differences of almost eight to one. Only a fault in basic assumptions or a significant change in circumstance can account for the variation found to exist between various estimates of the cost of water pollution control.

It may be argued that the concept underlying almost every cost estimate that has been made--that is, the idea of a fixed backlog--is no longer a valid assumption in light of the current status of waste treatment, as reflected in the 1968 Municipal Waste Inventory.

Water pollution is a process as well as a condition. It is dynamic in its occurrence, fluctuating in its circumstances. So water pollution control must be flexible in its approaches; and time forms an essential element in estimates of its cost.

This document, then, views the municipal costs of water pollution control within a context of dynamism. It gropes with the question of determining an appropriate rate of investment rather than establishing a final cost of water pollution control. In substituting the dynamic view for the static one, it recognizes the disagreeable fact that pollution control will continue to require expenditures, that pollution cannot be ended by spending any single lump sum. It loses something in apparent precision. It is felt, however, that the view compensates for any lack of definition by bringing us closer to a manageable statement of real conditions.

The changed way of looking at things imposes a broader view and forces a recognition of problems in relating Federal programs to events in such a way that the programs will not be out of date or mis-scaled by the time they are initiated. While all the ramifications of the approach are not understood, analyses now being undertaken can be expected to yield some insights over the coming year. These may be useful in recasting legislation after the expiration of current authorization in (Federal) Fiscal Year 1971.

THE INVESTMENT BACKGROUND

Over the period 1952-1966--broadly speaking, from the beginning of large scale post World War II public investment in water pollution control to the establishment of water quality standards under the Federal Water Quality Act of

TABLE 1

DISTRIBUTION OF GROSS
WASTE HANDLING INVESTMENT,
1952-1966

NATURE OF INVESTMENT	MILLIONS OF DOLLARS	PERCENT OF TOTAL
Public Treatment Plants	1704	11.3
Industrial Treatment Plants	2808 1/	18.6
Treatment, Total	4512	29.9
Interceptors and Outfalls	2018	13.3
Sanitary Sewers, Publicly Constructed	4869	32.2
Sanitary Sewers, Privately Constructed	2092	13.8
Sewers, Total	8979	59.3
System Rehabilitation and Mixed Contracts	1634	10.8
Total	15,125	100.0

1/ Including value of industrial connection to municipal systems.

1965--the U.S. invested some $15 billion in water pollution control equipment and facilities.

Investment was concentrated on waste collection and transmission systems. Almost 60% of identifiable capital expenditures was for sewers of some description; and of the 11% of the water pollution investment budget that was used for expansion, replacement, and alteration of systems, some indeterminate portion was also devoted to collection facilities.

The most visible effect of those large expenditures, however, was the construction of over 7000 new municipal sewage treatment plants--70% of them in communities with a population of less than 5000 persons. Almost all of the industrial waste treatment plants in the nation have also been constructed since 1952; and the degree of treatment provided in many plants built before or during the period has been raised.

While the level of investment has increased, the rise has been unsteady. Degree of increase has varied sharply with Federal policy,dividing the time span into several distinct periods; and the general economic environment has stifled investment in some areas, promoted it in others, as well as causing a reversal of the upward trend in isolated years.

There can be little question of the great influence of Federal policy on pollution control expenditures. Each shift in the Federal approach to pollution control has been mirrored in expenditures.

Federal funds have been available to local government since 1956 for construction of waste treatment plants and interceptor and outfall sewers. Those elements of the pollution control system have reacted to the pull of grants, receiving a constant portion of the rising total investment in the case of treatment plants, a rising share of the total in the instance of interceptor sewers. In distinction, the share of the investment dollar going into installation of relatively unsubsidized sanitary sewers has progressively declined. The overall level of investment rose sharply with the inauguration of Federal construction grants in 1956, and again with the major increase in funding that occurred with the 1961 amendments to the Federal Water Pollution Control Act.

TABLE 2

SHIFTING STRUCTURE OF INVESTMENT, 1952-1966

TYPE OF INVESTMENT	ANNUAL RATE OF INCREASE IN INVESTMENT 1952-66	PERCENT OF TOTAL INVESTMENT 1952-56	1956-60	1961-64	1965-66
New Public Treatment Plants	7.6%	11.3	11.8	11.5	9.6
Industrial Treatment Plants	16.5%	9.5	16.5	20.9	28.0
Interceptors and Outfalls	13.9%	9.9	14.4	14.9	12.9
Sanitary Sewers, Publicly Constructed	4.2%	37.9	32.9	29.9	26.9
Sanitary Sewers, Privately Constructed	-2.7%	21.6	14.5	10.5	8.4
Public System Rehabilitation and Mixed Contracts	9.2%	8.8	9.1	12.1	12.9
TOTAL INVESTMENT ($ Millions)	7.2%	3591	3798	5009	2805
AVERAGE ANNUAL INVESTMENT ($ Millions)		718	760	1252	1403

The incentive features of the Federal program may be discerned, too, in a rapid increase in spending for pollution control facilities by manufacturers. Industrial investment has assumed a rising share of a steadily growing market. In this case, incentives have not been financial, but more direct influences have proved to be highly effective. The appeal to the national interest, strengthened enforcement powers, establishment of water quality standards, and technical assistance have produced a notable response from industry. It should be stressed, however, that the rising efforts of industry relative to those of local government are in part due to other factors. Industrial expenditures for pollution control started from a very low base; and their rapid rise reflects in good part the enormous unfilled need for treatment that existed at the beginning of the period. Too, the 1960's have been marked by strong industrial capital formation. Many new manufacturing plants have been built, and more have been expanded, since 1960. Management generally has recognized the desirability of installing pollution control facilities as a basic part of plant design; and manufacturing plants built recently have generally incorporated a degree of waste control.

A constant--and expectable--feature of the shift in the distribution of investment funds has been a steady increase in public expenditures for replacement, expansion, and improvement of systems. It is only normal that replacement costs should increase as the capital base expands, but the rate of increase of this investment element has been disproportionately large. Widespread upgrading of primary waste treatment to secondary treatment, an expansion of municipal treatment facilities to handle a growing share of the wastes of manufacturing, and increased recognition of the need to rehabilitate waste handling systems that are poorly located, under-designed, or otherwise inefficient probably accounts for the relative vigor of the replacement portion of the market.

MEASURING PROGRESS AGAINST GOALS

In reviewing the rate of investment for pollution control facilities, the analyst and the policy maker have been hampered by a lack of norms against which performance can be measured. There are good data available with respect to local government contract awards for pollution control facilities; and increasingly reliable estimating techniques provide insights into the level of private investment by manufacturing

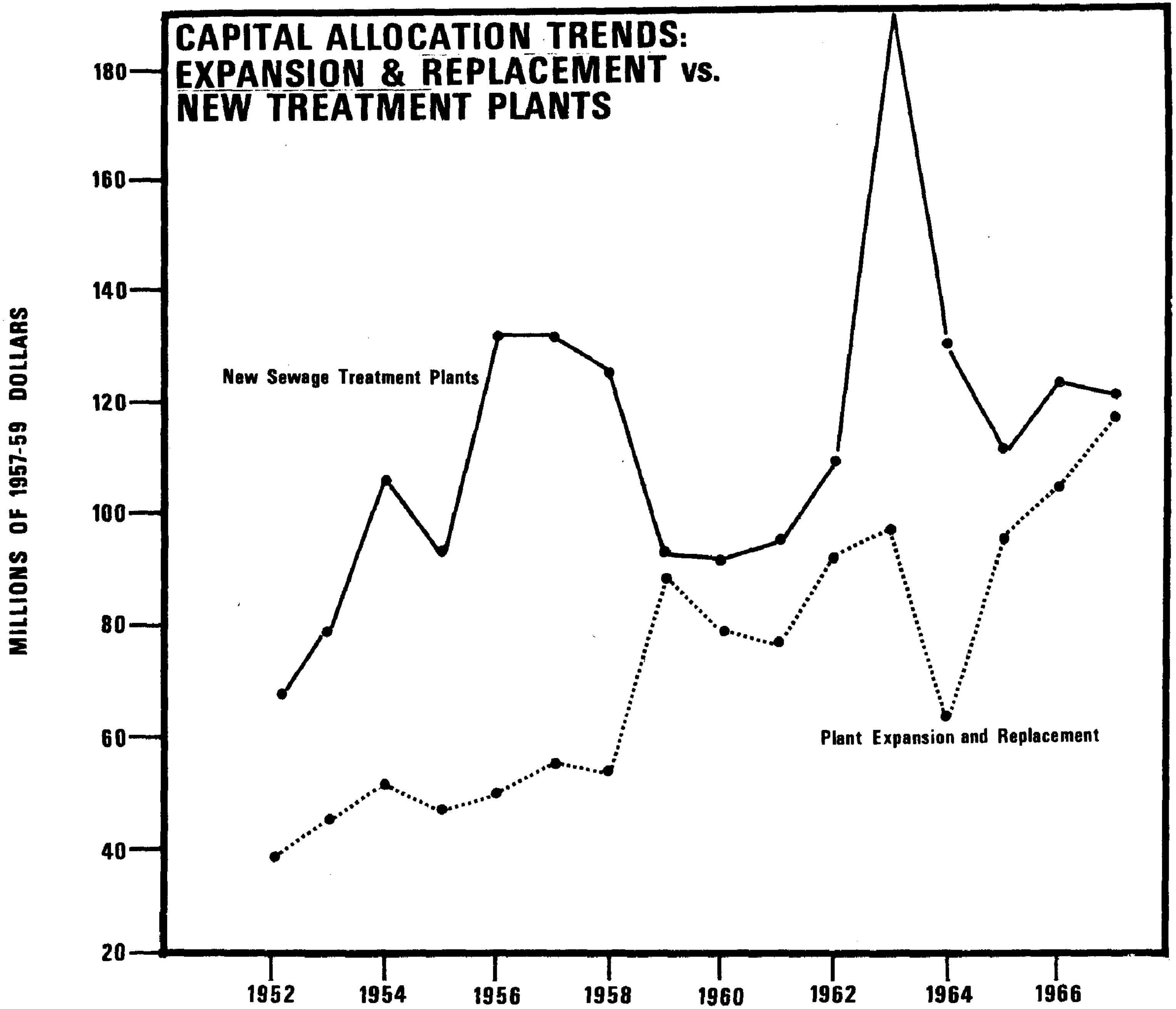
CAPITAL ALLOCATION TRENDS:
EXPANSION & REPLACEMENT vs.
NEW TREATMENT PLANTS
MILLIONS OF 1957-59 DOLLARS
180
160
140
120
100
80
60
40
20
New Sewage Treatment Plants
Plant Expansion and Replacement
1952
1954
1956
1958
1960
1962
1964
1966

Figure 1

firms and in connection with residential construction. But though we have become aware, and with increasing precision, of what the nation has been investing for water pollution control, we have had little feeling for the significance of the amounts.

Publication of The Cost of Clean Water has to some degree removed the lack of providing a normative investment scale. We are now able to measure progress against some tangible goal.

It should be observed that the goal provided by The Cost of Clean Water is provisional. It is hoped that continuous refinement of method and the broadening base of knowledge will bring us increasingly closer to investment goals that can be more reliably equated with defined water quality improvements. But regardless of any deficiencies in estimating cost, it is a distinct step forward in that it does let us gauge in a tentative way how rapidly we are moving toward some maintenance level of control of water pollution. And a rapid review of the level of investment indicates that--on the face of things--the nation during 1967 fell behind in progress toward its provisional five year goal.

Table 3 presents a comparison of the pattern of capital expenditures in 1967 against the goals provided by The Cost of Clean Water. Investments for municipal facilities are equated with those reported in Sewage Treatment Contract Awards, 1967 (pre-publication data) with an incremental estimate for privately constructed sanitary sewers.1/

Manufacturers' investments for waste treatment equipment are taken from two sources; the McGraw-Hill capital spending survey, which was expanded in 1968 to include an estimate of investment for air and water pollution control, and a National Industrial Conference Board survey of 201 firms that obtained information on water pollution control expenditures. Since neither Federal nor State governments collect data of this nature with regard to industrial pollution control costs, the McGraw-Hill and National Industrial Conference Board efforts are the only indicators available to assess magnitude of the industrial effort on a comprehensive basis.

1/ Estimated to equal 4% of the value of residential construction put in place, a relationship postulated by the Department of Housing and Urban Development in its 1965 report, Public Facility Needs and Financing.

TABLE 3

COMPARISON OF CALCULATED INVESTMENT REQUIREMENTS
WITH REPORTED RATE OF WATER POLLUTION CONTROL INVESTMENTS, 1967

	Millions of Dollars		
	1967 Goal	Indicated Expenditure	
		Contract Awards	
New Waste Treatment Plants	334.9	149	
Plant Expansion, Upgrading, Replacement	1057.3	213	
Interceptors and Outfalls	216.6	188	
Sanitary Sewers	1200.0	606	
Total Municipal Investment	2798.8	1156	
		McGraw-Hill	NICB
Food and Kindred Products	46.0- 48.7	13.2	34.0
Textile Mill Products	5.3- 15.1	10.6	46.7
Paper and Allied Products	19.1-142.6	80.4	51.0
Chemical and Allied Products	76.0- 95.9	50.0	37.7
Petroleum and Coal	22.9- 27.1	67.6	117.2
Rubber and Plastics	7.0- 9.6	1.6	2.3
Primary Metals	51.9- 61.1	79.4	>45.0 3/
Machinery	5.7- 7.9	5.0	25.7
Electrical Machinery	2.1- 2.9	6.1	10.8
Transportation Equipment	8.0- 10.9	12.7	318.5
Other Manufacturing	24.8- 34.9	57.7	15.9
Electric Generating	220.0	180.0	N.A.
Total Industrial Investment	489.7 1/ - 683.5 1/	564.3 2/	>704.8 4/

Mid-pt. value = 586.6

1/ Includes both waste treatment and cooling facilities.

2/ McGraw-Hill Survey distributed per NICB questionnaire.

3/ Iron and Steel Only.

4/ Excludes Electric Generating.

The picture that emerges from these limited data is, in general, one of a deficiency in public investment, concomitant with a rate of industrial investment that comes very close to the established target. The same pattern extends (c.f. Table 4) into 1968--though here the investment data are far less reliable. On the municipal side it represents a projected rate of investment based on the level of Federal grants awards. On the industrial side it covers manufacturers' forecasts of expected capital spending during the year rather than an accounting of actual expenditures.

The effects of Federal grants are sharply apparent in the form taken by the municipal investment deficiency. Treatment plant investments are fairly close to the estimated need for construction; and rates of investment for interceptors and outfalls are very close to the level of the indicated requirement. But sewer, replacement, and expansion shortcomings seem to be developing. The relative lack of Federal or State assistance for sewer installation, and a construction grant allocation method that favors initial installation of small waste treatment plants may, because they lend a distinct unbalance to investments, be partially responsible. It is more probably true, however, that The Cost of Clean Water assumption of complete connection of the urban population to sewer systems is unrealistic, and that the rate of development --if not the amount--of the expansion need is overstated in the goals.

The apparent correspondence between indicated investment targets and the reported rate of industrial spending for water pollution control is encouragingly close in the case of the McGraw-Hill data but should not be taken at face value. For one thing, the target--particularly in its detail--suffers from insufficient information in the development. For another, the reported rate of investment is drawn from a sample rather than a full scale canvass. It is puzzling that the NICB survey--when the 201 sampled firms' experience is extrapolated to cover all manufacturing--indicates a rate of investment in 1967 almost double that drawn from McGraw-Hill; that for 1968, the NICB figures remain 50% higher than McGraw-Hill's, if the electrical generating industry is excluded to make the two surveys compatible. Probable explanations may be found in the broad composition of the NICB sample, which includes diverse non-manufacturing industrial activities, and in the fact that the reported results excluded all responses that failed to indicate expenditures, thus probably resulting in overstatement of extrapolated results.

TABLE 4

COMPARISON OF CALCULATED INVESTMENT REQUIREMENTS[1/]
WITH ESTIMATED RATE OF WATER POLLUTION CONTROL INVESTMENTS, 1968

Millions of Dollars

	1968[1/] Goal	Projected Expenditures	
		Contract Awards	
New Waste Treatment Plants	335.3	140	
Plant Expansion, Upgrading, Replacement	1091.1	215	
Interceptors and Outfalls	223.5	195	
Sanitary Sewers	1238.4	700	
Total Municipal Investments	2888.3	1250	
		McGraw-Hill	NICB
Food and Kindred Products	67.4- 69.9	15.6	38.1
Textile Mill Products	10.1- 20.3	25.0	43.1
Paper and Allied Products	23.8-196.7	74.6	47.0
Chemical and Allied Products	98.8-243.6	65.0	36.5
Petroleum and Coal	23.6- 27.1	74.2	129.0
Rubber and Plastics	8.3- 11.1	1.9	3.0
Primary Metals	109.0- 83.1	82.2	>46.5
Machinery	7.8- 10.6	8.0	29.3
Electrical Machinery	4.1- 5.7	59.2	12.6
Transportation Equipment	12.7- 17.9	12.8	318.5
Other Manufacturing	34.7- 44.3	99.9	17.2
Electric Generating	236.1	240.5	
Total Industrial Investment (Mid-Point value=801.4)	636.4-966.4	758.9	>721.1

1/ Adjusted for price level change at 3.2%.

It should be noted that the McGraw-Hill survey aggregated air and water pollution control investments. Distribution of total capital spending by industry as presented in Tables 3 and 4 follows the pattern provided by an earlier survey conducted by the National Industrial Conference Board. It is admittedly clumsy to be forced to assume that there is an unvarying pattern to pollution control expenditures; but in the absence of better data, the NICB survey was considered the best available basis for allocation. In favor of its use is the logical assumption that the basic process of an industry determines the distribution of its pollution control budget, all other things being equal.

With respect to the details of the two sources of estimate of industrial investment compared with the targets for each industry, several industrial segments seem very much out of balance. One obvious explanation is that the normative investments postulated in The Cost of Clean Water may be badly appraised. Another explanation might focus on sampling weaknesses or the unreliability of a one-point-in-time-survey as the basis for allocations of air vs. water pollution control investments in subsequent years. It might also be argued that some industries are doing more than their share for water pollution control, while others are laggards.

Though each of these possibilities has some merit, there are other possible explanations for the divergences--explanations that rise out of the practices of an industry or the method of compiling and presenting the statistics.

1. The food and kindred products industrial category shows a decided investment deficiency for both 1967 and 1968. The industry has an historical pattern of discharging wastes to municipal sewers rather than operating its own treatment facilities. Maintenance of established industry practice, then, would dictate a low capital budget for water pollution control, with costs incurred in the form of annual charges against taxes or operation to maintain a portion of what is a predominantly municipal investment.

2. The chemicals, petroleum refining, and plastics industry groups are all far from target levels in both 1967 and 1968. This may relate to the characterization of industrial units rather than to substantive differences. The industries are closely related, and often compose integrated or sequential operations in practice. While investment goals are expressed in terms of the predomina value of products of manufacturing establishments, the

McGraw-Hill and NICB data are presented in terms of the firms making the investment. Thus, for example, a Humble Oil and Refinery Company Plant producing petrochemicals might well be included under Chemicals and Allied Products on the "goals" side and under Petroleum and Coal on the "expenditures" side. If the three industrial categories are considered to be a single unit, correspondence of investment goals and reported expenditures is close in both years:

		MILLIONS OF DOLLARS		
			INDICATED EXPENDITURE	
		GOAL	McGraw-Hill	NICB
1967	High	132.6		
	Mid-point	119.2	119.2	157.2
	Low	105.9		
1968	High	281.8		
	Mid-point	206.2	141.1	168.5
	Low	130.7		

3. The extremely high 1968 investment indicated by the McGraw-Hill survey in the category Electrical Machinery must be admitted to be a puzzle. No explanation from the nature of the industry presents itself. A sampling error, a weakness of allocation, or a deficiency in cost development in the first report of this series are equally likely explanations.

4. Similarly, an enormous investment by Transportation Equipment suggested in the NICB survey--almost all of it in the subcategory Motor Vehicles and Equipment firms, which are indicated to devote 18.1% of their capital budgets to water pollution control--is staggering. Eight sampled firms that were found to estimate investments at $96.6 million in 1967 and $120.1 million in 1968 were responsible for the reported investment. Discussion with the NICB revealed that the firms involved do not in any sense compose a representative sample. In the absence of a better guide, however, extrapolations were retained to complete the tables. Until a comprehensive industrial waste expenditure survey became available, such gross anomalies must continue to be an inescapable part of water pollution control planning.

Other significant assessments of capital spending levels were made during the last year. Crossley, S-D Surveys reported for the American Petroleum Institute on expenditures in the petroleum industry.(1) Chemical and Engineering News compiled an estimate of anticipated 1969 expenditures for air and water pollution control equipment. The National Council for Stream Improvement estimated capital expenditures of the pulp and paper industry for the years 1966 through 1968.

The American Petroleum Institute survey pegged the petroleum industries' capital spending for water pollution control at a $79 million level in 1966 and $113.7 million in 1967. Most of the expenditures--77.1% in 1966, 64.8% in 1967--were incurred in production, transportation, and marketing. Only $18.1 million in 1966 and $35.2 million in 1967 were attributed to manufacturing operations, i.e., refineries, chemical plants, and their satellites. Using their own estimates, the industries' investments were far below indicated targets, and below the level indicated by either the McGraw-Hill or NICB survey, as allocated in Tables 3 and 4.

The projection of capital spending prepared by Chemical and Engineering News on the basis of a compilation from other publications and trade associations was presented in very rough terms. It indicated an industrial investment on the order of $445 million for waste treatment in 1969, and investment by various levels of government of about $520 million, presumably excluding collection systems. While the public investment seems to fit closely with recorded levels of recent years, the industrial estimate falls well below either the level of need postulated in the Cost of Clean Water or the NICB and McGraw-Hill assessments for 1967 and 1968. Like the American Petroleum Institute survey, the broad estimate diverges from other sources that seem to agree, at least roughly.

The National Council for Stream Improvement's estimate of pulp and paper pollution control investment placed it at $54 million for 1966, $66 million for 1967, $79 million for 1968--values that fall comfortably into the mid-point of the range of estimated needs, and compare well with the estimates based on the McGraw-Hill Survey.

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(1) Numbers in parentheses refer to References Cited on page 219.

THE ELEMENTS OF INVESTMENT

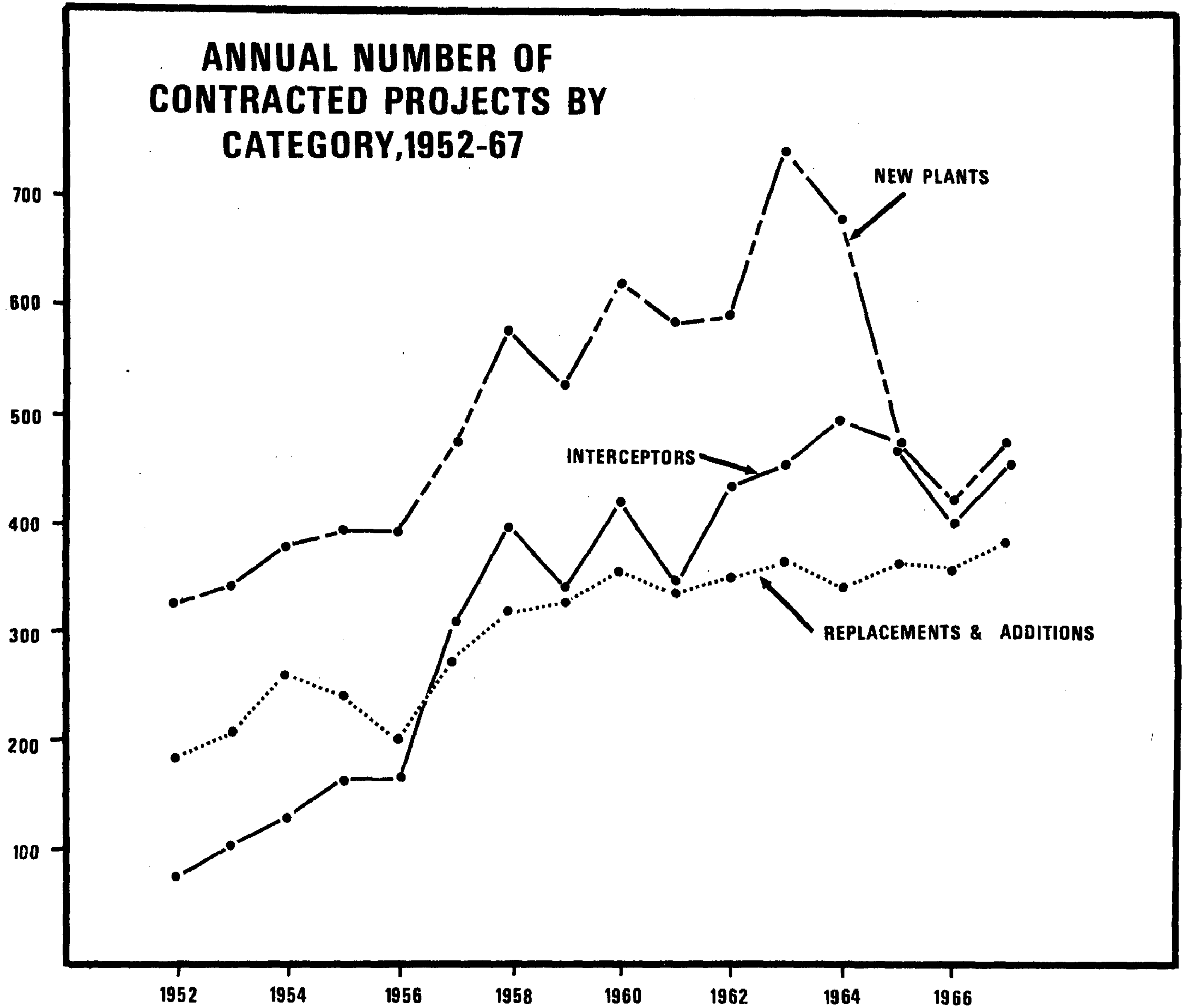
Evaluation of pollution control needs must consider all elements of a complex system--the use to be made of the water-body, the hydrologic and climatic regimen of the watershed, and volume, kinds, and sources of polluting materials. Within each system, there are sub-systems. Municipal waste treatment is only one such sub-system--though it is the one that has received the majority of attention.

Within that system there are a number of elements that require distinct investment consideration. In addition to construction of new waste treatment plants, a constant stream of capital must be devoted to collecting sewers, to interceptor sewers, to plant maintenance and replacement, and to increasing the degree of treatment as conditions demand or as technology allows. The relative wieght given to any element by fund availability or public decisions can strongly affect the efficiency of the total system; and no reasoned assessment of the whole is possible in the absence of a careful review of the interaction of its elements.

WASTE TREATMENT

Investment emphasis on construction of new municipal waste treatment plants has declined steadily since 1963, when, under the stimulus of an accelerated public works program, 710 new plant projects having a value of $216 million (c.f. Tables 5 and 6) were initiated. In the most recent year of record, 1967, new plant projects had dropped to 447, and their value to $145 million. Nor was the 1967 experience a matter of a one year slump; new plant starts in that year were up almost 15% over the previous year. In some respects, 1963 may be viewed as the point when most of the heritage of neglect embodied in the backlog concept had been overcome and cities of the nation began as a group (without recognizing the fact) the major long-term task of maintaining and increasing waste treatment capabilities rather than initiating them. Since 1963 the construction of new waste treatment plants has been declining relative to the other major categories of investment that qualify for FWPCA construction grants--replacements, additions, and installation of interceptor sewers.

The decline in new treatment plant projects should not be a surprise. (Throughout this report, new plants are considered to be those providing waste treatment for the first time to a sewered community.) The nation has built an enormous number



SEWAGE RATE AND WATER WORKS CONSTRUCTION (1952 Through 1967)

TABLE 5

SUMMARY OF WASTE HANDLING INVESTMENTS
1952-1967

MILLIONS of CURRENT DOLLARS

Type of Expenditure	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967
Public Expenditures																
Sewers 1/	225	286	244	301	305	247	310	336	359	380	320	405	396	356	399	504
Interceptors & Outfalls 1/	29	67	40	75	148	134	155	124	136	169	196	201	181	184	179	188
New Treatment Plant 1/	52	64	88	80	122	129	128	96	97	101	117	216	144	125	145	149
Replacement and Expansion 1/	31	36	43	41	46	55	55	92	83	80	99	106	70	108	123	142
Mixed Contracts 1/	26	20	58	6	12	12	22	14	14	33	71	76	71	59	73	72
Private Expenditures																
Sewers 2/	157	150	161	171	140	127	144	155	125	129	131	136	130	128	108	102
Industrial Treatment* 3/	45	55	66	80	97	117	142	174	195	219	246	276	310	348	438	385
Sewer Total	411	503	445	547	593	508	609	615	620	678	647	742	707	668	686	794
Treatment Total	154	175	255	207	277	313	347	376	389	433	533	674	595	640	779	748
Public Total	363	473	473	503	633	577	670	662	689	763	803	1004	862	832	919	1055
Private Total	202	205	227	251	237	244	286	329	320	348	377	412	440	476	546	487
TOTAL EXPENDITURES	564	678	700	753	869	821	956	991	1009	1111	1180	1416	1302	1307	1464	1542

TABLE 5 (Cont'd)

SUMMARY OF WASTE HANDLING INVESTMENTS
1952-1967

Millions of Constant (1957-59) Dollars 4/

Type of Expenditure	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967
Public Expenditures																
Sewers	295	355	293	347	330	255	309	321	338	351	292	358	344	304	329	402
Interceptors & Outfalls	38	83	48	86	160	138	154	118	128	156	179	178	157	157	148	150
New Treatment Plants	68	79	106	92	132	132	126	93	92	95	109	199	130	111	124	124
Replacement & Expansion	40	45	52	47	50	56	54	89	79	76	93	98	63	96	105	118
Mixed Contracts	34	25	70	7	13	12	22	14	13	31	66	70	64	52	62	60
Private Expenditures																
Sewers	206	186	194	197	151	131	143	148	118	119	119	120	113	109	89	81
Industrial Treatment	59	68	80	92	105	119	140	168	186	207	230	254	280	309	375	320
Sewer Total	538	624	535	630	641	525	606	587	584	627	590	656	614	569	566	633
Treatment Total	201	217	308	239	300	319	342	363	371	409	498	621	538	569	666	622
Public Total	475	587	569	579	685	593	665	635	650	709	739	903	758	720	768	854
Private Total	265	254	274	289	256	250	283	316	304	326	340	374	393	418	464	401
TOTAL EXPENDITURES	740	841	843	868	941	843	948	951	955	1035	1088	1277	1152	1138	1232	1255

*Prior to 1967, estimate includes value of industrial hook-up to municipal systems - perhaps 20-30% of the total in any year.

1/ Sewage and Water Works Construction.

2/ Estimated on Basis of New Housing Starts.

3/ Estimated on Basis of U. S. Dept. Commerce Reports of Equipment Sales.

4/ Adjusted by Sewage Treatment Plant Construction Cost Index and Sewer Construction Cost Index.

TABLE 6

NEW TREATMENT PLANTS CONSTRUCTED
1952-1967

Number of New Plants, By Size of Place

Year	Pop Unknown	Under 500	500-999	1000-2499	2500-4999	5000-9999	10,000-24,999	25,000-49,999	50,000-99,999	100,000-250,000	Over 250,000	Total
1952	61	29	30	57	35	31	24	17	8	3	4	299
1953	80	30	41	50	33	28	30	3	8	6	6	315
1954	70	31	48	65	37	35	23	7	6	13	16	351
1955	61	42	54	69	39	31	34	10	8	5	12	365
1956	54	42	49	80	36	30	23	15	6	14	16	365
1957	18	39	61	107	63	48	44	23	9	19	14	445
1958	34	66	66	127	78	52	46	34	11	12	23	549
1959	49	68	74	88	69	53	43	17	9	15	15	500
1960	70	83	76	146	70	46	38	18	7	15	23	592
1961	74	84	85	102	55	50	33	17	14	19	24	557
1962	87	58	74	95	71	59	42	22	21	13	18	560
1963	56	84	120	155	101	59	45	19	21	19	31	710
1964	56	89	112	153	75	55	34	20	23	16	18	651
1965	64	54	49	91	41	53	35	17	11	15	17	447
1966	2	61	61	83	47	42	36	20	17	6	16	391
1967	3	83	75	123	45	34	32	16	15	7	14	447
Total New Plants	836	943	1075	1591	895	706	562	275	194	197	267	7544
Plants in Service, 1968	755 3/	1492	1777	2783	1697	1240	1013	364	206	132	192	11,651
No. of Communities, 1960	-	N.A.	9598 1/	4747 2/	2152	1394	1134	432	201	81	51	19,790

1/ Includes places of less than 500 population.

2/ Includes urban places (as defined by census) of less than 1000 population.

3/ Excludes 1962-68 changes in N. Y., Penn., N. J., Iowa, Ark.

of new plants since the end of World War II, more than 7500 between 1952 and 1967. The great majority of the sewered population now receive some sort of waste treatment. New plant needs, then, have subsided to little more than the level required to serve the newly sewered portion of the nation's population.

It would be a mistake of the first order, however, to equate a steadily reducing need for new waste treatment plants with a falling absolute need for waste treatment investment. A number of mechanisms that are operative in today's economy will sustain demand for waste treatment capital; and with the stable level of investment that has been evident since 1963, it is unlikely that the nation is capitalizing the municipal waste treatment effort sufficiently to continue to reduce the number of residual untreated situations and to adequately undertake necessary replacement, upgrading, and expansion of facilities.

The apparent truth at this point is that reduction of the obvious need for treatment of untreated wastes does not eliminate capital needs. The quantitative shifts in the waste treatment situation have introduced some qualitative changes that have a direct influence on potential capital requirements.

Increasing Marginal Costs

One of the reasons that we cannot anticipate any substantial over-all reduction in investment requirements is the simple fact that the program to increase the national level of municipal waste treatment has been so very successful. Most of the large cities where a substantial incremental population can be served as the result of a single project have already installed some degree of waste treatment. In the nation, only four cities with a population of 250,000 or more remain available for initial waste treatment investments--Honolulu, New Orleans, Memphis, and parts of New York City. Because there are well defined economies of scale in the construction of waste treatment plants, the smaller size of communities building plants for the first time implies that total costs will be much higher in the future to achieve any given degree of waste reduction.

Concentration of investments in areas of increasing marginal costs will have continuing and cumulative impacts. Not only does it cost more per person to build small waste treatment plants than to build large ones, of comparable design, but per-capita costs of operation, maintenance, upgrading, and replacement are also higher. So, as we build a growing small plant component into the fixed capital structure, we must expect to incur costs that rise at rates that are greater than the consequent rate of improvement in effluent quality, as the investment/improvement ratio has manifested itself in the past.

Table 7 indicates something of the degree to which investment for new plants is concentrated in small towns. Towns of less than 10,000 persons have always accounted for the largest number of treatment plants that are built, simply because there are so many small towns. But the table demonstrates that such communities are reaching the point where they also account for almost half of the dollar value of investment for new waste treatment plants, a significant shift in the placement of investment.

TABLE 7

Percent of Total New Treatment Plant Investment Made in Towns of less than 10,000 Persons, 1952 to 1967

Size of Place	Percent of New Plant Investment in Period		
	1952-55	1956-63	1964-67
Less than 1000 persons	5.9	7.4	7.4
Less than 5000 but more than 1000	18.3	22.3	22.4
Less than 10,000 but more than 5000	12.0	13.0	14.7
Total, places less than 10,000	36.2	42.8	44.7

(Two factors make the progressive increase in the small town share of new plant investment more notable than appears on the face of things. First, small communities are most apt to discharge their waste treatment requirements either through use of lagoons, which have very low unit costs, or through transportation of wastes for treatment by another community, in which case treatment needs are met through an investment in interception rather than for a new treatment plant. Second, amendment of the Federal Water Control Act in 1966 included grant provisions distinctly more favorable to the larger communities that had been relatively slighted by the previous form of the Act--though State priority systems admittedly stress the small town investment in many cases.)

Higher Treatment Requirements

The principle of increasing marginal costs applies, too, as treatment requirements increase with the evolution of economic conditions. In general, waste treatment needs are a function of concentration; the higher the concentration of materials in water, the greater the need for treatment. Conversely, the lower the concentration of materials that must be attained in the final effluent, the higher the cost of treatment.

It has been national policy that--with specifically defined exceptions--all sewered wastes should receive secondary treatment, that is, that they must undergo a biological process to stabilize the major part of the suspended and dissolved organic matter remaining in the waste stream after primary treatment.

Conditions change and as they change so do waste treatment requirements. Population is increasing. Migration tends to accelerate the rate of population concentration. Factory waste discharges grow with industrial expansion; and their growth exerts a corollary pressure for more complete treatment of all waste sources. Even changes in the quality of life may have implications for waste treatment though such changes may be so pervasive and gradual that they may not be readily recognized. Consider, for example, the water quality impact of two unregarded shifts in personal consumption behavior. During the 1950's phosphorus-based detergents gradually replaced soap in the American marketplace. Detergents are more profitable than soap, and they do a better job of cleansing. Unfortunately, their use results in the discharge to public sewers of wastes whose concentrations of phosphorus are well in excess of the requirements of the bacteria that effectuate the secondary treatment process. The residual phosphorus not removed with sewage sludges has been discharged into the nation's waterways, fertilizing luxuriant blooms of algae and water weeds that constitute a particularly noxious form of water pollution. There are waste treatment implications, too, in the potential pollutional effects of a constant rate of acceptance of the simple home garbage disposal system. The handy appliance roughly doubles the sewered output of solids and biochemical oxygen demand of the household that employs it. If garbage disposals are to become universally used, they will accomplish an increase in organic waste loading equivalent to 50 years of population increase at existing rates, suggesting an early need in many watersheds for treatment beyond the secondary level.

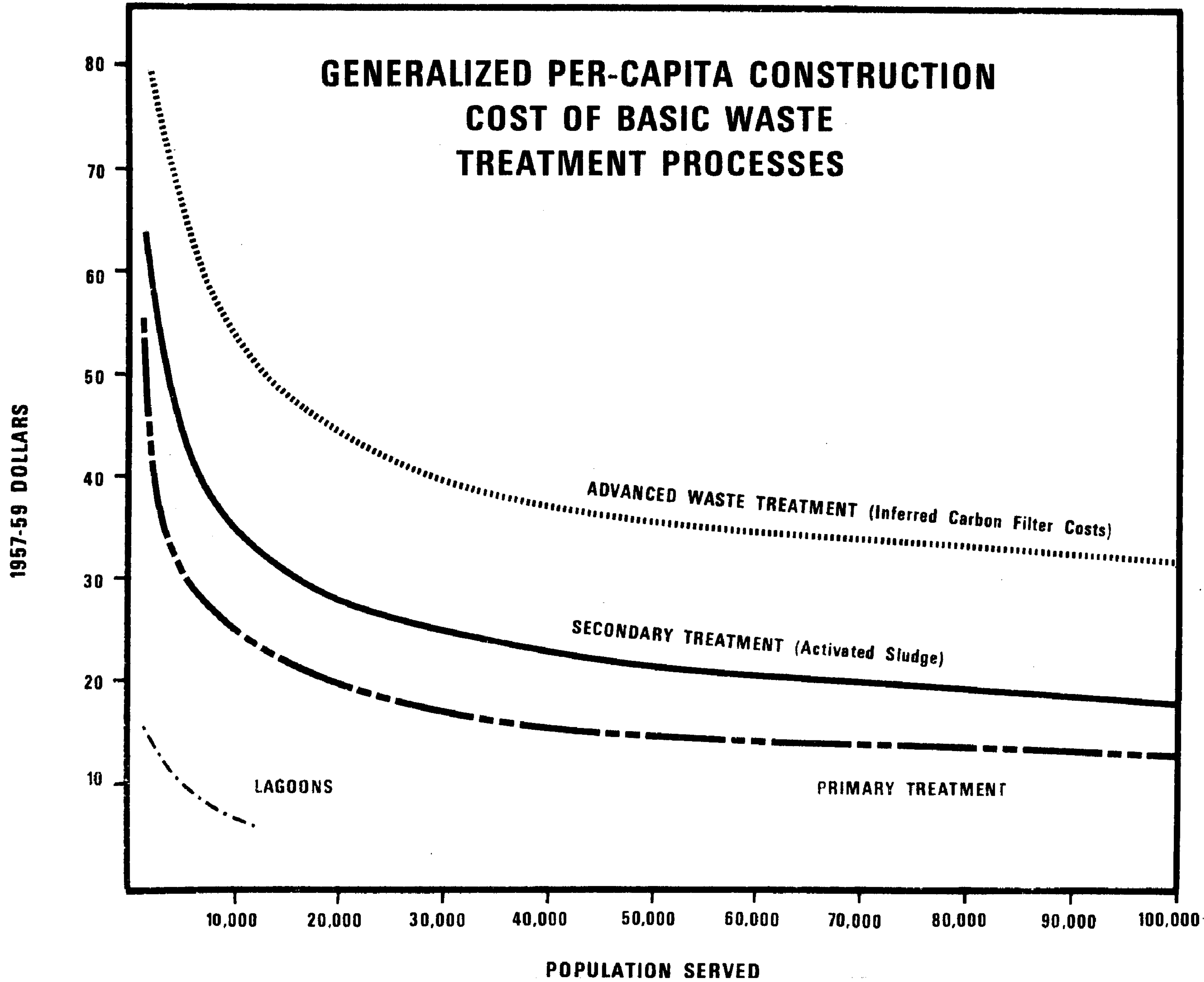
Phosphorus reduction is now being required in the Lake Michigan watershed and is under active consideration for the Lake Erie drainage. Tertiary or advanced waste treatment is a State goal for many Indiana communities by 1977, is contemplated for some Ohio towns, is being phased into the Chicago system, and is planned for a part of Long Island. Increasing waste loadings resulting from population concentration or technological changes will unquestionably make advanced waste treatment or treatment for reduction of specific polluting materials increasingly common as time passes.

The investment consequences of such developments are by no means slight. Reference to Figure 3, which generalizes the cost experience of waste treatment plants by size of plant and by degree of treatment, provides some insight into the potential effect on investment requirements of the twin functions of higher waste treatment and of concentration of investment in smaller scaled plants. It is clear that both of the principal direct influences that bear upon investment cost have the effect of pushing them upward.

Increasing Size of Plant

Another upward pressure on current investments is somewhat more difficult to judge as to ultimate effect on unit investment costs. Waste treatment plants are being constructed with more capacity per person served than was formerly the case. The median capacity of municipal waste treatment plants in 1962 was between 1.2 and 1.4 times that required by the population served by the plant. By 1968, the median size had advanced to 1.4 to 1.6 times population requirements, as a result of constructing significantly larger plants between 1962 and 1968--and one plant in 13 was scaled to handle more than four times the waste loadings justified by its domestic connections.

The larger the community, the more capacity (i.e. with respect to human population served) tends to be built into the plant. For cities in the population size range between 50,000 and 500,000 persons, median capacity in 1968 was 1.6


GENERALIZED PER-CAPITA CONSTRUCTION
COST OF BASIC WASTE
TREATMENT PROCESSES
80
70
60
50
40
30
20
10
1957-59 DOLLARS
ADVANCED WASTE TREATMENT (Inferred Carbon Filter Costs)
SECONDARY TREATMENT (Activated Sludge)
LAGOONS
PRIMARY TREATMENT
10,000
20,000
30,000
40,000
50,000
60,000
70,000
80,000
90,000
100,000
POPULATION SERVED

to 1.8 times the population served, and the modal (most frequently observed) size was 2.0 to 2.5 times population served.

There are a number of reasons discussed below why plants are getting bigger. While it is impossible to draw a balance between cost-reducing and cost-increasing effects, the general impression is that the installation of additional capacity will tend to reduce long term costs.

(1) It has always been common practice to design capacity in excess of current needs into waste treatment plants, usually on the basis of a straightforward projection of waste loadings or of population. The practice is prudent and desirable, since it guards against underdesign--especially so because constructing additional capacity costs less than would later expansion of the plant to a similar capacity. In addition, local conditions often require more than normal capacity to deal with unusual peak loads, abnormal infiltration, combined sewer systems, and perhaps other causes. It would appear, though, that scaling standards of the past are being exceeded in current plant designs, as demonstrated by the increase in the median size of plant. (It might be argued that the increase in median design size is due simply to the younger average age of plant in service in 1968. The argument is refuted by the consideration that the proportion of new plants--in the sense that a plant built in the previous five years would be considered new--to plants in service was somewhat greater in 1962 than it was in 1968.)

(2) The Federal Construction Grants Program provides some incentive to design to meet future needs. The availability of Federal funds makes it much easier for a municipality to finance the larger plant. From the viewpoint of the municipality this has the added advantage that existence of waste treatment availability may often provide an industrial location incentive.

(3) An inadequate understanding of discounting procedures, together with the inflexible property tax revenue base characteristic of American cities, may lead to an effort to reduce the threat of inflation by designing treatment plants ambitiously in order to anticipate needs that would otherwise have to be met in an atmosphere of materially higher construction costs. This may not be an irrational reaction for the individual community, even with existing levels of interest rates. For the nation as a while, however, the mechanism simply feeds inflation and is ultimately costly to the community.

TABLE 8

Ratio of Designed Plant Size to Actual Domestic Loading in 1968

>50%

Size of Place	Plant Size as a Multiple of Population Served: under 0.5	1.0	1.2	1.4	1.6	1.8	2.0	2.5	3.0	3.5	4.0	over 4.0	Total Plants
Unknown	Percent of Plants in Each Size Category												
under 500	2.7	17.8	11.2	10.9	9.0	6.2	6.6	7.7	5.0	3.4	2.3	17.2	1748
500 - 1000	3.6	22.0	13.7	12.3	10.7	7.4	5.7	8.3	4.9	2.1	2.4	6.8	1736
1000 - 2500	4.2	19.5	11.4	13.8	11.6	7.7	7.2	10.3	3.7	3.2	1.7	5.9	2592
2500 - 5000	5.2	19.8	14.2	12.9	9.6	7.8	6.0	10.4	4.4	2.4	2.0	5.2	1408
5000 - 10000	4.9	18.4	12.7	11.4	10.6	8.8	7.7	9.2	7.5	2.0	1.6	4.7	1059
10000 - 25000	5.1	15.4	10.7	12.8	10.8	8.7	7.6	11.3	6.3	4.3	2.2	4.8	806
25000 - 50000	3.8	17.4	11.1	12.9	8.7	10.4	9.4	10.8	7.7	2.8	2.4	2.4	287
50000 - 100000	4.0	13.7	6.9	13.1	9.1	12.0	10.3	16.0	6.9	2.9	3.4	1.7	175
100000 - 250000	7.6	9.7	5.4	6.5	12.0	9.2	8.7	18.5	9.2	2.2	3.3	4.3	92
250000 - 500000	10.3	10.3	10.3	3.5	10.3	10.3	6.9	13.8	6.9	10.3	0	6.9	29
over 500000	6.5	12.9	6.5	9.7	16.1	12.9	9.7	19.4	3.2	0	0	3.2	31
1968 Totals	4.2	18.9	12.1	12.4	10.4	7.8	6.9	9.8	5.1	2.9	2.0	7.5	9963
1962 Totals	6.5	21.8	11.0	11.1	9.8	7.7	6.9	9.3	5.1	2.6	2.0	6.2	7646

TABLE 9

Increase or (Decrease) in Number
Of Plants of Various Design Capacities,
1962-1968

Size of Place	under 0.5	1.0	1.2	1.4	1.6	1.8	2.0	2.5	3.0	3.5	4.0	over 4.0	Recorded New Plants 1962-67
	Plant Size as a Multiple of Population Served												
	Percent of Plants in Each Size Category												
under 500	(2.9)	17.5	19.5	16.6	11.1	6.5	6.1	5.5	3.1	3.4	(0.5)	13.8	671
500 - 1000	(4.3)	22.7	15.9	16.3	14.6	5.4	1.3	8.0	4.8	1.9	4.1	8.9	458
1000 - 2500	(2.4)	(1.6)	12.6	19.0	15.9	11.0	7.4	13.9	5.5	3.7	1.8	12.8	608
2500 - 5000	(6.5)	(1.6)	16.8	15.7	5.4	13.0	11.9	19.0	0.5	4.8	2.7	17.9	184
5000 - 10000	(9.6)	(8.8)	24.1	19.3	20.1	(3.2)	9.6	12.9	20.1	3.2	4.8	7.2	124
10000 - 25000	2.7	4.1	9.7	14.5	6.9	10.4	5.5	11.8	6.9	9.7	4.1	13.1	144
25000 - 50000	(9.8)	29.4	19.6	9.8	(13.7)	23.5	25.4	9.8	-	5.8	3.9	(3.9)	51
50000 - 100000	(3.8)	15.3	(5.7)	5.7	11.5	11.5	15.3	30.7	3.8	-	7.6	-	52
100000 - 250000	(12.5)	(25.0)	(12.5)	12.5	6.2	6.2	6.2	56.2	12.5	(6.2)	12.5	18.7	16
250000 - 500000	(20.0)	(20.0)	-	20.0	-	20.0	-	40.0	(40.0)	60.0	-	40.0	5
over 500000	-	-	25.0	-	75.0	(25.0)	-	-	-	-	-	25.0	4
1962-1968 Total	(3.3)	9.5	15.6	16.7	12.3	8.2	6.7	11.1	4.9	3.7	2.2	11.9	2317

The information available, however, allows no judgment about the prevalence of this or other judgmental factors.

(4) Increasing municipal treatment of industrial wastes requires larger plants in a growing number of instances. Large industrial waste treatment requirements can most reasonably account for the number of municipal treatment plants designed to handle more than three times loadings contributed by the connected human population. Plants scaled to that size accounted for 15.9% of all plants in service in 1962. By 1968, the proportion had grown to 17.5%.

Accelerating Industrial Connections

The evidence that is available suggests that the growing pattern of municipal treatment of industrial wastes is the largest single influence in the trend toward larger treatment plants. Reference to Table 10 strongly bears out the point. The table indicates that 40% of the plants in the nation treat a greater volume of wastes than would be expected on the basis of their connected populations.

It must be conceded that the table does not positively indicate that 40% of the nation's waste treatment plants treat a significant volume of industrial wastes. Standards for per capita waste production are simply not accurate enough to draw that positive a conclusion. Local and regional water use differences, errors of estimate, and necessary weaknesses in the calculating procedure all suggest a great deal of uncertainty as to what should be considered a threshold per-capita flow that indicates the presence of a significant industrial waste component. The 14% of the nation's plants that handle two or more times the volume justified by reported population connections can be considered to treat a large measure of wastes of industrial origin. The 11% of the nation's plants that handle between 1.2 and 2.0 times a normal waste discharge for the size of the service population probably also treat a significant amount of industrial wastes.

Even more meaningful than the proportion of all plants whose loading pattern indicates industrial wastes is their size distribution. Towns whose population exceeds 10,000 show a marked adherence to a pattern of loadings that exceeds what is expectable from connected population. The number of such plants has been growing very rapidly. On the basis of a rough calculation of expectable and actual loadings as they

TABLE 10

Ratio of Total Waste Loadings to
Domestic Waste Loadings 1968, By Size of Place

	Waste Loading as a Multiple of Expectable Domestic Wastes											
	under 0.5	1.0	1.2	1.4	1.6	1.8	2.0	2.5	3.0	3.5	4.0	over 4.0
Size of Place	Percent of Plants in Category											
under 500	23.2	41.0	8.4	4.1	3.4	2.0	2.3	3.2	1.3	1.0	0.6	8.6
500 - 1000	26.0	40.7	8.3	4.5	4.4	3.3	2.5	3.3	1.2	0.9	0.7	3.6
1000 - 2500	18.8	43.6	8.3	6.2	4.4	3.5	3.0	4.2	2.0	1.2	0.9	3.3
2500 - 5000	16.8	43.3	12.1	7.0	4.8	4.0	2.6	3.7	1.7	0.8	0.5	2.0
5000 - 10000	14.0	40.6	13.0	7.9	6.7	4.4	4.1	2.9	2.2	1.1	0.7	1.8
10000 - 25000	11.2	36.6	15.9	10.3	7.6	4.6	4.1	4.5	0.5	1.4	0.5	2.2
25000 - 50000	9.5	36.3	17.3	6.8	9.8	6.5	3.6	5.5	2.2	1.6	-	0.3
50000 - 100000	9.8	32.7	13.6	8.7	10.3	5.4	6.0	7.1	3.2	2.1	0.5	-
100000 - 250000	6.2	31.2	11.4	15.6	12.5	5.2	3.1	8.3	3.1	1.0	1.0	1.0
250000 - 500000	12.9	16.1	12.9	6.4	19.3	9.6	12.9	3.2	3.2	-	-	3.2
over 500000	5.5	22.2	11.1	16.6	5.5	11.1	11.1	8.3	2.7	2.7	-	2.7
TOTAL	18.9	41.1	10.3	6.3	5.1	3.6	3.1	3.8	1.6	1.1	0.7	3.8
		>50%										
Number of Plants in Category, 1968	2087	4521	1139	697	567	402	343	426	186	125	80	418
Change in Number of Plants in Category, 1962-68	(427)	709	375	245	237	165	132	153	55	62	37	211
Change as a Percent of Plants in Category in [illegible]	(16.9)	18.5	49.0	54.2	71.8	69.6	62.5	56.0	41.9	98.4	86.0	101.9

are distributed through the system of municipal waste treatment plants, it would appear that in 1968 municipal plants treated a volume of industrial wastes that was roughly equal to their throughput of domestic wastes. The statement may seem hard to credit in view of the fact that the median level of loadings is equal to or less than expectable loading from connected municipal populations. But the 1235 identified plants whose loadings are two or more times indicated domestic loadings are concentrated in cities with populations over 10,000; while 40% of the 6600 places treating no more than their expectable domestic loading were communities of 1,000 persons or less, so that the prevalence of industrial loadings at large plants overweighs the greater number of small plants treating domestic wastes only.

The apparently approaching preponderance of industrial wastes as a source of municipal waste treatment requirements has very large investment implications. A comparison of the table that presents design as a multiple of domestic connection with the table that shows loading as a multiple of domestic connections (Tables 8 and 10) suggests strongly that at least half of the indicated surplus capacity of municipal waste treatment plants is currently taken up by industrial waste discharges. The large number of facilities whose treatment responsibilities seem to include a significant industrial component indicates that much of municipal government and industrial management has accepted as normal the municipal responsibility to treat industrial wastes. That public utility relationship of municipality to factory may involve large expansion and plant modification expenditures. Finally, it should be noted that while joint municipal/industrial treatment arrangements are beneficial in that they result in attainment of economies of scale and of specialization, they also represent a significant increase in required public sector waste treatment expenditures. At the local level, methods of cost sharing, user charges, or lump sum payments can be utilized to mediate the burden that treatment of industrial wastes would constitute for the individual taxpayer. But that portion of the investment made up from Federal matching grants invariably represents a significant shifting of the costs of treatment away from the cost structure of the products that create the need for treatment and into the public sector of the economy. Federal construction grants must be recognized, then, to constitute a substantial incentive to industrial waste treatment. The problem raised by the trend to municipal treatment of industrial wastes revolves on the fact that industrial production--and the consequent need for industrial waste treatment--is growing at about three times the rate of population. Obviously, then, we must be prepared to accept a more emphatic need for expansion capital for public waste treatment plants than might have been anticipated from consideration of either the raw rate of population growth or the rate of new sewer connections.

Technological and Institutional Development

The influences that bear upon the level of waste treatment investment are not uniformly pressing upward. It has been noted that an increase in the average size of plant and an enlarging tendency for municipalities to treat industrial wastes can both act to reduce long term investment requirements, even though their initial impact may take the form of a larger public capital outlay. Other cost-reducing mechanisms are also operative.

For the most part these occur as a series of separate, minor technological improvements--often directed at the incremental reduction efficiencies that are becoming necessary in an increasing number of instances and that would have proved to be very expensive in the technological environment of a few years ago. For example, the use of polyelectrolites to induce settling improves waste treatment efficiency at a relatively minor increase in operating costs. Use of plastic filter media rather than graded aggregates has improved trickling filter performance, and may cause long term maintenance costs to be reduced. Equipment improvements, design modifications, hybrid treatment systems such as extended aeration and aerated lagoons--a continuous trickle of engineering improvements has entered the marketplace and is having a moderating effect on treatment costs.

The principal improvements in unit cost expectations, however, derive from two simple concepts: use of the oxidation pond (lagoon) as a method of treatment and cooperative use of facilities by two or more municipal jurisdictions.

Waste stabilization ponds, or oxidation ponds, or lagoons are simple in concept. They consist of earthen basins scaled to accommodate that volume of wastewater which can be processed to an acceptable level of quality by the simple natural processes of settling, organic decomposition, and bacterial dieoff without the interposition of chemical or mechanical aids. Since time, gravity, and atmospheric contact can achieve in a state of nature exactly the same effect as normal secondary treatment, the lagoon provides a simple and inexpensive way to take advantage of those natural purification processes.

Lagoons have drawbacks, of course. The over-riding one is the space requirement. Without the artificial acceleration of natural processes that is provided by conventional waste treatment, lagoons must be large enough to hold wastewater until the decomposition and settling processes are far advanced. Further, the lagoon must be shallow to be effective, since it demands natural aeration at all depths to adequately oxidize organic waste materials; and restricted depth implies extensive surface area. (Anaerobic lagoons and aerated lagoons are special situations, as is the extended aeration process. These may reduce the space requirement, but by inducing equipment or staging needs, they substitute other cost elements for space.) Because space requirements are great, relative to those of mechanical treatment, use of lagoons is effectively confined to small towns, where volume of wastes to be treated is physically limited, and to places where land is available and cheap.

There are drawbacks in operation--a tendency to overstimulate algal growths, percolation into the ground, evaporation (a prime evil in an arid area), freezing--but the method has been enthusiastically adopted by small towns in the West, and to a lesser extent in the South, as a convenient, inexpensive means of achieving a high degree of waste treatment.

Simple as lagooning may be in concept, it is a rather late acquisition to the arsenal of waste treatment methods. Development occurred in the late 1940's and early 1950's and acceptance of the method is still not universal. Quite aside from its real drawbacks, there is considerable hesitation on institutional grounds to utilize lagooning among States of the Northeast, where mechanical treatment processes continue to be the rule even for very small communities.

In spite of regional reservations, use of the lagoon continues to advance almost annually. (cf Table 11.) Lagoons accounted for almost 36% of all new waste treatment plants constructed between 1962 and 1967. In some western and southern States, lagoons made up more than half of the new plants brought into service during that period: in Alabama, 59%; in Idaho, 83%; in Iowa, 67%; in Kansas, 73%; in Minnesota, 52%; in Mississippi, 86%; in Missouri, 87%;

TABLE 11

Lagoons as a Percent of Total New Plants

Lagoons as % of Total New Plants By Size of Place

	Population Unknown	Under 500	500-999	1000-2499	2501-4999	5000-9999	10,000-24,999	25,000-49,999	50,000-99,999	100,000-250,000	over 250,000	TOTAL
1952	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	1.3
1953	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	4.4
1954	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	8.5
1955	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	12.8
1956	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	15.8
1957	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	16.4
1958	-	45.4	21.2	21.2	17.9	17.3	8.6	2.9	-	8.3	4.3	18.3
1959	4.0	50.0	29.7	20.4	20.2	13.2	6.9	11.7	-	-	-	20.4
1960	8.5	45.7	30.2	30.8	21.4	13.0	7.8	16.6	14.2	6.6	4.3	23.9
1961	10.8	59.5	54.1	39.2	27.2	18.0	39.3	5.8	21.4	15.7	8.3	34.1
1962	14.9	65.5	56.7	33.6	21.1	22.0	23.8	18.1	19.0	7.6	5.5	30.8
1963	17.8	59.5	50.8	41.2	27.7	22.0	22.2	15.7	14.2	21.0	9.6	35.0
1964	12.5	69.6	54.4	36.6	29.3	27.2	17.6	25.0	13.0	6.2	11.1	36.8
1965	4.6	61.1	61.2	32.9	29.2	24.5	14.2	11.7	18.1	20.0	11.7	30.2
1966	50.0	62.2	50.8	39.7	19.1	21.4	30.5	15.0	35.2	33.3	25.0	37.5
1967	33.3	69.8	64.0	40.6	44.4	35.2	21.8	12.5	20.0	0	28.5	45.8

in Montana, 79%; in Nebraska, 64%; in New Mexico, 91%; in North Dakota, 94%; in Oklahoma, 78%; in South Carolina, 72%; and in South Dakota, 83%.

From the economic point of view, the great merit of lagooning is that the method has its maximum application in exactly those small communities where unit costs are greatest for conventional mechanical treatment processes. The disadvantage of lagoons is that average reduction efficiency may be distinctly below that achieved by the traditional secondary treatment processes.

Just as lagoons provide a method of reducing unit costs for rural communities, so joint treatment offers cost-reduction advantages in the highly urbanized or metropolitan context. The idea is a simple one. Instead of building and operating several waste treatment plants, an area may construct one large enough to handle the needs of several communities. The larger the population to be served, the less the unit cost of treatment.

Here, too, there are obvious drawbacks that constrain use of the technique. On the physical side, there is a limit to the volume of organic residues that any waterbody can accept from a treatment plant without becoming polluted. No matter how good the treatment, some pollutants remain in the effluent. Where several plants are dispersed along a stream, its self-purification properties may sustain its quality; but sufficient concentration of discharges at a single point may result in water pollution.

In some instances, there exist institutional barriers to the successful implementation of regional waste collection and treatment. The absence of viable political organizations and legal mechanisms for combined regional works may often lead to an inefficient mix of small treatment works.

There is an economic limit, too, to the application of joint treatment. Though economies of scale are expressed by constructing and operating large treatment plants, their operation depends on the transmission of wastes to the plant. Transmission is costly, and only slight economies of scale are inherent in building longer sewers. The economies of the larger treatment plant, then, only exist insofar as they are not offset by added transmission costs.

Whatever their drawbacks may be, cooperative municipal waste treatment arrangements are widely practiced. (cf Table 12). In 1962, 520 municipalities provided treatment for 1560 other jurisdictions. Population of the communities served by others exceeded 24 million; and the total population served by systems that included more than one municipal unit was almost 54 million, or 45% of the sewered population of the U. S. Prevalence of joint treatment arrangements is known to have increased since 1962, with total population included within such systems now estimated to be something over 60 million. In fact, the very wide acceptance of the concept prevents a precise quantitative assessment. Between 1962 and 1968, enough of these joint treatment arrangements were regularized into specific quasi-municipal instrumentalities (sewer district, conservancy district, county or metropolitan systems) that assumed a legal identity, that it proved impossible to trace through the <u>1968 Municipal Waste Inventory</u> the number of distinct municipal sub-units that are contained within organizations for the specific purpose of providing waste treatment services.

There can be no question of the broad acceptance of joint treatment arrangements, regardless of the lack of a current numerical assessment. In a good number of States, more than half of the sewered population is served by a system that handles the wastes of more than one community. In California, 70% of the sewered population was included in joint systems in 1962; in Colorado, 52%; in Delaware, 84%; in Illinois, 75%; in Maryland and the District of Columbia, 90%; in Massachusetts, 62%; in Michigan, 73%; in Minnesota, 61%; in Nevada, 54%; in New Jersey, 53%; in Ohio, 62%; in Pennsylvania, 77%; in Rhode Island, 69%; and in Wisconsin, 58%. Among the highly industrialized States, only New York and Texas do not have the majority of their sewered population served by some combination of cooperative waste handling arrangements.

INTERCEPTOR SEWERS

Interceptor sewers--the lines that collect effluent from trunk sewers for conveyance to the waste treatment plant--are an element of the waste handling complex that steadily increases in significance. There are clear reasons for the elevation of investment requirements for interceptor sewers,but before considering them it may be well to review the magnitude of the relative growth of investment for interceptors and for other elements of the waste handling complex. As Table 5 demonstrates, investments

TABLE 12

PREVALENCE OF JOINT MUNICIPAL FACILITIES, 1962;
NUMBER OF COMMUNITIES AND POPULATION SERVED, BY SIZE OF PLACE

Size of Communities Served	Size of Communities Providing Service								TOTAL	
	Under 500	500-1000	1000-5000	5000-10,000	10,000-25,000	25,000-50,000	50,000-100,000	Over 100,000	Communities Served	Population Served
	Number of Communities Served									
Under 500	8	4	33	15	13	9	13	42	137	38,724
500- 1000	1	5	22	16	24	7	15	40	130	96,570
1000- 5000		3	44	44	81	38	60	194	464	1,156,616
5000- 10000		1	9	22	23	27	27	158	267	1,698,899
10000- 25000		1		7	33	16	29	235	321	4,139,265
25000- 50000			2	3	5	8	10	115	143	4,135,486
50000-100000					3	2	4	65	74	4,544,044
100000-250000							1	13	14	1,498,655
250000-500000								8	8	2,480,165
Over 500000								2	2	4,290,405
TOTAL	9	14	110	107	182	107	159	872	1560	24,078,829
Communities Serving Others										
No Treatment	2	3	8	9	10	1	5	13	51	3,639,933
Primary Treatment	3	2	32	24	39	24	25	41	190	25,924,316
Secondary Treatment	7	7	46	48	59	37	32	43	279	24,186,407
Population Served	6900	17,230	310,835	629,980	2,121,685	2,341,502	4,592,265	43,704,259		53,750,656

Source: Municipal Waste Inventory

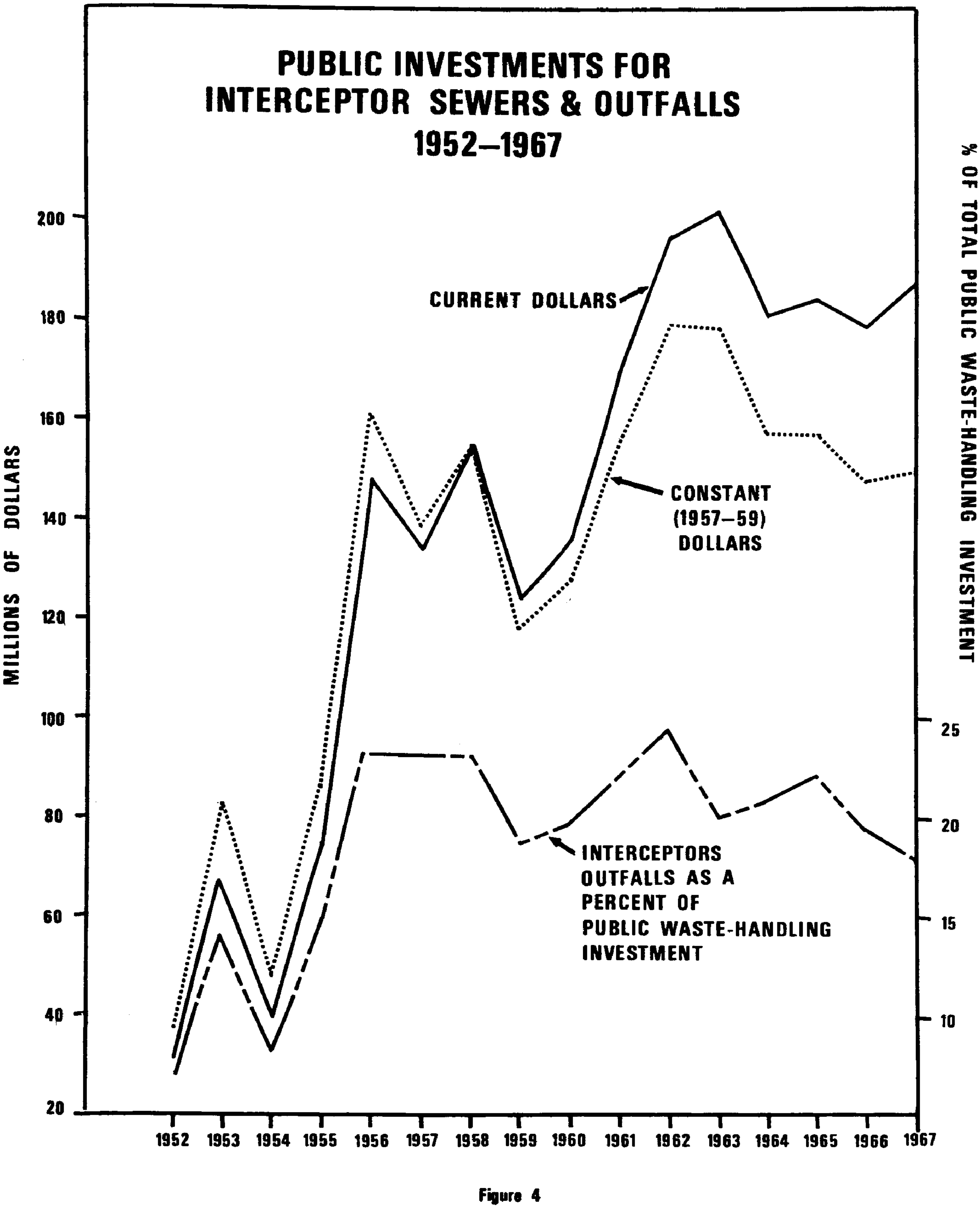

PUBLIC INVESTMENTS FOR
INTERCEPTOR SEWERS & OUTFALLS
1952–1967
MILLIONS OF DOLLARS
% OF TOTAL PUBLIC WASTE-HANDLING INVESTMENT
200
180
160
140
120
100
80
60
40
20
25
20
15
10
CURRENT DOLLARS
CONSTANT
(1957–59)
DOLLARS
INTERCEPTORS
OUTFALLS AS A
PERCENT OF
PUBLIC WASTE-HANDLING
INVESTMENT
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967

Figure 4

for interceptors in 1952 were less than 60% of investments for new waste treatment plants, and only about 13% of investment for collection sewers. But with accelerated progress toward water pollution control that occurred through initiation of Federal matching grants for construction, the level of investment in interceptor sewers began to exceed that of new treatment plants--a relationship it has maintained with the single exception of 1963, when an accelerated public works program resulted in a one year jump in new treatment plant starts. Moreover, interceptor investments have steadily amounted to about 20% of public waste handling investments of all types since 1956.

Since 1960, the nation has spent an average of $185 million a year for interceptors, about 30% more than it has spent to build new waste treatment plants. Since 1956, expenditures for interceptors have maintained an average annual rate of increase of 2.2 percent a year, compared to an increase of 1.8 percent for municipal waste treatment plants. The relative vigor of interceptor investments is somewhat surprising, in view of the fact that need for interceptors rises with size of place, while Federal construction grants were until very recently framed to be of maximum assistance to small towns.

Two factors are thought to account for the strength of demand for interception. The first is physical, and its impact is inescapable. As the prevalence of waste treatment rises, it becomes necessary to go further afield to collect remaining sources of waste. The success of the postwar investment program in the area of municipal waste treatment has forced the nation out further along the line of increasing marginal costs. In the early phase of the effort, it was possible to take advantage of existing collection systems and to discharge waste treatment needs by the simple installation of a treatment plant. But with the initial, facile additions to treated population accomplished, municipalities are now in the process of hooking up those portions of their service areas which--by reasons of location, built-up conditions, or other physical difficulty--had not been connected to central collection systems. Concurrently, municipalities must go out into outlying suburbs to bring into the system the wastes of newly sewered populations.

The process is expensive. Indeed, it would seem that the unit costs of interception are rising more steeply than are the unit costs of waste treatment. On the face of things, this would seem unlikely in that waste treatment plants are going into increasingly smaller communities, are being designed with growing measures of excess capacity, and reflect pressures for more specific and more complete materials removal. But, as shown in Table 13, a comparison of the number of additional persons receiving waste treatment between 1957 and 1962 and between 1962 and 1968 with total investments in each category indicates that the incremental costs of providing waste treatment have risen for interceptor installations as well as for waste treatment plants.

TABLE 13

COST PER PERSON ADDED TO POPULATION SERVED BY WASTE TREATMENT, 1957-1962 and 1962-1968

	1957-62	1962-68 1/
Added Population Served	27,532,000	17,412,000
Investment, New Waste Treatment Plants (1957-61 & 1962-67)	$550,480,000	$894,264,000
Investment, Interceptor Sewers	$545,776,000	$962,043,000
Per Capita Treatment Investment	$20.00	$56.35
Per Capita Interception Investment	$19.80	$55.25

1/ Excludes New York, Pennsylvania, Iowa, Arkansas, and New Jersey

The second reason for additional emphasis on interception is institutional, and its consideration provides conclusions that modify the high apparent per-capita cost of incremental installations of interceptor sewers.

Since World War II there has been a persistent movement toward integrated metropolitan waste-handling arrangements; and these have been duplicated in many cases by smaller scale local arrangements involving groups of communities or communities and factories. In addition to Chicago, a pioneer in such arrangements, the District of Columbia, Seattle, Los

Angeles County, St. Louis, Pittsburgh, Cincinnati, and other metropolitan areas have created far-flung waste handling systems intended to bring all of the liquid wastes of an extended area under a common administrative focus--and often into a single waste treatment plant.

The concept has many advantages. It eliminates overlapping jurisdictions, centralizes operational responsibilities, allows orderly and programmed system development, provides a higher measure of control over effluent quality, offers more advantageous access to financial markets, and eliminates many of the problems of staffing and operator training encountered in smaller waste treatment systems.

Not the least of its advantages is the economies of scale it provides in both the construction and the operation of waste treatment plants. Larger plants cost less per unit of capacity to build and to operate than do smaller plants. Moreover, one large plant requires less capacity to operate effectively than do a number of smaller plants that serve a similarly scaled waste loading, since the collection network serves the additional function of regulating reservoir, in that time of passage from the more distant points of the system acts to prolong peaking periods and reduces the need to install peak loading capacity.

The obvious advantages of such systems, however, can only be attained through recourse to an extensive and costly system of interception. It is, in effect, the investment for interceptors that permits realization of the economies of scale that become available at the treatment plant. For this reason, costly and elaborate sewer networks become increasingly prevalent as urbanized areas of the nation move to revamp the system of individualized waste handling arrangements that has been the rule for over a century. (One of the costs of integrating treatment systems is the abandonment of capital involved in ceasing to operate effective waste treatment plants when a community is brought into a larger system. It is difficult to know how prevalent that sunk capital effect may be, but it is known to exist. Perhaps the imperatives of financing and initiating a metropolitan system often require an immediate decision as to whether a community shall or shall not join its neighbors in such arrangements; but in the interests of capital preservation, there would appear to be good reasons to provide for staged connections and interim arrangements in many if not most cases.)

The conclusion is clear; per-capita interception costs have risen in good part because they are being substituted for treatment plant costs. A second conclusion flows from this one: if metropolitan waste treatment systems provide a means to lessen total waste handling costs, and if metropolitan populations are growing more rapidly than the popula- as a whole, then interception costs should continue to account for a large component of total investment costs.

There are, of course, limits to the extent to which consolidation of waste treatment services can be applied to reduce costs. The available economies of scale come into being at the waste treatment end of the line; interception costs are fairly constant. The cost of transmission, then, will always set the limits to the economic size of any waste handling arrangement.

Figure 5 establishes, in a very general way, the relative rate of accretion of economies of scale for waste treatment plants and for interceptors. It is obvious that the scale economies of the interceptor are far more limited than are those of the treatment plant. Even when the interceptor's two to one advantage in normal operational life and lower operating and maintenance costs are taken into account, there is clearly a point beyond which extended interception will not reduce costs.

The figure is illustrative, and the disadvantages of obtaining relief from treatment plant costs by incurring additional costs for interception are not as great as may seem from reference to the figure. The unit cost disadvantage applies only insofar as the interception cost must exceed that which would be incurred by locating a treatment plant at the most convenient place rather than transporting waste for treatment at a central location.

Over and above that, it is questionable that per-capita analysis of installation cost is appropriate in considering the installation of sewers. The shape of the interceptor cost curve was calculated in a very rough fashion after a number of regionally differentiated interceptor projects were subjected to a regression analysis of the correlation of cost with population served. In most instances, the derived curves (all of which had very low coefficients of correlation) had moderately descending slopes--although in one case, costs assumed a unitary relationship across the size scale. In point of fact, the principal determinants of the cost of sewers are physical--length of sewer lines, depth of trench,

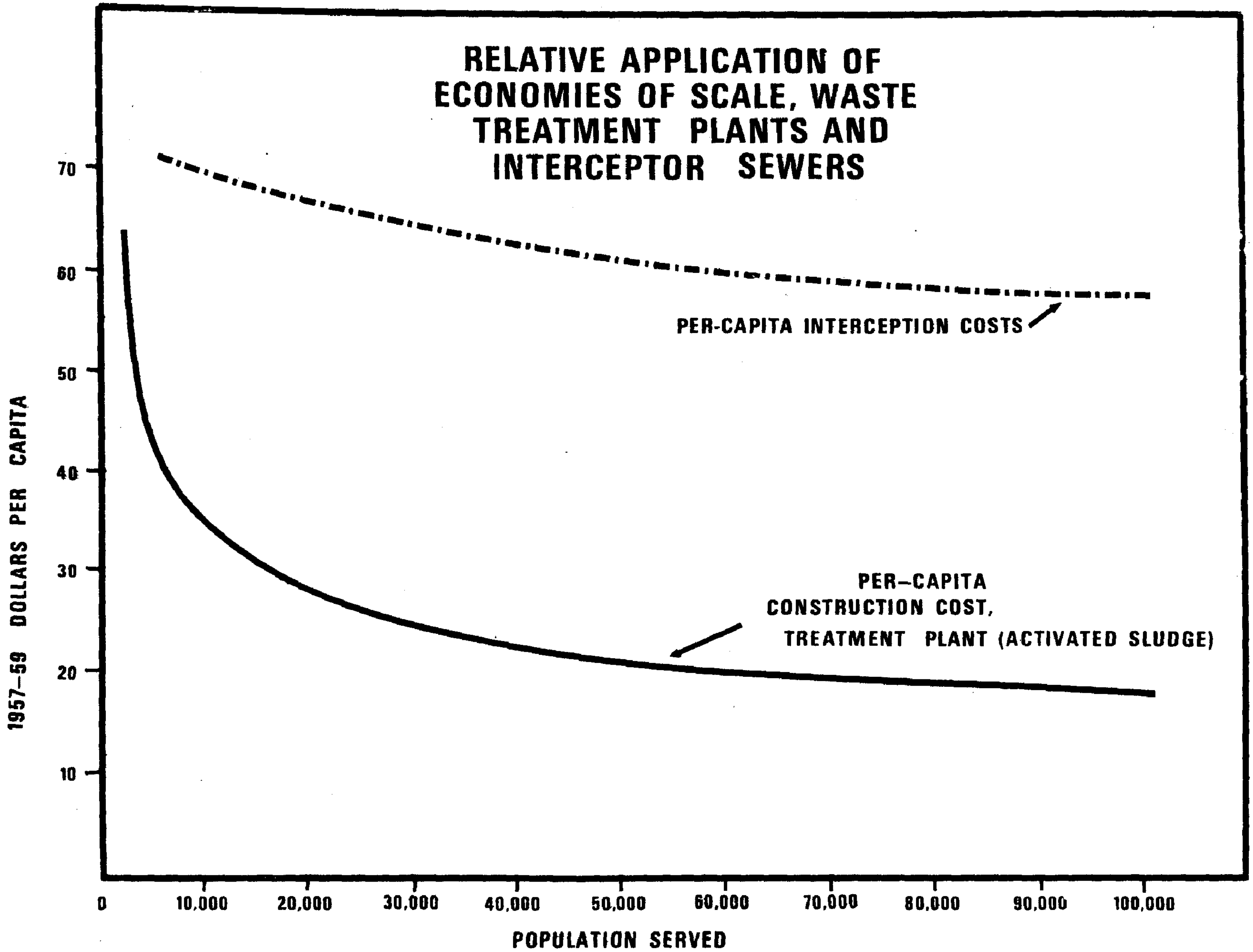

RELATIVE APPLICATION OF ECONOMIES OF SCALE, WASTE TREATMENT PLANTS AND INTERCEPTOR SEWERS
1957-59 DOLLARS PER CAPITA
70
60
50
40
30
20
10
PER-CAPITA INTERCEPTION COSTS
PER-CAPITA CONSTRUCTION COST, TREATMENT PLANT (ACTIVATED SLUDGE)
0
10,000
20,000
30,000
40,000
50,000
60,000
70,000
80,000
90,000
100,000
POPULATION SERVED

Figure 5

slope, geologic conditions, and the nature of improvements to land along which the sewer line is located, relate far more intimately to the cost of a sewer project than does the size of population which the project is intended to serve.

Because of the pattern of development of metropolitan waste treatment arrangements, the preponderance of interception costs are borne by large cities of the nation. The investment requirements are not exclusively the problem of larger cities. Towns and smaller cities share the requirement--though without the complications of scale and growth that weigh upon the metropolis. Too, the smaller community is often able to secure more meaningful direct Federal assistance in coming to grips with its sewering problems, including that of interception, by taking advantage of the vagueness of the distinction between trunk sewer and interceptor sewer. Even without the advantages of uncertainty in definition, the ratio of interceptor cost to total sewer system cost relates conversely with size of community. Therefore, the smaller communities, whose relative sewering needs are least, are best situated to use FWPCA construction grants to ease those needs.

The extent to which interception costs come to dominate water pollution control program costs as size of cities increases is indicated by Table 14, which lists by size of place the proportion of municipal construction costs (excluding those for collecting sewers) devoted to installation of interceptors during the period 1956 to 1966. It is clear that the larger the community, the more dependent it is on interception investments to maintain the integrity of its waste-handling system. For places of more than 25,000 population, interceptor investments have consistently exceeded in amount investments for new waste treatment plants.

The pattern is unlikely to be broken. Irrespective of the initiation of new metropolitan waste-handling arrangements, the majority of the nation's population that will be newly connected to waste treatment plants in the future, as in the last decade, will be most likely to obtain that connection through an extension of interception. The reason is simple. The larger communities that serve the majority of the nation's sewered population have, for the most part, installed waste treatment; and their plants appear to possess sufficient excess capacity to accept substantial increased loadings. (Cf. Table 15.) Extension of interceptors to take advantage of the available capacity that exists in many places of the size where population

TABLE 14

PERCENTAGE OF PUBLIC WASTE TREATMENT INVESTMENT FOR INTERCEPTORS AND OUTFALL SEWERS, BY SIZE OF PLACE, 1956-1966

Population Category	Interceptor and Outfalls As a Percent of Total Waste Treatment Investment[1/]			
	Median Year	High Year	Low Year	1965-67
Population unknown	9.8	27.7	0	15.7
Under 500	16.6	34.5	9.3	16.4
500-999	19.9	31.6	15.8	19.7
1000-2499	24.5	29.7	18.5	23.5
2500-4999	25.3	45.6	20.1	27.1
5000-9999	30.7	36.7	21.6	28.5
10,000-24,999	32.4	38.7	27.1	30.4
25,000-49,999	38.5	52.2	29.0	36.2
50,000-99,999	42.0	52.9	34.4	42.7
100,000-250,000	41.9	47.9	22.3	37.3
Over 250,000	58.9	76.6	34.9	46.5

1/ Excludes Collection Sewer

TABLE 15
PREVALENCE OF WASTE TREATMENT AND AVAILABILITY OF TREATMENT CAPACITY IN MAJOR CITIES

All Communities for Which Data Are Available	SIZE OF PLACE		
	100,000-250,000	250,000-500,000	>500,000
Lacking Waste Treatment	8	2	2
With Primary Waste Treatment	18	9	6
With Secondary Waste Treatment	39	10	9
Percent of Installed Plants 1/			
With Capacity ≤ 1.0 times loadings	37.5	29.0	27.7
With Capacity > 1.0-1.6 times loadings	39.5	38.7	33.3
With Capacity > 1.6-2.0 times loadings	8.3	22.5	22.2
With Capacity > 2.0-4.0 times loadings	13.5	6.4	13.8
With Capacity > 4.0 times loadings	1.0	3.2	2.7

1/ Most cities in these size classes have more than one treatment plant.

growth and outlying residential construction are most marked is a likely way to increase the prevalence of treatment services.

COLLECTING SEWERS

Although sewer systems fall, for the most part, outside of the direct area of activity of the Federal Water Pollution Control Administration, their significance to water pollution control and their specific relevance to municipal waste handling arrangements are inescapable. Unfortunately, there is little quantitative information upon which to frame a judgment of the necessary future costs of sewer installation, and generalized appraisal has been attempted in the absence of a more substantive basis for evaluation.

The 1962 Inventory of Municipal Waste Facilities in the United States lists 11,665 sewer collection systems in place in 1961. These included over 270,000 miles of pipe, together with manholes, pumping stations and lift stations with an estimated aggregate replacement value, according to the Department of Housing and Urban Development, of over $8.5 billion. Between 1961 and 1967, another $3.1 billion worth of sanitary sewers and appurtenances have been installed, adding an estimated 42,000 miles of pipe to the system. Population served by sanitary sewers is currently estimated to exceed the total urban population of the U.S.

Capital expenditures for collection systems have, when adjusted for price level changes, trended slightly downward over the last decade and a half. (See Table 5.) In part, the decline may be traced to a distinct drop in the level of new housing starts since the mid-1950's. Roughly a fourth of all sanitary sewer installations are financed by private contractors in connection with new housing construction, with the cost of the sub-system passed on to the ultimate purchasers of the dwellings. In part, the static level of investment may be considered to be due to the relative completeness of the existing network of sewers.

But there is reason to believe that at least a portion of the low level of activity in sewer installations may be due to the postponable nature of such construction, in combination with financial strictures. Until recently, there have been no meaningful State or Federal assistance programs for sewer construction, so the activity was excluded from what has been an increasingly significant source of local

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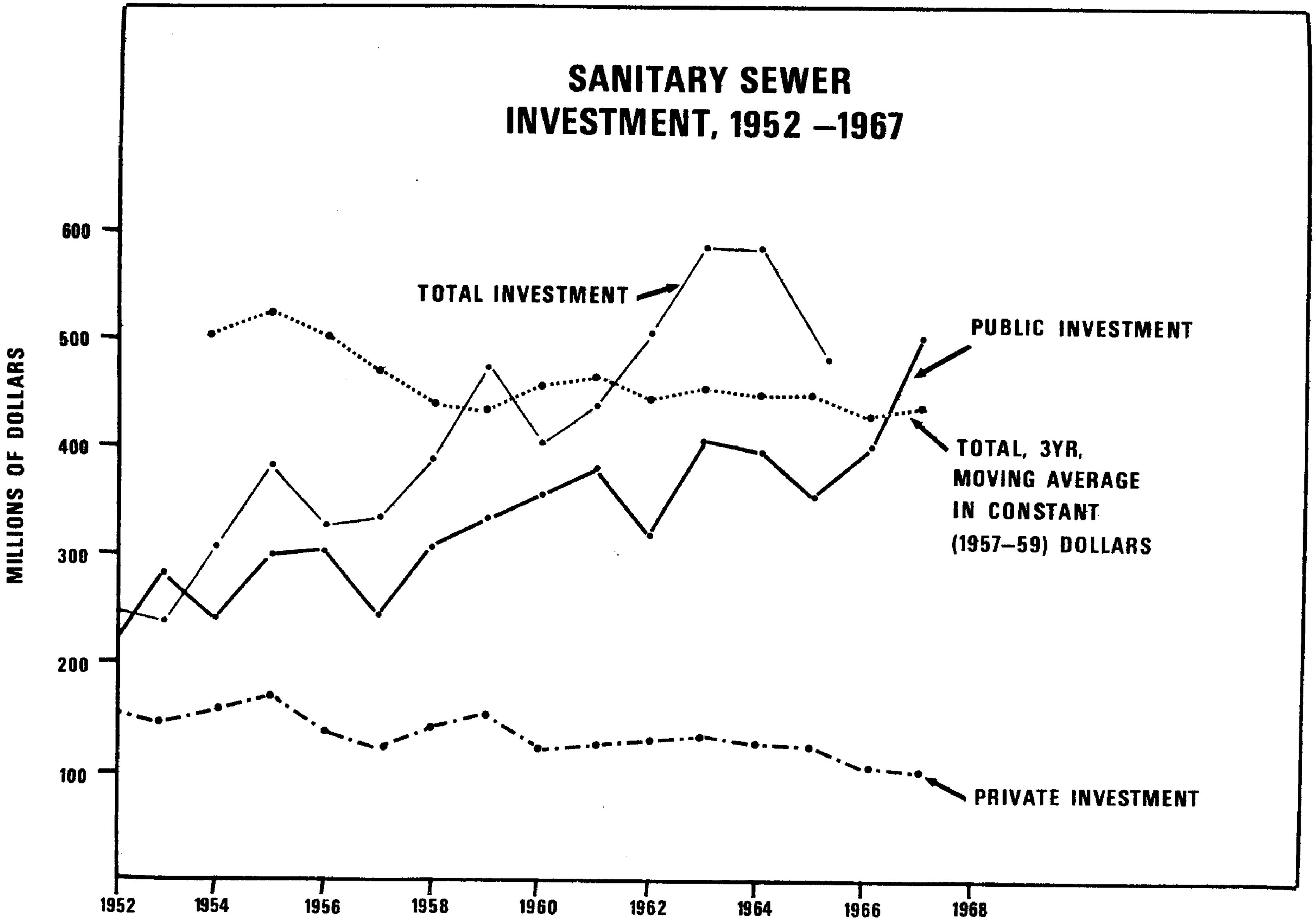

Figure 6

government revenues. Moreover, the steady escalation of interest rates since the early 1950's has imposed a relative restriction on all forms of local government construction activities. Municipalities have tended to progressively reduce the ratio of their capital outlays to their current expenditures for education, social programs, and debt servicing. Given the absolute constraint of tight money and the relative constraint of the incentive to channel funds to take advantage of matching grants, it would not be surprising if local government were found to be slighting a need to install additional sanitary sewer capacity.

There is some reason to believe that the nation's counties and municipalities are accumulating a significant requirement for sanitary sewers. An estimate of the need--based entirely on unsewered urban population, normal population growth during the period 1963-73, average per capita costs, and without reference to replacement--was made in the first report of this series. That assessment indicated a need for $6.2 billion of sanitary sewer construction in the years 1969 through 1973. The Department of Housing and Urban Development in a 1966 report prepared for the Joint Economic Committee2/ presented a very similar estimate. The HUD assessment assumed the provision of sewer services to an additional 41 million persons by 1975, normal replacement, and some progress toward separation--or other solution to the problem--of combined storm and sanitary sewers. The HUD estimate projected a need to expend $5.15 billion over the period 1969-73. Adjusting the 1965 dollars in which the estimate is expressed to 1968 costs and adding to it the differences between estimated requirements and actual investment during the years 1966-68, HUD's appraisal comes to $6.68 billion over the years 1969-73, very close to FWPCA's. Both, of course, are well above the current level of sewer installation activity.

It is questionable, however, that the divergence of either estimate of need from the actual course of investment is in itself a cause for concern. Both estimates are crude in the extreme. They rest largely on an assessment of the number of persons not connected to sewer systems and the probable course of population growth in urban areas. Sewering requirements can only be established on a place-by-place basis by techniques that take into account soil conditions, rate of loading, water supply arrangements, and anticipated settlement

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2/ *Included in* *State and Local Public Facility Needs and Financing.*

TABLE 16

SEWER SYSTEMS
INSTALLED, 1857-1960

PERIOD	SYSTEMS INSTALLED	RATIO OF POPULATION SERVED TO URBAN POPULATION AT END OF PERIOD
1857-1860	10	.17
1860-1870	90	.50
1870-1880	100	.63
1880-1890	250	.72
1890-1900	500	.81
1900-1910	650	.82
1910-1920	1400	.87
1920-1930	2100	.89
1930-1940	3156	.94
1940-1950	2344	.89
1950-1960	850	1.02
1960-1967	N.A.	1.06

patterns. Because the decision to sewer must properly rest on local assessments of local conditions, broad estimates of need can be nothing more than convenient fictions. (cf. State of California, State Water Control Board: Final Report: Useful Waters for California, Sacramento, 1967, for an excellent discussion of the difficulties of determining state-wide sewer needs and a justification of a decision not to attempt to estimate such needs.)

But if no accurate price tag can be assigned to the current need for sewers because a comprehensive assessment of the physical need does not exist, there is reason to be uneasy about the adequacy of the existing rate of investment in collecting sewers. While sewers continue to account for a majority of public waste handling investment, their constant dollar share has been falling slightly but perceptibly over the last decade and a half, even though the determinants of demand for collecting sewers continue to increase. Population of the nation is growing at a rate of almost 1.2% a year; metropolitan area population is increasing at a 1.6% annual rate; new household formations, conditioned by the high post-war rate of population growth, are taking place at about a 1.8% annual rate. Yet capital investment reflects neither a presumably rising curve of replacement needs nor the growing demand base.

A significant aspect of the presumptively retrograde course of sewer investment is general acceptance by local planning and health authorities of the use of individual septic tanks in subdivision construction as an interim measure. Suburban growth has been a major characteristic of metropolitan development over the last 20 years; and in many instances that growth has taken place in an atmosphere in which no local authority has had either the clearly defined responsibility to enforce, or the funds to supply, sewering requirements. Approval of septic tank permits on a massive scale was, under the circumstances, not only expedient but inescapable. But acceptable levels of ground disposal depend on soil types and loading levels. Protection of water supplies, health considerations--and in some areas of the country, surface water depletion--limit the extent to which ground disposal of wastes may be permitted. In critical situations, it has often become necessary for zoning authorities to deny building permits that included provisions for septic tanks. In other areas, population density standards have been established beyond which use of septic tanks has not been considered acceptable. But all local governments are not sufficently endowed to ensure adequate standards of safety; and local conditions may become unsanitary or may result in pollution of ground water without recognition of the fact. In view of the rapid rate of suburban development and the seemingly laggard course of new sewer installations, there is reason to suspect that a significant need for sewers has been accumulating over the years.

Another factor that raises doubts about adequacy of sewer installation rates is an apparently growing replacement requirement. Over 85% of the sewer systems in the nation have been installed since 1910, as shown in Table 16. Because the normal design life of a sewer is 50 years, local government should probably anticipate a very sharp increase in replacement costs over the next three decades, a period that corresponds with the maximum rate of sewer system installation half a century earlier.

The dimensions of that replacement and rehabilitation need cannot be estimated with precision--but some assessment can be hazarded. Taking as a point of estimate the $11.6 billion estimated current replacement value of sewers in place and assuming a two percent annual rate of replacement derived from the 50 year normal life of a system, local governments are incurring a replacement requirement at a level of almost a quarter of a billion dollars a year. If, on the other hand, it is assumed that in the course of the present decade the five percent of the urban population whose service dates from the period 1910 to 1920 must have sewer facilities renewed at the current average cost of $139 per capita (1968 dollars), then the minimum replacement need is established at about $90 million per year. Not only is there a wide range of estimate as to replacement needs but there is also some question about how much actual replacement is performed under the guise of maintenance or repair in place. The fact is that great uncertainty exists with respect to sewer needs, including those for replacement.

The complexities of sewer system renewal will add to its cost. Replacement costs based on new construction conditions are entirely inadequate estimating tools. Thinly populated residential areas of 50 years ago have become built up, and have in many cases become commercial or industrial sites or locations of concentrated, multiple dwelling housing. To tear up streets, interrupt communications, and alter waste transmission under such conditions can be enormously expensive. To attempt to measure that expense by per-capita expenditures that are based largely on investments made in conjuction with new residential construction is obviously little better than guessing.

The significance of the sewer problem and the large sums spent annually for installation of sewers make the general uncertainty which surrounds the subject extremely serious and potentially very costly. The circumstances suggest the need for a comprehensive study of the nation's sewer system, including such of its aspects as relation to urban drainage and waste treatment, value of facilities in place, desirable technology, rate of system installation, and rate of depreciation. While the Department of Housing and Urban Development is the logical focus for such a study, State and local government bodies and the Federal Water Pollution Control Administration might well contribute to it.

REPLACEMENT AND DEPRECIATION

HISTORICAL REPLACEMENT EXPENDITURES

After 20 years of high levels of construction activity, the nation has amassed a large body of fixed capital in the form of waste treatment plants and collection systems. The existence of this capital has created a need for its maintenance, and a requirement that it be replaced over time.

Though the dimensions of the current replacement investment are not clearly identifiable because of inconsistencies in designation, it is very clear that such expenditures have been rising at a more pronounced rate than have new plant investments. Contract awards for replacement and expansion of facilities have been rising in number and value, as opposed to the declining trend of new treatment plant investments since 1963. Recorded expansion and replacement of facilities has involved the expenditure of more than a hundred million dollars a year in every year but one since 1963. Currently, such expenditures amount to about $140 million a year--roughly equal to investments for new sewage treatment plants--without taking into account the extent to which new plant investment includes replacement of abandoned facilities. Since 1963, the level of investment for expansion and replacement has been increasing at a five percent annual rate (or a 2.7% annual rate in constant dollars). In contrast, the level of investment for new treatment plants has declined at a 16.5% annual rate (19.7% in constant dollars). Relative maturity of the municipal waste treatment system of the nation is imposing a new set of priorities in the allocation of investment resources.

DEPRECIATION

The five percent rate at which recorded replacement expenditures have been rising reflects very imperfectly the growth in replacement needs that must increasingly be felt as the municipal waste collection and treatment system matures. That the rate of increase has been so modest can only be ascribed to the newness of much of existing fixed capital--more than 60% dates from 1950, and almost 40% from the initiation of Federal construction grants in 1956.

To estimate the economic implications of the replacement requirement, then, it is almost certainly unrealistic to project the current rate of expenditures at some appropriate historical rate of increase. Depreciation--the accountant's convention for quantifying the irregular fact of physical deterioration--seems a superior way of assessing the built-in replacement demand implicit in the substantial waste-controlling investments that the economy has provided to this time. It is recognized that most municipalities do not employ depreciation accounting, but the utility and validity of the concept are generally accepted. The idea of depreciation is appropriate in the economic sense which conveys "wearing out" of physical plant which need not necessarily be replaced in a given year but does represent a real economic cost which must at some time manifest itself as an expenditure to regenerate or replace the capital plant and equipment.

Generalized estimates of the level of depreciation are based on the sanitary engineering rule of thumb that assigns an average useful life of 25 years to a waste treatment plant and 50 years to a sewer. To the extent that such estimates are well-founded, depreciation estimates may be more meaningful in the present context than a great deal of depreciation accounting, where the tax laws are framed to provide private firms with an incentive to accrue depreciation at the most rapid possible rate.

Depreciation of municipal waste treatment plants and interceptor sewers currently occurs at a rate that is rising from $280 million (1968 dollars) a year, or about twice the level of recorded replacement expenditures. As has been noted, the discrepancy between estimated depreciation and actual replacement expenditures may be traced in large measure to the considerable portion of the total capital base which has been brought into being within the limits of the normal operating life of system components. Since the nation's capital facilities program has been of recent origin--only becoming active at the close of World War II, and tracing its maximum intensity from the enactment of the 1956 matching grants program of the Federal Water Pollution Control Act--significant acceleration of replacement activities will not become necessary for several years. After about 1971, however, replacement needs will--at least in concept--begin to climb very steeply as the plants built since 1946 are to be replaced.

The replacement schedule of the future can be charted with moderate precision (assuming that accepted depreciation rates are accurate). The total replacement need at any time is a simple function of the size of the capital base and the average age of the fixed assets being depreciated. Rapid growth of annual depreciation charges over the recent past mirrors the sustained expansion of facilities in place and will translate into similarly shaped curves of replacement needs after 25 and 50 years, in the respective instances of treatment plants and interceptors. The rate of increase in depreciation charges will, as the system matures, define the major dimensions of future investment programs.

The skyrocketing growth of the potential replacement need measured by depreciation is a direct reflection of expansion of the facilities base. It is possible, then, to calculate approximate dimensions of depreciation claims on future needs at given points in time, and thus to infer the dimensions of imminent replacement requirements. A tabular statement of hypothecated depreciation charges at five year intervals is presented in Table 17; and the same information is rendered graphically in Figure 7.

The calculation process used is straightforward. Value of plant in place was assessed in 1957-59 dollars on the basis of the 1957 and 1962 Municipal Waste Inventories. For succeeding years, and for the period 1952 to 1957, recorded investments, translated into constant dollars, were used to modify the base years' estimates and to provide a running assessment of the value of plant in place in each year. Per-capita investments for waste treatment plants and for interceptors were derived on the basis of the 1957 Municipal Waste Inventory, and applied to populations served by waste treatment as these were recorded in the 1940, 1945, 1948, and 1949 inventories. Gaps were bridged by the assumption of a constant rate of investment between years of record. It was assumed that treatment plant in place in 1940 had come into being in regular stages over the preceding 25 years, interceptors in regular stages over 50 years. Gross value of plant in place for each year (other than the inventory years 1957 and 1962) was adjusted to a net value by assuming that each increment of waste treatment investment passed out of service after 25 years, each increment of interception investment after 50 years. Price level adjustments were made by application to the Municipal Waste Treatment Plant Cost Index and Sewer Construction Cost Index. Subject to the reliability of the input data, the depreciation model is felt to provide a consistent approximation of the evolution of the nation's municipal waste handling fixed capital over time.

There is one huge gap in the model No values are assignable for collection sewers--whose value almost certainly

TABLE 17

INDICATED INCREASE IN DEPRECIATION

YEAR	Treatment Plants In-Place	Treatment Plants Depreciation	Interceptors & Outfalls In-Place	Interceptors & Outfalls Depreciation	Total Depreciation	From Previous Period	From 1940	From 1955	From 1960
	Millions of 1957-59 Dollars					Annual Rate (%) of Increase in Depreciation			
1940	1060	42	1220	24	66				
1945	1180	47	1395	28	75	2.6	2.6		
1950	1410	56	1575	33	89	3.5	3.0		
1955	1900	72	2125	43	115	5.2	3.8		
1960	2525	101	2975	60	161	6.9	4.5	6.9	
1965	3470	125	3920	79	204	4.9	4.6	5.9	4.9
1967	3885	130	4240	85	215	2.7	4.4	5.3	4.2
	Millions of Current Dollars 1/								
1940	410	16	480	10	26				
1945	460	18	550	11	29	2.9	2.9		
1950	600	24	660	13	37	5.0	3.6		
1955	980	39	1090	22	61	10.5	5.8		
1960	1605	64	1930	39	103	11.0	7.1	11.0	
1965	2625	105	2980	60	165	9.8	7.7	10.5	9.8
1967	3120	125	3380	68	193	8.1	7.7	10.1	9.4

1/ Total Estimated 1940 Plant is Evaluated in 1940 Dollars

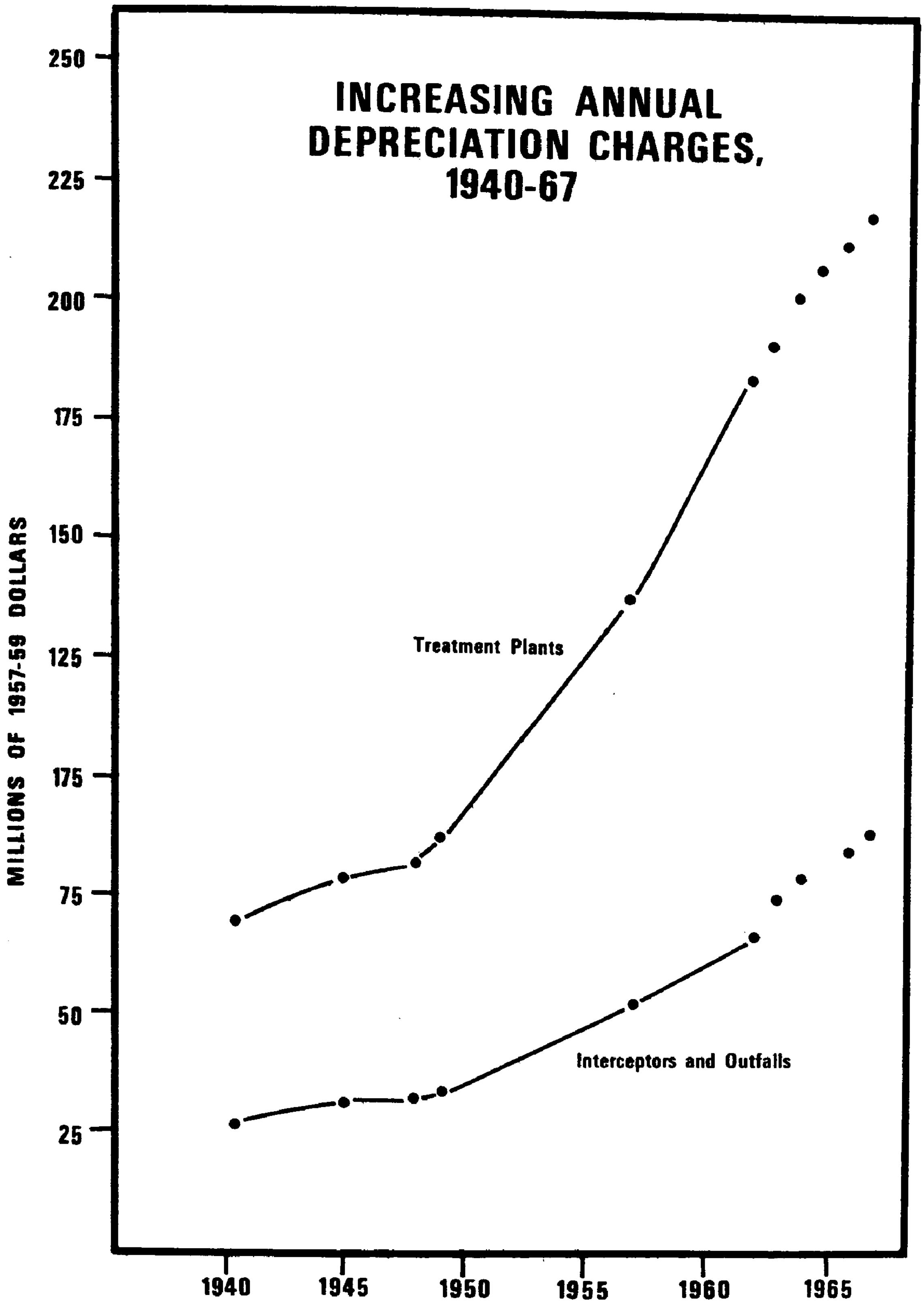
INCREASING ANNUAL DEPRECIATION CHARGES, 1940-67
MILLIONS OF 1957-59 DOLLARS
250
225
200
175
150
125
175
75
50
25
Treatment Plants
Interceptors and Outfalls
1940
1945
1950
1955
1960
1965

Figure 7

exceeds that of all other elements of the system, but which cannot be quantified with present knowlege except by the grossest kind of estimation process. A portion of that gap is made up of interceptor sewers serving the portions of the population without treatment at each time interval. Because value of interceptors in place was gauged on the basis of recorded relationships between value of treatment plant and value of interceptors where treatment is provided, no value for interception could be assigned for the sewered population without treatment, even though some portion of their needed interception facilities was unquestionably in place. The significance of the particular deficiency in the model becomes increasingly less with the expansion of the portion of the population that is served by waste treatment, since a value for interception is assigned by the procedure whenever a treatment value is recorded. The major distortion of the model at that point shifts from capital value of interception to accumulated depreciation, since the effect of the adjustment is to assign an effective life of 50 years to the incremental interception value, regardless of what the actual age composition of physical facilities may be.

At the current level of accruals--equivalent to about $280 million in 1968 dollars--estimated depreciation is occurring at more than twice the rate of recorded expansion and replacement, and constitutes an amount that is somewhat more than half of the value of all recorded investments for treatment plants, interceptors, and outfalls. And the steady rise in depreciation presages great growth in dimensions of future replacement expenditures.

Significantly, the growth curve is still rising vigorously. While the rate of increase is slowing, an absolute annual increment of about $8 million is occurring currently; and the dimensions of charges will continue to increase indefinitely. It has sometimes been presumed that at some future date any "backlog" of needed treatment works will have been eliminated. From that point, the new capital emplacement that results in rising depreciation charges would consist of an amount no greater than that required to serve population increases. In fact, however, there is no foreseeable end to the trend of rising replacement costs, short of a technological breakthrough that reduces unit investment requirements. Higher levels of waste treatment and increased public treatment of manufacturing wastes should continue to press capital requirements upward significantly for many years.

For this reason, it may be advisable to begin to view capital requirements arising out of waste handling demands in a somewhat different manner. The "backlog of treatment needs," as previously defined, has become an outmoded concept. Data from the 1968 Municipal Waste Treatment Inventory indicate that the backlog has been sharply reduced. Two distinct categories of investment currently account for the majority of local government waste treatment expenditures. On the one hand, funds are being spent for improvements in degree of treatment, in efficiency of system, and in consolidation. On the other hand, funds are being spent for replacement--or the partial reduction of the accumulation of past depreciation.

Of the two elements, it seems likely that, as time passes, the replacement segment of investment demand will come to constitute the major portion of the market. Indeed, it may be that we should not abandon the concept of backlog, but redefine the term. While the meaningful backlog of needed new facilities does not bulk large, there is an unquestionable accumulation of partially depreciated facilities. If we think of that accumulation as a backlog of foreseeable claims on capital, the concept is entirely valid and very useful. Emphasis is shifted from the concept of a one-time need to the sustained maintenance of national treatment capital.

The fact is important. Replacement is not a minor detail, it has become a major effort. If the nation is to continue to control municipal sources of water pollution, it must be prepared to sustain a continuous flow of investment capital for the effort. Should a state of equilibrium control be achieved, with no additional investments required to accommodate growth of waste sources or to increase the degree of waste treatment, it would still be necessary to replace facilities. And in that equilibrium condition, 48% of the total replacement value of treatment plants in place at any one time would be constituted by accumulated depreciation. (Of about $10.6 billion of current replacement value of interceptors, outfalls, and treatment plants existing in the U.S. today, just about half--within the accuracy of the evaluation model--represents accumulated depreciation).

PRICE LEVEL CHANGES

The total replacement need at any time is determined by the size of the capital base, the average age of capital facilities, and the level of prices. While accumulated

ACCUMULATED DEPRECIATION: INTERCEPTORS AND OUTFALLS

ACCUMULATED DEPRECIATION: SEWAGE TREATMENT PLANTS

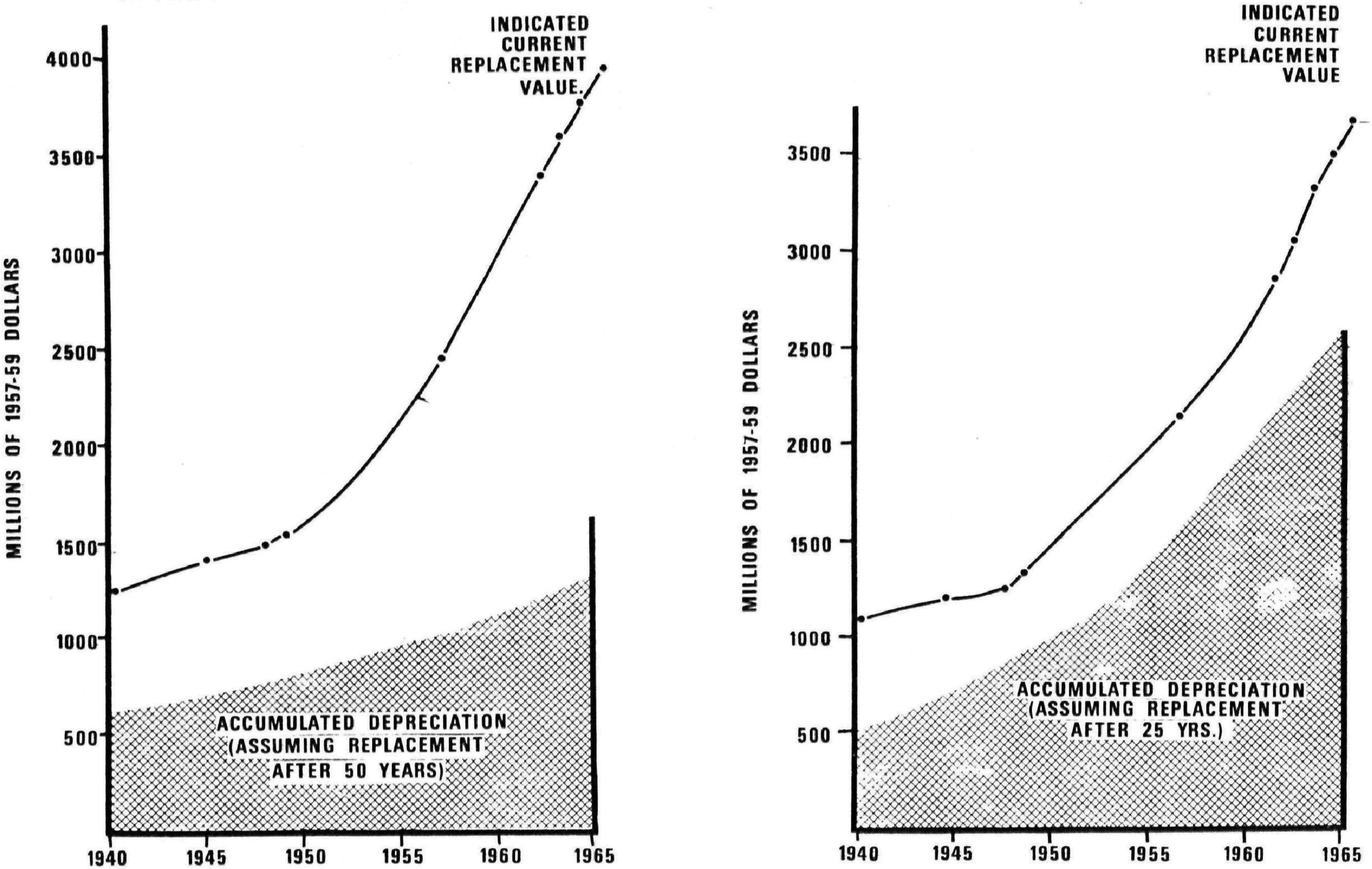

Figure 8

depreciation charges adequately reflect the size and age composition of facilities, they fall far short of measuring actual replacement dimensions in that they do not account for price level adjustments.3/

Where the period of useful life of fixed capital is long--as in the 25 years estimated for waste treatment plants--the difference between the initial cost of an item and the cost of replacing the same item can be great.

In the case of waste treatment plants and interceptor sewers, the increase in replacement costs that is traceable to inflation has been slightly greater over the past quarter century than that due to the increase in physical facilities in place. In current dollar terms, the rate of increase in depreciation has scarcely slowed since 1960, with rising construction costs more than counteracting influences limiting the rate at which new plant construction rises.

Nor does a simple comparison of current dollar depreciation estimates with constant dollar estimates adequately reflect the impact of inflation on replacement requirements. Current dollar depreciation rates reflect costs at the time of installation, just as constant dollar depreciation charges measure comparative value of replaceable facilities at different points in time. But any increase in replacement costs is expressed throughout the capital base, so that a revaluation of all facilities is implicit in any cost increase. From 1940 to 1967, waste treatment plant construction costs, as measured by the Municipal Waste Treatment Plant Cost Index, increased at a 4.3% compound annual rate, and sewer installation costs increased at a 4.4% compound annual rate. Over the same period, the constant dollar value of physical facilities put in place increased 4.4% per year. In sum, then, inflation has, in a general way, equalled investment as an influence on potential replacement costs.

For the future, the effects of price level changes may be expected to be the principal influence on replacement costs. The higher prevalence of waste treatment, the limited need for

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3/ It must be conceded that the concept of inflation is in some respects a distortion. The passage of time invariably involves technological improvements; and these are not normally taken into account in determination of price levels. Despite unmeasured qualitative differences, the quantitative impact of inflationary increases in construction costs has become enormous with the passage of time.

new treatment plants, as contrasted with expansion and replacement and the superior organization of resources that has been developed in reducing the extent of untreated wastes will all limit the effective size of increase of the value of physical depreciation. But price level changes are inescapable.

TABLE 18

RELATIVE IMPACTS OF DEPRECIATION AND INFLATION ON REPLACEMENT OVER TIME

Period	Annual Rate of Increase		Percent of Constant Dollar Investment Made in Period
	Fixed Capital	Construction Cost	
1940-45	2.6%	1.9%	5%
1945-50	3.5	10.3	7
1950-55	5.2	4.7	18
1955-60	6.9	3.8	25
1960-65	4.9	1.4	32
1965-67	2.7	3.4	13
1940-67	4.4%	4.4%	100%

To date, accidents of timing have reduced the impact of price level changes on total replacement requirements. Inflationary influences were at their maximum in the period of adjustment that followed World War II, and until very recently have been progressively moderated. Because a large part of the total physical plant devoted to handling of liquid wastes came on stream after inflationary stresses had eased--indeed, the period of maximum treatment plant construction coincided with the period of minimum inflationary effect--the net impact of inflation on replacement has been limited. As far as price level fluctuations were operative, the investment program for water pollution control could not have been better phased if it had been designed to operate as a contra-cyclical mechanism.

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GROWTH OF REPLACEMENT COSTS, 1940-1967, RELATIVE INFLUENCE OF DEPRECIATION AND PRICE LEVELS OVER TIME

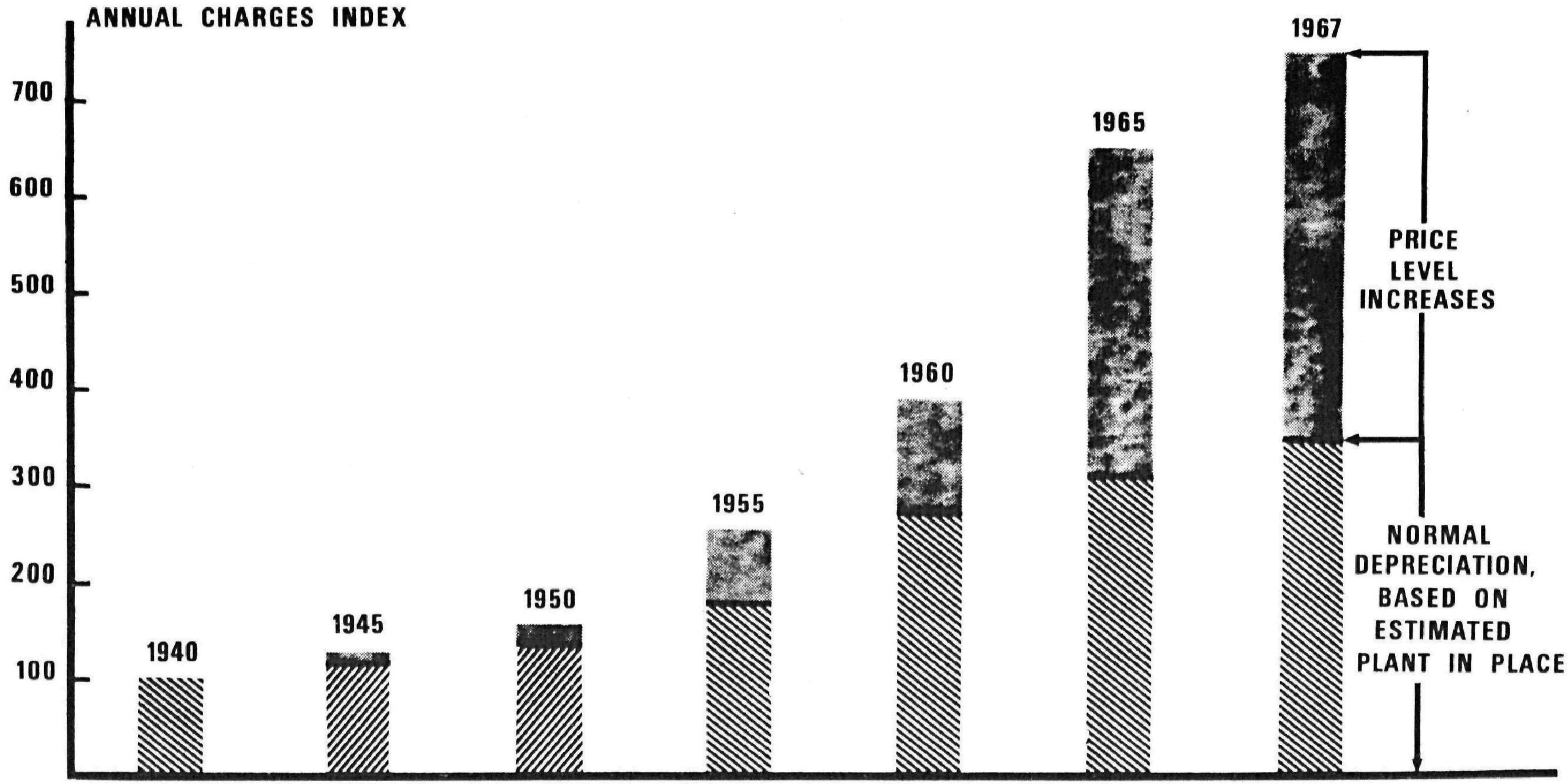

Figure 9

OPERATING AND MAINTENANCE COSTS

CURRENT LEVEL OF EXPENDITURES

Units of local government in the United States are estimated to currently be spending between $150 million and $200 million a year to operate and maintain waste treatment plants.4/ On a per-capita basis, the cost amounts to about $1.40 for every man, woman, and child being served by waste treatment.

The significance of operating and maintenance costs to local government has generally been overlooked. Preoccupation with installation of facilities needed to abate or avert water pollution has led to an imbalance of attention to investment aspects of municipal waste treatment; so governments have struggled with problems of engineering and financing works, paying relatively little attention to the operation and maintenance costs that will exceed capital expenditures over the life of a treatment plant.

Some idea of the magnitude of the annual expenditure connected with operating a waste treatment plant is provided by Table 19, which lists by size of place the average annual cost of operation by plant and by person served, on the basis of plants listed in the 1962 Municipal Waste Inventory. It must be emphasized that the figures are presented as a general guide to dimensions of average unit costs. Actual charges are influenced by technology, size of plant, degree of treatment, plant location, and other variables. The generalized values shown in Table 18 and succeeding tables represent a melding of all influences and are average costs; they cannot, then, be expected to apply to any particular place. (For

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4/ The figures were derived by calculating average operating costs for treatment plants in place in 1962, as they are listed in the Municipal Waste Inventory and apportioning investments for treatment plants between 1962 and 1967 according to established trends for prevalence of treatment processes among population size categories. It is a mathematical convention representing the most likely cost in a range of probability extending from $97 million to $314 million and not the result of a current survey. Further uncertainty arises from governmental accounting practices which may confuse the usual distinctions between operation and maintenance expense and replacement costs.

TABLE 19

Generalized Operating Costs by Size of Place
and Type of Treatment
Average Annual Operation and Maintenance Cost, 1957-59 Dollars1/

Size of Place	Activated Sludge2/		Trickling Filter3/		Lagoons		Primary4/		All Plants	
	P/Plant	P/Capita	P/Plant	P/Capita	P/Plant	P/Capita	P/Plant	P/Capita	P/Plant	P/Capita
Less Than 500	2,000	5.40	2,000	5.90	400	1.00	1,400	4.60	1,200	4.10
500- 999	2,900	4.15	3,300	4,800	500	.80	2,100	3.15	2,500	3.70
1,000- 4,999	5,800	2.50	6,400	2.80	1,100	.60	3,800	2.20	3,800	2.10
5,000- 9,999	14,000	2.00	11,000	1.70	1,500	.30	8,300	1.60	9,800	1.70
10,000- 24,999	25,000	1.75	15,000	1.30	1,800	.20	16,000	1.20	16,000	1.45
25,000- 49,999	45,000	1.50	27,000	1.05	-5/	-	32,000	1.10	30,000	1.25
50,000-100,000	73,000	1.45	55,000	.90	-5/	-	56,000	1.00	54,000	1.10
Over 100,000	360,000	1.20	61,000	.90	-5/	-	154,000	.65	133,0006/	1.00

1/ Based on average size of population served in each population category for each treatment process

2/ Relatively low per-capita rates in the lower population categories attributed to prevalence of extended aeration.

3/ Tend to have lower population served in every category than Activated Sludge.

4/ Excludes intermediate treatment.

5/ Population served by lagoons in these categories are more representative of the lower population categories, values were omitted to reduce possibility of misinterpretation.

6/ Strongly reduced on basis of average cost, by lagoons, which treat only a tiny portion of population served in this category.

example, in national terms, the constant dollar cost of operating a treatment plant declined slightly between 1957 and 1962, in spite of a great increase in prevalence of secondary waste treatment. The improvement in average costs was due almost entirely to two influences: widespread adoption of lagoons by small communities and assertion of economies of scale in the over-all composition of the nation's stock of treatment plants. Obviously, any cost advantage accrued only to new units or to established units in which excess capacity was taken up by growth of population served. For most plants in place in 1957, not only was there no improvement in operating cost experience, actual current charges had increased about eight percent over the five years as a result of inflation.)

Notably missing throughout this assessment of operating cost is any consideration of the cost of maintaining sewers. We know that sewers require maintenance; and we know that the replacement value of sanitary sewers is several times that of waste treatment plants. Unfortunately, there is a considerable gap in the technical literature of water pollution control at the point where information about the cost of operating and maintaining sewers should occur. Even if we allow for the fact that sewer systems are relatively maintenance-free, knowledge of the massive capital investments in sewers argues that the absolute level of maintenance costs must be as great or greater than operating and maintenance of treatment plants. If, for example, interceptor sewers and the pumping stations operated in connection with interception, could be adequately maintained for an annual expenditure equal to no more than three percent of their replacement value, that single segment of the sewer system would require the outlay of about $180 million per year, equal to expenditures to operate treatment plants.

INFLUENCES ON OPERATING COSTS

Waste treatment plant operating costs have been very sketchily examined. The technical literature tends to present such data as do occur in terms of specific--and often atypical--plant situations, and to fall back for comparison purposes on a very few and very general sources. Materials presented in this study depend largely on a 1961 statistical analysis conducted by the Public Health Service,(2) with some modification to accommodate data provided by later studies, particularly those resting on the large, but only partially analyzed, information library accumulated by the Construction

Grants Division of the Federal Water Pollution Control Administration. A detailed statistical study of operating costs is currently under way in the FWPCA. Its completion should provide a basis for firming or modifying any numerical or other conclusions drawn in this report.

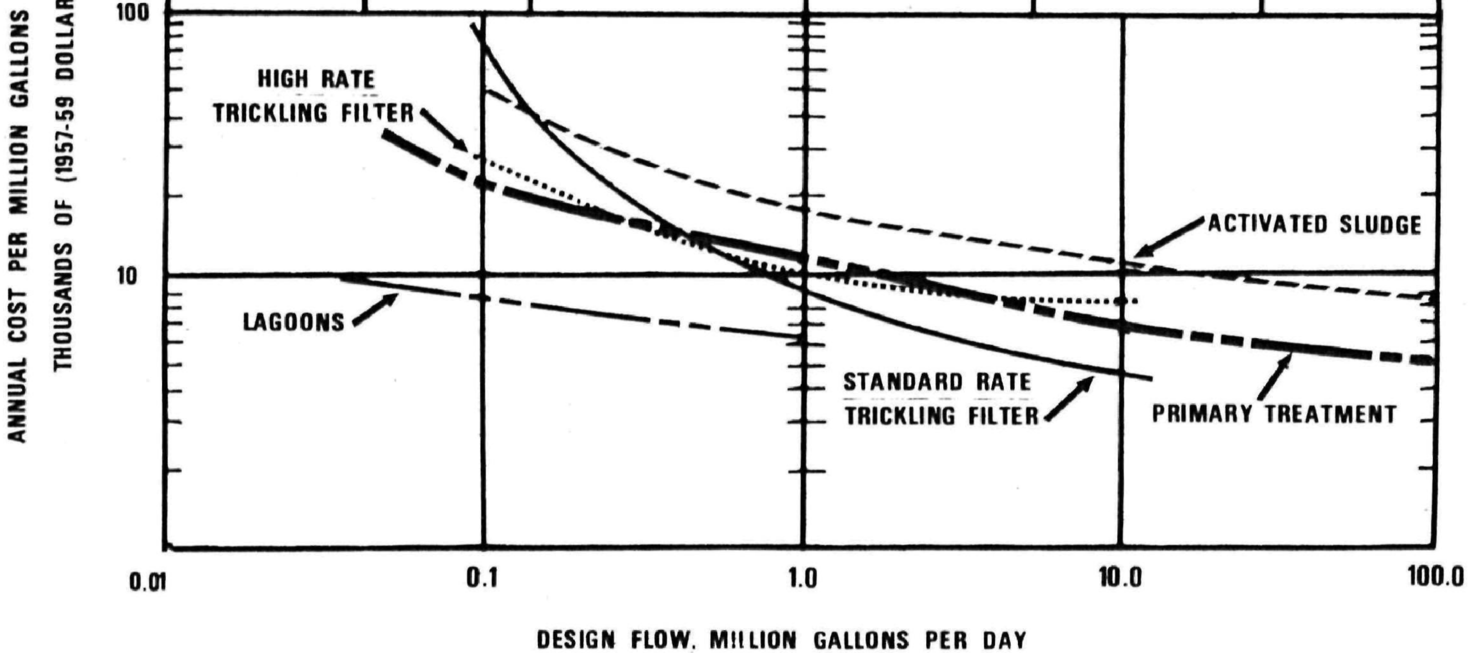
Though operating costs in any existing plant tend to be relatively inflexible, in that a plant in place offers little opportunity to change costs at a given level of efficiency, they are believed to be quite responsive to price level changes, and are known to adjust with changes in process. On a national scale, operating charges are subject to a great variety of influences, and adopt a variety of configurations when charted. Total costs, then, are subject to considerable control over time, as available tradeoffs come to be utilized to approach an optimum national waste treatment system. Labor, power, parts, and chemicals are the basic elements of operating costs, but their synthesis takes many forms, according to the requirements imposed on the individual treatment system. Wasteload, degree of treatment, method of treatment, and age of plant all have effects on the level of operating and maintenance costs; and there is good reason to believe that location and regulatory and other institutional factors have further power to modify operating costs.

Size of Plant

The most pervasive influence is that of size. Economics of scale come dramatically into effect as size of plant increases. For every treatment method, however, there is a consistent flattening of the cost to size curve, leading to the conclusion that the cost line becomes horizontal or turns upward beyond some point of diminishing returns. (cf. Figure 10.) And because of those inherent limits on efficiency, application of economies of scale can not be continuous since optimum operating costs may occur well short of the volume of a community's waste load. The variform shapes of the costs to size curves for different treatment methods, however, offer tradeoff possibilities. In general, these will be expressed as a balancing of capital with operating costs. Since collection systems comprise the major costs of the entire complex of waste treatment needs, there is an optimum point which the community should not exceed in collecting wastes to avail itself of economies of scale. Because current dollars are inherently more valuable than future dollars, there are limits to which the community should design excess capacity into the

OPERATING AND MAINTENANCE COSTS, BY TYPE OF TREATMENT

FLOW-IN MILLION GALLONS PER DAY	THOUSAND (1957-59) DOLLARS PER YEAR PER MILLION GALLONS PER DAY FLOW				
	PRIMARY	ACTIVATED SLUDGE	STANDARD RATE TRICKLING FILTER	HIGH RATE TRICKLING FILTER	LAGOONS
0.1	23.3	53.4	71.6	40.0	8.5
1.0	10.7	21.5	10.6	13.5	5.8
10.0	6.7	12.1	5.1	7.5	—
100.0	4.9	8.2	—	—	—



GENERALIZED OPERATING AND MAINTENANCE COSTS

Figure 10

system to take advantage of economies of scale in planning to treat expected increases in waste loads. But the two simple capital/operating cost tradeoffs should not be ignored in system design.

Treatment Processes

Technology, too, has a distinct impact on operating and maintenance costs. Each of the several methods of conventional primary and secondary waste treatment has its own characteristic cost curve; and the interaction of those curves deserves careful study in the selection of a means of meeting the long-term waste treatment requirements of a community in an optimum fashion. It is significant, too, that each treatment method has distinct limitations of scale. The cheapest is the simple oxidation pond or lagoon. But use of such systems is distinctly limited by land availability and a variety of other considererations. And though the addition of aerators increases the effective capacity of lagooning at a modest incremental cost, there is a definite limit to the applicability of the method in terms of volume. There appear to be limits, too, to the effective size of trickling filters, whose operating costs (and capital costs as well) tend to be well below those of activated sludge plants for most of the process size range. The planning consequence of the inherent size limitation characteristic of the various processes is that it provides additional design alternatives in terms of investing, at greater initial cost, in more, but smaller, plants of a process distinguished by lower operating costs against a lower investment in a larger but more costly to operate plant. For smaller communities, of course, such a choice does not exist. They must accept the treatment process best suited to their peculiar needs.

Degree of Treatment

Degree of treatment required from a facility has a very strong influence on cost. In general, the more concentrated a waste, the less it costs per unit of reduction to reduce its pollutional content. As a consequence, costs of treatment rise sharply as lower concentrations must be achieved in the final effluent. The effect is best indicated by the increase in costs that occurs with the transformation of a system from primary treatment to secondary treatment; and though experience with tertiary or advanced waste treatment processes is not great enough to draw precise conclusions about the dimensions of operating costs, the limited information available indicates that tertiary treatment may double the operating costs encountered in secondary treatment.

Nor does advance of costs with degree of treatment occur only in plateau-like steps as additional stages of treatment become necessary. Within the various treatment processes, levels of efficiency can vary, and with them operating costs. For two similar treatment plants, different removal efficiencies are possible. And with higher degrees of pollutant removal, detention time is lenghthened, sludge generation and handling requirements grow, pumping is increased, materials are less concentrated--all of the processing elements found in the plant are extended and carried out under increasingly less favorable conditions.

The principle of increasing operating costs at successive degrees of removal is illustrated in Figure 11 for a hypothetical community of a thousand persons. Here the marginal cost curves have been inferred rather than calculated, but the general form of the relationship is believed to be quite valid; and average costs have been calculated from the same sources used for other materials in this section. Cost of reduction of biochemical oxygen demand removal increases rapidly in primary treatment, and flattens with the addition of secondary treatment. The fact is inherent in the nature of the processes. Primary treatment is intended to reduce volume of floating and settleable solids in wastewater; reduction of BOD and suspended solids is almost an incidental side effect. (If the cost curves had been graphed for solids rather than oxygen demand, marginal cost curves would have become almost vertical at the point secondary treatment comes into play.) When the secondary stage of treatment is added to the system, BOD removal is initially increased at a very low incremental cost, to the point that removal efficiency approaches the practical limits of the process. Our hypothetical town can discharge its secondary treatment requirements with any of several technologies--each having its particular cost and treatment advantages. In the figure, the alternatives considered are a high rate trickling filter, which is relatively inexpensive to operate, but has definite limits on removal efficiency with a normal composition or waste, and activated sludge, which combines high relative removal with high relative costs.

The combination of primary treatment and trickling filter may be expected to remove about 80% of the biochemical oxygen

COST OF OPERATING AND MAINTAINING TREATMENT PLANT AT INCREASING DEGREES OF EFFICIENCY, TOWN OF 1000 PERSONS

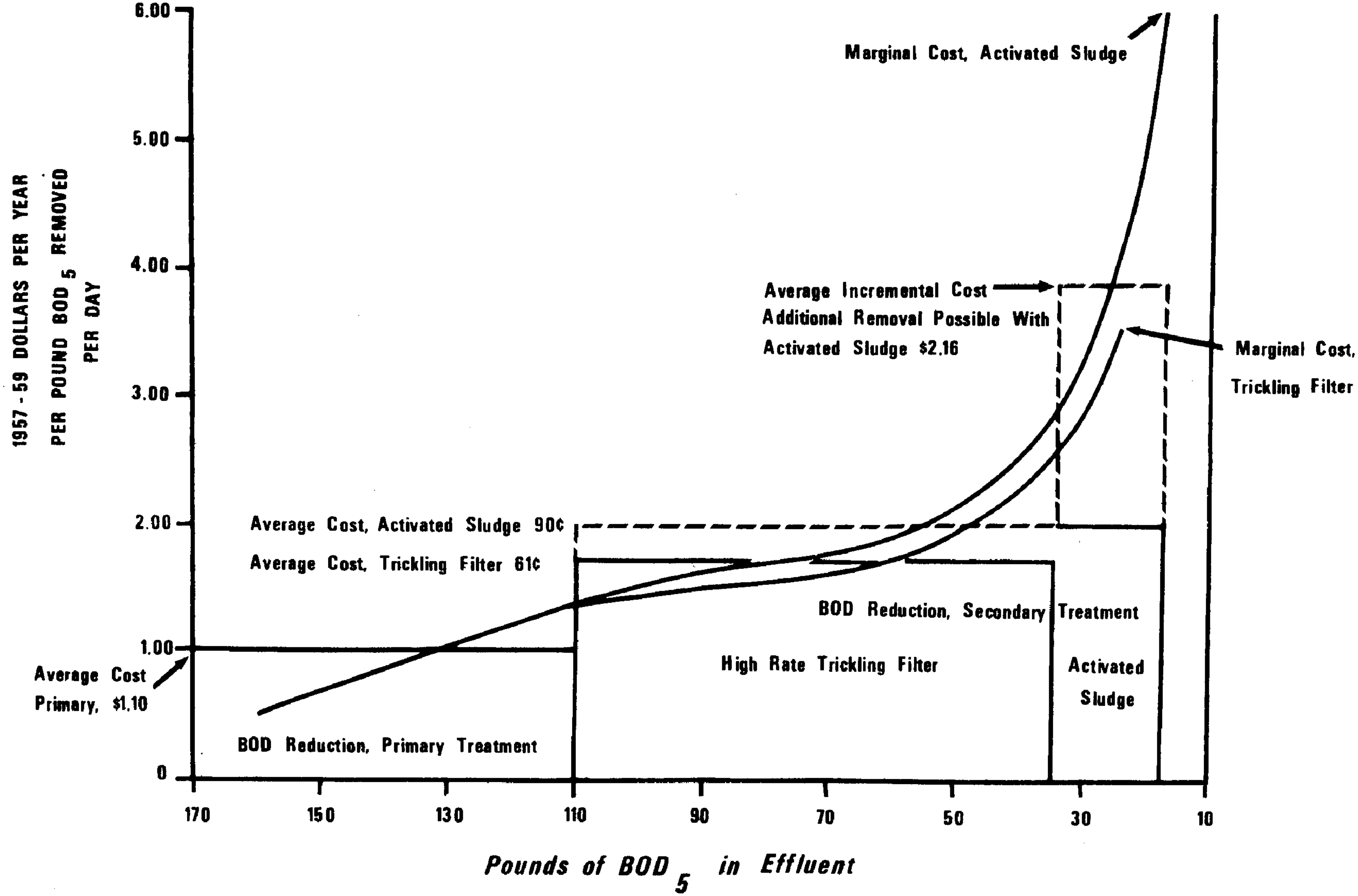


Figure 11

demand in the waste stream of the community illustrated, and do it quite effectively, at an annual cost per pound of BOD removed per day of about $1.10 in the primary stage and $0.61 in the secondary stage. If, however the community should see fit to utilize the activated sludge process in the secondary treatment stage of its plant, it could anticipate effective removal of about 90% of the biochemical oxygen demand in the waste stream, with an operating cost of $1.10 per year per pound of BOD removed per day in the primary stage and $0.90 per year per pound of BOD removed per day in the secondary stage. In terms of average costs, then, the more effective treatment method would increase operating cost of secondary treatment almost 50%. But when the differential operating charges of using the activated sludge system are entirely attributed to the 10% incremental reduction of BOD that becomes possible with the use of the system, the average operating cost per year per pound removed per day is calculated to be $2.16, or three and a half times the average cost to remove a unit of biochemical oxygen demand within the limits of the less effective process. Such expenditures may be necessary to achieve the benefits of improved water quality.

Having made the general point that increased removal involves increasingly higher incremental costs, it becomes necessary to point out that the interaction of the various influences on operating costs can completely upset the rule. Most evident is the influence of technology. Reference to Figure 10, which contrasts operating costs for various treatment processes, indicates that lagooning is less costly than other methods of treatment throughout its range of application. That advantage extends to any level of removal within the physical limits of the process. Similarly, trickling filters, known to achieve far higher BOD removals than primary treatment as well as some modest improvement in solids removal, are demonstrated by the graph to be operable at about the same cost as primary plants over a considerable range of plant sizes. The explanation lies, at least in part,5/ in the properties of the processes. Though parts and power costs are increased over those of primary treatment by the addition of trickling filters, sludge generation--which accounts for a large part of total operating costs--is not measurably increased; and cost of chemicals for disinfection is considerably lessened because of the

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5/ The reservation is due to the fact that 30% of the data relating to trickling filter costs was generated in southern States, as opposed to 20% of the data for primary treatment. Lower regional labor costs may have biased the sample.

reduced organic interference with chlorination that results from higher level of materials stabilization accomplished by secondary treatment. There is increasing emphasis on upgrading the operational efficiency of existing waste treatment plants including, as one means, a higher pay scale to attract better skilled operators. The implementation of such programs will tend to increase operation and maintenance costs in the future; but this increase should result in a higher level of treatment performance.

Wastes Composition

The disinfection cost/facilities cost balance found between primary treatment and trickling filters is analogous to many influences on operating cost that may be exerted by changes in the composition of wastes. Because domestic waste tends to be fairly homogeneous in composition throughout the nation and throughout the year, changes are usually found in connection with the hookup of industrial waste sources to a public treatment system. Existence of such arrangements can drastically alter average and marginal operating costs of treatment; but the variety of conditions that may occur and the complexity of their inter-relationships make it impossible to generalize mathematically about their cumulative impact. Because the joint municipal-industrial treatment plant is becoming more prevalent, and because theoretical treatment of the economic impacts of such arrangements has generally been limited to the economies of scale afforded by them, it is well to describe some of the other predictable influences on operating costs that they may involve.

There is no question that a change in the composition of wastes can in some circumstances increase operating and maintenance charges. Lingering opposition to joint municipal-industrial waste treatment depends in large measure on this fact. The clearest case in point is that where industrial wastes include materials that may be toxic to the bacteria that effectuate organic stabilization in conventional secondary treatment processes. The usual remedy is to require segregation or pretreatment of such waste streams, in which case the added cost is borne directly by the discharger creating the potential difficulty. But such arrangements cannot insure against the accidental spill which always constitutes a danger in connection with some industrial wastes.

Another possible source of added cost is, paradoxically, discharge by industry of a relatively uncontaminated waste, such as cooling water. Because unit costs of pollutant removal vary inversely, at least to a point, with the initial concentration of pollutants in the waste stream, diluting discharges of nearly pure water will increase system costs. Here pricing can afford a remedy. If charges to the system user are based in good part on volume of discharge, there is an incentive to segregate for direct discharge, or to recycle, those portions of the waste stream that do not require conventional treatment.

A more subtle upward influence on operating cost may occur with fluctuations in composition of the waste stream. The bacteria that effectuate secondary treatment are fragile organisms, and a sudden change in their environment has the power to short circuit the treatment system by causing a full or partial die-off.6/ Under normal conditions, the bacterial population will adapt itself to the changed environment, and after a period of time return to an equilibrium level. But a situation marked by sharp fluctuations in waste composition may largely nullify the possibility of secondary waste treatment.

These upward influences on operating costs tend to fall in the category of accident or of conditions subject to alteration by arrangement or by pricing. If the waste constituents are amenable to conventional treatment, the general effect of the change in waste composition that occurs with joint municipal-industrial treatment systems is thought to be beneficial with respect to operating costs. (The statement, of course, refers to total costs and not to their distribution. The

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6/ A dramatic example may be found in the case of the Kalamazoo, Michigan waste treatment plant. The bulk of the plant's waste loadings are of industrial origin; and it has for some years operated in so efficient a manner as to be cited as a model of enlightened cooperation in pollution abatement. In late 1967, however, a paper mill discharging to the treatment plant discontinued a minor production process. The changed composition of the wastewater resulted in an immediate drop in stabilization efficiency. As a consequence, discharges from the plant had a higher pollutional strength than before; and a considerable volume of partially stabilized organics was consistently incorporated in its sludges. Decomposition of such material in sludge drying beds created an odor problem, one which was solved at considerable cost by covering sludge beds. Maintenance of the covered beds has added to costs; and the reduced effectiveness of the treatment plant persists a year later.

point is that treating an industrial waste with a municipal waste is less costly than treating each separately. It is not intended to infer that economies would occur in great enough measure that total costs for the municipality would be less after accepting an industrial waste; unit costs, however, would be reduced in most cases. The point is examined in some length in Volume III of this report that deals with sewerage charges.)

Because the sources of operating cost benefits to be derived from widespread joint waste treatment are well defined, it is fairly predictable that such benefits will increasingly assert themselves on a national scale. For any given situation, however, their realization and extent will depend on the relationships between the specific wastes that occur. Too, the distribution of such cost advantages between the community and industry that share them will depend on the system of taxation or rate method used to finance the operations of the system. A biased pricing arrangement can abort realization of possible savings by discouraging industrial participation in the system, or it can result in gross inequities--the most obvious example being the use of general tax revenues to pay for operation of a system treating predominantly industrial wastes.

A major source of operating economies is to be found in the fact that most industrial processes using organic raw materials produce wastes more concentrated than normal domestic sewage. (cf. Table 20) To the point of overloading, the more concentrated the waste, the less the unit cost of treatment. Thus, the combination of a concentrated industrial waste with a relatively dilute domestic sewage normally has the effect of lifting efficiency of the secondary treatment system closer to a biological optimum. For the municipality, unit savings from this source may be more than offset by a major increase in volume of sludge to be handled. The problem, then, is one of setting a schedule of charges that adequately balances costs incurred in one area with savings achieved in another.

Another source of possible operating economies, and one that may assume major magnitude as time passes, is to be found in the chemical composition of domestic sewage and the stoichiometric balance of bacterial metabolism. Phosphorous and nitrogen constituents of domestic sewage exceed nutrient requirement of characteristic strains of treating bacteria, given the usual carbon, oxygen, and water content of organics in solution in sewage. Conversely, many industrial wastes are nutrient deficient, and in treatment require the addition of nitrogen and/or phosphorous. With a joint treatment system,

TABLE 20

RELATIVE CONCENTRATION OF BOD, DOMESTIC SEWAGE AND ORGANIC INDUSTRIAL WASTES

Waste Source	Mean BOD_5 Concentration, MG/L
Domestic Sewage	200
Beet Sugar Refinery	620 1/
Milk Processor	1000
Tannery	1100
Poultry Plant	480
Synthetic Fibre Producer	520
Brewery	610
Meat Packer	1100
Potato Processor	1340
Pulp Mill (Kraft)	290 1/
(Sulfite)	1100 1/
(Groundwood)	600
Paper Mill	160 1/

1/ Apparently includes cooling water dilution effects.

Source: W.W. Eckenfelder, Effluent Quality and Treatment Economics for Industrial Wastewaters.

the surplus nutrients of domestic sewage supply, at least in part, the deficiency of the industrial waste, thereby reducing chemical costs.

For most of the nation the potential savings to be found in redressing the nutrient balance may, at this time, be small. But it is the excessive phosphorous concentrations of treated domestic wastewaters that is now thought to be the prime source of excessive enrichment of waters. In circumstances--like those of Lake Erie or Lake Michigan--where treatment for phosphorous is to be required, the ability to incorporate the surplus phosphorous of domestic sewage in sludge by introducing a phosphorous-deficient industrial waste stream into the treatment plant should result in a very great saving over the cost of constructing and operating specific phosphorous-reducing processes.

Differences in wastes constituents, however, do not always favor joint treatment arrangements. As growing waste loadings require increasingly specific kinds of removal procedures, generalized waste treatment processes will steadily become less satisfactory for the critical pollutants. There is clearly no point in discharging industrial wastes which are pollutional by reason of inorganic content, toxicity, or temperature to a community's secondary waste treatment plant. The biological process would either have no effect on such wastes or would itself be less effective as a result of the addition of such wastes. Similarly, as phosphorus removal becomes more prevalent, it is questionable that the factory whose organic wastes are characterized by a near optimum nutrient balance should use the municipal plant. For the factory, it would involve payment for an expensive process that would be redundant because of the low phosphorous content of its effluent after conventional secondary treatment. For the community, it would probably result in higher unit costs, simply because dilution of the phosphorous content in the total effluent stream would, under normal conditions, be expected to increase the cost of removal.

Location

Local conditions, too, can affect the operating cost of waste treatment plants. Materials costs may be influenced by the nearness of suppliers. Low labor costs in parts of the nation or in rural areas may result in local savings. More significant, because more controllable, are attitudes-either embodied in regulation or simply resting in local habit--that lie outside of the accident of place and represent deliberate kinds of local choices. Perhaps the most obvious is an observable regional preference for one treatment method over another. West of the Mississippi, a majority of small communities have met their waste treatment requirements by resorting to the use of inexpensive but effective oxidation ponds. In the industrial Northeast, however, there is a definite pattern of preference for activated sludge plants in communities of all sizes.

OPERATING COST TRENDS

Operating and maintenance costs have demonstrated a strong secular uptrend over the last decade. Current municipal expenditures to operate treatment plants are estimated to be well over twice the level of 1957. To some moderate extent, that increase has been the result of inflation and of population growth; but most of the increase is due to a great increase in the prevalence and degree of treatment of municipal wastes.

Method of Assessment

Operating and maintenance charges have been calculated in gross fashion for the body of waste treatment plants listed in the 1957 Municipal Waste Inventory and the 1962 Municipal Waste Inventory. The method of calculation was: (1) to array listed treatment plants according to technology (lagoon, activated sludge, trickling filter, etc.) and population served (assumed to be equal to the total population served in each of the general categories used throughout this report, divided by the number of treatment plants of each description); (2) to multiply each size of service population by appropriate cost function derived from the Rowan, Jenkins and Howells statistical study (in some instances, the value was derived from a more recent or more specific study) in order to derive an average cost per plant; and (3) that value, in turn, was multiplied by the total number of recorded plants to provide a total cost for the treatment method and the population category. The sum of the various products is believed to provide a reasonably adquate estimate of operating and maintenance costs for each inventory year, since it accommodates--within the limits of data reliability--the major influences on operating cost: size of plant and method of treatment.

Because the <u>1968 Municipal Waste Inventory</u> was being compiled at the time that this study was under preparation, a similar calculation of operating costs could not be made for the current year. Lacking detailed data, an estimate was made on the basis of investment that has taken place in the interim between inventories. The basic elements of the estimate are presented in Table 21. The table indicates that there are two problems to making an assessment solely on the basis of value of plant in place in the various population categories:

(1) average rate of occurrence of costs must be gauged subjectively on the basis of cost trends and the technology that influenced those trends during previous reported periods; and (2) rate of abandonment of facilities is unknown. With respect to the latter, it is suggested that the in-place waste treatment capital of the nation is so predominantly new that an assessment based on normal rate of depreciation considerably overstates the rate at which facilities are being taken out of service. Reconciliation of capital values estimated to be in place in 1957 and 1962 with recorded investments between the years bears out the argument. Net investment between the periods failed to account for the increased assessed value of plant, suggesting that conventional depreciation schedules overstate the actual rate of replacement during the period.

All costs were estimated to a common base, the period 1957-59. Deriving current dollar values proved to be an uncertain process, in the absence of any index of comparative prices. Lacking comparative year cost data to construct such an index, reference has been made to analogy. It was reasoned that processing sewage into treated wastewater is essentially a continuous flow production process, very similar to some manufacturing processes in the circumstances that determine cost. Somewhat arbitrarily, then, operating costs have been assumed to react to price level changes in a manner that may be described by use of the <u>Wholesale Price Index</u>, <u>Intermediate Manufactured Materials</u>. On that basis, operating costs for relevant years were determined by use of these coefficients:

1957-59	-	1.000
1957	-	.925
1962	-	1.000
1967	-	1.080

It must be admitted that there are some rather large reservations about the use of the particular index. These center about the fact that the very modest rise in the index--as compared to the <u>Consumer Price Index</u>, for example--is due in good

TABLE 21

ELEMENTS OF CALCULATION, 1967 OPERATING COSTS

Millions of 1957-59 Dollars

Size of Place	Plant in Place 1957	Plant in Place 1962	Capital Changes 1962-1967: New Plant	Capital Changes 1962-1967: Other Adds.	Capital Changes 1962-1967: Depreciation 2/	Indicated 1967 Plant	Operation and maintenance as a % of Capital Exp. 1957	Operation and maintenance as a % of Capital Exp. 1962	Operation and maintenance as a % of Capital Exp. 1967 1/	$1,000's (1957-59) Indicated 1967 Charges
Under 500	33.4	33.8	18.3	8.8	(8.9)	43.2	3.6	3.7	3.7	1,598
500-999	75.7	75.7	29.7	14.9	(19.0)	101.3	4.1	4.6	4.3	4,356
1000-4900	448.8	536.9	137.7	76.9	(124.3)	627.2	3.3	3.0	3.3	20,698
5000-9999	260.6	320.6	97.2	69.0	(77.2)	409.6	3.3	3.4	3.5	14,336
10,000-24,999	278.4	426.3	77.7	83.4	(98.7)	686.1	3.7	3.7	3.7	25,386
25,000-49,999	173.5	296.4	59.4	65.4	(68.4)	352.9	3.9	3.6	3.6	12,704
50,000-100,000	209.1	223.0	53.8	53.7	(53.2)	277.3	2.9	3.9	4.1	11,369
Over-100,000	920.6	920.6	184.7	186.7	(214.2)	1077.6	5.6	5.4	5.2	56,035
TOTAL	2123.9	2836.6	658.4	558.8	(663.9)	3389.9	4.1	4.1	4.3	146.50
TOTAL, Excluding Depreciation						4053.8			4.3	173.86

1/ Assigned on the basis of new plant technology trends.

2/ Assessed @ 4% of cumulative gross value for each year; no retirement assumption is included for the period 1957-62.

measure to productivity improvements. There has been little apparent gain in productivity of any of the several basic waste treatment processes. Such productivity gains as have occurred seem to have been due to better utilization of technology--greater relative use of lagoons and utilization of economies of scale--rather than to technological improvements. Since the method of calculating costs reflects organizational advances, it is very possible that the calculating procedure and the chosen index both assess productivity changes, the effect being to increase the implied productivity coefficient. The other difficulty with use of the particular index is the fact that the wage structure in the particular activity is known, on the basis of scattered sampling, to be well below that in manufacturing, even in 1968. It is characteristic of low relative wages that they tend to rise faster than average labor costs during periods of full employment. Thus, the particular influence on operating costs may have had the effect of levering actual costs upward at a greater than normal (i.e., as measured by the index) rate. In reviewing comparative operating costs presented herein, it is well to keep in mind that the method of assessing them may have had the effect of understating their rise throughout the period of discussion.

Degree of Increase

Massive investment in waste treatment plants over the last decade has caused a substantial rise in the aggregate level of treatment plant operating and maintenance charges. Such costs are estimated to have amounted to about $80 million in 1957, to have exceeded $100 million by 1962, and to be about $200 million today.

The dimensions of the increase are not surprising, in view of the great increase in facilities being operated. There were 7,518 sewage treatment plants of all descriptions in operation in the U.S. in 1957. During the next 10 years, the nation built more than 5,000 new plants. In the five years between 1957 and 1962, the number of persons served by waste treatment increased from 69 million to 94 million. Nor do the gross figures on numbers of new plants and numbers of persons served provide an adequate view of the increase in waste treatment services that has occurred. Most of the new treatment plants coming on stream in the past 10 years have been secondary plants--between 1957 and 1962 the number of persons served by secondary waste treatment increased more than 40% as compared to a nine percent increase in the population of standard metropolitan statistical areas. The whole base upon which operating and maintenance costs are generated has surged enormously upward. Well over 90% of the nation's sewered population is now served by waste treatment, and 60% is being served by secondary waste treatment.

In view of the effective magnitude of the investment program that has been going on, the indicated increase in operating and maintenance costs is surprisingly low. The available evidence indicates that the growth of the service population and the upgrading of the average degree of treatment performed has been accomplished without inducing a corresponding increase in operating costs. Current calculations are not possible, because of the incomplete status of the 1968 Municipal Waste Inventory, but between 1957 and 1962:

number of treatment plants in service increased	24.7%
population served by waste treatment increased	36.1%
population served by secondary treatment increased	41.2%
operating costs, in constant dollars, increased	34.7%

The nation achieved an increase of more than a third in the number of persons receiving waste treatment, together with an increase in the prevalence of secondary waste treatment, for a rate of increase in operating charges no greater than might have been expected for the increase in treatment alone. In terms of operating costs, the benefits of secondary treatment were to a large extent a pure bonus. However, current emphasis on upgrading the performance of plants will probably cause these figures to increase in the future.

Improvements in average operating costs were spread fairly evenly through all sizes of community, but are most obvious in the case of very small towns--those with a population under 500 persons, and those which have had the largest relative increase in the prevalence of waste treatment. Per-capita operating costs between 1957-62 were unchanged for the total population served by waste treatment, except to the extent that the price level influenced such costs. In the lowest population category, however, per-capita operating and maintenance costs for all plants are calculated to have dropped about eight percent in constant dollars, or enough to fully offset the assigned effects of inflation. Average operating cost per plant rose moderately on a national basis, reflecting a general increase in the average size of plant as well as in the average degree of treatment. In some population-size categories, however, substantial decreases in average per-plant operating costs occurred. (cf Table 23).

TABLE 22

INDICATED TREND OF
GROSS OPERATING CHARGES, 1957-1967

Size of Place	ANNUAL OPERATING CHARGES, MILLIONS OF 1957-59 DOLLARS						
	1957			1962			1967
	PRIMARY	SECONDARY	TOTAL	PRIMARY	SECONDARY	TOTAL	TOTAL
Under 500	0.45	0.75	1.20	0.40	0.86	1.26	1.60
500-999	1.09	2.00	3.09	0.89	2.57	3.46	4.36
1000-4999	5.02	9.68	14.70	4.91	11.46	16.37	20.70
5000-9999	2.69	5.80	8.49	2.28	8.51	10.79	14.34
10,000-24,999	2.86	7.37	10.23	4.85	11.03	15.88	25.39
25,000-49,999	2.88	3.87	6.75	3.74	6.90	10.64	12.70
50,000-100,000	1.71	4.31	6.02	2.54	6.25	8.79	11.37
Over 100,000	12.11	24.17	36.28	13.67	36.03	49.70	56.04
TOTAL	28.80	57.96	86.76	33.28	83.61	116.89	146.50
As A Percent of 1957			100.00			134.7	168.8
Total Current Dollars	26.64	53.61	80.25	33.28	83.61	116.89	158.22
As A Percent of 1957			100.00			145.6	197.1
Excluding of Facilities: Depreciation							
1957-59 Dollars							173.87
Current Dollars							187.78

TABLE 23

TRENDS IN UNIT OPERATING COSTS
1957-1962

EXPECTABLE AVERAGE ANNUAL COST IN 1957-59 DOLLARS

Size of Place	Estimated Cost Per Plant		Estimated Cost Per Capita	
	1957	1962	1957	1962
Under 500	1500	1200	4.40	4.10
500-999	2300	2500	3.65	3.70
1000-4999	4300	3800	2.20	2.10
5000-9999	9900	9800	1.60	1.70
10,000-49,999	17,500	16,000	1.40	1.45
50,000-100,000	40,000	53,500	1.10	1.10
Over 100,000	156,000	123,000	1.00	1.00
Average	11,500	12,500	1.25	1.25
(Indicated Range)	(7,000-19,000)	(7700-21,000)	(0.80-2.10)	(0.75-2.05)
Average in Current Dollars	10,500	13,000	1.20	1.25

Cost-Moderating Influences-1957-62

Relative improvements in unit operating costs that occurred as a result of additions to waste treatment between 1957 and 1962 were accomplished as functions of the technological adaptation and assertion of economies of scale that occurred as a result of the investment program.

Technological change involved an altered pattern of process acceptance rather than development of improved treatment processes. A shift in the relative prevalence of processes was continuous throughout the period. To a degree, the change involved an increase in the use of relatively high cost methods of treatment; but, on balance, the effect of change was exercised in the direction of cost reduction.

Most notable change, in gross terms, was the relative decline in the use of primary waste treatment as the sole treatment. The total number of persons served by primary treatment increased by over seven million in the course of the five years, with at least 173 additional primary treatment plants coming into service. The net increase in population served, however, occurred entirely in higher population categories. More than balancing new primary plants installed in communities of 5,000 or more was apparent net retirement or conversion of 231 primary treatment plants in communities having populations under 5,000. As a proportion of total plants in service, primary treatment plants declined from 37% in 1957 to 29% in 1962. (cf. Table 24 for summary.)

While a decline in the prevalence of primary treatment relative to secondary treatment would normally be expected to involve increased operating costs, the way in which that decline took place was largely responsible for holding nationwide unit costs down. Net reduction of numbers of primary plants occurred in communities in the smallest population size categories, where unit costs are highest. Net increase in active plants and in population served, then, was concentrated in the larger communities; and, in terms of the national economy, incremental unit costs were sharply reduced by the consequent assertion of economies of scale. Summation of the negative value represented by operating costs of primary plants taken out of service or upgraded to secondary treatment with the operating charges for the increment of seven million persons served by added primary treatment plants indicates that the addition to primary treatment capacity was brought on-stream

TABLE 24

PATTERNS OF PROCESS CHANGE IN
WASTE TREATMENT, 1957-1962

Size of Place	CHANGE IN NUMBERS OF PLANTS					Percent Change	
	Activated Sludge	Lagoons	Other 1/ Secondary	Primary	Total	Primary	Secondary
Under 500	20	233	2	-22	233	-7.0	52.0
500-999	9	178	21	-119	89	-21.7	27.2
1000-4999	23	396	141	-90	470	-6.9	26.3
5000-9999	31	43	162	23	259	9.5	39.5
10,000-24,999	28	45	224	58	355	37.1	71.9
25,000-49,999	28	10	93	40	171	56.3	119.0
50,000-100,000	15	9	30	21	75	84.0	87.0
Over 100,000	57	4	135	31	227	50.0	230.5
TOTAL	211	918	808	-58	1879	-2.2	41.6
Percent of New Plants	11.2	48.8	43.0	-3.0			
Percent of 1957 Plants	7.9	5.8	49.3	37.0			
Percent of 1962 Plants	8.6	14.5	48.1	28.8			

1/ Includes extended aeration.

at a net per-capita operating cost of about $0.63 (1957-59 dollars).

It is precisely that low cost of incremental primary treatment that is mathematically responsible for holding the average operating cost level for the nation as a whole.

But if assertion of economies of scale in addition to primary waste treatment capacity are mathematically responsible for controlling unit costs, such control was only possible as a result of a change in acceptance of lagooning as an acceptable means of waste treatment. Almost half of the new plants coming into use during the period were lagoons; and these were concentrated in those population size categories that exhibited a net decline in number of primary treatment plants in operation. Availability of the efficient, low cost process encouraged small communities to adopt it. The effect on the cost structure was doubly beneficial. In the aggregate, lagoons were brought on-stream with their characteristically low unit operating cost; and small, expensive primary treatment plants were taken out of operation.

Increased prevalence of lagooning also exerted a moderating influence on the average cost of secondary waste treatment. Even more than economies of scale, the influence of lagoons on incremental operating costs was responsible for the fact that new secondary treatment plants, as a group, were brought into operation at an average operating cost of about $1.43 per capita.

All of the influences of process-selection, however, were not on the cost-reducing side of the ledger. Need, anticipation of need, or desire for more complete treatment led a growing number of communities to install activated sludge plants, the most efficient but the most costly to operate of the secondary treatment processes. Eleven percent of the net change in plants in service was provided through use of the activated sludge process, compared to its relative presence of only eight percent in 1957.

The way in which economies of scale, which were so largely responsible for controlling the rise of operating costs, were derived is significant. Scale economies were made available in large measure because of the composition of the total system of communities requiring waste treatment. They occurred because there was a distinct need in communities of every size.

Because of the availability of a large untreated component in every size category of community, the average population served by a waste treatment plant increased about 10% as a result of new plant construction between 1957-62. But within most population categories, the average size of the population served by waste treatment declined.

The average size of the added plant brought into service between 1957 and 1962 was greater than the average size of plant in place in 1957, then, only because of the availability of treatment requirements in cities at the higher end of the population size scale. The presence of a waste treatment plant seems to correlate with the size of a place: the larger the community, both absolutely and within each of the general population categories, the greater the likelihood that it provides waste treatment. Chance--more precisely, expression of the probabilities determined by the combination of community size and prevalence of waste treatment in 1957--rather than planning was largely responsible for controlling the overall rise of operating costs between 1957 and 1962.

It must be noted, too, that information on the efficiency of plant operation was not available for these analyses and, as previously stated, efficiency of removal has an effect on operating costs. The extent to which higher operating efficiencies might have increased calculated costs over the period cannot be ascertained with currently available data.

TOWARD THE DEFINITION OF AN APPROPRIATE RATE OF INVESTMENT

If the point of this report has been adequately expressed, it is recognized that no lump sum dollar value estimate can properly assess the ultimate dimensions of municipal waste treatment needs. The problem, then, is to determine a level of investment that will allow the nation to sustain and to extend its control over the municipal discharge of wastes over the next five years.

It should be clear that no completely comprehensive estimate of that rate of investment is possible. Within what time frame does the nation wish to establish what degree of waste reduction? What program priorities will be adopted at the national level and by the individual states? What technological improvements are in the offing? What social and productive mechanisms will act upon waste treatment requirements? Questions of this nature must be answered before any thoughtful analyst will hazard an opinion on the appropriate rate of investment for the next five years.

Even if we recognize the foolishness of attempting final answers about any aspect of the human condition, however, we can narrow the range of doubt that surrounds the question under consideration. By making certain limited assumptions, we can postulate that the existing level of investment for waste handling facilities is or is not consistent with definite program or policy goals, and whether it appears to be beneficial to extend or contract proposed times of accomplishment, to increase, decrease, or maintain the existing level of investment. The purpose of this section of this report is to compare indicated near term investment levels with those determined to be compatible with three basic assumptions of national water pollution control policy:

1) all sewered municipal wastes should receive the best practicable treatment before their discharge to a waterbody;

2) in most cases, secondary waste treatment meets the definition of best practicable treatment; and

3) the indicated degree of treatment is closely associated with the general national goal of meeting water quality standards by 1973.

THE CURRENT SITUATION

The general outline of the municipal waste treatment situation as it exists today is summarized in Table 25. There are in the U.S. more than 11,000 sewered communities. These include a population of about 131 million persons. About 14% of the sewered communities and eight percent of the sewered population are without waste treatment services. Nineteen percent of the communities and a third of the sewered population are served by primary or intermediate waste treatment. A majority of both sewered places and sewered population receives waste treatment services scaled at the secondary level.

Prevalence of waste treatment increased markedly over the last six years. More than 17 million persons were added to the inventory of those receiving waste treatment, 12 million through additions to the sewered population - additions that took the forms of both extension of sewer service and of net population growth in areas already provided with sewers - and five million through initial installation of treatment services in previously sewered places. (These are net figures. Within each category of sewerage service there were plus and minus components that resolve to the approximate quantities indicated. Several millions of persons who received primary treatment in 1962 had their service upgraded to secondary treatment, for example, but enough primary treatment additions were accomplished to both compensate for those moving out of the category as a result of upgrading and to provide an additional measure of increase.)

Occurrence of major changes in the level of municipal waste treatment between 1962 and 1968 is summarized by size of place and categories of waste handling service in Table 26. It should be noted that both Tables 25 and 26 present an inadequate sketch of 1968 conditions, in that they include 1962 rather than 1968 conditions for the States of New York, New Jersey, Pennsylvania, Iowa, and Arkansas. Those five States provided about 20% of all municipal capital expenditures for waste handling improvements between 1962 and 1968, but their current waste inventories were processed too late to assess the resulting level of improvement. While it is unlikely that national accomplishments were 20% greater than indicated by Table 26 -- the effectiveness of investment in the group of states surrounding New York, New Jersey, and Pennsylvania is half or less than the median for the nation -- there is no question that the two tables reflected current conditions in the five missing States, a brighter picture would emerge.

TABLE 25

1968 MUNICIPAL WASTE INVENTORY 1/

Size of Place	P R I M A R Y Treatment			S E C O N D A R Y Treatment			N O T R E A T M E N T	
1960 Census	Total Plants	Communities Identifiable	Population Served	Total Plants	Communities Identifiable	Population Served	Communi-ties	Population Served
Unknown	112	65	6,284,805	643	302	8,049,603	15	271,725
Under 500	261	239	587,361	1,231	1,117	1,820,942	252	79,640
500-1000	355	338	249,101	1,422	1,334	1,322,214	333	228,444
1000-2500	623	550	980,302	2,160	1,945	3,422,129	491	685,556
2500-5000	368	318	1,110,813	1,329	1,103	4,325,341	215	704,898
5000--10,000	279	239	2,532,269	961	781	5,763,512	143	1,649,878
10,000- 25,000	242	211	3,453,900	771	519	8,875,655	82	1,354,855
25,000-50,000	106	83	3,063,100	258	166	6,588,635	25	839,075
50,000-100,000	48	41	3,374,220	158	74	6,192,422	14	1,071,710
100,000-250,000	35	18	3,419,215	97	39	6,604,168	8	1,224,070
250,000-500,000	17	9	3,307,525	76	10	4,200,285	2	858,905
Over -500,000	22	6	15,372,410	77	9	18,620,880	2	2,305,900
TOTALS	2,468	2,117	43,735,021	9,183	7,399	75,785,786	1,582	11,274,656

1/ Includes 1962 rather than 1968 conditions for the states of New York, New Jersey, Pennsylvania, Iowa and Arkansas.

TABLE 26

INCREASED OR (DECREASE) IN MUNICIPAL WASTE TREATMENT
1962-1968[1]/

Size of Place	TYPE OF TREATMENT FACILITY Primary	Secondary	Untreated	INDICATED POPULATION SERVED Primary	Secondary	Untreated
Unknown	22	370	(12)	860,475	2,933,278	(773,340)
Under 500	(26)	521	45	(538,755)	1,606,031	13,312
500-1000	(67)	464	(71)	(26,038)	520,763	(51,487)
1000-2500	(175)	557	(220)	(119,810)	946,035	(297,935)
2500-5000	(54)	271	(106)	(15,050)	1,032,670	(300,305)
5000-10000	9	142	(65)	1,084,138	940,406	378,005
10000-25000	15	94	(38)	242,703	1,419,079	(495,180)
25000-50000	(8)	46	(12)	(537,729)	863,165	(243,050)
50000-100000	(3)	59	(9)	580,040	1,683,842	(574,400)
100000-250000	(6)	37	(6)	(337,094)	1,760,063	(562,070)
250000-500000		18	(2)	263,550	(71,345)	(548,000)
Over - 500000	(5)	(33)	(1)	1,643,770	275,340	(1,504,800)
TOTAL	(298)	2548	(497)	3,106,930	14,305,540	(4,959,250)
1962-68 change as a percent of the 1962 condition	(10.7)	38.4	(23.9)	7.6	23.2	(30.5)

1/ Excludes changes that took place in New York, New Jersey, Pennsylvania, Iowa, and Arkansas.

PREVALENCE OF WASTE TREATMENT IN EACH STATE, 1968

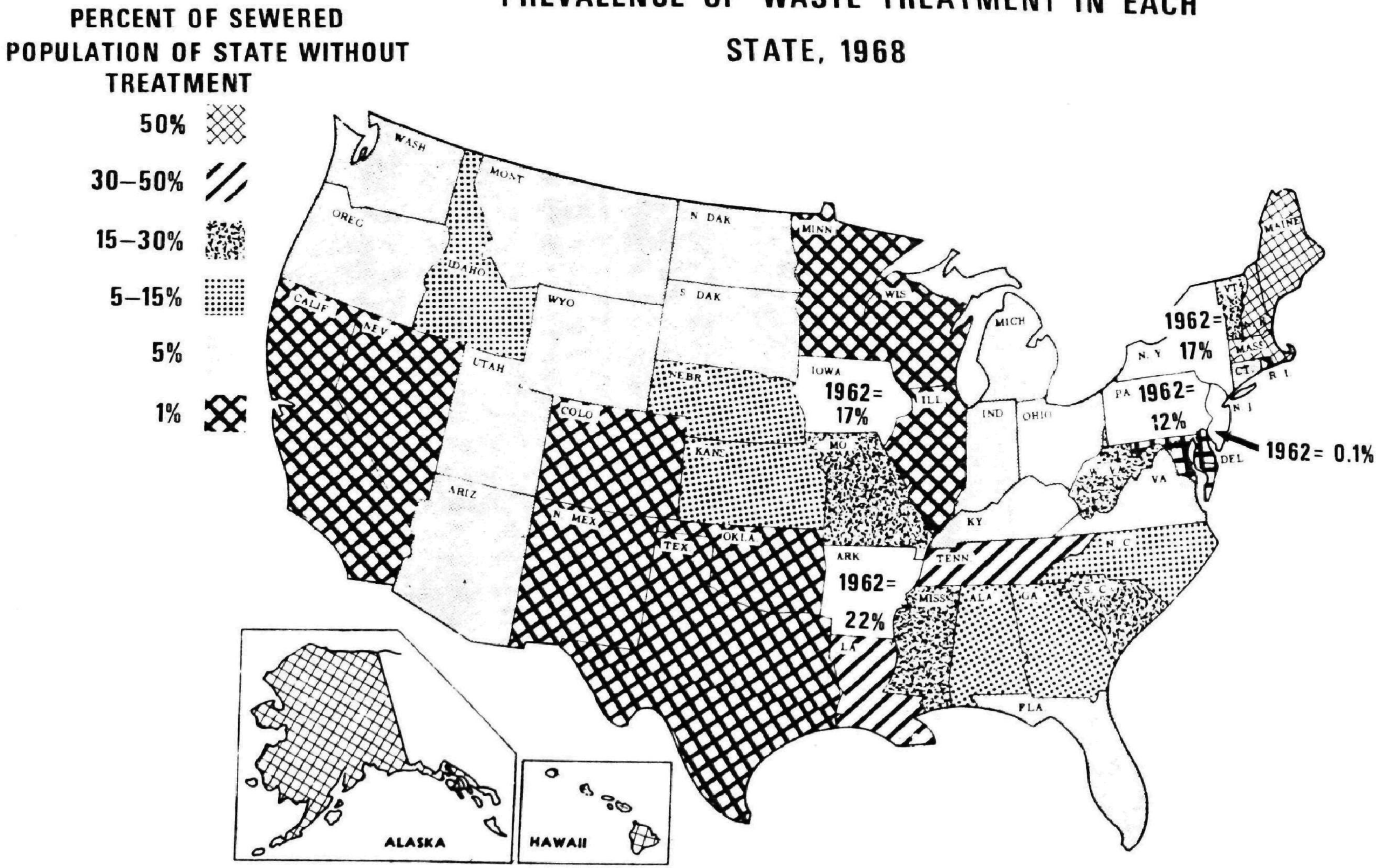

Figure 12

Consideration of the national situation is somewhat deceiving. Those cases in which sewered wastes are untreated are localized to an extraordinary degree. Over 95% of the sewered population of the coterminous States west of the Mississippi is connected to waste treatment plants. The six New England States, which contain less than six percent of the nation's population, account for 23% of its sewered population without waste treatment. And if the untreated components of the New York and Pennsylvania sewered population, as constituted in 1962, are added to New England's the eight northeastern states are found to contain almost 55% of the sewered but untreated population of the nation.

A secondary focus of abatement requirements may be found in the bloc of southeastern States. From North Carolina to (but not including) Florida on the south, and from the Atlantic seaboard through Louisiana, perhaps up into Arkansas and certainly up into Missouri, the prevalence of waste treatment is distinctly below that of the western and Great Lakes States. This area has been reducing its deficiencies at a much more pronounced pace than has the Northeast, however. And with the construction of waste treatment plants to serve the New Orleans and Memphis metropolitan areas, the untreated population of the southeast would recede to a very small number.

As one might anticipate, the general outlines of the regional pattern of prevalence of treatment extend to the distribution of secondary waste treatment among the States. There are significant differences, however, but some of these differences are a function of regulatory requirements and hydrology as well as accomplishments. The arid Southwestern States still lead the nation, but States around the Great Lakes compare much better than the Pacific Coast States with respect to this measure of intensity of municipal pollution control effort. Abundant water for dilution and assimilation of wastes has made primary treatment more acceptable on both coasts and along some major waterways--the Mississippi, the Ohio, the Tennessee, the Columbia, the Missouri--than in the drier interior regions of the nation. With respect to secondary treatment, too, New England trails far behind the rest of the nation; and Alaska and Hawaii have a low incidence in relation to their population.

STATES' VIEWS OF THEIR NEEDS

Existence of widely varying conditions from State to State -- arising from regional geography and hydrology, level of attainment of treatment, nature of industrial specialization, political configurations, engineering practices--has, as one would expect, a major influence on each State's view of its needs, as views have been formulated by appropriate public agencies. Certainly the local differences in attitude and practice of pollution control are critical in attempting an assessment of rate of investment, for it is State pollution control policy and authority that is the primary instrument for translating an abstract concept of needs into an investment program.

There are two sources, each unfortunately incomplete, of State estimates of pollution control needs. The water quality standards of 36 of the 50 States contained partially time-phased lists of needed treatment works specific enough to be utilized for this report. These have been compiled, by category of improvement and by size of place, and are presented in Table 27.

As a source of estimate for anticipated investment requirements, the water quality standards were not sufficiently specific in data. No compilation of needed municipal works could be arranged for 28% of the States. The lists were compiled rapidly under the extreme pressures involved in the preparation of water quality standards in a short period of time. Some States included works required only for interstate waters, others included needed improvements for both interstate and intrastate situations. There was no common method or common terminology employed in assembling the lists. In most cases, the State provided only a list of untreated places and indicated a need for a treatment plant without specifying what ancillary works would have to be installed in connection with the proposed treatment plant. (Almost the total list of needs in the outfall category, for example, was composed of notations in the standards submitted by the State of Washington). Few States indicated existence of improvement or replacement requirements. In many instances, lists included projects under construction. For all of these reasons, no effort was made to provide a dollar value assessment of the implementation plans on a State-by-State basis. It was felt that the implementation plans submitted in connection with the standards were not suitable for this purpose. (A table similar to Table 27 is presented for each of the 36 States in Volume II of this report).

A crude dollar value assessment of the compendium of water quality standards relating to municipal waste treatment is presented in Table 28. The evaluation rests on the assumption that

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PREVALENCE OF SECONDARY TREATMENT AMONG THE STATES,1968

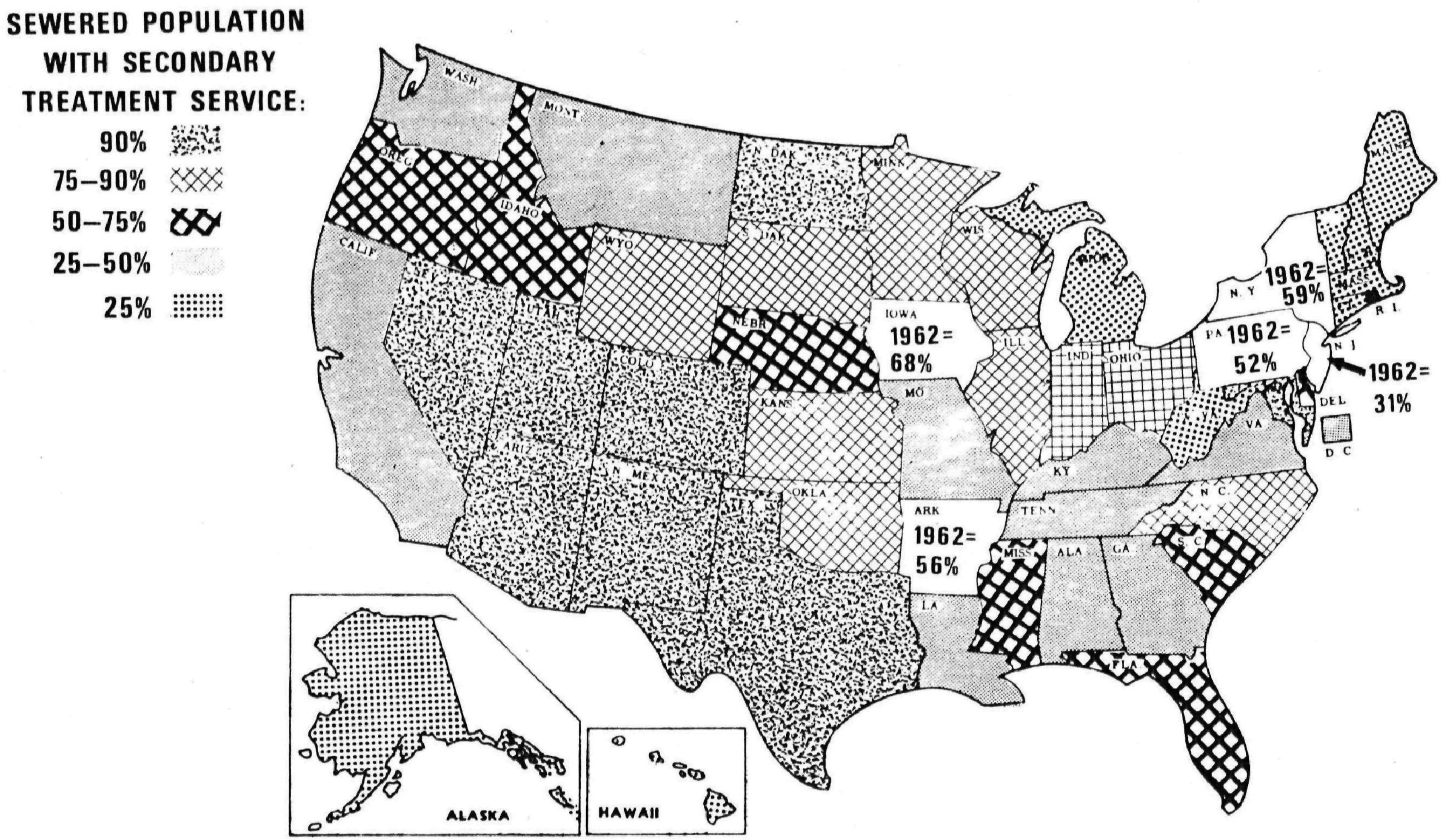

Figure 13

TABLE 27

Construction Requirements Defined in
State Water Quality Standards:
Total Projects, 36 States

SIZE OF PLACE	NEW PLANT		EXPANSION/UPGRADING/REPLACEMENT			INTERCEPTORS	ANCILLARY IMPROVEMENTS				TERTIARY TREATMENT		NUMBER OF
	Primary	Secondary	Prim. to Sec.	Primary	Secondary		Disinfection	Outfall	Interception	Plant	Phos. Reduction	Other	COMMUNITIES
Unknown	12	203	15	5	25	28	63	13	8	7	5	3	300
< 500		109	31	9	30	10	28	9	3	1			204
500–1000	12	96	56	5	48	8	66	8		3	1	4	265
1000–2500	7	142	92	9	87	15	129	7	3	9	4	4	441
2500–5000	5	55	53	4	47	18	65	18	2	8	5	18	246
5000–10000	6	44	42	3	51	13	63	8	5	3	1	15	221
10000–25000	4	41	56	8	43	13	62	7	2	6	1	9	205
25000–50000	3	9	22	3	25	8	25	4	8	4		3	80
50000–100000	2	7	8	1	10	5	9	4	1	3	2	1	36
100000–250000	1	5	9		4	5	12			2		4	22
250000–500000	1		3		2	3	6	2				1	8
> 500000	1	4	6		4	6	7						13
Total	54	715	393	47	376	132	535	80	32	46	19	62	2041
INDICATED COMPLETION DATE													TOTAL PROJECTS SCHEDULED PER YEAR
1968													294
1969													283
1970													315
1971													168
1972													386
1973 or later													312
Date not given													756
Total Projects													2514

listed improvements are distributed in such fashion that their average value is similar to that of the same classes of projects undertaken during the last three years. Multiplication of the number of projects of a given description by a value equal to the average amount of contracts for that kind of project, with the product raised by a factor that allows the average cost of projects undertaken between 1965 and 1967 to be expressed in 1968 dollar equivalents, provides an estimate of the assessed cost of listed requirements. On the assumption that requirements are distributed according to population between States whose implementation needs were supplied and those whose needs were not supplied, the $897 million list of needs is extrapolated to $1.1 billion for all States. The amount is far too low to be creditable, at least as it compares with either the recent history of investment or with other estimates of need.

TABLE 28

GENERALIZED EVALUATION OF
WATER QUALITY STANDARDS-DEFINED
POLLUTION CONTROL NEEDS

Category of Need	No. of Projects	Avge. Cost Per Project, 1965-67	Price Level Adjustment	Indicated Cost ($ Millions)
New Plants	769	325,000	1.034	258.4
Replacement & Addition	1429	364,000	1.034	537.8
Interception	132	374,000	1.034	51.0
Tertiary Treatment	81	364,000	1.034	30.5
Outfalls	80	235,000	1.034	19.4
Total, 36 States	2514			897.1
Indicated (on basis of population) for 50 States				1121.4

A far more comprehensive estimate of needs has been provided by most States in connection with applications for Federal program grants. Though less than complete, and lacking

NUMBER OF NEW TREATMENT PLANTS REQUIRED IN EACH STATE'S WATER QUALITY STANDARDS

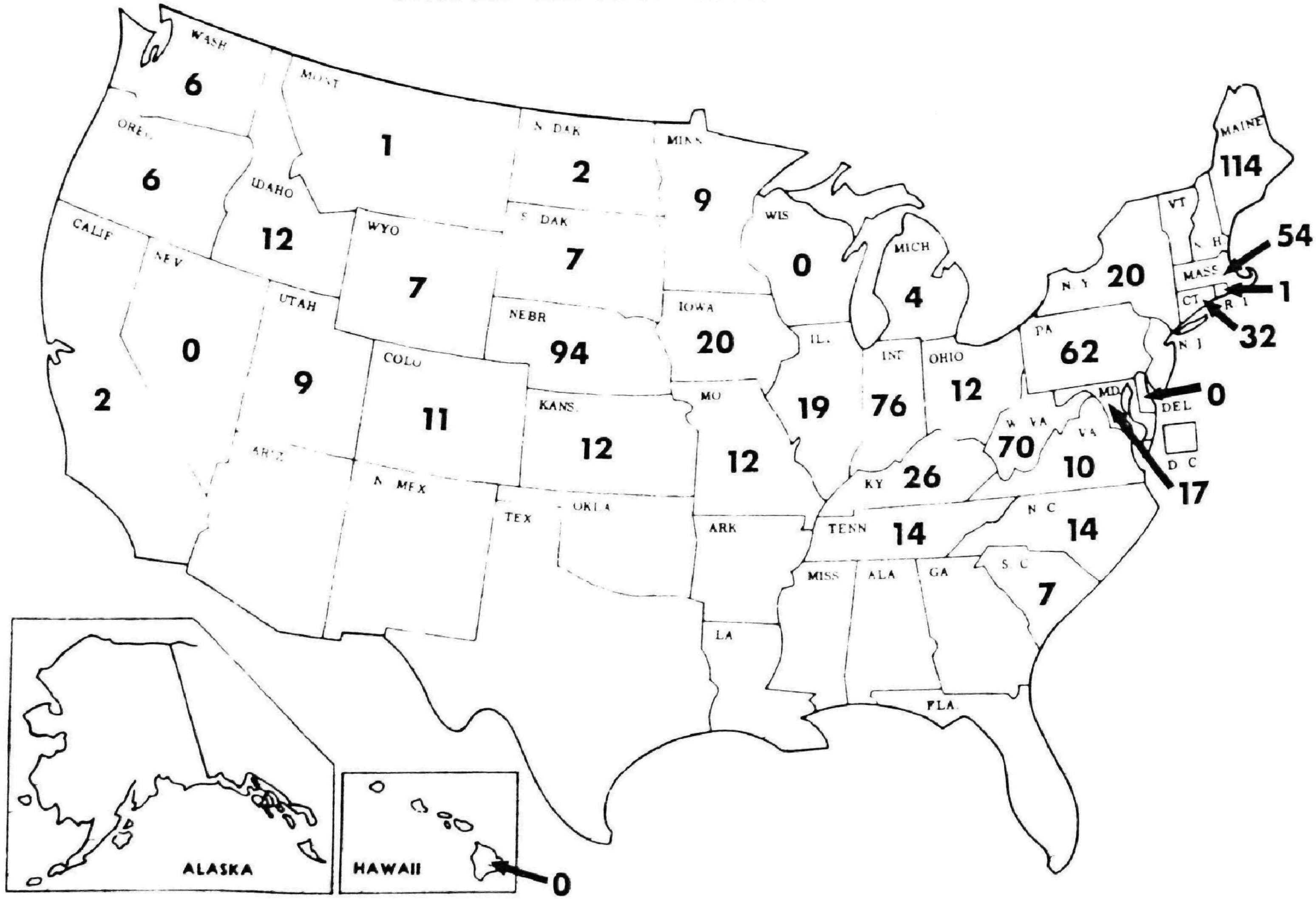

Figure 14

either a common method or common definitions, these estimates have the great merit of being evaluated in dollar terms by the States themselves, and of being related to real program possibilities. They are, in short, more or less complete assessments of the estimated costs associated with achieving definite series of program goals. They reflect, then, local estimates of the possible and the local sense of real world priorities.

When arrayed State by State against the estimates of municipal needs provided by FWPCA in its 1968 report, The Cost of Clean Water, as is done in Table 29, the two sets of values are seen to have a rough correspondence. The over-all similarity should not be belabored. It arises out of the major factor that shapes the relative dimensions of needs, the national distribution of population. Internal differences are much greater than simple numerical comparison would indicate.

Where the FWPCA estimate is a mathematical estimate based on the assumption of secondary treatment for most of the urban population of the U.S., the State estimates are pragmatic evaluations of program consequences. The FWPCA estimate assumes an additional $1.2 billion dollar per year investment in collecting sewers--and that level of sewering is critical to the $8 billion treatment plant requirement, because without an accelerated program of sewering, there would be no need for a good part of the proposed treatment plants. The State estimates in many cases include a component of sewer project costs. They also include a good number of miscellaneous system rehabilitation needs that could scarcely be accommodated by the FWPCA method.

It should be recognized that there are great weaknesses of estimate inherent in the States' assessments of needs. Lack of values for every State is a glaring deficiency, of course, as is the absence of a consistent rationale. It should be emphasized, too, that there are great differences in capability among States. Some staffs are sufficiently sized, trained, and experienced to be able to pinpoint the sets of local needs that go into such an estimate with great accuracy, and to evaluate with some precision their dollar value equivalents. Others are less capable, by reason of manpower deficiencies or program emphasis, in this regard. Cost estimates are in some cases deficient, particularly when many State definitions of need incorporate a major institutional constraint. Willingness to proceed with an indicated project is more apt in many cases to get that project identified than is a real physical requirement. Depending on the authority of any State to implement its program, the readiness of communities to meet their pollution

COMPARISON OF 1968 FWPCA ESTIMATE AND 1969 STATE PROGRAM PLANS ESTIMATE OF NEEDS

TOTALS	FWPCA 1968 Estimate	State Program Plans	
		Cost Estimate ($ Millions)	No. of Projects
Alabama	$131.0	$7.1[1]	15
Alaska	12.8	not available	--
Arizona	84.0	no estimate	104
Arkansas	45.5	17.3	85
California	645.2	530.0	188
Colorado	97.6	30.8	56
Connecticut	175.8	179.3	75
Delaware	30.1	46.4	36
District of Columbia	21.4	not available	--
Florida	347.0	174.5	89
Georgia	209.6	105.3	105
Hawaii	35.5	34.6	28
Idaho	23.0	2.1[2]	30
Illinois	367.0	313.4	530
Indiana	162.1	87.2[1]	94
Iowa	34.7	not available	--
Kansas	49.6	20.5	99
Kentucky	120.8	51.3	74
Louisiana	182.1	37.2	48
Maine	43.9	148.8	89
Maryland	128.4	151.0	116
Massachusetts	186.3	52.1[1][4]	96
Michigan	535.8	210.1	183
Minnesota	172.4	67.9	284
Mississippi	54.1	50.4	157
Missouri	126.8	35.2	61
Montana	25.5	11.1	26
Nebraska	29.0	4.4	71
Nevada	18.1	21.9	34
New Hampshire	32.6	59.2[4]	26
New Jersey	505.0	800.0[3]	n.a.

TABLE 29 (Cont'd)

COMPARISON OF 1968 FWPCA ESTIMATE AND 1969 STATE PROGRAM PLANS ESTIMATE OF NEEDS

TOTALS	FWPCA 1968	State Program Plans Cost Extimate	State Program Plans No. of Projects
New Mexico	37.6	not available	--
New York	963.6	1,414.7[4]	415
North Carolina	95.6	36.1[1]	26
North Dakota	11.3	1.6[1]	19
Ohio	461.7	262.2	181
Oklahoma	57.4	99.8	181
Oregon	130.2	37.2[1]	44
Pennsylvania	310.9	454.2	698
Rhode Island	38.3	47.9	21
South Carolina	93.9	not available	--
South Dakota	12.5	9.9[1]	69
Tennessee	147.8	25.0[1]	24
Texas	323.6	159.7	203
Utah	127.4	10.6[1]	45
Vermont	17.7	34.9[1]	62
Virginia	194.7	74.5[1]	75
Washington	155.3	13.1[1]	23
West Virginia	50.4	42.3	79
Wisconsin	122.4	not available	--
Wyoming	9.0	1.2	43
Guam	no estimate	7.6	11
Puerto Rico	no estimate	not available	--
Virgin Islands	no estimate	not available	--
TOTALS	$7,994.0	$5,181.6	5,018

1/ State Program Plan does not distinguish between one-year and five-year needs.
2/ Estimate Covers Only 8 Projects.
3/ Estimate provided by FWPCA Northeast Regional Office
4/ Other estimates provided by the Northeast Region Office indicate substantial differences from State Program Plans. These estimates are: Massachusetts, $400 million; New Hampshire, $120 million; New York, $2,065 million. The differences, however, cannot be explained as the underlying assumptions for the estimates are not explicitly stated.

control obligations is always critical to such assessments. (One State representative phrased it that, "Some of these are what we can get; but some we really need. They've been gleams in the district engineers' eyes for years, but we don't know when we'll ever get them.") Thus, in a major sense, these estimates represent expectations concerning levels of capital expenditure over the next five years rather than expressions of need for treatment facilities to meet stated goals.7/ The difficulty of comparing these estimates of expenditures with the accomplishment of the three national goals stated above is further complicated by the fact that there is not a total correlation between the programs proposed for these expenditures and the program necessary to meet national goals. For example, the expenditures estimates include such items as storm-water control projects, collection sewers, and plant capacity for industrial wastes which were not incorporated in the municipal waste control cost estimates made by FWPCA, these items being estimated as separate elements. The extent to which such items are included in the State estimates is not fully known.

Having expressed the obvious reservations about the State plans, it is necessary to point out that the assemblage of individual plans unquestionably constitutes the soundest basis yet achieved for estimating anticipated capital expenditures. Uneven though it may be, it has the virtues of specificity, local information, and recognition of the possible. It is flawed by neither an excessive artificiality nor by a lack of recognition of the dynamics of water pollution control, since the States which submitted program plans demonstrated an almost unanimous awareness that they were time-conditional and in no sense an ultimate expression of objectives.

A surprising feature of the State program plans is their general repetition of the recent pattern of investment. A majority of States see a need to invest just about as much in the next five years as in the last six years--and often without respect to the apparent accomplishments of the last five years. Some of the more successful States indicate an easing of near term investment requirements, but others appear to view maintenance and upgrading requirements as being very significant forces. For example, Delaware, with some form of waste treatment for all of its sewered population accomplished, sees a

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7/ It seems clear that these expenditure expectations are conditioned by expectations concerning the level of Federal grant support. It appears, too, that the expected levels of other sources of funds are implicit in these estimates, since the level of expenditure expectations tends to fluctuate with the fate of proposed bond issues.

need to invest more than three times as much in the next five years as in the last six; Colorado, with almost complete secondary treatment, sees little relief from investment pressures; and the same situation holds for Nevada, Utah, and Texas. The States of the Northeast are apparently well aware of their situation in municipal waste treatment-without exception they have proposed expansion of investment programs. Other relatively deficient States--Hawaii, Louisiana, Alabama among them--either propose no increase, or actually forsee a decrease in investment intensity. Table 30 provides the State-by-State comparison in a summary of the salient elements of State municipal pollution control programs.

REGIONAL COST DIFFERENCES

One of the elements that State cost estimates do not adequately reflect is the enormous disparity among States in the effectiveness of an investment dollar. All communities do not receive the same benefit from their investments in terms of unit cost even for comparable types and sizes of plant. To some extent, it is only natural and expectable that there be great variation from State to State in average return on investment: average size of place, degree of treatment, interception costs, industrial load component, added capacity factor, design and equipment standards all vary from State to State and all of these affect cost.

But the degree to which variation manifests itself appears to exceed the relative weight of any of these factors; and even possible record-keeping discrepancies seem unlikely to account for the apparent differences in what the inhabitants of one State pay for waste treatment as opposed to the costs borne by residents of another State.

Potential explanatory factors for apparent differences observed from aggregate data, aside from construction cost differences, include the following:

1) States installing a preponderance of secondary treatment plants would in the aggregate show a lower cost per pound of BOD removed than States in which a significant amount of primary treatment was installed, since the former is more cost-effective in this measure than the latter.

2) States that did not estimate growth of population served over the period 1962-67 would tend to show higher per capita costs in terms of aggregate data.

TABLE 30

SUMMARY OF MUNICIPAL POLLUTION CONTROL
PROGRAM STATUS, BY STATE

	Increase (Decrease) in Service, 1962-68			Treatment Status, 1968			Investment, 1962-67		For comparison
	Pop. served by secondary treatment	Pop. served by primary treatment	Sewered Pop. without treatment	Secondary Treatment % of sewered pop.	Primary treatment % of sewered pop.	Untreated pop. % of sewered pop.	TOTAL ($Millions)	Excluding Collecting sewers	State estimated needs 1/ ($ Millions)
TOTALS	14,305,540	3,106,930	(4,959,250)	57.9	33.4	8.7	5198.4	3091.3	5981.6
North East									
Connecticut	115,567	(27,348)	(30,720)	22.2	75.9	1.9	128.4	58.9	179.3
Delaware	367,374	(18,582)	(4,263)	60.6	39.4	.0	14.0	10.8	46.4
Maine	19,250	83,260	(39,448)	6.3	20.6	73.1	22.3	18.1	148.8
Massachusetts	14,699	98,135	21,665	14.7	34.6	50.7	124.5	68.7	52.1
New Hampshire	19,640	57,950	(52,700)	10.1	34.3	55.6	20.4	17.5	59.2
New Jersey							222.2	109.8	800.0
New York							389.3	236.5	1,414.7
Rhode Island	13,970	(1,850)	(130)	66.9	32.3	0.8	28.9	17.8	47.9
Vermont	6,900	81,078	(63,565)	7.3	70.0	22.7	21.0	18.9	34.9
Middle Atlantic									
Maryland/D.C.	584,695	23,375	(31,140)	94.3	5.5	0.2	148.7	103.7	151.0
North Carolina	565,846	(28,795)	(318,298)	86.3	6.9	6.8	121.0	92.9	36.1
Pennsylvania							345.2	162.0	454.2
South Carolina	145,564	(82,927)	(60,507)	60.2	11.8	28.0	45.3	32.8	N.A.
Virginia	158,514	(23,542)	(250,231)	40.4	58.5	1.1	114.7	73.6	74.5
Southeast									
Alabama	391,287	268,375	27,045	41.7	44.9	13.4	73.2	46.0	7.1
Florida	661,932	(185,445)	(26,385)	69.6	26.3	4.1	149.2	62.5	174.5
Georgia	371,348	58,830	(347,252)	49.6	42.0	8.4	76.8	56.7	105.3
Mississippi	356,451	(15,150)	(131,160)	67.7	2.5	29.8	34.1	31.3	50.4
Tennessee	133,483	38,886	1,669	43.2	21.5	35.5	125.5	57.4	25.0

TABLE 30 (Cont'd)

SUMMARY OF MUNICIPAL POLLUTION CONTROL
PROGRAM STATUS, BY STATE

	Increase (Decrease) in Service, 1962-68			Treatment Status, 1968			Investment, 1962-67		For comparison
	Pop. served by secondary treatment	Pop. served by primary treatment	Sewered Pop. without treatment	Secondary Treatment % of sewered pop.	Primary treatment % of sewered pop.	Untreated pop. % of sewered pop.	TOTAL ($Millions)	Excluding Collecting sewere	State estimated needs 1/ ($ Millions)
Ohio Basin									
Indiana	319,550	4,180	(6,815)	80.9	15.3	3.8	166.0	108.8	87.2
Kentucky	202,272	(6,185)	(85,160)	42.1	56.4	1.5	79.2	39.0	51.3
Ohio	724,815	(477,155)	(245,045)	75.2	23.1	1.7	273.5	143.7	262.2
West Virginia	58,403	284,590	(264,378)	18.7	60.4	20.9	40.9	31.8	42.3
Great Lakes									
Illinois	275,506	431,676	(207,445)	88.5	11.1	0.4	291.2	197.3	313.4
Iowa							69.7	44.6	N.A.
Michigan	432,105	59,995	62,195	24.1	74.0	1.9	240.2	113.2	210.1
Minnesota	1,178,655	(1,036,755)	(47,590)	86.2	12.9	0.9	112.9	60.9	67.9
Wisconsin	483,824	(284,105)	(5,220)	84.4	15.3	0.3	180.3	140.3	N.A.
Missouri Basin									
Colorado	912,775	(576,465)	(14,075)	97.9	1.4	0.7	47.9	40.0	30.8
Kansas	259,155	97,575	70,740	75.3	12.7	12.0	64.9	32.3	20.5
Missouri	239,520	721,260	(1,348,790)	47.2	36.3	16.5	158.3	120.9	35.2
Nebraska	110,770	208,800	(270,730)	58.5	35.8	5.7	45.5	28.8	4.4
North Dakota	135,933	(41,315)	(42,725)	94.3	3.5	2.2	8.2	4.8	1.6
South Dakota	26,485	13,060	(31,060)	85.7	10.4	3.9	12.5	10.3	9.9
Wyoming	43,075	(9,800)	(3,000)	76.6	20.8	2.6	1.6	1.3	1.2
South Central									
Arkansas							50.4	43.0	17.3
Louisiana	362,572	158,380	(340,720)	42.8	16.2	41.0	103.4	63.5	37.2
New Mexico	77,845	(3,596)	(1,100)	99.8	0.2	0.0	23.1	21.1	N.A.
Oklahoma	209,039	10,225	(4,960)	87.8	11.8	0.4	39.5	26.6	99.8
Texas	958,838	(50,545)	(34,995)	98.1	1.8	0.1	185.8	102.6	159.7

TABLE 30 (Cont'd)

SUMMARY OF MUNICIPAL POLLUTION CONTROL
PROGRAM STATUS, BY STATE

	Increase (Decrease) in Service, 1962-68			Treatment Status, 1968			Investment, 1962-67		For comparison State estimated needs 1/
	Pop. served by secondary treatment	Pop. served by primary treatment	Sewered Pop. without treatment	Secondary Treatment % of sewered pop.	Primary treatment % of sewered pop.	Untreated pop. % of sewered pop.	TOTAL ($Millions)	Excluding Collecting sewers	($ Millions)
South West									
Arizona	31,995	(26,624)	(4,750)	95.8	1.2	3.0	48.5	30.5	N.A.
California	1,816,747	2,548,436	(40,995)	32.7	67.0	0.3	398.9	213.1	530.0
Hawaii	11,125	10,220	73,625	7.9	9.8	82.3	35.6	31.9	34.6
Nevada	414,580	(3,790)	(5,125)	99.1	0.7	0.2	22.1	22.1	21.9
Utah	287,210	4,525	(212,700)	94.4	3.2	2.4	19.6	16.0	10.6
Northwest									
Alaska		2,860	(2,860)		20.8	79.2	8.1	1.9	N.A.
Idaho	75,671	3,620	(23,420)	53.8	40.8	5.4	9.7	6.2	2.1
Montana	41,760	(28,200)	(3,100)	38.0	60.6	1.4	11.2	6.9	11.1
Oregon	330,720	(101,498)	(23,290)	53.1	43.5	3.4	59.7	30.8	37.2
Washington	238,384	460,277	(467,330)	33.7	62.3	4.0	172.7	116.3	13.1

1/ Municipal Listing

3) States in which a significant amount of capacity came on stream to treat wastes of industrial origin would indicate artificially high costs on the basis of population or estimated loadings based on population.

After extensive investigation of aggregate data, it was concluded that the information content of such data was inadequate to explain the factors at work in causing regional differences in cost. Therefore, acquisition and analysis of microeconomic data will be initiated to better come to grips with the problems and causal relationships involved in such differences for incorporation into a more detailed analytical model which will provide better estimates of cost on a finer geographical basis than is currently possible.

THE DEVELOPING INVESTMENT GAP

The investment outlook through 1973 is set within a fairly fixed range of conditions that may be summarized from the preceding discussions.

1) The States, as a group, anticipate programs that will involve a level of spending very close to that of the last six years. They expect investments of about $6 billion dollars from 1969 through 1973, judging by the $5.1 billion program estimate set by 40 of the 50 States.

2) New plant needs are concentrated in the eight northeastern States, Alaska and Hawaii which show a low percentage of treatment relative to their population. The northeastern group of States envisage a decided uptrend in their level of expenditures; but no similar overall increase in spending is contemplated in the programs proposed by most of the other States showing pronounced deficiencies--only Georgia and Mississippi among such states have indicated a substantially augmented program of capital expenditures.

3) In many cases, those States that have some form of treatment for all of their sewered population anticipate a need to invest as much or more in the next five years as in the last six years, the need arising from various replacement, upgrading, expansion, industrial treatment, and new sewer connections.

4) Unit costs are rising, a result not only of inflation, but of underlying changes in waste treatment practice and in the type of communities still available for initial waste treatment investment. Superimposed upon these basic upward pressures on cost is the fact that a very significant portion

of the needed new investment of the nation occurs in precisely those places where cost experience in the past has been highest.

It would appear, then, that there may be a substantial gap opening between the amount the nation expects to spend--as measured by State program plans and by the level of Federal construction grant appropriations--and the amount that will be required to complete the connection of all sewered places to waste treatment plants and to expand, replace, and upgrade treatment where it now exists.

The fact that the States as a group anticipate programs that will involve a level of spending very close to that of the last six years is a cause for major concern, despite the major accomplishments of the last six years. The findings of this report show that investment requirements imposed by new plant construction, expansion, replacement and upgrading of plants, accelerating acceptance of industrial wastes in the municipal plant, increasing levels of waste reduction being required, and the fact that a very significant portion of needed new investment occurs in precisely those places where cost experience in the past has been highest, will all result in pressing capital requirements upward significantly for many years.

Comparison of State expectations of expenditures during the next five years with prior estimates of the costs of meeting national objectives also points to the inadequacies of these existing estimates. This highlights the importance of bringing the concepts explored in this year's report to bear in the future in defining an appropriate rate of investment needed to meet national goals.

In defining such rates of investment, the costs of providing new treatment plants to sewered but untreated areas will be of diminishing significance. Other factors, which to date have not been adequately considered, will be more important determinants of the needed investment rates. These factors will include determination of the rate at which the unsewered population will become connected to sewers, thereby creating an additional need for treatment works. This will require taking into account such factors as population increases in urban fringe areas and the impact of Federal support programs for the construction of collecting sewers. A more realistic consideration of depreciation factors will be necessary to reflect the fact that replacement will become an increasingly important part of national investment patterns. The rate of needed upgrading and expansion of facilities will have to take into account the increasing need for application of technological improvements such as nutrient removal and advanced waste treatment. The rate of acceleration of industrial connection to municipal systems will also have to be further delineated. Regional cost differences--that very important but little understood element in determining national costs--need further exploration.

During the next year we will continue to explore these factors with the objective of determining more accurately the annual normative levels of investment needed to meet national goals. With expiration of the current construction grants authorizations in FY 1971, such information should be of key importance in outlining new legislative needs.

STORM AND COMBINED SEWER POLLUTION CONTROL

About 65% of the nation's population, or 125 million persons, are served by combined or separate sanitary sewer systems. The 1968 report, Volume II, delineated an "order of magnitude" estimate of $49 billion for correcting the combined sewer problems of the nation. The estimate was based on the cost of separating storm and sanitary sewers, a generally accepted estimating base. Consideration of the possibility of utilizing alternative corrective measures indicated that the cost might be reduced to about $15 billion. The application of holding tanks was employed as the cost base for this estimate.

The discussion presented here attempts to summarize briefly the scope of the problem and some of the investigations or additional studies now under way in specific localities. No new estimates are made in this section of the report. However, it is anticipated that the results of the studies and projects now in progress will provide a basis for future refinement of the original projected cost estimates.

The FWPCA has for the past two years been intensively investigating new or improved methods for the control and/or treatment of combined sewer overflows and storm water discharges. There are now about 60 active demonstration grant and contract projects. Preliminary information obtained from these projects indicates that several control and treatment methods are technically feasible.

The principal source of data for this section and last year's discussion of the storm and combined sewer problem was a study prepared for FWPCA by the American Public Works Association.(3) A summary of its findings was recently published. FWPCA conducted this study to provide a current assessment of the magnitude of this problem and an estimate of the costs required to control the resulting pollution.

SCOPE OF PROBLEM

Communities have not generally greatly expanded active efforts to undertake major projects to control combined sewer overflows. The apparent reluctance to attack the problem is largely due to the magnitude of financial resources that would have to be committed to the effort and the lack of technical information to adequately plan alternative projects to complete

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sewer separation. Communities need assurance that a chosen control or treatment method will be effective before they are willing to commit millions of dollars to such construction. Priority of need is also a factor since overflow control must be weighed in terms of need and relative priority against basic wastewater treatment facilities, schools, streets, urban renewal, and other important areas requiring large amounts of municipal expenditures.

Remedial actions have been initiated where the proper stimulus motivated the community. Other metropolitan problem areas associated with or related to combined sewers such as street and basement flooding are typical motivating influences. Replacement of overloaded sewers or construction of relief sewers is the most frequent solution or partial solution to such problems. In the case of urban redevelopment, sewers are usually separated during construction to avoid disruption of services if separation is required at a later date.

Gradual changes in attitude and increasing recognition of the impact of overflows on water quality are occurring resulting, in some cases, in higher priorities for combined sewer remedial projects. This is evidenced by the existence of 24 municipal storm and combined sewer demonstration grant projects involving $45.4 million in construction costs. The local funding of these projects amounted to $29.5 million in October 1968.

The establishment of State water quality standards will have additional impact on the level of effort communities will expend on the problem within the near future. The standards of 30 States, the District of Columbia, and the Virgin Islands recognize that combined sewers constitute a significant pollution source and that control of overflows will be necessary.

In some instances, Federal enforcement conferences have spelled out specific actions. For example: The Conference on Pollution on Lake Michigan, and its tributary Basin (Wisconsin -Illinois-Indiana-Michigan), which concluded on March 12, 1968, resulted in the following recommendations:

1) Adjustable overflow regulating devices are to be installed on existing combined sewer systems, and be so designed and operated as to utilize to the fullest extent possible the capacity of interceptor sewers for conveying combined flow to treatment facilities. The treatment facilities shall be modified where necessary to minimize bypassing. This action is to be taken as soon as possible and not later than December 1970.

2) Effective immediately, combined sewers are to be separated in coordination with all urban reconstruction projects, and prohibited in all new developments, except where other techniques can be applied to control such pollution. Pollution from combined sewers is to be controlled by July 1977.

Overflows from combined sewers cause pollution as measured by oxygen-consuming materials, bacteria, gross solids, esthetic effects, nutrients, and toxic materials. While all water uses are impaired by such discharges, recreational uses are most severely impacted. Swimming, fishing, and other water contact sports are frequently severely affected after storms. Closed beaches frequently result due to bacterial pollution and the discharge of gross solids. Floating materials, greases and scums discharged in the immediate waters and on the shorelines result in undesirable esthetic conditions for non-water contact recreation, such as sunbathing and picnicking. The closing of beaches in the Chicago area for an extended period of time during the 1968 bathing season was attributed to combined sewer overflows.

Actions in Illinois and Pennsylvania are good examples of efforts being made to establish control programs. The Illinois water quality standards, coupled with the aforementioned enforcement conference, has resulted in the formulation of control planning by the Metropolitan Sanitary District of Greater Chicago. Adjustable overflow devices will be installed by December 1970 to utilize the storage capacity of interceptor sewers and a 10-year program is being considered for virtual elimination of overflows by mid-1977 utilizing a deep tunnel storage and treatment system.

The Commonwealth of Pennsylvania has ordered 16 communities to develop applicable solutions for their overflow problems as the first step toward the implementation of a control program. Other States such as Wisconsin and Michigan have issued orders to communities for correction of combined sewer overflow problems.

LOCATION OF COMBINED SEWER PROBLEMS

Estimated costs for separation of storm and sanitary sewers were presented in the 1968 report. The top 12 states with estimated costs of approximately one billion dollars or greater are listed in Table 31.

TABLE 31

STATE	COST OF SEPARATION ($BILLIONS) 1/
1. New York	11.47
2. Illinois	6.70
3. Michigan	3.98
4. Ohio	3.94
5. Pennsylvania	3.70
6. Indiana	2.58
7. Massachusetts	2.35
8. New Jersey	1.74
9. Missouri	1.58
10. California	1.26
11. Washington	1.09
12. Wisconsin	0.99
	41.38

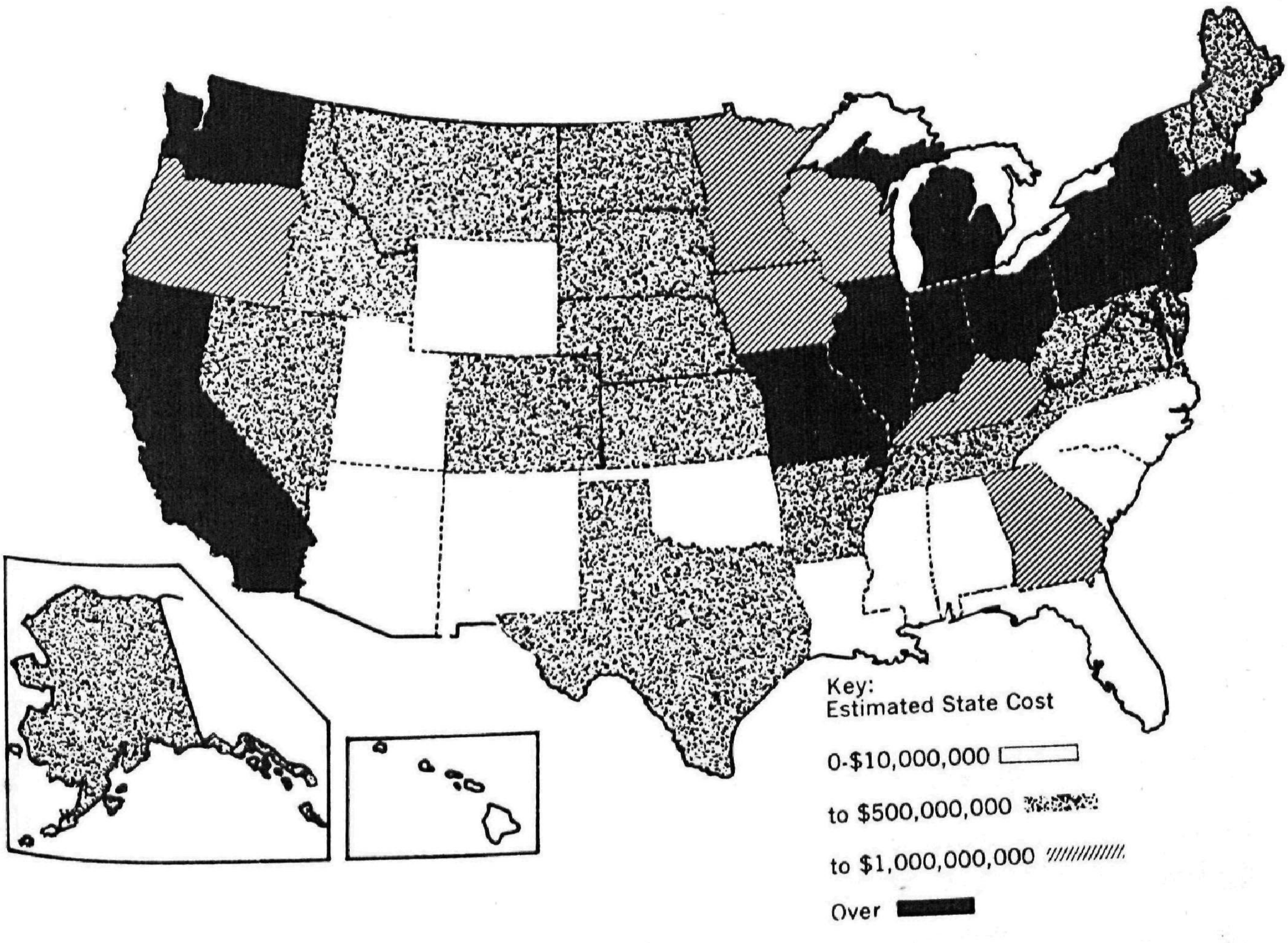
1/ ROUNDED TO THE NEAREST $10 MILLION.

The tabulation indicates that approximately 85% of the estimated cost for controlling combined sewer overflows utilizing separation would be incurred in 12 states, based on estimates of the cost of separation ($48.7 billion) prepared by the American Public Works Association.(2) The location of the states in the table is interesting since it indicates a regionalization of the problem. Figure 15 depicts the estimated cost distribution for the entire United States.

Actual costs for controlling overflows will be borne by the individual communities having combined sewers. Table 32 lists United States communities with 10,000 or more acres served by combined sewers. The table was compiled from previously unpublished data obtained by the 1967 APWA survey.

The communities listed account for approximately 50% of the total combined sewered area and 70% of the total combined sewered population found in the survey, which included a

RELATIVE COST OF COMPLETE SEWER SEPARATION BY STATES.*



*From the American Public Works Association Research Foundation Report, "Problems of Combined Sewer Facilities and Overflows - 1967".

FIGURE 15

TABLE 32

AREA AND POPULATION OF COMMUNITIES SERVED BY COMBINED SEWERS
(Greater than 10,000 Acres)

NUMBER	COMMUNITY	AREA SERVED (ACRES)	POPULATION SERVED
1	Chicago, Ill.	144,000	3,500,000
2	New York, N.Y.	105,624	6,667,296
3	MSLSD, Mo.	101,000	770,000
4	Detroit, Mich.	88,000	1,600,000
5	Cincinnati, Ohio	47,215	472,000
6	Philadelphia, Pa.	45,000	1,000,000
7	Cleveland, Ohio	44,000	876,000
8	East St. Louis, Ill.	39,100	58,000
9	Seattle, Wash.	38,000	426,000
10	Indianapolis, Ind.	37,000	400,000
11	Pittsburgh, Pa.	32,533	558,000
12	Atlanta, Ga.	28,920	108,073
13	San Francisco, Calif.	28,000	750,000
14	Portland, Ore.	27,100	309,536
15	Youngstown, Ohio	27,000	150,000
16	Omaha, Neb.	25,000	276,000
17	Des Moines, Iowa	23,200	144,000
18	Richmond, Va	22,000	200,000
19	Spokane, Wash.	21,790	163,000
20	Kansas City, Mo.	21,000	308,000
21	St. Paul, Minn.	20,700	207,000
22	Milwaukee, Wisc.	17,300	407,000
23	Boston, Mass.	16,668	712,000
24	South Bend, Ind.	16,130	129,140
25	Kokomo, Ind.	16,000	88,000
26	Gray, Ind.	16,000	180,000
27	Peoria, Ill.	15,000	100,000
28	Nashville, Tenn.	14,720	180,000
29	St. Joseph, Mo.	14,400	66,000
30	Anderson, Ind.	14,000	50,000
31	Evansville, Ind.	14,000	90,000
32	Rochester, N. Y.	14,000	240,000
33	Saginaw, Mich.	13,000	99,800
34	Toledo, Ohio	12,844	163,717
35	Hammond, Ind.	12,800	119,000
36	District of Columbia	12,740	400,000
37	Syracuse, N. Y.	12,000	150,000
38	Albany, Ga.	11,980	49,300
39	Dearborn, Mich.	11,900	107,000
40	Ft. Wayne, Ind.	11,200	114,200
41	Augusta, Ga.	10,577	73,400
42	Scranton, Pa.	10,400	110,000
43	Augusta, Maine	10,000	19,000
44	Columbus, Ohio	10,000	530,000
45	Saugerties, N. Y.	10,000	4,353
TOTAL		1,283,841	23,124,815

total of 641 jurisdictions. Based on the data obtained from these 641 jurisdictions, the APWA estimated that there are 3,029 million acres and 36 million persons served by combined sewers in 1329 United States jurisdictions.

The figures in Tables 31 and 32 indicate that 64% of the projected combined sewer population and 42% of the projected combined sewer area are located in the large cities (45 communities, or less than four percent of the jurisdictions) and in the most populated States. Since the cost can be estimated on an average per capita basis, it would follow that these 45 communities represent 64% of the estimated cost. This is true from a national standpoint, but it must be recognized that the small communities have serious local overflow problems also, even though they are difficult to define with the data available. In most cases the magnitude of the smaller community problem is just as large in relation to local funding capabilities as are the problems faced by the large cities and metropolitan areas. The priority and impact on the local economy for the large number of small communities faced with combined sewer problems have yet to be determined.

Some small communities are still faced with the difficult task of constructing the basic wastewater treatment facilities, which must be accorded a priority above combined sewer control needs. Planning for control of overflows should begin now, however, since it is clear that prevention and control of overflows can have an impact on the hydraulic load at the wastewater treatment facilities. The extent of such impact depends on the control method selected and should be considered when the treatment plant is under design.

The 1967 APWA study confirmed earlier opinion that very few communities maintain adequate records relating to the sewerage system, overflows, regulator maintenance, sewage and overflow volumes, and other system data which are badly needed during the course of engineering studies and design of remedial facilities. As a result, available data do not permit an accurate delineation of the combined sewer overflow problems. Their extent can only be broadly estimated from both technical and cost standpoints.

CASE STUDIES

Several projects carried out during 1968 provide additional insight into the magnitude of combined sewer overflow problems, the difficulty of the engineering and construction task to be faced, and the costs involved. The case studies presented in the following sections will serve to outline these factors.

1) <u>The Metropolitan Sanitary District of Greater Chicago</u>

The Metropolitan Sanitary District (MSD) of Greater Chicago has recently completed a detailed study of the feasibility of utilizing large tunnels deep (several hundred feet) under the entire metropolitan area for the purpose of controlling combined sewer overflows. The feasibility report outlined a 10-year plan for accomplishing control of overflows including:

(a) Interception of excess storm and sanitary flows from existing main sewers at their points of overflow to the waterways, by vertical shafts.

(b) Discharge from the vertical shafts into high velocity, concrete-lines, conveyance tunnels, excavated in solid rock.

(c) Discharge from the conveyance tunnels into a large mined reservoir approximately 850 feet below Lake Calumet.

(d) Pumping of the combined sewer overflows to a surface reservoir, after temporary storage underground.

(e) Recycling of water between the upper and lower reservoirs for hydroelectric power generation.

(f) Treatment of the polluted stormwater overflows.

(g) Discharge of treated effluent to the waterway system at controlled rates.

Capital costs for the 10 year program are estimated to be $1.27 billion. Of this, $200 to $250 million could be financed by revenue bonds from the sale of hydroelectric power from generating facilities incorporated in the project, with the remaining costs financed by general obligation bonds and current taxes. The cost for sewer separation within the sanitary district has been estimated to be $3.3 billion, not including any of the intangible costs.

A significant direct benefit to the Sanitary District would be substantial relief from surface flooding problems which a conventional sewer separation project would not achieve. Present planning would result in control of overflows from a storm which can be expected once in 100 years, which would result in much more control capability than is normally achieved in drainage control. Most frequently, drainage facilities are designed to control flows resulting from a storm which may be expected once in five or 10 years. A 50-year storm is occasionally used for design, but a 100-year design basis is seldom used. Thus, the MSD project will offer an unusually high degree of control.

The magnitude of the construction effort involved is such that staged construction will be required. The 10-year program has been divided into five construction zones. The first zone would involve $258 million for construction costs, with completion in 1973. When completed, the first zone would serve an area of 39,600 acres, 87% of which are served by combined sewers, including some 60 over-flow locations.

Designed to accept a runoff of 0.5 inches per hour it would limit overflows to insignificant amounts from the maximum storms of almost 100 years of record. A pumping-generating station with a capacity of 500,000 kilowatts/eight hour weekday would be included. This plan includes treatment of the overflow including primary, secondary, advanced treatment, and chlorination. The advanced treatment will probably include phosphate removal, nitrogen removal, and filtration.

Alternate costs for the first construction zone have been estimated as follows: separation - $600,000,000; holding tanks with capacity of 0.25 inches of overflow - $140,000,000 and to be as effective as the Deep Tunnel System - approximately $750,000,000; and the use of very high rate treatment facilities at overflow points equivalent to the Deep Tunnel System Treatment - four to eight times as high.

2) <u>Cleveland, Ohio</u>

The feasibility of utilizing a stabilization-retention basin constructed in Lake Erie as a means of controlling combined sewer overflows was investigated. The project report recommends the construction of a 900-acre basin in Lake Erie for the treatment of a number of large combined sewer overflows, several polluted streams, and the effluent from the secondary wastewater treatment plant. Cost of the facility is estimated to be approximately $83.5 million with an annual cost of $4.8 million. For the study area under consideration, separation would cost about $278 million or approximately three times the cost of the basin.

The study area comprises 38,800 acres, contains a population of 453,000 and is about 33% served by combined sewers.

Design criteria for the stabilization basin and shoreline collector system have been established as follows:

(a) Overall detention period to be 30 days, based on average flows from treatment plant, combined sewer overflows and surface streams, plus runoff and overflow from a 3-day storm of intensity expected to occur once in three years.

(b) Volume of basin to be 30,000 acre-feet, which is the total volume required by (a) plus allowance for displacement by wave action, increase in future runoff rates and hydraulic inefficiencies.

(c) Surface area of basin to be 900 acres, and mean depth to be approximately 34 feet.

(d) Basin to be subdivided into three zones; an aerobic, mixed zone for bio-oxidation; a facultative quiescent zone for sedimentation; and a reaeration and chlorine contact zone prior to discharge of effluent.

(e) Structural design of basin wall to comprise a cellular steel sheet piling cofferdam, filled with sand, crushed stone or other suitable fill. Cell diameter and fill characteristics are to be determined after completion of detailed design studies based on foundation and subsoil investigations. Preliminary design based on 67-foot diameter cells, having 10-foot freeboard, and concrete capped. Approximately 410 cells are required.

(f) Hydraulic design flow based on peak runoff rate occurring from a 1-year storm, after routing to the point of design.

(g) A combination of gravity flow conduits with pumping stations and force mains was found to be the most economical collection system, and is recommended in preference to an all-gravity system. Four pumping stations are required.

(h) The most economical route for the collector conduits and force mains is at the beach line rather than in tunnel or in deep cut in the shoreline bluff.

(i) At collector basins, trash removal and chlorination of excess flows will be provided.

Anticipated benefits of the project in addition to combined sewer overflow pollution abatement, include protection against shoreline erosion, creation of an invaluable sheltered recreational bay, potential impoundment for dredging spoil, replacement of a municipal chlorination contact chamber, provision of nutrient removal facility, and potential as an aquatic pollution control research tool.

3) Boston, Massachusetts

Four principal methods of combined sewer overflow pollution abatement for Boston Harbor and the adjacent waters were developed in September 1967 following an engineering feasibility study. The four methods with estimated costs for the five-community Boston region (Boston, Brookline, Cambridge, Chelsea, and Somerville) are:

	Estimated Costs 1/ 2/ Millions of Dollars		
Method	Construction	Capitalized Operation and Maintenance	Total
Complete Separation	550.0	34.0	584.0
Chlorination Detention Tanks	400.0	133.0	533.0
Holding Tanks	715.0	99.0	814.0
Deep Tunnel Plan	430.0	66.0	496.0

1/ Costs do not include replacement of existing storm drains of combined sewers.

2/ At interest rate of 4.00%

Design criteria for the Boston deep tunnel storage plan would handle the runoff resulting from a rainfall of a 15 year frequency and 24 hour duration (total rainfall depth of five inches) and dispose of this runoff within a two day period without surcharging the tunnels. The stored stormwater would be disinfected and then discharged well out to sea through a 45,000 foot long outfall with twin 5800 foot long diffuser pipes.

In addition to being what appears to be the most economical solution, the following advantages of the deep tunnel are:

(a) The deep tunnel plan provides the best and most practical regional solution to the problem of handling mixed sewage and storm water and assures abatement of water pollution due to both sewage and surface runoff.

(b) The plan is adaptable to any conceivable development of Boston or the regional area in the future.

(c) The plan is an economical means of eliminating overflows to the surrounding waters.

(d) The estimated total cost of the plan is less than for alternative methods, including complete separation, and this plan may become less expensive in the future as rock boring technology improves.

(e) The plan will occupy very little valuable land area.

(f) Construction of the deep tunnel will not cause interference with traffic or surface activities.

(g) Construction of the deep tunnel will permit efficient draining of all areas that now flood during heavy rains and high tides.

(h) The plan will provide the means for disposing of all polluted surface water and sewage well out to sea. The ocean outfall will permit safe discharge to sea of all treated or untreated waste water from the Deer Island facilities.

(i) Sections of the deep storage tunnels will parallel the Boston Metropolitan District Commission main drainage tunnel and have lower inverts to complement the existing MDC sewerage system.

(j) The large quantity of rock excavated from the tunnels during construction will be available at low cost for fill in connection with the expansion of Logan International Airport, site development for the proposed 1975 Worlds Fair or other fill operations in and around Boston Harbor.

The Metropolitan District Commission consultant also recommends that until such time as the city makes a commitment to adopt the proposed deep tunnel plan, it should continue its present policy of complete separation of sanitary sewerage and storm drainage systems.

The report points out that in addition to the deep tunnel plan, a recommended initial construction program would cost $118,900,000.

Importantly, if the harbor and adjacent waters are to be made suitable for proposed uses, i.e. to meet water quality standards, the solution must include the elimination of combined sewer overflows.

4) Minneapolis-St. Paul Sanitary District (MSSD)

The Minneapolis-St. Paul Sanitary District serves 11,200 acres and 20,700 acres of combined sewers in Minneapolis and St. Paul, respectively. In June 1968, the MSSD began the operation of the first real-time computer-assisted control of a combined sewer system. The objective is to fully utilize the interceptor sewer system capacity to reduce drastically the incidence of combined sewer overflows and produce much of the same effect as sewer separation programs many times more expensive which would require many years to complete. This $1.5 million project is supported in part by an FWPCA demonstration grant. It is too early to determine if the objective stated above is being fully met. It can be said at this time, however, that this approach appears promising and will materially assist the very serious problem eliminating dry-weather discharges resulting from defective regulators. It can almost be generalized that every community must increase its capability to monitor the overflow regulators and immediately correct any unwarranted overflows. Detroit, Michigan, and Seattle, Washington (METRO) are also engaged in similar grant projects.

The cost of this type of control appears to be several magnitudes lower than complete separation. It must be cautioned, however, that to be effective the sewerage system must have certain physical characteristics, such as excess storage capacity, and the level of control required must be carefully determined.

INDUSTRIAL POLLUTION

SUMMARY OF LAST YEAR'S ESTIMATES

Last year's study projected national requirements for industrial waste treatment at $2.6 billion to $4.6 billion over the 1969-1973 period. (Table 33). The $2.6 billion estimate was based upon expert estimates set forth in the ten Industrial Waste Profiles prepared in 1967, while the $4.6 billion estimate was based on census-municipal projections.8/

The $2.6 billion figure included $1.1 billion to meet the existing backlog of treatment facility needs, $0.7 billion to provide for industrial growth, and $0.8 billion to replace obsolete equipment. The $4.6 billion estimate included $2.6 billion for meeting the estimated backlog, and $1.0 billion each for growth and for equipment replacement.

The study emphasized that these estimates were highly tentative and largely dependent upon certain assumptions. For example, a most important, but highly tentative, assumption was that the equivalent of secondary waste treatment of municipal wastes (i.e., no less than 85% removal of standard biochemical oxygen demand - BOD_5 - and of settleable and suspended solids) comprised an adequate approximation of industrial waste treatment as reflected by approved State water quality standards. An illustrative set of estimates indicated that BOD removal costs rise precipitously as removal levels in excess of 85% are sought. It was pointed out, moreover, that many industrial wastes are characterized by pollutants more difficult to treat than pollutants normally found in municipal wastes and that the removal of such industrial pollutants could well require greater expenditures than were estimated.

The estimated $1.1 billion backlog in industrial waste treatment facilities represents the difference between the estimated $4.0 billion in treatment facilities required in 1968 and the existing $2.2 billion in industrial waste treatment facilities and the $0.7 billion in municipal facilities (for handling industrial wastes), respectively. These estimates are broken down by major industrial category in Table 34. That

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8/ See discussion of basis for census-municipal projections in The Cost of Clean Water, Volume II, FWPCA, U.S. Department of the Interior, January 10, 1968 table indicates that primary metal industries, for example, required the largest investment to attain the prescribed treatment level in 1968 but that, after accounting for existing facilities, the chemical and allied product industries would require the largest additional investments over the next five years. Table 35 shows the regional distribution of industrial waste treatment requirements. Table 36 shows estimated investments required to reduce existing requirements over the five year period, broken down on a projected year-by-year basis.

TABLE 33

ESTIMATED CASH OUTLAYS TO MEET 1968 AND PROJECTED INDUSTRIAL WASTE TREATMENT REQUIREMENTS, FY 1969-1973 (CONSTANT 1968 DOLLARS)

	Wastewater Profiles ($ BILLION)	Census Municipal Projections ($ BILLION)
1968 Needs	$4.0	$5.0
Less Equipment in place	2.9	2.4
Difference (Backlog)	$1.1	$2.6
Five-Year needs		
Backlog	$1.1	$2.6
Growth	0.7	1.0
Replacement	0.8	1.0
Total Needs 1969-1973	$2.6	$4.6

Source: The Cost of Clean Water, Volume II, FWPCA, U. S. Department of the Interior, January 10, 1968.

Estimated outlays over the five year period for operating and maintaining industrial waste treatment works were projected to fall within a range of $3.0 billion to $3.4 billion (see Table 37 for estimated annual outlays). As the backlog of needed industrial waste treatment facilities is worked off over the next five years and industrial output increases over the

TABLE 34

ESTIMATED VALUE OF INVESTMENT, INDUSTRIAL WASTE TREATMENT REQUIREMENTS, 1968

(Based on Industrial Waste Profiles)

Industry	Million of 1968 Dollars			
	Total Plant Required	Currently Provided By Municipalities	Currently Provided By Industry	Additional Investment Required
Food and Kindred Products	743.1	340.7	182.4	220.0
Meat Products	170.8	98.7	36.9	35.2
Dairy Products	104.0	73.1	7.8	23.1
Canned and Frozen Foods	137.0	80.0	23.0	34.0
Sugar Refining	175.2	2.3	105.5	67.4
All Other	156.1	86.6	9.2	60.3
Textile Mill Products	165.2	85.4	53.3	26.5
Paper and Allied Products	321.8	21.1	225.0	75.7
Chemical and Allied Products	379.7	12.0	87.9	279.8
Petroleum and Coal	379.4	27.4	275.0	77.0
Rubber and Plastics	41.1	5.1	5.1	30.9
Primary Metals	1,473.8	55.1	1,269.2	149.5
Blast Furnaces and Steel Mills	963.8	-	865.6	98.2
All Other	510.0	55.1	403.6	51.3
Machinery	39.0	11.2	2.9	24.9
Electrical Machinery	35.8	22.8	4.5	8.5
Transportation Equipment	216.0	115.1	59.2	41.7
All Other Manufacturing	203.7	35.5	50.8	117.4
All Manufactures	3,998.6	731.4	2,215.3	1,051.9

Source: The Cost of Clean Water, Volume II, Federal Water Pollution Control Administration, U.S. Department of the Interior, January 10, 1968

TABLE 35

REGIONAL DISTRIBUTION OF WASTE TREATMENT REQUIREMENTS, 1968, BY WASTEWATER PROFILES AND ESTIMATES

Regions	Millions of 1968 Dollars		
	Total Plant Required	Value of Plant in Place	Additional Investment Required
North Atlantic	814.0	575.5	238.5
Southeast	276.1	208.0	68.1
Great Lakes	973.4	784.2	189.2
Ohio	658.5	526.7	131.8
Tennessee	80.4	47.8	32.6
Upper Mississippi	205.1	149.9	55.2
Lower Mississippi	230.1	144.8	85.3
Missouri	88.2	64.2	24.0
Arkansas-White-Red	49.2	33.0	16.2
Western Gulf	286.8	168.9	117.9
Colorado/Great	25.9	17.0	8.9
Pacific Northwest1/	167.6	121.1	46.5
California2/	143.3	105.6	37.7
Total	3,998.6	2,946.7	1,051.9

1/ Includes Alaska

2/ Includes Hawaii

Source: The Cost of Clean Water, Volume II, Federal Water Pollution Control Administration, U.S. Department of the Interior, January 10, 1968

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TABLE 36

ANNUAL INVESTMENT REQUIRED TO REDUCE THE EXISTING INDUSTRIAL WASTE TREATMENT DEFICIENCY IN FIVE YEARS
(Wastewater Profiles and Estimates)

Industry	Millions of 1968 Dollars					
	Annual Investment To Reduce Existing Requirements	Total Investment to Reduce Waste Treatment Requirements and Meet Growth Needs				
		1969	1970	1971	1972	1973
Food and Kindred Products	43.9	63.2	65.4	69.9	70.0	69.9
Meat Products	7.0	10.1	11.2	11.2	11.7	11.6
Dairy Products	4.6	5.1	5.7	5.5	5.5	5.5
Canned and Frozen Foods	6.7	11.4	12.4	12.6	12.9	13.0
Sugar Refining	13.5	19.3	18.4	22.6	21.4	21.5
All Other	12.1	17.3	17.7	18.0	18.5	18.3
Textile Mill Products	5.3	9.8	10.9	11.1	11.0	11.6
Paper and Allied Products	15.1	19.1	25.5	26.0	26.4	27.0
Chemical and Allied Products	56.0	75.7	76.9	77.7	79.4	77.9
Petroleum and Coal	15.4	15.4	18.1	30.5	31.7	32.1
Rubber and Plastics, n.e.c.	6.2	7.0	7.9	7.1	7.2	7.1
Primary Metals	29.9	83.6	91.3	93.3	96.2	97.8
Blast Furnaces and Steel Mills	19.6	52.4	59.1	60.1	63.0	63.0
All Other	10.3	31.2	32.2	33.2	34.2	34.8
Machinery	5.0	6.9	6.9	7.1	7.1	7.3
Electrical Machinery	1.7	3.6	3.8	3.8	4.0	4.1
Transportation Equipment	8.3	11.7	11.9	12.2	12.1	12.3
All Other Manufacturing	23.5	32.3	32.6	33.0	33.5	33.8
All Manufactures:						
By Wastewater Profiles and Estimates	210.3	328.3	351.2	371.7	378.6	380.9
(By Census-Municipal Projections)	(528.5)	(676.9)	(705.8)	(731.5)	(740.2)	(743.1)

Source: The Cost of Clean Water, Volume II, Federal Water Pollution Control Administration, U.S. Department of the Interior, January 10, 1968

TABLE 37

ANNUAL OPERATING AND MAINTENANCE COSTS
1968-1973

Industry	Annual Operating and Maintenance Costs (Millions of 1968 Dollars)					
	1968	1969	1970	1971	1972	1973
Food and Kindred Products	85.4	95.9	107.0	118.7	130.4	142.1
Meat Products	15.3	16.4	17.7	19.0	20.3	21.6
Dairy Products	16.1	17.1	18.3	19.4	20.5	21.6
Canned and Frozen Foods	17.9	19.9	22.0	24.2	26.5	28.7
Sugar Refining	19.1	22.5	25.8	29.8	33.5	37.3
All Other	17.0	20.0	23.2	26.3	29.6	32.9
Textile Mill Products	39.0	41.7	44.8	47.9	51.0	54.3
Paper and Allied Products	33.3	35.9	39.3	42.8	46.4	50.0
Chemical and Allied Products	21.1	37.2	53.5	70.0	86.8	103.3
Petroleum and Coal	60.5	63.6	67.2	73.3	79.6	86.1
Rubber and Plastics, n.e.c.	1.8	3.0	4.4	5.7	7.0	8.2
Primary Metals	137.8	146.5	155.9	165.7	175.7	185.9
Blast Furnaces and Steel Mills	90.1	95.5	101.6	107.9	114.4	121.0
All Other	47.7	51.0	54.3	57.8	61.3	64.9
Machinery	2.5	3.7	4.9	6.2	7.5	8.7
Electrical Machinery	4.8	5.5	6.1	6.8	7.5	8.2
Transportation Equipment	29.4	31.4	33.4	35.5	37.5	39.6
All Other Manufacturing	15.3	21.0	26.8	32.6	38.5	44.5
All Manufactures:						
By Wastewater Profiles and Estimates	430.9	485.4	543.3	605.2	667.9	730.9
By Census-Municipal Projections	(348.7)	453.6)	(565.6)	(679.9)	(802.1)	(921.7)

Source: The Cost of Clean Water, Volume II, FWPCA, U.S. Department of the Interior, January 10, 1968 period, the annual cost of operating treatment plants is expected to rise by approximately 60% and to amount to almost three quarters of a billion dollars by 1973.

COMMENTS ON INITIAL ESTIMATES

In full awareness of the gross nature of these first industrial waste treatment cost estimates, and the great need for developing more accurate estimates, positive efforts were made by the FWPCA to elicit industry reaction to them. Copies of The Cost of Clean Water were sent to 15 major trade organizations with the request that they review the estimates and forward any comments to FWPCA to use in refining the estimates. All these organizations did respond. However, their responses varied widely in depth and content. Several replies merely acknowledged receipt of the report. Other respondents commented on the overall report solely in general terms. Some organizations concentrated largely or exclusively on the industrial waste profile which related to the industry which they represent. None of the replies, however, provided a basis for adjusting any of the industrial waste treatment cost projections included in last year's report.

Responses to the Commissioner's letters of April 26 and September 3, 1968 are included in Volume II of this report.

INDUSTRY EXPENDITURES

In the earlier section on the backlog concept, comparisons are made between calculated investment requirements for processing and for power generation and estimates of recent water pollution control investments by industry. That analysis indicated that, on the basis of available evidence, industrial expenditures for waste treatment facilities in the last two years were close to target expenditures established in last year's report.

WATER QUALITY STANDARDS

State water quality standards implementation plans as they relate to municipal pollution lend themselves reasonably well to estimating national requirements and costs. However, the standards plans as they apply to the more varied, complicated, and less understood industrial pollution problem do not make it feasible to utilize generalizations as to treatment level in arriving at industrial waste treatment cost estimates. Accordingly, use of the standards implementation plans as a basis for estimating industrial waste treatment costs must await the development of more specific information on the waste disposal practices of various industries.

ORGANIC CHEMICAL WASTE PROFILE

Preparation of a wastewater profile of several major segments of the organic chemical industry represented the most significant progress in 1968 towards refining industrial treatment cost estimates included in last year's report. This profile does not provide a sufficient basis for adjusting any of those initial estimates inasmuch as it covers only a portion of the "chemical and allied product" industries for which a single, total projection was made last year. However, the profile does serve two specific purposes. First, it provides a range of cost estimates, based upon the most comprehensive cost data yet obtained, for given levels of pollutant removal for a large portion of an extremely important industry. Second, it provides a methodological base for projecting outlays for necessary waste treatment for other industries. This method will be tested in the coming year by application to available industry waste treatment cost data.

The C. W. Rice Company, Pittsburgh, Pennsylvania was the prime contractor for the profile which was designed to develop five year projections of costs required by organic chemical plants in attaining various levels of pollutant removal. Other experienced industrial wastewater control firms and experts contributing to the report include the Roy F. Weston Company, West Chester, Pennsylvania; W. Wesley Eckenfelder, Jr. of W. Wesley Eckenfelder and Associates, Austin, Texas; and Dr. Robert N. Rickles of Resource Engineering Associates, Inc., Stamford, Connecticut. Both Professor Eckenfelder and Dr. Rickles have served the Manufacturing Chemists' Association in several capacities. All data used were derived from information in the files of the contractors and every possible attempt was made to maintain the anonymity of the companies whose operations and treatment costs were used.

Specifically, the profile entitled "Projected Wastewater Treatment Costs In The Organic Chemicals Industry" is an analysis of total estimated cost (including capital costs and operating and maintenance costs) required to be expended by specific removal levels for significant pollutants. The industries covered are those included in the updated 1967 Standard Industrial Categories: 2813 - Industrial Gases (Organic only); 2815 - Cyclic Intermediates, Dyes, Organic Pigments (Lakes and Toners), and Cyclic (Coal Tar) Crudes; 2871 - Fertilizers (Ammonia and Urea only); and portions of 2879 - Agricultural Chemicals, not elsewhere classified.

Methodology

The costs of unit wastewater treatment methods developed in the profile were presented as a series of mathematical models and cost function graphs. These data were then used to calculate capital costs of waste treatment facilities in relation to degrees of pollutant removals attainable for 20 hypothetical plants. Both the unit cost data and the design criteria for these plants were checked for reliability and representativeness on the basis of cost data from 53 plants.

Analysis of the available data indicated that estimates of industry-wide costs in the organic chemicals industry would best be made on the basis of estimated costs per plant and estimated numbers of plants. Alternative calculations could have been made on the basis of estimated costs per unit volume of wastewater and estimated wastewater volumes. Cost estimates are based, additionally, upon the assumption that wastewater generation per unit of production will decrease as wastewater treatment facilities are installed.

Capital Costs

Last year's study estimated that water pollution control equipment worth about $380 million would have to be in place by the end of the next five years if the entire chemical and allied industries are to attain 85% removal of BOD at that time. The organic chemicals segment of the industry is estimated to require a total of approximately $243 million by the end of the five years to attain a comparable (83%) level of BOD removal. (Table 38).

The profile indicates the extent to which capital costs for treatment facilities escalate as higher levels of pollutant removal are sought. Table 38 shows, for example, estimated projected five year capital outlays rising by only $60 million (from $183 billion to $243 million) to increase BOD removal from 10% to 83% but projected capital outlays increasing by $407 million (from $243 million to $650 million) to increase BOD removal from 83% to 99%.

Although there may be more diversity of expert opinion as to chemical oxygen demand (COD) removal rates, compared with BOD removal rates, the profile indicates that it would be far more costly to attain high levels of COD removal than comparable levels of BOD removal. For example, an estimated 99% BOD removal would require a capital outlay of $650 million whereas complete removal of COD would require $1.4 billion - almost twice the cost.

TABLE 38

Estimated Capital Outlays to Attain Specified Levels of BOD, COD, and Suspended Solids Removal, 1969-1973

Removal level for Critical Pollutants (% Removal)			5-Year Projected Capital Outlays (Millions of Dollars)
BOD	COD	Suspended Solids	
10	10	65	182.5
83	13	71	242.6
98	30	89	608.1
99	33	99	649.6
100	100	100	1378.1

Source: Projected Wastewater Treatment Costs In The Organic Chemicals Industry, The Cost of Clean Water and its Economic Impact, FWPCA, U.S. Department of the Interior, January 1969

On a percentage removal basis, suspended solids can be removed at far lower costs than COD removal and at fairly comparable costs with BOD removal.

Operating Costs

Assuming that the operating costs associated with the discharge of industrial wastes to municipal sewers amount to 10 cents per 1000 gallons, the total operating costs are expected to be around $16.8 million in 1969 and to rise yearly over the period in proportion to increases in treatment facilities in place.

It perhaps should be emphasized that the total costs presented in the profile are for the construction and operation of waste treatment facilities for the industry as a whole and cannot be used to determine costs for individual plants. Organic chemicals plants vary greatly in size, level of technology, product mix, and so forth, and a "typical" or "average" plant exists only in a statistical sense. The costs given are for waste removal levels which treatment facilities alone may be expected to attain. That is, the costs entailed in process changes, disruption of plant operations, sewer segregation, and monitoring and reporting waste treatment efficiency are not included. Such costs are practically impossible to estimate in the aggregate but yet may add 40% or more to the installed costs of facilities. Total costs for a given plant can only be estimated by detailed engineering studies. The unit costs in the profile should be of value to engineers in making such estimates.

The Organic Chemicals Industry

The important products of the organic chemicals industry are miscellaneous cyclic and acyclic organic chemicals and chemical products, flavor and perfume materials, rubber-processing chemicals, plasticizers, pesticides, and other synthetic organic chemicals. Of total shipments in 1967, 75% were miscellaneous acyclic chemicals, a large number of which are generally designated as petrochemicals. The expansion of the petroleum industry into chemical production is of particular significance insofar as the growth and complexity of the organic chemicals industry is concerned.

Total sales in the organic chemicals industry are projected at $11.9 billion in 1969 and $15.6 billion in 1973. Production is estimated at 135.6 billion pounds in 1969, and projected to increase to 201.6 billion pounds by 1973. Growth in the industry is not expected to be uniform either among the various segments of the industry or in the various geographical areas in which the industry operates.

Organic chemicals industry pollutants originate from several sources. These sources include the incomplete removal of principal products or raw materials from chemical reactions, the production of non-recoverable or useless by-products, from equipment cleaning operations, and from such water uses as cooling and steam production. Wastewater generation in the industry per unit of product varies so widely that an average value has little meaning. For example, wastewater generation varies from less than 100 gallons to more than 100,000 gallons per ton of product. The principal contaminants in the industry's wastewaters are BOD, COD, oil, suspended solids, acidity, heavy metals, color, taste and odor-producing compounds, and residual organic products and by-products.

The production of organic chemicals results in many types of contaminated wastewaters, and the treatment methods employed cover the range of known practical techniques. In-plant control is the first step in instituting treatment practices. Such controls include the salvage of unreacted chemicals, recovery of by-products, multiple reuse of water, good housekeeping techniques to reduce leaks and spills, and changes in processing methods. These controls can reduce the concentrations of almost all potential pollutants and can, most importantly, reduce the volumes of wastewaters requiring treatment. Physical treatment methods, such as sedimentation or flotation, are used primarily to remove coarse suspended matter and floating oils and scums. Filtration is used as a form of tertiary treatment for reuse or as a pretreatment for deep-well injection. Chemical treatment is used primarily as a pretreatment prior to sedimentation, filtration, or biological treatment. Biological treatment is most widely used because of the nature of the wastes; that is, their general susceptibility to biodegradation as evidenced by relatively high BOD values.

Joint municipal-industrial treatment has proved very effective in treating organic chemical wastewaters, particularly for smaller chemical plants located near large municipal treatment systems. Treatment costs play an important role in governing the expansion of joint treatment participation. Rates established by municipalities vary widely. The chemical industry has generally found that in-plant, separate treatment has economic advantages, particularly when significant quantities of contaminated wastewater are involved. Accordingly, no significant percentage increase is expected in the near future in the amount of organic chemical wastewaters that will be treated in joint treatment systems.

Improved Methodology for Wastewater Treatment Cost Estimation

The methods which have been developed and used in this study of the organic chemicals industry can be utilized to refine our estimates of wastewater treatment costs for other industries. The methodology is intended to be used in establishing and projecting costs for an industry or for groups of industries, rather than for individual plants. Cost estimates for individual plants are readily calculable by conventional engineering techniques to almost any degree of precision desired, depending upon the effort to be expended and the intended uses of the information. Costs for an industry could, of course, be determined precisely by calculating the costs of treatment facilities for each individual plant in an industry and totaling these costs. Alternatives to this obviously impractical method are to estimate the number of plants involved and multiply by the "average" cost per plant or to estimate the volume of wastewater involved and multiply by the "average" cost per unit volume of wastewater. Such alternative methods are practical and offer a degree of accuracy sufficient for purposes of industry-wide planning and economic impact studies. The suggested methods for determining the total costs to an industry of attaining specified degrees of wastewater effluent quality over a time period are outlined in the profile in the following sequence:

1. Characterization of the Industry
2. Projection of Industry Growth
3. Characterization of Wastewaters
4. Wastewater Treatment Methods Determinations
5. Sample Plant Data Acquisition
6. Sample Data Analysis
7. Unit Wastewater Treatment Methods Costing
8. Determination of Cost vs. Effluent Quality Relationships
9. Projection of Industry Wastewater Generation
10. Projection of Industry Costs

Guidelines have been established for the use of this methodology and its use has been demonstrated in the organic chemicals industry profile. Each industry has its own peculiar characteristics, however, and care must be taken to accommodate such characteristics in applying any general schemes. For example, in the organic chemicals profile, production-related parameters were shown to be of prime importance. A reliable estimate of numbers of plants was available and the "average" plant costs were closely estimated by two alternative techniques. In another industry the most logical set of data for use might well be different.

THERMAL POLLUTION

1968 COST ESTIMATES

The 1968 report indicated a total estimated investment of $1.8 billion (in 1968 dollars) in cooling equipment would be required over FY 1969-1973 to return water to its original temperature before use, or $2.0 billion based upon a continuation of historical construction cost increases during the period. The $1.8 billion estimate was based upon a current backlog of about $1.0 billion, an estimated $0.6 billion to accommodate growth, and $0.2 billion for replacement over the FY 1969-1973 period. Of this $1.8 billion outlay, an estimated $1.3 billion would be required of the thermal power industry and about $0.5 billion would be incurred by major manufacturing establishments.

The $1.8 billion estimate overstates estimated required capital outlays to the extent that it is based upon the return of cooling water temperature to its original temperature while water quality standards permit some increase in the temperature of water used for cooling where no harmful effects will occur. In actual practice, adequate heat dissipation probably will be attained with some portion of the $1.8 billion estimate.

Any increase in installed cooling equipment will be accompanied by increased operation and maintenance costs. It is difficult to estimate operation and maintenance costs because of the extreme difficulty of estimating capital outlays over the next five years. However, based upon the assumption of $1.8 billion projected additional capital outlays, it was estimated that operation and maintenance costs for water cooling would total almost $900 million during the next five years - from about $79 million in FY 1969 to approximately $280 million in FY 1973.

These estimates must be recognized as being extremely tentative and most likely overstated, because they are based upon necessarily arbitrary assumptions (an overall decrease of 13°F in cooling water temperature to approximate its before-use temperature and cooling by mechanical draft cooling towers only). Meaningful refinements in these cost estimates will be possible only after stream quality standards applicable to permissible cooling water temperature effects are completely approved and a site-by-site estimate of cooling equipment requirements at power generation plants has been made. Accordingly, efforts will be initiated as soon as possible to develop an inventory of cooling water treatment needs. For the present, therefore, the first estimates of five-year projected costs of a maximum of $1.8 billion in capital outlays and $0.9 billion in operation and maintenance costs remain the best available estimate of cost.

As indicated earlier, comparison between calculated investment requirements for power generation and the 1968 estimated rate of water pollution control investments are shown in the section on the backlog concept.

Water Quality Standards

All 50 States, the District of Columbia, and the Territories of Guam, Puerto Rico, and the Virgin Islands submitted water quality standards containing temperature criteria to protect designated water uses, particularly aquatic life propagation. The numerical criteria, controlling artificial temperature changes and setting maximum limits, vary from State to State. All standards include a narrative statement limiting artificial temperature increases to levels not considered to have deleterious effects on beneficial water uses. As of December 1, 1968, standards relating to thermal pollution had been approved in whole or part for 37 States and other jurisdictions.

Generally speaking, States have not specified the implementation measures that will be necessary to assure compliance with the temperature criteria. Specific implementation measures were omitted because it was felt that, without special studies, information was unavailable or insufficient for specific waterbodies or stretches of waterbodies on the need for heat dissipation equipment to meet specific temperature control standards. It was concluded, therefore, that the effect of heat discharges on existing water temperature needs to be studied on a case-by-case basis.

FWPCA research and technical studies, under way in the Pacific Northwest, will be of sufficient scope to cover the nation. Studies will concentrate on the following subjects:

--An inventory of heat sources, present control or treatment provided, effects of heat loads on water quality, and abatement needs.

--Determination of the best way or ways to apply temperature criteria.

--Assessment of the magnitude and location of future heat sources and potential effects on water quality with a view toward requiring treatment or control devices (possibly including outfalls and diffusion devices) prior to beginning of operations.

--Study of treatment and control measures and their costs.

--An evaluation of existing temperature data, and an assessment of the areas where data is needed, followed by programs to collect and evaluate such data.

INDUSTRIAL WASTE INVENTORY

There is a critical need for quantitative information on industrial waste treatment costs if effective plans are to be made by industry and Government decision makers relative to the control of industrial waste. The dearth of such data was illustrated, for example, by the assumptions which had to be used in preparing the industrial discussion in last year's study, The Cost of Clean Water, and the lack of treatment cost data reflected in the reaction of the industrial community to that report.9/

Present FWPCA plans are to develop information on industrial waste treatment costs by two different approaches. One approach is to project costs by developing mathematical models and cost function graphs applicable to various industry groupings as described in the earlier discussion on the organic chemicals industry. In order to be sure, however, that this theoretical approach is providing adequate estimates of costs, it is necessary to utilize a complementary approach for developing information on industrial waste disposal practices and their associated costs. This second approach will comprise an industrial waste inventory whose findings will serve as a cross-check on the adequacy of treatment costs developed by the modeling approach.

A national inventory of industrial wastewater disposal practices is in an advanced planning stage. As planned, it will ultimately cover an approximate 10,000 manufacturing or processing plants, each of which use over 20 million gallons of water annually and which, in the aggregate, account for about 97% of the water used in the country for industrial purposes. Selection of plants in this category for inclusion in the survey was prompted largely by the total water usage involved and the likelihood that the essential dimensions of the national industrial water pollution problem can be delineated adequately by utilizing this sample of plants. It is recognized, however, that smaller processing establishments, particularly those discharging effluents to relatively small

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9/ *This matter was also discussed in The Critical Need For A National Inventory of Industrial Wastes, 30th Report by the Committee on Government Operations, House Report No. 1579, 90th Congress, 2nd Session.*

streams, may well be significant contributors to the nation's industrial water pollution problem and such establishments may be included in the inventory at a later date.

Plants to be surveyed will be selected from a commercial directory currently listing more than 300,000 manufacturers. Criteria to be used include participation in an industry identified in the 1963 Census of Manufactures, "Water Use in Manufacturing", as being among the largest water users in terms of volume of gross annual sales and number of employees.

The form to be used is in the final stages of design. It will provide for identification of the plant by name, parent corporation where applicable, and geographical location and mailing address and principal product(s) produced. Other data and information requested include: (a) Names and types of sources and discharge points for various kinds of water use and wastewater effluent; (b) Original costs of treatment and control facilities, annual expenditures for operation and maintenance, and estimated outlay of funds for treatment and control over the next five years; and (c) Water quality data for both intake water and effluent for each different type of wastewater coming from the plant.

It is anticipated that this inventory will be initiated in the near future.

OTHER EFFLUENTS

The series of pollutional sources and effects which are included in the following section are much more difficult to quantify, and in many cases to even delineate, than the costs of controlling municipal and industrial wastes. The "other effluents" include such pollutional effects as those caused by, or resulting in, sedimentation and erosion, salinity from the use of irrigation water, nutrients from land runoff or municipal and industrial wastes, mine drainage, oil field and chemical brines, concentrated animal feedlot runoff, accidental discharges from all sources, and drainage from sanitary landfills.

In last year's report, it was pointed out that the kinds of pollutants for which there are either no controls or for which existing controls are diffuse, excessively costly, uncertain, or difficult to quantify occur in large part as a result of natural drainage which is the cause of several major "other effluent" problems. This makes it impossible to calculate and almost impossible to estimate meaningfully at present either the timing or the magnitude of necessary control costs.

Last year's report set forth the problems and possible solutions involved in controlling effects of "other effluents" to the extent that such information was available. Important contributions to this section were made by several other agencies of government, particularly the U.S. Department of Agriculture. In preparing this report, greater emphasis was placed on quantifying these problems and their remedial costs. Descriptive discussion is generally limited to summarization of last year's report or to material not included in the first report which represents a worthwhile updating contribution to this year's report. In this connection, considerable information was obtained from material prepared by an Ad Hoc Committee on Agricultural Pollution of the Office of Science and Technology.

As water quality standards relating to "other effluents" are developed further their impact on costs and technology will be assessed. Also, as greater knowledge of these problem areas is developed, these factors will be analyzed in terms of their interrelationships and the results will be reflected in future updatings of this report.

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WASTES FROM WATERCRAFT

This year's review of the watercraft wastes problem did not lead to any significant changes in the total cost estimates for correcting the problem. However, it was considered important to refine the estimation technique, to discuss some possible alternative control methods or treatment devices, and to show how the estimates were developed. Since more refined estimates must be predicated upon the cost of control devices needed to meet the effluent standards that are finally set for watercraft wastes, it is not practical to make further cost modifications at this time. Therefore, under the present circumstances it is estimated that control of pollution from watercraft wastes will cost around $660 million (compared to the $600 million estimate in the 1968 report) for equipment alone. Additional costs will be incurred in treating or disposing of the wastes but these costs cannot be estimated at this time.

Scope of the Problem

The problem of pollution from watercraft is as varied as the products and technologies of our times. Pollution of harbors, rivers, and other waters can result from vessels as large as aircraft carriers to the many smaller recreational boats which use the nation's waters. It has been determined that approximately 46,000 Federally registered commercial vessels, 65,000 unregistered commercial fishing vessels, 1,600 Federally-owned vessels and eight million recreational watercraft use the navigable waters of the United States. A complete breakdown of the types of ships involved is not available. For the purpose of estimating costs of installing pollution control equipment aboard, the figures in Table 39 were used.

As shown in Table 39, the total human pollution potential from watercraft is estimated to be equivalent to just over 500,000 persons, comparable to a city the size of Cincinnati, Buffalo, or San Diego.

At the present time, a very small percentage of the watercraft using the nation's waters are equipped with sewage treatment devices. Approximately 40 of the vessels operating on the Great Lakes and about 100 of the Coast Guard vessels are now so equipped. The Corps of Engineers has equipped, or is in the process of equipping, all of its vessels with sewage treatment devices. A very small number, if any, of the ocean going merchant vessels and tankers which use the nation's waters treat their sewage prior to discharge.

TABLE 39

SUMMARY OF UNITED STATES VESSELS
WITH SANITARY FACILITIES USING UNITED STATES WATERS, 1967

Type of Vessel	Number of Vessels	Occupancy Rate Man-Years/Year
U. S. Navy	700	134,200
U. S. Coast Guard	404	6,600
U. S. Army Corps of Engineers	321	2,900
Maritime Administration (NSTS)	170	700
Tankers	2,000	1/
Tugboats	4,000	1/
Towboats	3,900	1/
Great Lakes, Domestic	209	1/
Merchant Vessels	16,000	1/
Recreational	1,300,000 2/	170,000
Total	1,327,704	513,400

1/ Occupancy rate for all commercial vessels has been estimated to be 199,000 man-years/year.

2/ Estimated

Water Quality Standards

Most of the State implementation plans recognize that wastes from watercraft could be the source of significant pollution problems. However, few of the States have any control programs in effect although many of them are proposing legislation that would require treatment devices or holding facilities for toilet equipped boats. Other States concluded that rules and regulations concerning watercraft waste disposal could not be adopted until more uniform standards for equipment approval were available or until more acceptable treatment or disposal methods were developed.

Treatment Methods

Sewage equipment for use aboard watercraft is available in the form of holding tanks in which to collect sewage to keep it out of the waters, incinerators to burn up wastes so they no longer present a water pollution problem, biological treatment facilities to remove the bulk of the solid matter, followed by disinfection and discharge as acceptable effluent, and macerator-disinfectors that grind up the solids, dose the mixture heavily with a disinfectant, and discharge an effluent which is essentially free of harmful bacteria.

Physical characteristics of waste-handling equipment play a major role in the choice made for the different kinds of watercraft. Some general comments regarding currently available equipment follows along with Table 40, which lists the major advantages and disadvantages of the various types of equipment.

1.) Holding tanks-A holding tank is a closed container for retaining sewage on board a watercraft until it can be properly emptied, usually into an onshore sewage receiving facility. As considered in this report, a holding tank would include chemical toilets, recirculating flush toilets, and any other device which simply retains the sewage for future disposal at an appropriate site.

2.) Incinerators-A shipboard incinerator is a device designed to destroy by burning, sanitary wastes and other shipboard wastes. The heat necessary for an incinerator may be generated by electric heaters or by burning fuel oil or liquified petroleum gas.

3.) Biologic treatment systems-This type of system usually utilizes the extended aeration activated sludge process similar to that used for land-based sewage treatment although other types are available. When properly designed and operated, this type of system provides secondary treatment for the sewage. The U.S. Corps of Engineers, U.S. Coast Guard, and several commercial ship operators have installed this type of system on their vessels. At the present time there are no data available on the effectiveness of systems now operating aboard vessels. FWPCA has undertaken a program to evaluate several of these systems for the Corps of Engineers.

4.) Maceration-disinfection systems-These systems macerate the toilet wastes and mix them with a disinfection chemical before discharge into the water.

TABLE NO. 40

SUMMARY OF THE ADVANTAGES AND DISADVANTAGES
OF CURRENTLY AVAILABLE WASTE-HANDLING EQUIPMENT

System	Advantages	Disadvantages
Holding Tank	1. The device, if designed properly, completely prevents the sewage from being discharged into waters. 2. They can be adapted to various sizes and used on most vessels. 3. Minimizes mechanical or human failure	1. Large and heavy, especially if designed for prolonged use. 2. Essential shore support facilities not available in adequate numbers. 3. Odor control chemicals may be required for acceptable operation. 4. Can be pumped out in unauthorized areas unless properly designed.
Incinerator	1. Reduces wastes to a sterile ash. 2. Relatively light and requires little space.	1. Currently available electric models have high power requirements. 2. Increases fire hazards. 3. Requires exhaust stacks.
Biologic Treatment	1. Achieves secondary treatment of sewage. 2. Can adequately handle other wastes generated aboard the vessel (e.g., galley, laundry, and shower wastes).	1. Large and heavy. 2. Requires long retention times. 3. May be adversely affected by ship's motion. 4. Is not readily adaptable to vessels with small crews. 5. Relatively long start-up period. 6. Proper operation requires trained personnel.
Maceration-Disinfection	1. Requires little space and is light in weight. 2. Is easy to install.	1. Provides virtually no reduction in BOD or suspended solids concentration. 2. Degree of disinfection depends on frequency of toilet use. 3. Currently available models discharge identifiable sewage solids. 4. Macerator can be operated without addition of the disinfectant.
Dynamic Separation	1. Relatively small due to the short retention time during liquid phase 2. Can be started and stopped in short time periods. 3. Reduces solids to a sterile ash.	1. Depends on quick solids separation. 2. Has little effect on dissolved BOD. 3. Is not easily adaptable to small vessels due to its relatively high energy requirements.

5.) Dynamic separation disposal systems-These systems separate incoming sewage into solid and liquid phases for subsequent treatment. The separated solids may be incinerated, subjected to decomposition under heat and pressure, or accumulated in a container for disposal ashore. The liquid phase may be disinfected by: (a) addition of a hypochlorite solution, (b) chlorine generated by electrolysis of sea water, or (c) pasteurization with waste heat or electric heating elements instead of chlorinating to kill bacteria present.

The FWPCA recently requested industry to submit proposals for developing and demonstrating methods for controlling or treating wastes from various types of watercraft. Proposals were solicited either for the development of techniques or devices for on-board treatment or for storing and transferring waste products to shore-based treatment or disposal facilities. It is expected that two contracts will be awarded in the near future based on this solicitation. In addition, an application has been received from the city of Chicago for a grant to demonstrate the feasibility of extending municipal sewerage lines to a dock area and of pumping out sewage holding tanks aboard vessels.

The U.S. Coast Guard has a program under way to develop a more effective aerobic treatment plant requiring less space and weight than existing plants, making such a system more attractive for shipboard use. A prototype, designed for installation aboard a vessel having a 75-man crew, is currently being evaluated. After a land-based evaluation, the treatment system will be installed aboard a Coast Guard buoy tender for evaluation under shipboard conditions.

The U.S. Navy has undertaken a three-part research and development program related to shipboard waste disposal. This effort includes the development of an electro-mechanical incineratory type sewage treatment system, the evaluation of maceration-disinfection equipment, and the development of equipment to separate oil from ballast and bilge water. In addition, the Navy has awarded a contract to determine the most practical method of treating submarine sanitary waste. During FY 1969, the Navy planned to award a study contract to determine the most cost-effective method of treating surface ship wastes.

American industry also has responded to the need for adequate treatment devices for shipboard use. Several companies are devoting in-house research and development efforts towards solving this problem. Over the long term, additional research is needed to improve present concepts and to develop entirely new ones which may yield better methods. Ideally, treatment devices should require less space and weight and should require minimal attention of the watercraft operator.

Costs

The installed cost of outboard equipment for properly handling watercraft wastes varies greatly, depending upon the size of the vessel and the type of equipment required. Proposed legislation, if enacted, would direct the Secretary of the Interior to establish effluent standards for watercraft wastes. These standards will, to some extent, influence the type of equipment required and therefore the costs involved. Another factor, which at present has not been defined, is the cost involved in installing sewage treatment equipment on existing vessels.

The installation costs used here are based on the limited data available which were obtained primarily from other Federal agencies.

The U.S. Navy has tentatively estimated that the cost for implementing a program to install sewage treatment equipment on existing Navy ships, where feasible, and to provide pollution control equipment on new ships, will require approximately $253 million. The portion of this amount to be expended through FY 1974 depends upon development of the necessary equipment, promulgation of effluent or treatment standards, and appropriation of the necessary funds.

The Coast and Geodetic Survey, U.S. Department of Commerce, is estimating an expenditure of $600,000 for purchasing and installing pollution control equipment on its vessels through FY 1974. In addition, that agency estimates as an expenditure of $180,000 during this period for operation and maintenance of vessel pollution control equipment.

The Corps of Engineers is planning an expenditure of slightly more than $2 million for sewage treatment equipment aboard vessels through FY 1972. No accurate data are available on the number of commercial vessels which will require sewage treatment equipment or the cost of the equipment to be installed. For the purpose of obtaining estimated costs the following assumptions were used:

1) Average cost of equipment and installation aboard recreational watercraft - $100.

2) Average cost of equipment and installation aboard tugboats, towboats, and tankers - $3,000.

3) Average cost of equipment and installation aboard merchant vessels - $15,000.

4) Average cost of equipment and installation aboard Federally-owned Naval vessels - $361,400.

5) Average cost of equipment and installation aboard other Federally-owned vessels - $9,400.

Table 41, based on the assumptions listed above, summarizes the costs involved in equipping the nation's watercraft with sewage treatment equipment. It is not possible to determine what percentage of these funds will be expended through FY 1974. At the present time no data are available on the costs involved in the operation and maintenance of vessel pollution control equipment.

TABLE 41

ESTIMATED COST THROUGH 1974
OF EQUIPPING VARIOUS CLASSES
OF VESSELS WITH SEWAGE TREATMENT EQUIPMENT

Type of Vessel	Number of Vessels	Estimated Cost Per Vessel 1/	Total Cost (Millions)
Recreational (Equipped with sanitary facilities)	1,300,000 2/	$ 100	$130.0
Tugboats, towboats, and tankers	9,900	3,000	29.7
Merchant Vessels	16,169 2/	15,000	242.5
Navy Vessels	700	361,400	253.0
Other Federally-owned Vessels	800	9,400	7.5
		TOTAL	$662.7

1/ Estimate includes cost of equipment and installation on existing vessels.

2/ Estimated figure.

On the basis of the limited data available, it is estimated that the total cost of equipping the watercraft of this nation with pollution control equipment will be in the order of $660 million. Further refinements in this estimate can be made only after the establishment of treatment or effluent standards and after more experience is obtained in manufacturing and installing the required equipment.

EROSION AND SEDIMENTATION

This report is a summary of the erosion and sedimentation problem as delineated last year with additional data on control areas that were amenable to cost estimation.

Damages to the nation's waters from erosion-caused sedimentation are significant. Although the costs of controlling such·erosion from all sources cannot be predicted or estimated completely at this time, estimates can be made of the costs of controlling certain facets of the problem. The initial costs of controlling erosion from streambeds and roadways, have been estimated to range from $300 million to $10.0 billion. Annual erosion control costs for urban construction and roadways are estimated to range from $140 million to $1.4 billion. On the other hand, the cost of controlling erosion from agricultural lands cannot be estimated now because of the size, complexity, and lack of data concerning the problem. However, it is known that both the costs and benefits of land erosion control will be large and diverse.

Nature of the Problem

Sediment produced primarily by erosion of the land surface, is the most extensive pollutant of surface waters both because it is the greatest source of suspended solids in waterbodies and because it constitutes a loss of soil, often with damaging effects, whenever it comes to rest.

There are several principal sources of sediment. These include: (a) sheet erosion by regional surface runoff, (b) gullying, the channeling effect of runoff, (c) roadway and roadside erosion of cuts and fills, (d) erosion from construction activities such as those involved in urban and industrial development, (e) stream channel erosion, (f) flood erosion, the scouring of floodplain lands by floodflows, and (g) mining wastes and industrial wastes dumped into streams or left in positions in which they can be transported into streams by erosion.

The impact of fluvial sediment upon the nation's economy and the quality of our environment is of tremendous significance. The estimate needs refinement, but it is quite likely that sediment damages, considering the many ramifications of the problem, are well in excess of $500 million annually. In addition, the U.S. Department of Agriculture has estimated that the value of the soil resources that are lost through erosion is several times greater than the combined direct and indirect value of the sediment damages. (4)

The presence of sediment in water greatly increases the cost of making water usable. For example, capital investments in water treatment facilities are required when sediment-laden water is needed for municipal and industrial uses. The greater the amount of sediment in water used for such purposes, the greater the costs required both for removing the material and for more frequent cleaning of sedimentaion basins.

The use of water to recharge underground aquifers is another example of added costs attributable to suspended sediment. Suspended sediment clogs the aquifer pore spaces, thereby requiring outlays to clear the water before the aquifer is recharged. Water-borne and deposited sediment also damages commercial fisheries, particularly those involving shellfish, and the habitat of game fish.

Sediment also may carry harmful chemicals and minerals into the watercourses. Tests have established that salts and nutrients, particularly phosphorus, are adsorbed on sediment particles and redissolved in receiving waters after agitation of the sediment. These nutrients then become sources of enrichment which accelerate eutrophication of surface waters and lakes. Pesticide residues also may be carried by sediment and released in the stream flora and fauna. Sediment in the streams frequently hinders the oxidation of organic pollutants, thereby requiring increased treatment of municipal and industrial effluents.

Silt deposited in rivers, lakes, and reservoirs is a very costly polluting agent. The inflow of silt depletes the storage capacity of artificial reservoirs at an estimated rate of about one million acre-feet each year.(5) It is estimated that the cost associated with this annual reduction in reservoir capacity is some $100 million. In addition, about 380 million cubic yards of silt must be dredged from the nation's harbors and waterways at an estimated annual cost of $125 million.

Scope of the Problem

Sheet erosion and gullying are associated generally with agricultural lands. Because of the tremendous area involved, agricultural lands supply the greatest amount of sediment to the total load carried by the streams. Numerous measurements on plots without conservation practices have shown soil losses from land in continuous row crops ranging from 10,000 to 70,000 tons per square mile per year, depending upon the characteristics of soils, crops, tillage practices, topography and climatic factors.

There are approximately 3.7 million miles of roads in the United States.(6) Of this total, about 14% are located in municipalities and do not contribute to the erosion problem. Of the remaining roads, about 24% are primary roads and 62% are secondary and rural roads. Although erosion from primary, secondary, and rural roads is extremely active where protection from erosion has not been provided, the major erosion problem is from an estimated 470,000 miles of the secondary and rural roads.

Road construction is a large contributor to the sediment problem if erosion control is not provided. The average sediment yield during a rainstorm at highway construction sites was found to be about 10 times greater than that for cultivated land, 200 times greater than for grass areas, and 2,000 times greater than for forest areas, depending upon the rainfall, the land slope, and the exposure of the bank.(7)(8) It has been shown, for example, that such disturbances in Scott Run Watershed in Fairfax County, Virginia, produced sediment at the rate of some 89,000 tons per square mile per year at the source and about one-half this amount was measured downstream at the gauging station.(9)

Rates of sediment production from commercial and industrial construction activities in urban areas are similar to those found in road construction. For example, the Potomac River Basin discharges about 2.5 million tons of sediment into the Potomac estuary each year.(4) While agricultural lands of this basin produce the major portion of the sediment, the urban areas in and around metropolitan areas of Washington, where disturbance of the land surface by construction is intensive, produce a large share of the sediments.

Erosion is a serious problem on at least 300,000 miles of the nation's streambanks. Depending upon flow, sediment load, and other factors, sediment is either deposited on streambanks or eroded from them. Because the banks of the streams and rivers are essentially a part of the water conveyance system, material eroded from these banks is immediately available as damaging sediment. A serviceable estimate of the relationship of this load to the total sediment load is not available except in areas where specific studies have been made.

Approximately two million acres of unreclaimed or inadequately reclaimed stripmined land exist in the United States. These areas are critical sources of sediment since their sediment yields can be as much as 1,000 times that of a forest. The sediment problem from strip-mines is discussed in more detail in the mine drainage section of this report because it is closely interrelated to the acid pollution problem.

Water Quality Standards

Over two-thirds of the States discussed the problem of erosion and sedimentation in their implementation plans. Most of the plans described erosion to be a serious pollution source but generally concluded that the diverse nature of the problem made it difficult to implement full scale control programs at this time. In almost all cases the primary efforts of the States have been directed toward fostering cooperation between their pollution control programs, soil conservation agencies, and watershed management programs.

Many of the States also recognized the problem of erosion from construction sites. Here again the major effort has been in the area of working through and with other governmental agencies to encourage or require erosion control at the construction site.

In North Carolina the State Highway Commission has an extensive seeding program in connection with its projects. The State also is cooperating with the U.S. Corps of Engineers and the Soil Conservation Service of the U.S. Department of Agriculture in their programs. The State Roads Commission of Maryland has upgraded its specifications to provide more control over construction erosion. The State also cooperates with local governmental units in an effort to control urban construction erosion and with conservation agencies to control erosion from land areas.

On a broader scale that affects all States, the U.S. Bureau of Public Roads, using guidelines developed in cooperation with the Soil Conservation Service, is now requiring adequate erosion control measures during construction of new highways being built with Federal assistance. This program, of course, fits well with the present State programs of cooperation with other agencies in the elimination of erosion from construction activities.

Control Methods

Erosion prevention, where feasible, provides the most effective method for sediment control. However, in certain remote arid areas in the United States such practices would be extremely expensive while on certain construction sites this would be completely impractical.

With regard to agricultural land, the control of erosion by land management is multibeneficial, preserving land and vegetation resources and at the same time reducing sediment yield. Where practicable, and depending upon soil and climatic conditions, converting cultivated fields from row crops to contour cultivation, to small grain, or to crop rotation, may reduce soil loss from sheet erosion from 60% to 90% and may eliminate gully erosion.

Excessive sediment transport from highways can be significantly decreased by reducing the period of time during which the ground is exposed to erosion and/or preventing the sediment from making its way to waterbodies in the area. One control approach is to "treat" the exposed roadside immediately by mulching, seeding to grasses, or sodding prior to paving or final grading. Where such practices are not feasible, channels can be constructed at the outset for impounding sediment or for diverting or spreading surface runoff.

Urban development, as in the case of highways under construction, results in the loss of large quantities of sediment to receiving waters. Control measures similar to those employed in road construction can also be employed to minimize pollutional effects of urban construction. However, because of the nature of the urban construction industry it is not practicable to seed or sod during construction. Instead, it is more practical to grade construction areas to divert waters to spreading basins for debris and sediment entrapment.

The control of streambank and streambed erosion usually requires emphasis on special construction measures, including construction of stabilization structures, riprap of streambanks, inducing deposition, and sloping and vegetating of eroding banks, However, many of these measures may not be complementary to other water uses.

Control of sediment from mining operations is discussed in more detail in the mine drainage section of this report. However, prevention of sedimentation from strip mines is generally accomplished through reclamation of the land areas effected. The extent and total cost of such reclamation depend upon the use that is to be made of the land after it has been reclaimed.

Costs

The costs associated with the control of agricultural erosion cannot be estimated. The cost in many cases is minimal since it may involve only simple, inexpensive erosion control practices by land users. On the other hand, much of the gully erosion can be stopped only by filling, seeding, or damming. Such projects are more costly than merely following good land management practices. Moreover, even good land management practices may have significant hidden costs. For example, crop rotation may require the operator to plant a crop that provides a lower return per acre than single cropping. In such cases, the cost to the operator is the difference between his actual return and the return that he could have received had he planted the higher valued crop. Conversely, effective erosion control may increase the land available for productive crops and thereby increase the operator's net income.

Control of erosion from roadways may add an equivalent of $1,000 per mile of new highway and $1,000 per construction project per year. For the 470,000 miles of secondary and rural roads which require erosion control measures, it is estimated that the costs of control may range as widely as $275 to $15,000 per mile.(10) An additional $50 per mile per year would then be required for maintenance of adequate control. Therefore, the initial costs for highway erosion control may be estimated to range from $130 million to as much as $7 billion while annual maintenance cost could run around $23 million.

Control of erosion at urban construction projects is estimated to cost between $100 and $1,000 per project depending upon the size and location of the project. During 1967 there were approximately 1.3 million new housing units started, while the average number of starts for the five years ending in 1967 was somewhat over 1.4 million.(11) Assuming that housing starts account for the bulk of the acreage that is subject to erosion due to urban construction, the annual cost of erosion control on such projects can be estimated to range from $140 million to $1.4 billion.

It is estimated that costs for renovating the 300,000 miles of streambanks to minimize sediment pollution would range from $200 million to $3 billion.

As reported in the mine drainage section, the cost of a basic program to reclaim the two million acres of unreclaimed and inadequately reclaimed surface-mine land is estimated at $750 million. Additional reclamation to make the land suitable for cropland, pasture land, range land, recreation, etc., would raise the cost to at least $1.2 billion.(12) However, current information indicates that the cost of the more complete reclamation may be in excess of $2.0 billion.

From the foregoing discussion of costs it can be seen that the problem of erosion control cannot be reduced to total cost estimates at this point. Estimates of the cost of erosion control for agricultural lands are not available, while the costs of erosion control from mines are interwoven with the mine drainage problem.

This year's report again points out that correction of the mine drainage problem will require major expenditures. However, even these new estimates are extremely tentative. For example, last year's report estimated that an 80% acid pollution reduction would cost slightly over $3.0 billion and could be accomplished basically by reclamation of surface and underground mines. Since that time our research has indicated that even higher costs might be incurred. The research shows that in selected areas treatment of the mine discharges, both from operating and reclaimed mines, will be required to meet water quality standards. If we were to assume that all acid mine drainage would have to be reduced by 95%, the total cost could run an additional $4.0 billion. Based on a summation of cost estimates made by major mining States and FWPCA, it appears that mine drainage pollution abatement costs may require outlays to $7 billion. However, these cost estimates include some reclamation activities that are more extensive than would be required simply to alleviate the pollution problem.

Because of the magnitude of the mine drainage problem it is still under study. As additional studies of the entire mine situation become available, future estimates of abatement costs should be more accurate.

Although the extent of the mine drainage pollution problem in the United States has not been fully documented, a recent study by the Department of the Interior(12) was an important step in outlining the magnitude of the problem associated with surface mining. In addition, the FWPCA is conducting a number of surveys to determine further the extent of the mine drainage problem, both from surface and underground mines.

Despite a lack of comprehensive information on mine drainage, the scope of several aspects of the problem has been either documented or estimated. A review of those various aspects can be used to develop a gross estimate of the total mine drainage problem.

Nature of the Problem

Mine drainage degrades the affected waters primarily by chemical pollution and sedimentation. Acid formation and some sedimentation occur when water and air react with the sulfur bearing minerals in the mines or refuse piles to form sulfuric acid and iron compounds. The acid and iron compounds are then

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transported by the water into ponds and streams creating acid and sediment pollution problems. Most of the sedimentation, however, occurs when water erodes soil and minerals and carries them into the streams and ponds.

Damages

Although acid pollution is usually limited to coal field areas, suspended solids and sedimentation damage can extend much further downstream. Changes in the stream characteristics as a result of coal mine drainage include increased acidity, increased total hardness, and added quantities of undesirable compounds such as iron, manganese, aluminum, sulfate, and other elements and suspended materials including silt.

Damages resulting from mine drainage include degradation of municipal and industrial water supplies, reduction of recreational uses, lowered aesthetic quality of waterbodies, corrosion of boats, piers, and other useful structures, and miscellaneous adverse effects.

1) Municipal and industrial water supplies. Costly damages to water supplies are caused by increased acidity, iron, manganese, hardness, color, silt, fines, and sulfates. Additional damages from acid conditions occur from corrosion of intake facilities and other equipment.

2) Recreation. Mine drainage has a deleterious effect upon fish and related water life in streams and lakes. The increased acidity, high iron content, and silt loads either kill fish and other aquatic organisms or inhibit their growth and reproduction thus eliminating sport fishing as a recreational activity in the affected waterbodies. During 1967, over a million fish were reported killed by mine discharges,(13) ranking mine drainage as one of the primary causes of fish kills in the United States. Mine drainage polluted streams are often rendered unsuitable for swimming, boating, and other recreational activities.

3) Aesthetics. The aesthetic features of mining areas and mine polluted streams are often so impaired that property values decrease and individuals and industries are unwilling to locate at these sites. Local people lose their incentive to maintain and improve their property, intensifying the problem even further and decreasing land values. Tourists are reluctant to visit these degraded areas and their money is spent elsewhere. All of these factors result in an economic loss.

4) Corrosion. Acid corrosion causes substantial damages to navigation equipment and structures located on streams acidified by the addition of mine drainage. Corrosion of concrete, as well as metal, is the cause of significant monetary losses in operation, maintenance, and replacement of boats, barges, bridges, culverts, dams, and other structures which are in contact with the water.

5) General adverse effects. Mine drainage pollution causes a number of other adverse effects which result in damages to the local economy. Streams polluted by mine drainage are by-passed by firms as industrial sites, thereby reducing employment opportunities and sources of revenue to the local municipality. Mine drainage polluted waters are often unsuitable for agricultural uses, such as irrigation and livestock water supply.

Scope of the Problem

Total unneutralized acid drainage from both active and unused coal mines in the United States is estimated to amount to over 4.0 million tons annually. About twice this amount of acid is produced annually but roughly one half is neutralized by natural alkalinity in mines and streams. In Appalachia alone, where an estimated 75% of the coal mine drainage problem occurs(14), approximately 10,500 miles of streams are reduced below desirable levels of quality by acid mine drainage. About 6,700 miles of these streams are continuously degraded; the remainder are intermittently degraded.

In addition to the acid pollution problem, mine drainage also contributes large quantities of sediment to the nation's streams. The amount of sediment pollution is not known. However, a large part of it is known to come from surface (strip and auger) mines and some information is available as to the extent of the surface mine problem.

The analysis of the surface mining problem(12) indicated that 3.2 million acres of land in the United States had been disturbed by surface mine operations prior to January 1, 1965. Of these 3.2 million acres, approximately two million acres are either unreclaimed or only partially reclaimed. An additional 153,000 acres are disturbed each year, only part of which are reclaimed annually.

Sediment yields from strip-mined areas average nearly 30,000 tons per square mile annually - 10 to 60 times the yields of agricultural lands.(15) At this rate the two million acres of strip-mined land in need of reclamation could be the source of about 94 million tons of sediment per year. In addition to being a major source of eroded soil, strip-mining has been estimated to be the source of as much as one-quarter of the acid pollution problem.(16)

Characteristics of Mine Drainage

The characteristics of mine drainage depend upon the type of mineral being mined, the method of mining, and the characteristics of the material adjacent to the mined mineral. Table 42 lists the pollution problems associated with various minerals. Pollution by suspended solids is found in connection with all types of minerals, and is due primarily to the method of mining. Surface, placer, and hydraulic mining are major causes of suspended solids.

TABLE 42

POLLUTION PROBLEMS ASSOCIATED WITH MINING

Mineral	Pollution Problems
Coal	Suspended Solids, Low pH, Acidity, Iron, Hardness, Sulfate, Metals
Phosphate	Phosphate, Suspended solids
Sand & Gravel	Suspended solids
Clay	Low pH, Acidity, Iron, Hardness, Sulfate, Metals, Suspended solids
Iron	Iron, Suspended solids, Hardness
Gold	Suspended solids
Copper	Copper, Iron
Aluminum	Suspended solids, Iron, Aluminum

Even for the same mineral, drainage characteristics vary from location to location, seam to seam, mine to mine and even within the same mine. These are attributable to geology, the nature of the material, hydrology, and other factors not fully understood. Coal mine drainage is a good example of this variation. Although there is no "typical" coal mine drainage, such drainage usually falls into one of the four classes outlined in Table 43. The wide variation in chemical quality is apparent from these values. For example, pH may vary from 2.5 to 8.5 over the range of classes and sulfate content has been found to range from 500 to 10,000 milligrams per liter within a single class of mine drainage.

In addition to mine drainage, refuse piles, tailings ponds, and washery preparation residues are also important indirect sources of pollution from mining. For many minerals, such as phosphate, the pollution from processing operations exceeds that resulting directly from the mining operation. The pollution from coal mines in Indiana and Illinois, for example, stems primarily from refuse piles, tailings ponds, and preparation plants. However, no national estimates are available which show the volume or relative importance of pollution from these sources.

About 60% of the mine drainage pollution problem is caused by abandoned mines with the greatest share coming from abandoned drift (above drainage) mines. Table 44 shows the percent of acid pollution contribution by type of mine as estimated by the U.S. Bureau of Mines.

Water Quality Standards

Water quality standards submitted by states and approved by the U.S. Department of the Interior set limits on pH and mineral levels in the various stream stretches. These standards could limit pollution from active mines even though there is no specific mention of mine drainage. Even where mine drainage is a specific problem and standards have been set to control the problem, several of the States do not specify the implementation measures that would be necessary to assure compliance with the standards.

In many cases implementation plans have been impossible to develop because the major source of mine drainage is inactive mines where control measures have not been adequately developed and where the responsibility for bearing control costs cannot always be fixed. In these cases the States generally have taken the position that when adequate control measures are developed and when money is available they will then come to grips with the problem.

TABLE 43

COAL MINE DRAINAGE CLASSES

	Class I Acid Discharges	Class 2 Partially Oxidized and Neutralized	Class 3 Oxidized and Neutralized and Alkaline	Class 4 Neutralized and Not Oxidized
pH	2.5 - 4.5	3.5 - 6.6	6.5 - 8.5	6.5 - 8.5
Acidity, Mg/l ($CaCO_3$)	1,000 - 15,000	0 - 1,000	0	0
Ferrous Iron, Mg/l	500 - 10,000	0 - 500	0	50 - 1,000
Ferric Iron, Mg/l	0	0 - 1,000	0	0
Aluminum, Mg/l	0 - 2,000	0 - 20	0	0
Sulfate, Mg/l	1,000 - 20,000	500 - 10,000	500 - 10,000	500 - 10,000

Source: In-house studies, FWPCA

TABLE 44

CONTRIBUTION OF ACID POLLUTION
IN THE UNITED STATES BY TYPE OF MINE (PERCENT)

Type of Mine	Active	Abandoned	Total
Drift (above drainage)	26	48	74
Shaft and slope (below drainage)	5	5	10
Strip and auger (surface)	9	7	16
TOTAL	40	60	100

Source: U. S. Bureau of Mines In-house report, Pittsburgh, Pa., July 1968.

The implementation plans deal most often with the problem of drainage from active mines. However, for many of the States this merely means that such mine drainage problems are being handled on a case-by-case basis or that the extent of the problem is unknown and is being studied further.

Pennsylvania has the most comprehensive implementation plan which is tied to its long-term mine drainage abatement program. For active mines the State requires that all discharges be alkaline and that the iron content be less than 7.0 mg./l. After these mines are abandoned the owners must prevent any future pollution. For abandoned strip mines this includes complete backfilling and planting. Abandoned mines are considered to be a public problem and are to be handled with public funds. However, funds are not available at the present time to deal with this problem.

West Virginia also dealt with the mine drainage problem in its implementation plan. The plan requires active mines to hold a permit and permits are not issued until the State is assured that the discharged water will not pollute the receiving waters. However, the State has not developed an abandoned mine control program stating that such a program could not be developed until completion of sufficient research on control and construction costs.

The Indiana implementation plan deals with the mine drainage problem basin-by-basin. In general, the plan provides that all industries will be required to provide a degree of treatment or control that is equivalent to that required of municipalities on the same stretch of stream. This would usually be secondary treatment or its equivalent. In certain cases additional control will be required of specific mining firms by the end of 1972. The abandoned mine problem is not dealt with because of the inability to find persons who can be held financially responsible for the abandoned mines.

Control Methods

Although the ultimate method of controlling mine drainage pollution is the prevention of its formation, this method does not fully meet current needs because preventive methods have not been completely developed and shown to be effective. In the interim, treatment appears to be a generally more practical mine drainage control method, particularly in the cases of active mines, situations not amenable to preventive control, control of residual pollutants after application of prevention control measures, and mineral preparation and processing plants.

Preventive Measures

Prevention of acid and sediment drainage from surface mines is generally accomplished through renovation of the mined area. Regrading, in varying degrees, when coupled with adequate revegetation is a very effective method of mine drainage control. However, there are still technical problems which need to be solved. For example, better methods need to be found for forming and stabilizing the soil, and for developing plant species which will flourish in mined areas.

Preventive measures for mine drainage fall into three categories as outlined in the following sections. The estimated effectiveness of the various preventive methods are presented in Tables 45 and 46.

1) Reduction of oxygen availability. Oxygen is an essential element in the formation of acid mine drainage. Therefore, if oxygen can be eliminated or its concentration reduced within the mine atmosphere, mine drainage pollution will be reduced accordingly. Oxygen can be prevented from coming into contact with the acid forming material by covering the pyrites with earth or water. Both of these techniques are used with surface mines, and water (flooding) has been used on underground mines.

TABLE 45

EFFECTIVENESS OF DRIFT AND SHAFT MINE
PREVENTIVE CONTROL METHODS

Methods	Effectiveness Percent 1/	Remarks
Flooding of mine	50-90	Effectiveness depends on complete and permanent flooding of pyrites. May be a safety problem in above-drainage mines. Two types: natural flooding of below-drainage mines, and flooding of below and above drainage mines. Effectiveness depends on sound engineering and knowledge of mine.
Mine sealing to prevent water entrance	25-90 2/	Effectiveness depends on the ability to locate and seal all water passages to mine.
Mine sealing to prevent air entrance	10-60 2/	Effectiveness depends on the ability to locate and seal all air paths to mine workings.
Control and rapid removal of water within mine (active mining)	25-50 2/	Effectiveness depends on characteristics of material in mine and rate of removal.

1/ Estimated effectiveness in preventing acid pollution.

2/ Estimated values, little if any data to substantiate.

TABLE 46

EFFECTIVENESS OF SURFACE MINE
PREVENTIVE CONTROL METHODS

Method	Effectiveness Percent 1/	Remarks
Water diversion (active & inactive mines)	75-95	Effectiveness depends on ability to direct as much water as possible in a properly designed structure.
Rapid removal of water	25-75 2/	Effectiveness depends on characteristics of the spoil and the amount of time water is in contact with spoil.
Burying toxic material in final cut	50-85 2/	Effectiveness depends on characteristics of the spoil material and placement.
Flooding of toxic material in final cut	50-95	Effectiveness depends on complete and permanent covering of toxic material.
Regrading to facilitate the rapid movement of water away from workings	25-75 2/	Effectiveness depends on characteristics of the spoil and slope of land.
Revegetation (for erosion control)	10-95	Effectiveness depends on type of cover, (grass is better than trees), soil conditioning and the amount of cover.

1/ Estimated effectiveness in preventing acid pollution and erosion.

2/ Estimated values, little if any data to substantiate.

The reclamation of surface mines as soon as possible after completion of mining has been shown to be the most effective and cheapest procedure. For underground mines, oxygen also can be prevented from entering the mine by sealing mine portals, bore holes, and other cracks or openings into the mine. In addition, oxygen can be replaced in the mine with inert gases such as carbon dioxide and nitrogen.

The practical applications of the "reduction of oxygen" techniques have yet to be proven. Only covering by soil or water has been shown to be highly successful, particularly in surface and below drainage mines. A comprehensive research and development effort, initiated in 1967, is under way in this area.

2) Preventing water from entering mines. Water is another important element involved in acid mine drainage formation. Regardless of the type of mine involved, prevention of water contact with potential acid forming material provides a positive method of prevention. Contact is prevented by preventing surface drainage from entering the surface or underground mine by diversion, by surface sealing, and by improved mining systems. Diversion and/or control of underground drainage may be required.

3) Inhibiting acid formation. Chemicals such as carbonates and phosphates may reduce the reaction rates of pyrite oxidation by chemical reaction, microbiological growth inhibition, or chelation. Biological inhibitors such as bacteriophage may reduce the reaction rate by controlling the bacteria that catalyze the reaction. These techniques are in the experimental stages and require further refinement before application in the field.

Treatment

Table 47 outlines various methods suggested for treatment of mine drainage and Table 48 presents an estimate of their effectiveness. Neutralization is the method of common usage. Over 70 permits have been issued by the State of Pennsylvania for construction of neutralization facilities. The demineralization processes produce a high quality water which would probably be utilized as domestic or industrial water supplies.

Settling ponds and holding ponds are the common methods utilized for removing suspended solids from effluents of preparation plants, surface mines, and placer mines. When properly

TABLE 47

POTENTIAL TREATMENT PROCESSES FOR MINE DRAINAGE

Process	Comments	Benefits	Problem Areas
Neutralization	Process usually includes aeration and sedimentation. Lime and limestone used as alkaline agents.	Removes acidity, iron, aluminum, and manganese. Increases pH. Water less corrosive.	Does not remove hardness, sulfate. Sludge is a major problem.
Reverse Osmosis	Three basic types of modules, i.e., spiral wound, plate, and tube.	Demineralization	Requires pretreatment for removal of sediment and control of organisms. $CaSO_4$ precipitation. Brine disposal. Resulting water has low pH and is corrosive and requires post-treatment for stabilization.
Electrodialysis		Demineralization	Pretreatment to remove iron, manganese, sediment, and microorganisms required. $CaSO_4$ precipitation. Brine disposal.
Crystallization	Freezing process.	Demineralization	Brine disposal. Ice separation.
Ion Exchange	Various schemes have been proposed. Each scheme has its own operating characteristics and removes different ions.	Demineralization, possible reduction of acidity.	Determination of best ion exchange scheme. Brine disposal, regeneration, iron fouling, precipitates.
Distillation	Total dissolved solids of acid mine drainage often too low for economic removal.	Demineralization	Brine disposal. Corrosion problems

TABLE 48

EFFECTIVENESS OF MINE DRAINAGE TREATMENT

	Efficiency (Percent Removal)				
	Acidity	Iron	Sulfate	Hardness	Water Recovery
Neutralization	98-100	90-100	0	0 3/	67-90
Reverse Osmosis 1/	95-99	95-99	95-99	98-100	70-90
Electrodialysis 1/	90-95	0 2/	85-95	85-95	40-60
Crystallization	90-99	90-99	90-99	90-99	25-50
Ion Exchange	80-99	70-99	80-99	90-99	60-95
Distillation	95-99	98-100	98-100	98-100	60-80

1/ May require staging

2/ May increase

3/ May not operate at high iron and manganese concentrations designed, operated, and maintained, these methods are highly successful.

Costs

The costs associated with the control of mine drainage cannot be directly related to the water quality standards since most of the States have not developed implementation plans to assure that the standards are being met. In those States where implementation plans and criteria provided an adequate basis, the estimated costs of meeting the specific standards were used in developing the total cost estimates.

1) Unit costs. Although unit treatment costs can be estimated for each of several control methods, the probable total costs that would be associated with each of the various control methods can not be estimated. Before such estimates can be made more needs to be known about the effectiveness of each method, and the characteristics of a problem which makes it most amenable to a given treatment method.

Estimated unit costs for various control methods are presented in Table 49. Costs for neutralizing mine drainage can also be expressed as \$25-\$110 per ton of acid neutralized (average \$70).(14)

The costs for treatment per 1,000 gallons range from \$0.05 for neutralization to \$3.24 for distillation. The costs for prevention, rather than treatment, are not comparable since they are for differing units of measure. However, the costs for mine seals range from \$1,000 to \$30,000 each, surface reclamation costs range from \$125 to \$3,000 per acre, and impoundment costs range from \$350 to \$1,000 per acre-foot.

2) Total costs. A Department of the Interior study(12) has estimated that \$300 million would be needed for a limited program to reclaim the abandoned mines where stream pollution, soil conditions, and land erosion problems were judged to be most severe. The study further estimated that \$750 million would be required to eventually provide a basic reclamation program for the entire two million acres of unreclaimed and inadequately reclaimed surface-mined land.

The Commonwealth of Pennsylvania(17) estimated the cost of abating pollution from abandoned mines in that State at one billion dollars for the period through 1974. Over a longer period of time, the total cost, including that for active mines

TABLE 49

ESTIMATED UNIT COSTS FOR DRAINAGE CONTROL

	RANGE OF COST (DOLLARS)	CONTROLLING FACTORS
	-Treatment-	
Neutralization-per 1,000 gallons	0.05-1.10	Water quality, size of plant.
Reverse Osmosis-per 1,000 gallons	0.68-2.57	Size of plant.
Electrodialysis-per 1,000 gallons	0.58-2.52	Size of plant, amount of pretreatment, dissolved solids concentrate.
Crystallization-per 1,000 gallons	0.67-3.10	Freezing process, size of plant.
Ion Exchange-per 1,000 gallons	0.30-2.53	Size of plant, ion exchange scheme, dissolved solids concentration.
Distillation-per 1,000 gallons	0.33-3.24	Size of plant, type of distillation unit.
	-Prevention-	
Sealing Underground Mines-per seal	1,000-30,000	Mine opening condition, type of seal.
Cost of complete surface reclamation-including diversion, grading, planting-per acre	125-3,000	Nature of surface, and overburden, slope of land. Proposed use of land.
Impoundments-per acre-foot	350-1,000	
Inhibitory Chemicals-per acre	Unknown	Still in research phase.
Inert gases-per acre	Unknown	Still in research phase.

which may be abandoned in the future, will be two or three times this estimate.

The abatement cost for the Upper Ohio River Basin(18) has been estimated at $851 million, exclusive of costs for engineering study, design, maintenance, and other program development, costs. Total cost including these factors would exceed two billion dollars.

Some overlap exists between the Pennsylvania area and the area covered by the Upper Ohio River Basin studies. However, after taking into consideration the overlap and the areas in Maryland, West Virginia, Ohio, Kentucky, Tennessee and other States not included in these estimates, it can be conservatively estimated that over five billion dollars will be required to correct the mine drainage problem in the Appalachian Region. Up to an additional two billion dollars would probably be required to correct the problem for the remainder of the United States yielding a total estimate of almost $7 billion. Table 50, details cost estimates based upon reduction of acid in mine drainage through reclamation of underground and strip mines, treating residual acid from these reclaimed mines, and treatment of acid drainage from operating mines. The table, which does not include interest costs, shows that total estimates for reducing acid mine drainage range from $1.7 billion for 40% reduction to $6.6 billion for 95% reduction.

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TABLE 50

Estimated Cost to Reduce Acid in Mine Drainage
by 40 Percent and 95 Percent over the Next 20 Years
(Constant 1968 Dollars)

Method	Cost ($ Millions)	
	40% Removal	95% Removal
Reclaiming Stripmine Areas (Including land costs)	440	2,200
Reclaiming Underground Mines (Including sealing costs)	225	1,000
Treatment-Including Construction and Operation	900	2,800
Engineering and Administration @10%	155	600
TOTAL	1,720	6,600

Source: In-House Document, Federal Water Pollution Control Administration, U. S. Department of the Interior, July 1968.

OIL FIELD AND CHEMICAL BRINES

Oil and saline water (brine) are generally found together in the same subsurface areas. Consequently, a mixture of the oil and brine is unavoidably brought to the surface during oil production. The oil and brine are subsequently separated with the oil being forwarded through the process chain for ultimate consumer use. The brine, on the other hand, has no commercial value and therefore must be disposed of. However, proper disposal is required in order to prevent the brine from polluting fresh water supplies. In addition, other brine solutions which result from, or which are used in, chemical processes also must be properly disposed in order to avoid pollutional effects.

Annual costs of oil field brine disposal will probably fall in a range of $43 million to $758 million, depending on State disposal requirements. The chemical brine disposal costs, although probably much smaller than oil brine disposal costs, cannot be estimated at this time because data on the volumes of chemical brine produced and on the disposal methods are not available. Brine disposal from oil field operations and chemical processes could be considered in conjunction with the total industrial waste disposal problem. However, the size of the problem in relation to the uniqueness of the disposal methods and the limited geographical distribution of the problem make it more amenable to separate treatment when estimating water pollution control costs.

Nature of the Problem

Oil and gas occur in commercial amounts in restricted subsurface areas within porous sedimentary rocks. The rock layers that contain hydrocarbon deposits are water saturated throughout the remainder of the subsurface environment. In most oil fields, the water that is associated with the oil is more saline than seawater, frequently containing 300,000 milligrams per liter or more of dissolved solids. Sodium chloride is usually the major dissolved salt in oil field waters.

Calcium, magnesium, sulfate, and bicarbonate ions also frequently occur as important brine constituents and other elements such as barium and iodine may be present in significant amounts in some brines. Such brines are utilized for their mineral content by the chemical industry.

Scope of the Problem

During the initial stages of production from some oil fields, little or no oil field brine is brought to the surface with the oil. In other fields, brine is brought to the surface during the early life of the field. Generally, more brine is produced per barrel of oil as the field becomes older. Table 51, shows that almost 24 million barrels per day, or about 8.6 billion barrels (42 gallons per barrel) per year, of brine were produced along with oil during 1963.

TABLE 51

PRODUCTION AND DISPOSITION OF OIL FIELD BRINE IN THE UNITED STATES (1963)

	Quantity (barrels per day)	Percent of Total
Disposition		
Injected for Water Flood	7,821,601	33.0
Injected for Disposal	9,182,173	38.8
Unlined pits	2,796,587	11.8
Impervious Pits	21,326	.1
Streams and Rivers	1,030,869	4.4
Miscellaneous	2,829,471	11.9
PRODUCTION TOTAL	23,682,027	100.0

Source: Research Committee Interstate Oil Compact Commission, 1964, Water Problems Associated with Oil Production in the United States: Interstate Oil Compact Commission, Oklahoma City, Oklahoma.

The amount of brine produced for overall chemical industry purposes is relatively small as a national pollution problem but it can be a significant problem in localized areas. The disposal of brines used as a raw material for chemical production poses a difficult problem in some cases. For example, production of sodium bicarbonate from brines by the Solvay process requires large quantities of natural brine. The spent brine cannot be returned directly to the same stratum from which it came since it would mix with the remaining formation water and reduce its chemical quality. For this reason, extensive surface water pollution has resulted at several locations, particularly in the East Central United States. However no new Solvay process plants are being built since a more economic source of the product now appears to be available. Therefore, it is likely that this brine disposal problem will ultimately be solved by changes in production technology.

Another significant water pollution problem, occurring in areas of the Southwest, is the leakage of brines from abandoned oil and gas wells into surface and ground waters. Correcting this pollution problem can be difficult and costly. However, no reliable estimates of the total costs are currently available.

Water Quality Standards

There are few water quality standards or State implementation plans that refer specifically to brine disposal. However, many of the numerical and narrative criteria would have a direct bearing on brine disposal methods. Where the implementation plans refer to brines they generally set limits on injection pressures and on disposal points. Texas, for example, does not allow the use of pits for brine disposal. Kansas requires permits for well disposal and prohibits brine discharges to surface waters. Louisiana allows brine disposal to streams and lakes under certain conditions; however, in a few parishes any brine flow to rivers or lakes is forbidden. In these parishes the brine must be disposed to subsurface areas or permanently retained in adequate pits. In addition, most oil producing states have an agency, other than the water pollution control agency, that sets some form of pollution control requirements relating to exploration, drilling, and production. In the case of leasing State lands for oil exploration and production, the State agency will usually (if not always) include pollution control requirements in the lease.

Control Measures

The methods generally used for disposing of brine are release into surface waters, release into lined pits, release into unlined pits, and injection into porous and permeable underground strata.

Release into surface waters may be acceptable, for example, at coastal locations where the brine can be piped into saline waters.

Release into lined pits can be used for limited quantities of brine in areas where the evaporation rate is great enough to remove the water, leaving the salt to be covered over or transported away. However, this requires virtually complete separation of oil and water since even an extremely thin film of oil will significantly retard evaporation.

Release into unlined pits has been a major cause of brine pollution of surface and ground water and, therefore, is not considered an acceptable disposal method.

Injection of brine into porous and permeable underground strata that are dry or already contain saline waters is the most desirable disposal method. When properly practiced this method returns the brine to the subsurface where it originated which insures protection of fresh surface and ground water. In addition to preventing water pollution, subsurface injection can be of significant benefit to oil production when the injected water is used as a secondary recovery method for repressuring of the oil-bearing formation or for water-flooding. However, effective subsurface investigation and adequate well construction and maintenance practices must be employed to protect the subsurface from leakage or migration of the brine into adjacent or overlying fresh water aquifers.

Table 51, shows that in 1963 about 72% of the produced oil field brine was reinjected. However, at least 16% was released into unlined pits and freshwater streams. Since 1963, the Texas Railroad Commission has virtually banned the use of pits for brine disposal and this regulation, along with the tightening of disposal regulations in other States, has no doubt significantly increased the percentage of brine being injected into underground strata.

Costs

Relatively little data are available on the cost of oil field brine disposal and these data are not recent. In a rather comprehensive discussion of oil field brine disposal in California, Smith and Olson (19) reported injection disposal costs ranging from $0.12 to $2.10 per 1,000 gallons of brine, depending upon the amount of preinjection water treatment needed, the depth of rock stratum being used for injection, the volume being injected, and the injection pressure. This cost range is adequately representative of other geographic areas and is applicable to chemical brines as well as oil field brines. The cost of brine injection may be less than $0.12 per 1,000 gallons in cases where preinjection water treatment is not required and where the rock strata being used as injection intervals are shallow and permeable.

Over 30% of the oil field brine disposed of in 1963 was used as part of a secondary recovery method for oil production. (Table 51). In such cases, costs of injection cannot be solely attributed to pollution control. However, there are no available estimates as to the allocation of such costs between recovery benefits and pollution control.

As additional quantities of brine are required to be disposed of through injection or the use of pits, the total annual disposal costs will increase. For example, if all oil field brine were ultimately required to be disposed of through injection methods, the total annual costs, using the $0.12 to $2.10 range cited previously, would range from $43 million to $758 million. A more precise estimate, which cannot now be made, would show the actual total costs falling somewhere between these two figures. Costs of chemical brine disposal cannot be estimated until information is available on the volume and character of brine involved and the probable disposal methods.

POLLUTION BY OIL AND HAZARDOUS SUBSTANCES

Dumping and accidental spilling of oil and other hazardous materials continue to constitute major pollution threats to the water resources of the nation.

This report summarizes last year's discussion of the oil pollution problem and general approaches for its correction. In addition, the report also includes a discussion of problems presented by hazardous substances and the National Multiagency Contingency Plan for Oil and Hazardous Material. Although cleanup costs of accidental oil spills and oil industry expenditures for water pollution control are discussed, lack of data prevent estimation of total oil pollution control costs.

Oil industry expenditures in 1968 for water pollution control are estimated at $223 million with approximately 65% being spent in areas of production, marketing and transportation. Cleanup costs are also substantial and for accidental oil spills have ranged up to the $15 million estimated for cleanup of the Torrey Canyon oil spill. On a per unit basis, it appears that minimum cleanup costs per ton of oil on the water will be around $250 for dispersion techniques, with significantly higher costs anticipated under adverse conditions or if complete removal is desired.

Nature of the Problem

Pollution by oil and other hazardous substances may occur in any of the nation's waterways, coastal areas, or the high seas as a result of deliberate dumping, accidental spills, breaks in pipelines and storage facilities, or the breakup of transportation equipment.

Damages caused by oil pollution can be significant and diverse. Such pollution can destroy or limit marine life, ruin wildlife habitat, kill birds coming in contact with the oil, limit or destroy the recreational value of beach areas, contaminate water supplies, and create fire hazards. Damages caused by other hazardous substances can be just as significant and diverse as those caused by oil pollution. However, the sheer volume of oil transported or used makes oil pollution the largest single source of pollution of this type.

Scope of the Problem

Oil pollution may come from several different sources. A summary of the sources or potential sources of oil pollution as discussed in last year's report includes:

1) Gasoline service stations-350 million gallons of used oil disposed of annually.

2) Tank cleaning facilities-Some facilities are not equipped to treat oily wastes. The extent of oily wastes dumped into the water from such facilities is not known.

3) Industrial transfer and storage-6,000 facilities for transfer of commodities between land and water. These are possible sources of pollution spills.

4) Pipelines-200,000 miles carrying more than a billion tons of oil and hazardous substances. The pipelines cross waterways and reservoirs and are subject to cracks, punctures, corrosion, and other causes of leakage.

5) Offshore oil exploration and production-Mainly in the Gulf of Mexico, Southern California coastal waters, Cook Inlet in Alaska, the Great Lakes, and the East Coast. Potential blowout of wells, dumping of drilling muds, oil-soaked wastes, and the demolition of offshore drilling rigs by winds are significant pollution sources.

6) Waterborne sources-Shipwrecks are a prime cause and the damage can be extensive when several million gallons of pollution enter the water at one time. As can be seen in Table 52, which lists recent ship disasters, the largest spill to date was 29 million gallons in 1967 which required $15 million for cleanup with limited effectiveness.

Hazardous substances can enter the nation's waters in many of the same ways as oil. Spills caused by accidents or ruptures of containers are important sources of pollution by hazardous substances. For example, a train wreck on January 2, 1968, at Dunreith, Indiana spilled a compound that released cyanide into Bucks Creek, a tributary to the Big Blue River. The cyanide moved with the flow of the streams and an estimated 1,600 pounds passed the town of Carthage on the Blue River, downstream from the site of the accident. The cyanide caused fish kills in the affected streams, more than 25 cattle were reported killed, at least one industrial plant temporarily ceased operations, and groundwater was contaminated by the discharge from the damaged rail cars.

TABLE 52

RECENT LARGE SHIP DISASTERS
INVOLVING OIL POLLUTION

Date	Gallons of oil pollution (millions)	Area affected by the pollution	Cost of clean-up
9/67	6	Wake Island-small boat harbor and three miles of beaches	None - cleaned up by destructive typhoon action
2/68	Potential of 8.4	Potentially New York to North Carolina coastal area.	None - Ship was towed to port before serious pollution could occur
3/68	2.0 Potential of 5.7	Puerto Rico area - Recreational beaches and San Juan harbor	$2.0 million Additional cleanup costs were avoided because temperatures promoted beneficial bacterial action, and favorable winds moved the oil out to sea and dispersed it.
1967	29	Coasts of France and England	$15 million Cleanup was not considered satisfactory

Incidents similar to the cyanide spill are not uncommon and can be of tremendous importance to the affected areas. More than 2,000 spills of oil and hazardous materials of varying severity are reported each year. Other spills that go unreported now will probably be recorded as discovery and notification systems are improved. Further, the number of spills is likely to increase due to the increasing volumes of oil and hazardous materials being transported by vessels, in pipelines, by rail, and by truck.

The magnitude of each individual spill is likely to increase as the size of the carrier increases. The Universe Ireland, a ship launched in August 1968, has a cargo capacity of over 90 million gallons of oil and the construction of even larger ships is under consideration. The potential pollution from a ship of that capacity is about three times greater than that resulting from the Torrey Canyon spill.

Water Quality Standards

Oil pollution is not recognized as a significant problem by most States. Those States that mention it as a problem in their implementation plans are usually either oil producing States or States where oil tankers or barges could be potential sources of oil pollution.

Action called for in the implementation plans ranges from handling spills on an emergency basis to the Louisiana program of inspection and prevention. This program is designed to cover such potential oil pollution sources as drilling rigs, barges, pumping wells, producing wells, storage tanks and pipelines. The regulations require destruction of oil, oily wastes, and mixtures that are pollution sources in a manner sufficient to eliminate any pollutional hazard.

Control Methods

A large share of the oil pollution problem can be eliminated by preventing accidental spills and dumping. For example, last year's report stressed the abatement of pollution from shipwrecks through improved systems of navigation, guidance, and control. The report also pointed out that many of the other sources of pollution could be controlled by automatic shutdown systems, special pipeline installation, marking, more intensive preventive measures, and (when necessary) by prohibition of dumping into municipal sewer systems. It will take years of development and effort before all of the preventive measures discussed last year can be implemented. However, even when these measures are fully implemented it is unlikely that all accidental spills can be avoided.

Some of the concepts being studied to help in implementing preventive measures and for controlling pollution once it occurs are:

1) Identification-The source of many spills is unknown. Therefore, a study is planned to determine the most effective means for tagging and identifying the source of oil spilled or dumped. For example, a minute quantity of inexpensive material added to each oil shipment could be used to give it a singular identity.

2) Containment-Mechanical and pneumatic barriers to contain the floating oil and to remove such contained oil from harbors and adjacent areas are being tested.

3) Removal-The use of a large sponge roller to pick up and load spilled oil from the surface of the water is being tested. Vacuum pumps are also being used. However, the success of either method is dependent upon availability of equipment, the size of the spill, and the condition of the sea.

4) Treatment-The capabilities of biological systems to assimilate oil are being studied. Also, a full scale test project for treatment of an oil-water emulsion discharged by a steel rolling mill is under way.

Where spills do occur it is often possible to minimize the resulting damage by a quick cleanup or neutralization of the spill. In the case of the Dunreith, Indiana, cyanide spill, early action was taken to neutralize the cyanide by dumping calcium hypochlorite into the polluted area.

During the past year, a National Multiagency Contingency Plan for Oil and Hazardous Material has been developed, at the direction of the President, by the Secretary of the Interior with cooperation from the Secretaries of Transportation and Defense. This plan provides for a coordinated Federal response in cases of spills of oil or hazardous material. It makes the mobilization of Federal and, where practicable, State and local resources possible so that action can be taken when and where necessary without funding and jurisdictional problems. When fully developed, by early 1969, subsidiary plans within the framework of the national plan will be available for all of the nation's coastal and navigable inland waters.

Costs

The effect of water quality standards on costs of pollution control cannot be estimated in a meaningful way at present. Costs associated with control of pollution at the sources cannot be estimated until information on the number of potential sources and the probable control measures can be developed. However, an indication of the magnitude of the pollution control expenditures that will be required is included in a survey sponsored by the American Petroleum Institute.(1) This survey includes responses from 35 companies that process over 97% of all the crude oil refined in the United States. According to the survey, an estimated capital outlay of $222.7 million was planned for all types of water pollution control in 1968. In 1967, approximately 65% of the expenditures were in areas such as production, transportation, and marketing, in contrast to 35% for expenditures related to processing.

In addition to expenditures for pollution control, major costs can also be incurred when large, accidental spills occur. It was estimated, for example, that the generally acknowledged inadequate cleanup of the Torrey Canyon oil spill cost around $15 million.

In the case of accidental spills, the cleanup costs and the costs in terms of damages to wildlife, property, beaches, recreational uses, and water supplies can often run into the millions of dollars. However, the random nature of such spills makes it impossible to predict the size, location, season, or any of the other factors that may affect their control or cleanup costs.

Despite the unpredictability of accidental spills, minimum cleanup costs can be estimated on a per unit basis. In situations where dispersion of the oil might be an acceptable cleanup method, costs per ton of oil would be in the range of $250. If conditions are not ideal, or if the oil reaches high value shorelines and recreational areas, the cost of the cleanup operations can become considerably higher. For example, a recent 86,000 gallon spill in San Diego Bay involved cleanup costs of about $1,250 per ton of oil discharged.

In the past the responsibility for cleaning up oil spills after ship disasters has not generally been fixed and the governments or affected land owners have had to bear the costs. Now, however, the tanker vessel industry is moving toward a voluntary acceptance of the responsibility for such spills. Several major oil companies have proposed a voluntary plan that would insure tanker owners for their liability in cleaning up oil spills.

The insurance would reinburse either the tanker owner or the government, within the financial limits set by the plan, for the cost of cleaning up oil spillages. These limits are proposed to be the lesser of $100 per gross registered ton of the vessel or $10 million. On the other hand, proposals being discussed for possible future legislative action have included liability limits for a single ship disaster of the lesser of $15 million or $450 per gross ton of the vessel. For shore installations the discussion limit has ranged up to $10 million per disaster.

FEEDLOT POLLUTION

Modern feeding methods utilizing highly concentrated feed and minimum sized confinement areas for large numbers of animals have created serious water pollution sources. Beef cattle, poultry, and swine feeding operations, along with dairy farms are the major sources of actual or potential water pollution from animal wastes.

This report summarizes the feedlot pollution problem and the current status of efforts to assess its magnitude and to estimate its abatement costs. In general, recent analyses have concluded that water pollution from animal wastes continues to be a serious and growing problem. Despite this general knowledge of the problem, there is a specific lack of information regarding such components of the problem as: the volume of wastes that actually contribute to water pollution, the amount of such wastes that can easily be removed as sources of water pollution by simple changes in feedlot location or drainage, the amounts that can best be handled by better housekeeping methods such as frequent cleaning of the lots and application of the wastes to the land, and the most practicable treatment methods to use on the remainder of the wastes.

Current research efforts are aimed at characterizing runoff in order to utilize existing treatment methods and to aid in developing new treatment processes. Therefore, some of the information lacks mentioned above will be overcome by ongoing and planned research projects, and by the site inventories of the feedlots that are now under way. When this information becomes available it will provide a more adequate basis for estimating the actual scope of the feedlot pollution problem and its remedial costs.

Nature of the Problem

When animal wastes find their way into the nation's waters they can contribute to pollution in several ways. Heavy concentrations of animal wastes in water may: (a) add excessive nutrients that unbalance natural ecological systems causing excessive aquatic plant growth and fish kills; (b) load water filtration systems with solids and thereby complicate water treatment; (c) cause undesirable tastes and odors in waters; (d) add chemicals that are detrimental to both man and animals; (e) increase consumption of dissolved oxygen which can produce stress on aquatic populations and occasionally result in septic conditions; and (f) add microorganisms that are pathogenic to animals and to man.

In the past two decades production of animal products has been increasing rapidly. The technology of this increasing production requires that animals be confined in a minimum space and fed a concentrated ration, both of which increase the pollution potential of animal wastes. The heavy concentration of wastes precludes their natural decomposition and assimilation on pastures as is the case where animals are more dispersed. The heavy concentration also makes it difficult to find nearby farmland that can use manure as an economical source of fertilizer. In addition to being heavily concentrated in small areas, wastes from concentrated feeding operations have a high oxygen demand when they are being degraded and they may contain a high proportion of roughages that are not readily biodegradable.

As shown in Table 53, the wastes of different types of livestock vary quite widely in content. Poultry wastes, for example, are lower in moisture content and more highly concentrated than are the wastes of other types of livestock. Even within the same species the composition of manure will vary widely, depending largely upon the ration's digestibility, its protein and fiber content, and the nature of its elements. Manure composition also varies because of the environment, feed additives used, and the amount of its mixing with bedding, wastefeed, or water.(20)

TABLE 53

LIVESTOCK WASTE CHARACTERISTICS1/

Parameter	Dairy Cattle	Beef Cattle	Poultry	Swine
Animal Weight (lbs)	1400	950	5	200
Manure Production (ft. 3/day)	1.3	1.0	0.0062	0.28
Manure Density (lb./ft.3)	62	60	60	62
Moisture (%)	85	85	72	82
Nitrogen (% dry solids)	3.5	3.1	5.4	3.3

1/ Fresh mixed manure and urine

Source: Hart, S. A., "The Management of Livestock Manure," Trans. ASAE 8 1965.

Scope of the Problem

The magnitude of the livestock pollution problem is primarily dependent upon the number of animals that are needed to meet the demand for their products. The average population increase in the United States is about 2.5 million people per year. At 1966 consumption rates, each additional million people will require another 172,000 beef cattle, 24,500 dairy cattle, and 433,000 hogs. Thus, it can be seen that if these consumption rates continue, the amount of animal wastes will continue to increase significantly. In addition, the trend to increased use of confined feeding and concentrated rations will add to the pollution potential of the animal wastes.

Refinement of last year's estimates of the animal feedlot problem are not feasible at this time. As more information becomes available from the States that are studying and inventorying the animal wastes pollution problem, better estimates can be made of the magnitude of the problem. Though considerable information is available on the characteristics of animal wastes as they are deposited in the feedlot, there is virtually no information on the characteristics of the seepage or runoff as it is affected by livestock density, feed, proximity to receiving waters or aquifers, intensity and duration of rainfall, ground cover, slope, and general climatic conditions.

Treatment Methods

In the past, treatment methods have been almost exclusively confined to the use of natural processes. Runoff was usually collected and held in anaerobic basins where some biological degradation occurs but the effluent remains more potent than raw municipal wastes. In some cases the runoff is also treated under aerobic conditions but research utilizing aerobic processes with forced aeration indicates that extensive handling after treatment will be required to meet water quality standards of receiving streams.(21) Thus, it may be necessary to consider application of more advanced waste treatment processes to provide a quality of effluent that will meet water quality standards. Such processes may parallel techniques utilized for treatment of municipal and high BOD industrial wastes and could include chemical treatment, denitrification, sedimentation, activated sludge, micro-screening, phosphate removal, or combinations of such treatment methods. Evidence collected so far indicates that development of a single process or system for handling animal wastes is not probable. Rather, it is concluded that a variety of management and treatment systems will have to be developed to meet the problem.(20)

Water Quality Standards

Animal wastes were included as significant pollution sources in the water quality standards of several States. In the implementation plans, discussions of handling the animal feedlot problem range from very general statements concerning control needs to specific requirements for registration of feedlots or the installation of treatment facilities.

Kansas, for example, requires that feedlots with 300 or more head of animals confined register with the Kansas State Department of Health. The feedlots are then site-surveyed to determine if they need water pollution control facilities. If the feedlot is considered a significant contributor to water pollution, Kansas law requires that detention ponds be provided to retain runoff and that the wastes from the ponds be disposed of. Approximately 900 feedlot registrations involving some 1.3 million head of livestock have been received. These lots are now being site-surveyed to determine their pollution potential.

Colorado requires feedlot operators to take all reasonable preventative measures to avoid water pollution. Such minimum measures may include sealed collection and retention ponds, adequate drainage to prevent the collection of surface waters within such enclosures, disposal of wastes, and diversion of surface runoff of drainage waters prior to contact with contaminating areas or substances. If the Colorado Water Pollution Control Commission finds preventative measures to be inadequate, feedlot operators may be required to undertake necessary measures, including installation of a treatment facility.

Costs

As additional waste treatment methods are adopted the costs of treatment will increase when compared to the natural biological processes used in the past. However, only the runoff will require extensive treatment and this is directly related to rate and intensity of rainfall and the location of the feedlot in relation to the receiving waters.

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Information on required treatments is not yet available; therefore, total costs cannot be estimated. However, an intensive effort is under way to characterize the runoff in order to utilize existing practices or develop new processes which will provide an adequate treatment for animal wastes. This information, added to the inventory information being collected, will provide a more adequate basis for estimating the pollution problem for animal feedlots and its remedial costs.

SALINITY FROM IRRIGATION

No estimates of the scope of the salinity problem or its abatement costs are made in this report. However, the report does summarize the problem, discuss the States' reactions to the problem in their implementation plans, and points out that current research and demonstration projects are setting the stage for developing estimates of abatement costs.

Nature of the Problem

Irrigation return flows can lead to increased water pollution through the buildup of salts and minerals in the waters that remain after evaporation and transpiration. The increase in salinity may take place during the downward movement of irrigation water through the soil profile and/or during sub-surface contact with soil or rocks that contain readily soluble components. Effective irrigation requires that some water be applied in excess of the evapo-transpiration requirement of the crop in order to prevent a buildup of residual salts in the root zone. If an effective salt balance is not maintained there will be a resulting reduction in crop yield or an eventual inability of the soil to sustain a particular irrigation program. The leaching of fertilizers can also be a significant source of pollution unless properly applied and suited to the crop needs.

Water Quality Standards

Several States discussed the irrigation return flow problem in their implementation plans but most of the States concluded that economically feasible control measures are not presently available. The States, in general, are studying, inventorying, or monitoring the problem and encouraging water conservation practices to reduce the severity of the problem.

The water conservation practices most frequently considered are: reduction of seepage losses in transporting irrigation water from the point of diversion to the place of use; improvement in the efficiency of irrigation practices; selectivity in the development of irrigable lands to minimize the contact of excess water with highly mineralized soil and rocks; and greater efficiency in the application and utilization of fertilizers.

Costs

A further review of the pesticide and irrigation return flow problems since last year's report provided no basis for setting forth new estimates of abatement costs.

Research

Salinity is the most serious water quality problem in the Colorado River Basin. Like many streams in the arid West, the Colorado River displays a progressive increase in both salt loads and concentration as the water moves downstream from the headwaters areas of the upper basin to Imperial Dam in the lower basin. Federal and State water resources agencies, as well as the users of Colorado River water, are becoming increasingly concerned about the growing magnitude of the salinity problem. The Colorado River Basin water quality control project of the FWPCA has been making detailed studies of the salinity problem for the past several years. The project will complete by the end of FY 1969 a comprehensive report which will provide detailed information on salt loads and concentration, causes of salinity increases, its effect on water uses, its economic impact, and technical possibilities for salinity control.

At the beginning of FY 1968, the FWPCA and the Bureau of Reclamation initiated joint salinity control reconnaissance and demonstration studies in the upper basin. In addition, the FWPCA is currently sponsoring several other salinity control research and demonstration projects which are being carried out by local groups and universities. These projects will make major contributions toward the development of salinity control measures.

Research and demonstration projects of the type described above, together with related technical investigation, must be completed and expanded as necessary in order to develop a sound basis for estimating the cost of controlling and minimizing salinity problems.

No additional information regarding the scope of the pesticide water pollution problem or its abatement costs has been developed in the past year. However, the implementation plans of a few States mentioned pesticides as water pollutants but most of the plans indicated that the problem was still in the study and evaluation stage.

Of the states actively regulating pesticides, the New Mexico Department of Agriculture licenses commercial applicators of pesticides under the State's Pesticide Applicator Law. To obtain a license, applicators must demonstrate their knowledge and ability to properly use pesticides and they must be bonded. In Oklahoma, the State Department of Agriculture licenses commercial pesticide applicators, supervises application of pesticides, and maintains laboratory facilities for pesticide analysis. In addition, the States usually require that the pesticides used meet Federal or State labeling standards.

Research is being carried out by governmental and private agencies in an effort to develop pesticides that will not be sources of water pollution. Other research is aimed at quantifying the problem and determining abatement measures that can be taken until new pesticides or substitutes are developed.

RADIOACTIVE INDUSTRIAL WASTES

The January 1968 report included a section on the estimated costs of treating radioactive discharges from nuclear generating plants as well as wastes produced in uranium milling operations. It is estimated that installation of waste treatment facilities for nuclear generating plants amounts to about one percent to two percent of the total cost of the plant and that operation and maintenance costs of the system account for about 0.3 percent of total generating costs. Application of these estimates to existing and planned nuclear plants through 1973 yielded estimated costs ranging from $60 million to $120 million for capital costs and about $42 million for operation and maintenance.

Total uranium milling treatment costs were estimated at $3.2 million a year over the next five years - or a total cost of about $16 million. The $16 million estimate was broken down to $13 million for operation and maintenance costs and $3 million for capital outlays.

Since the first report, no additional cost data have been developed which would justify any change in the cost estimates which were made.

NUTRIENT ENRICHMENT

The problem of nutrient enrichment arises primarily from municipal wastes and secondarily from agricultural runoff. Therefore, this problem will be discussed in the more appropriate sections in future reports. This report summarizes the nutrient enrichment problem and points out that it is largely a factor of municipal wastes.

Nature of the Problem

The problem of accelerated eutrophication, or nutrient over-enrichment of streams attributable to human activities, is an extremely difficult one. Excessive nutrient enrichment results in the prolific growth of algae and other vegetation which, in turn, exert a dissolved oxygen demand through biological degradation and thereby affect adversely the growth and death of algae. Excessive algal growth imparts undesirable tastes and odors to water supplies, releases toxins which kill animals, interferes with sandfiltering operations in water treatment plants, and reduces the recreational value of waterbodies because of the nuisance algae represent.

Significant among plant nutrients are inorganic compounds. Nitrogen and phosphorus, particularly as nitrates and phosphates, are considered to be the principal compounds involved in plant growth although research has indicated that extremely small concentrations of other elements also may be critical to the growth of aquatic vegetation under certain conditions.

Last year's report dealt largely with accelerated eutrophication resulting from agricultural runoff -- the transmission of nitrogen, phosphorus, and other nutrients by drainage from such sources as ranch lands, barnyards, and animal feedlots. The solution of this aspect of the nutrient problem appears to lie in more effective agricultural and soil conservation practices to reduce soil erosion.

Municipal wastes represent, in many cases at least, a far more important source of phosphate over-enrichment of lakes and streams. For example, the FWPCA estimates that the phosphorus contribution to the Lake Erie nutrient problem(22) is composed of 72% from municipal wastes, 17% from rural runoff, four percent from industrial wastes, and seven percent from urban runoff. Accordingly, efforts are under way to determine the most effective way to remove phosphate at municipal treatment plants.

Costs

National cost estimates of removing nutrients at municipal waste treatment plants must be developed on a case-by-case basis and, accordingly, are beyond the scope of this year's report. As erosion from agricultural lands is controlled and fertilizer applications are geared more appropriately to the soil conditions involved, the problem from agricultural runoff should be largely eliminated.

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