THE SEWAGE LAGOON: ITS SOCIAL ECONOMIC, AND PLANNING IMPLICATIONS

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I. REVIEW OF LITERATURE

In an attempt to review all of the literature pertaining to the water pollution problem posed by the discharge of municipal wastes, it was found that a great deal of information was being published ranging from daily newspapers and periodicals through text books. As a result of this great quantity of information, an attempt was made to utilize only that information submitted by the more informed sources and from governmental agencies.

During the initial research stages of this paper, correspondence with the various State Water Pollution Boards and the Department of Health, Education and Welfare proved invaluable with their suggested references and directed research. These agencies submitted a large number of pamphlets and papers as well as published speeches presented at Water Pollution Conferences. In addition to these governmental agencies, correspondence with the editors of Public Works Magazine resulted in a wealth of information concerning actual surveys and current studies as well as additional sources to be investigated.

In a review of the many publications and books on sewage disposal methods, in that portion concerning sewage lagoons, much of the material was considered inadequate and outdated. Many of the articles were full of enthusiam, but were of little professional interest. Most of the text -

books reviewed were merely cognizant of sewage lagoons, and devoted only a minimum explanation of their history of use and performance characteristics. However, most of the textbooks were published during the early periods of lagoon development.

The material most highly valued in the research of the lagoon method of sewage disposal was that submitted by the United States Public Health Service which dealt with actual performance studies of pilot projects. The State Water Control Boards of Virginia and Pennsylvania also submitted observations recorded at pilot lagoon projects. Although the number of articles discussing the inherent problems of lagoons and their doubtful (sic) future were more numerous than the articles advocating further study and use of the lagoon method, the more optimistic articles were based upon specific studies and observations. These articles, devoted to the continued use and expansion of usage were very convincing when backed up with performance figures, and were further endorsed by correspondence with state officials in the states most familiar with the lagoon system of disposal. Correspondence was received from sixteen different states, and from several departments of state government from each of the contacted states.

In summarizing this review of literature, it should be said that arguments have been presented for and against the use of sewage lagoons as sewage disposal plants. However, the articles reviewed that were based upon actual observations of pilot projects indicate a prevailing optimistic attitude on the performance and potential of the sewage lagoon system. As the author points out in this study, the lagoon system has merit, but it does present certain problems. Without more study and research, this potentially cheap and effective method of sewage disposal might be lost primarily due to poorly informed officials and engineers.

II. THE PROBLEM OF WATER POLLUTION

Water in its natural state is never really pure. As precipitation occurs, the water gathers impurities from the atmosphere. Its contact with man-made objects and man's activities add additional impurities in various forms.

Water can purify itself only to a point by natural processes, but there is a limit to what it can accomplish. Rivers, lakes and oceans can take, diffuse, and oxidize mechanically and chemically some specific quantity of certain additives, without destroying the general balance of nature involved, or making the water offensive or a health hazard to man. Yet, slightly beyond this tolerance point, the entire process becomes unbalanced. With some significant exceptions, it is the cities that are now the great offenders--they are placing a great strain on the natural resources of clean water.

Pollution is a major cause of resource waste. The real reason may be the absence of any effective use of the technology available on how to control pollution. Thus, it becomes a problem of political dynamics, and of the public authorities' willingness to deal with the cause of pollution effectively. Public controls must be used to prevent overloading--technology must be used to correct pollution that has reached the danger point.

In this era of technological progress, industrial expansion, and home building, we are experiencing a use of water never before recorded by any nation. Experts are becoming increasingly concerned about our water supplies. The reason for this concern is quite evident, when the figures are projected. In the United States, our population uses more than 300 billion gallons of water each day, and by projecting this present use, it is expected that by 1980, the population will be using all of the available water that we are able to develop.(1)

The water need in the United States is expected to increase 150% over the next 20 to 30 years. Industry alone will account for 95% of the new water needs.(2)

To meet these future requirements, it is apparent that we must fully utilize all of our existing water, and further requires the reuse of our waters over and over again. In order to reuse water, it is necessary that the water possess a usable quality maintained by adequate pollution controls.

A study conducted in 1955, categorizes the major uses(3) of water for each family, using a total of four persons per family.

Municipal and rural-domestic supplies	445 gpd	or 8%
Irrigation	2,520 gpd	or 46%
Industry (self-supplied)	2,520 gpd	or 46%

Of this total of 300 billion gallons, another survey[4] shows that of all withdrawals, 73% is taken from streams, lakes and reservoirs; 19% is obtained from fresh ground water; 8% is saline water, mostly from oceans; and about 0.1% is from reclaimed sewage.

Of that withdrawn for municipalities, approximately 10% is consumed; 60% is used for irrigation; 2% is used for industry; and the remaining 12% for miscellaneous purposes. Approximately 30% of this total is consumed and the remaining 70% returns to the streams.

A portion of the water returned to streams is contaminated and unless it is pretreated, its availability for reuse is reduced. This is essentially true of all return from municipal, domestic, industrial, and even a small percentage of that water used for irrigation purposes.

A large portion of the fluid wastes from municipalities and industries can be feasibly reclaimed, especially for uses that do not require water of the purest grades. Public health standards and industrial requirements both demand water of high chemical or bacteriological purity or both. Yet, our major centers of population and industry create ever increasing quantities and kinds of toxins and other pollutants that are indiscriminantly dumped into streams. There, they ae allowed to pollute our useable water sources.

Some of the newer pollutants have resulted from the production of chemical products. Synthetic organic chemicals often are undetected and seldom suspected. Household detergents, radioactive wastes, thermal pollution, agricultural insecticides, and even the exhaust from outboard motors add to the seriousness of the pollution problem. A very important problem is that of improving the quality of inferior waters, as well as abating and/or inhibiting pollution.

FRINGE AREA SEWAGE PROBLEMS

Not only are many of our surface waters polluted, but at times the land itself becomes polluted. In our suburban rings, we now have large acreages of septic tanks, many already beyond the carrying capacity of the land. With just a little more density, a few more subdivisions, and a large number of suburbanites will find their sewage in their cellars.

In the absence of public water and sewage systems, suburbanites are resorting to wells for water, and a variety of sewage disposal systems. The most commonly used treatment device is that of the septic tanks. Septic tanks will not work efficiently when the water table is too close to the surface, and where there is not sufficient drainage available. Soil percolation tests determine the degree of porosity, and where the soil is impermeable, the septic tanks will not operate satisfactorily.

For example, less than half of the septic tanks surveyed in a five-state area of the mid-west are working properly.[5]

It is becoming increasingly apparent to the sanitary engineers that "the only satisfactory way to dispose of domestic sewage is by public sewers with subsequent adequate treatment."[6]

An outstanding deficiency, leading to sewerage problems in fringe areas, is the lack of planning.

The New York Public Health Association Committee, studying the problem of providing public sewerage in realty subdivisions, opposed the installation of septic tanks in the built up, or potentially built up areas--regardless of soil and ground conditions. They recommend the use of septic tanks only in predominantly rural and undeveloped areas.(7)

The effects of infiltration of sewage liquids into ground water aquifiers are becoming more evident in the ground water supplies. This infiltration of sewage liquids is being drawn into the areas of pumping and thereby contaminating the sources of the ground water. In many areas previously thought to be suitable for the use of septic tanks, the ground has become saturated and water stands on the surface--contributing to the health problem as well as devaluating the surrounding properties.

If, then, septic tanks are being considered as unsatisfactory, what is the solution? There is no single or simple answer to this question. Until the time comes when each home will possess an independent sewage disposal plant,(8) thereby cutting itself off from the only remaining major link with the municipality, it will probably be necessary to join together with the neighboring households to provide a superior service--and often at a lower cost than individual septic tank treatment.

RESTRICTIVE LEGISLATION

The measures adequate for resolving the water management problem are beyond the competence or jurisdiction of private enterprises and are regional, state, national, and sometimes international in scope. The necessary jurisdiction of water management can be expected to increase.

Congress has the power, under the constitution, to control all navigable waters that are coastal, interstate, and intrastate. Under these powers, it has adopted legislation prohibiting the deposit of "any refuse matter of any kind or description whatsoever (other than that flowing from streets and sewers and passing therefrom in a liquid state), into any navigable water of the United States, or into any tributary of any water from which the same shall float or be washed into such navigable water."[9] However, it consistently has delegated the responsibility of water-pollution control to the states.

Responsibility for pollution abatement for the protection of water resources is shared by local, state, and federal agencies. Under the American tradition of community responsibility, each city and industry has a clear obligation to construct, operate, and maintain all the pollution abatement works necessary to assure that its wastes will not cause harm to others.

Water laws of the states vary widely, but legal decisions consistently support the right of riparian owners to be protected against pollution. It can be expected that the management of the projects will oppose, in some instances, the commonly accepted "rights" of individuals in the use of water. In effect, future plans will involve extensive pooling of individual rights to create a common cooperative.

The governments in the United States are poorly organized at all levels to offer the unified management and continuing planning of water resources that is required for each natural drainage basin. Local and state boundaries do not respect the watershed boundaries. The division of functions and activities among federal, state, local, and private organizations only complicates the problem.

Lyle E. Craine of the Department of Conservation, University of Michigan, states the problem as, "Actually, although federal water development agencies profess a dedication to the water management concept, they are not equipped to implement it. They possess multiple purpose authorities, but they are dominated by single service oriented clientele. Furthermore such services as municipal and industrial water supply, pollution abatement and recreation, which are increasingly important in water management programs, are peculiarly of state and local concern, and federal agencies are in no position to make the decisions necessary to integrate these into federal water management schemes. In short, no federal agency, nor the federal government itself is in a legal management program."(10)

Federal laws concerning water pollution date back many years. The first law was the Rivers and Harbors Act of 1899. This act prohibited the deposit of waste materials other than that flowing from streets and sewers in a liquid state, in or on the banks of navigable waters and their tributaries. The Oil Pollution Act following in 1924, provided for the prohibition of the discharge of oil into coastal navigable waters of the United States. Both of these acts were administered by the Department of Defense, and were primarily concerned with preventing damage to shipping.

The first major enactment was a provision in the Public Health Service Act of 1912. This provision gave authority to that service to conduct investigations of the pollution of streams and lakes by sewage and other causes. The Public Health Service carried out early research, and investigation that provided valuable information as well as establishing the basis for information and consultive services.

The first pollution control act of a comprehensive nature was the Water Pollution Control Act of 1948. This act authorized expanded activities by the Public Health Services and added to the principles of State-Federal Cooperative activities. It also provided limited federal enforcement authority and financial aid.

Further concern of the Federal government in the growing national pollution problem, was demonstrated in the Water Pollution Control Act of 1956. Many of its principles and provisions are carryovers from the Act of 1948. Under this law, the federal government assumed pollution control enforcement in areas where polluted waters endanger the health or welfare of persons in a state other than the one in which the pollution originates. The Surgeon General and Secretary of Health, Education and Welfare is empowered to take action to enforce its control. Enforcement actions have been taken in twelve interstate pollution situations to date.

The Federal responsibilities are primarily of a supporting nature--designed to assist and strengthen state programs. They include research and technical assistance on particularly difficult problems, or other resources now always available to individual state agencies. They are also charged with the promotion of coordinated interstate action and limited enforcement on interstate pollution problems. These services and grants were increased by amendments to the 1948 Act in 1956.

The 1948 Water Pollution Control Act established the principal of limited federal assistance to municipalities for the planning and construction of sewage treatment plants by authorizing annual appropriations. It initiated cooperative state-federal development of comprehensive programs. These programs have progressed to the point that preliminary data has been published for all of the nations' major river basins. Completed comprehensive programs have been adopted, and are being instituted by state agencies in fourteen drainage basins. The adoption of a comprehensive program alone does not result in pollution control, but it does allow the citizens of the basin to know and to assume their responsibilities.

One survey shows a total of six agencies designed specifically for pollution control, but many other interstate compacts are concerned with pollution control as a subordinate objective.[11]

Interstate cooperation has been further aided by the adoption of new water pollution control legislation or amendments to existing legislation by more than half the states since 1948. The improved legislation, incorporated from basic principles set forth by the Public Health Service, has resulted in stronger state programs and a more uniform, consistent approach to pollution control.

WATER POLLUTION RESEARCH

Research on the health-related aspects of pollution has a long history, beginning late in the 19th Century with the work of Pasteur, Koch, and Lister--who established that certain types of diseases were transmitted by polluted water.

The Lawrence Experiment Station of the Massachusetts State Health Department pioneered pollution research on the state level in 1886. Field studies were begun about 1910, by the Public Health Service, and in 1938, the first full scale investigation to develop an overall pollution control plan and program for a major river basin was initiated by the Corp of Engineers for the Ohio River Basin.[12]

The development of a comprehensive nationwide pollution control plan was provided for in the Water Pollution Control Act of 1948, and later as amended in 1956. This blueprint for action called for a compilation of data on pollution sources, quantities, and characteristics. It would determine agreements on desired water uses and establish standards of quality for the desired uses--and more important, it would determine treatment requirements to preserve the quality for desired uses.

Today the number of research projects and agencies conducting these projects has grown from a few projects to a total of 280 projects with expenditures of over $4 million.

TABLE NO. 1

1958 WATER SUPPLY AND POLLUTION CONTROL,

RESEARCH INVENTORY OF ACTIVE PROJECTS

Agencies	Number of projects	Percentage of projects	Cost of projects	Percentage of projects costs
Universities	205	73.2	$ 143,000	4.1
State & inter-state agencies	25	8.9	928,000	26.5
Federal agencies	23	8.2	1,878,000	53.6
Independent organizations	17	6.1	464,000	13.3
Local agencies	10	3.6	87,000	2.5
Totals	280	100.0	$4,300,000	100.0

Source: Water Supply and Pollution Control: 1958, United States Department of Health, Education, and Welfare, Public Health Service, Washington, D. C., 1960, pp. 3-5.

These projects have revealed a total of 22,000 pollution sources; 11,800 municipal sewer systems, and 10,400 independent factory outlets in the United States. An estimated 92 million people are served by sewer systems, but only 54.5 million are provided with sewage treatment facilities. Despite the reduction of pollution by existing treatment plants, untreated or inadequately treated organic sewage and wastes equivalent to those from a population of more than 150 million are still being discharged into rivers and lakes.[13]

On the basis of this preliminary data, it has been estimated that the total cost of the needed projects was about 2.5 billion dollars. In addition, each year's needs resulting from population increase and plant replacement would require construction expenditures of approximately 200 million dollars.[14]

In spite of the increased treatment plant construction rate, stream pollution remains such a problem that any gains experienced now, must be considered only as an attempt to keep abreast of new pollution created by additional growth. The Department of Commerce estimates that of the total amount of investment in water resources to be spent between now and 1975, approximately one third will be devoted to municipal sewage treatment plants. A similar outlay of funds by new industry will be necessary to abate the present and potential discharge of factory wastes.[15]

Now many of our cities have begun new treatment plants or are at present operating and expanding existing facilities. However, it is apparent that a great number of cities have not complied with their obligation to treat thëir wastes before dumping it into our streams. The reasons for this neglect or refusal have not been fully determinëd, but the main reasons may be ascribed to a lack of funds or financial ability and the need for stronger enforcement of pollution control regulations. Sewage is a liability to the community producing it, and no process of domestic sewage treatment has been developed to deliver a profit <u>per se</u>. However, the secondary benefits that could be derived from a well planned facility may prove to be an overall benefit to the municipality.

With the advent of state and federal financial aid, many cities are beginning to meet their obligation. The Federal Water Pollution Control Act is best known through its construction grants authority. This act authorizes federal aid to state, interstate, municipal or inter-municipal agencies. Individual grants cannot exceed $250,000 or 30 percent of the estimated project cost, which ever is smaller. The 1961 budget[16] contains $45 million in federal funds for this purpose.

Under this program, 2,156 projects have been approved through June 30, 1960. These projects are located in every state, including Puerto Rico and the District of Columbia. The average project serves 14,700 people and costs $480,000 and receives grants of $83,000.[17]

The present grants and enabling legislation available to cities still do not make it possible for all municipalities to participate in the pollution control programs. This inability to comply with the restrictive legislation suggests the need for additional sources of revenues for cities, additional state and federal aid, or cheaper methods of sewage treatment.

The sewage lagoon will be examined as one method of accomplishing sewage treatment at lower costs adaptable to the needs of the smaller cities.

III. SEWAGE LAGOONS

Photographs of an experimental lagoon are shown in Appendix A. These photographs illustrate how a well-managed lagoon can and should appear. The lagoon can be in the form of a single pond or cell, or it can be constructed with multiple cells or ponds. The appearance and the treatment achieved is directly related to the design and maintenance of the lagoon.

In recent years there have been many studies reporting the use and operation of sewage lagoons for both municipal sewage and industrial uses. These studies describe the varied uses, some as single stage operations, others as auxiliary treatment in connection with conventional plants, and still others as industrial wastes treatment. There are examples of outstanding successes, and others of dismal failures. During the past few years, many state and interstate organizations have joined with the United States Public Health Service to conduct studies on the lagoon system of sewage treatment to determine the most effective operating procedures and practices.

The sewage lagoon is one method of achieving treatment that is available for smaller communities who are unable for one reason or another, to achieve a conventional sewage treatment facility. Many arguments have been presented in opposition to the use of sewage lagoons. These arguments contain elements of truth. Unfortunately they have deterred many engineers who might otherwise have developed the necessary solutions to the inherent problems. In this connection, C. G. Gillespie of the California State Department of Health says:[18]

> That oxidation ponds (sewage lagoons) are not more used can be explained by their crudity compared to neat engineering structures, the unattractive green coloration of the effluent and perhaps by the fact that too few engineers are aware of the potentialities for oxidation of organic matter. Properly laid out for size and embodying a few simple details, oxidation ponds absorb and destroy the odors of sewage, leaving nothing worse than the smell of a swamp. The effluents are permanently stable with B. O. D. values as good or better than those of trickling filter effluents. As a destroyer of sewage bacteria, they possess almost unbelievable efficacy. Final overflow from ponds designed for 15 days detention will show 5-50 B. Coli per cc. compared to something like 100,000 per cc in the original sewage. Such results continue day after day and therefore will rank with or outrank, the results from chlorination in reliability.

The use of ponds or lagoons for the retention of sewage and other wastes has been practiced throughout the world for many years. The purposes for this retention was not always the same. The uses ranged from water storage and removal of suspended matter to fish propagation[19] and biochemical stabilization of organic matter. A new use is now being studied; this is an experiment to convert nutrients found in wastes into algal protoplasm which can be harvested as protein.[20]

Waste stabilization lagoons for the treatment of raw sewage have received increased interest in recent years, particularly among small communities unable to afford conventional treatment plants.

The use of stabilization ponds as a complete method of treatment is a comparatively recent innovation, beginning in 1948 with the installation at Maddock, North Dakota, based upon observations at Fessenden, North Dakota, where its accidental discovery has been functioning for a twenty year period.(21)

Fessenden, a small town in North Dakota, had installed a new sewer system. Because of the unexpected expense of the sewer construction, there were no funds available for a sewage treatment plant. As a result, the town was forced hurriedly to construct a pond at the edge of town to receive the sewage from the system. Later, upon investigation, town and state officials found a high degree of purification in the pond effluent. The reduction that had occurred in the pond was superior to any that could have been achieved by a conventional system.(22)

With the first planned installation in North Dakota in 1948, the use of the sewage lagoon has spread rapidly throughout the United States. By 1956, there were 73 lagoons in operation in the Dakotas, and their use had spread into the Missouri River drainage basin where 136 lagoons were serving more than 125,000 persons.[23]

Some of the lagoons handled raw sewage, and some received primary or secondary effluents. The size of the communities ranged from a population of 100 to 11,000. A recent survey conducted in 1959 indicates that there are approximately 700 lagoons operating throughout the United States and Canada (see Appendix B). In addition to the lagoons found in the United States, other countries have adopted the lagoon process and have attained a high degree of efficiency.[24]

The increased number of lagoons in operation and those planned reflect a growing approval of lagoons. The enlarged acceptance of this method of sewage treatment is better illustrated by the fact that between December, 1956, and December, 1958, 254 projects were approved for construction under the Construction Grants Program of Public Law 660.[25]

LAGOON PROCESS

In this modern age, we often resort to complicated procedures which result in highly technical and expensive installations in order to satisfy our needs. Actually nature can accomplish this job on nearly every type of waste, with the exception of certain kinds of industrial wastes, with very little assistance from man.

One of nature's oldest wonders is its methods of purifying sewage. It is safe, simple and inexpensive. Treatment is accomplished by providing the necessary time and sunshine to allow bacteria and algae, with the help of wind action, to stabilize the organic matter in domestic waste.

An explanation of nature's process of purification begins with the sewage flow into the lagoon. When the velocity of the flow is reduced upon entering the lagoon, the suspended solids will be deposited. Wave action induced by the wind will then disperse the solids around the lagoon. These solids plus the dissolved organic matter provide the food for nature's forces.

The bio-chemical process called "symbiosis" occurring in the lagoon is dependent upon both algae and bacteria. The algae are simple, one-celled green plants that exist in most streams. These plants and the bacteria work together in the process of purification.

The breakdown of the waste by bacteria creates carbon dioxide and the algae then convert the carbon dioxide and other nutrients into protein by photosynthesis and in the process release oxygen. Additional oxygen is supplied on the surface and is mixed into the water by wind agitation. Sunlight is necessary for photosynthesis to occur. Algae can produce more oxygen than can normally be held in the water. As a result, the water becomes super-saturated with oxygen. Because of the dissolved oxygen found in lagoon effluent, lagoon effluents are highly desirable in this respect.

The design of the lagoon determines whether or not an effluent will be discharged. It may be desirable in some areas to rely upon evaporation and percolation if the land is available to provide sufficient area to eliminate the discharge of effluent.

The effluent will possess a large amount of organic nitrogen, phosphorus, potassium and sodium. They in turn will act as further nutrients. All of these nutrients are necessary for the proper purification process to be achieved. If, for any reason, these items are lacking, as in some industrial wastes, it will be necessary to add the necessary nutrients. In industrial wastes, toxic materials may be present, requiring a neutralization process by many before the waste can be treated by natural processes.

Lagoon effluent may contain more organic matter than the original sewage. The increase in organic matter is due to algae cells and may be a liability as it can discolor the water and produce odors. However, the algae cells are not harmful and are usually utilized as food by aquatic life. Because the biochemical reactions occurring within the lagoon are under natural conditions, their rate is dependent upon the climate. During the winter the efficiency decreases, but the process increases during the summer due to the amount of sunlight or solar radiation available. The rate of decomposition is also lower in cold water than in warm water. This need not be a defect in the process, since streams run full in the winter and will dilute the effluent more than in the summer when the streams are lower.

PERFORMANCE OF LAGOONS

The use of sewage lagoons originated in sparsely populated regions where land values were relatively low and where the majority of the municipalities were of small populations.[26] These lagoons were utilized primarily as waste detention chambers. The biological action occurring in the lagoon prevented the development of nuisance. Evaporation and seepage action were relied upon to maintain the water below overflow level to prevent the contamination of surface streams. Contamination to ground water was rarely considered in the construction of lagoons because the areas where they were constructed were generally in soils of low porosity where it was assumed the seepage would have no effect upon ground water supplies.[27] Today seepage is considered undesirable in many areas due to its contamination potential.

The results of early lagoon performance soon demonstrated that they reduced pollution and that overflows of effluent from adequate facilities were not detrimental to stream life. Later lagoons were constructed allowing the overflow of effluent to surface streams when the level of purification was sufficient. This type of lagoon is being constructed more frequently than those of the retentive type.

Studies have been made concerning the biotic relationships and general processes affecting treatment in facilities of this type. They show a lack of information in certain basic design principles and further indicate a need for controlled field studies to resolve many fundamental design considerations.[28]

The study of anaerobic-aerobic ponds by Parker[29] indicated that from the standpoint of work load, the anaerobic ponds do a greater amount of work. Odors have not been a problem. As a result of Parker's study in Australia and in California, the Public Health Service has provided a grant for three years research which will serve as a continuation of an investigation of stabilization pond loadings conducted at Pullman, Washington.[30]

The specific aim of this investigation will be to determine the type of biological organisms which contribute to stabilization in anaerobic-aerobic lagoon systems at high loadings, and to relate them to the physical and chemical changes which occur in the process. The principal investigator states:[31]

> The anaerobic-aerotic type of pond has seldom been used in this country and consequently, there is a need for basic data on this combination. Although this investigation is fundamentally basic in nature, results of this study should contribute information necessary to establish a basis for designing ponds of minimum size for particular loadings, thereby improving the economics of lagoon treatment.

Herman and Gloyna[32] have developed a formula for determining pond loading volumes that considers the number of people, the B. O. D.,* the concentration of raw waste, and the temperature developed in the lagoon.

Another study by Oswald and Gotaas[33] have developed a formula to indicate the fraction of available light that could be expected to be utilized. This process is based upon intensity of solar radiation at various latitudes.

More work on solar radiation has been conducted by the United States Public Health Service[34] observing the optimum rates of loading as related to intensity of available light. This study used the Langleys-per-day-per-month basis of solar radiation and their studies "would appear to be a reasonably reliable standard."[35]

The primary objectives of the United States Public Health study in Missouri were to determine the degree of purification achieved and the development of nuisance. This study was chosen to illustrate the lagoon performance because of its late completion date. All of the study has not been released as of this date and is yet to be published.[36]

The performance that was achieved can be observed in Appendix C. It reveals that the performance, operating in a series system, was considered outstanding by all standards of measurement.

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* B. O. D. = Biochemical Oxygen Demand. The quantity of oxygen used in biochemical oxidation of organic matter in a specified time and at a specified temperature (usually five days at 20 degrees centigrade).

With the exception of cells, or ponds, with daily loadings of 60 to 100 pounds B. O. D./Acre which produced odors at periods of ice thaw, all of the ponds performed very well on a monthly basis. All ponds had average coliform-type* bacteria removals in excess of 99.99 percent.

Removal of B. O. D. averaged above 80 percent in all units; alkalinity was decreased over a range of 39 to 43 percent; nitrogen utilization varied from 94 to 98 percent of quantities contained in raw sewage; and phosphorus reduction had a range of 83 to 92 percent.

The in-series operation was determined to be more dependable for maintenance of effluent quality than the use of a single cell.

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* Formerly termed "Colon Bacilli." Harmless bacteria found in sewage, excreted by men and warm-blooded animals. Expressed in numbers of coliforms in raw or treated water.

DESIGN CHARACTERISTICS

The design characteristics of sewage lagoons must be adapted to each individual site, but the general specifications as determined by the United States Public Health Service are as follows.

Generally, the recommended loading factor is a B. O. D. loading of between 20-50 pounds/acre/day with a minimum of 100 days retention time. The loading factor determines the actual area needed for ponds on the basis of the population served.

The number of cells or ponds are dependent upon the needs of the population, the topography, the efficiency of the operation and the costs. Series operation, two or more cells working together, have proved beneficial where a high level of B. O. D. or coliform removal is important. Many lagoons provide for a flexibility of use so that units may be operated either as a series or as a parallel operation. This system has certain advantages in costs and in efficiency of operation. Construction of an in-series facility will usually entail less expense than a single cell large enough to give the desirable winter loading. For example,[37] a community with a daily waste load of 180 pounds B. O. D. could be served by two 3-acre cells where nine acres would be needed for a single cell for a 20 pound B. O. D./acre/day loading. Construction costs are also evident when considering earth moving operations in some hilly areas.

The location of sewage lagoons, like other sewage treatment facilities, depends upon many factors and each installation merits individual consideration. The factors to be considered include odors, windfree sites, costs and expansion plans. Each factor will be discussed in turn.

One of the most objectionable items related to location is that of odor. Of all the studies reviewed on performance, odor has been detected during brief spans of the lagoon operation; and with but only one exception, they have always occurred in the period of spring ice thaw. Since odors are frequently thought of in connection with the lagoon treatment process, daily observations were conducted at three pilot study plants.[(38)]

A Virginia State Water Control Board experimental project, located at Farmville, Virginia, began observations in February, 1959, that lasted through September, 1959, and reported no noticeable odors at a distance of more than 20 feet away with but one exception when odors were detected at a distance of 250 feet. The one exception occurred during an exceptionally hot and humid day with no wind.[(39)]

A United States Public Health experimental lagoon at Lebanon, Ohio, reports:[(40)]

> During the winter months, sludge accumulated on the bottom of the pond and remained relatively

inert. As water temperature increased, a continuous decrease in dissolved oxygen was noticed and by the 8th of May, no dissolved oxygen was measured. A gradual change in color from green to black occurred and the surface was covered with gas bubbles and gas-lifted solids. This condition prevailed for nine days, and although septic odors were noticed when standing on the inner slope of the dikes, no odors were detected downwind of the pond at distances greater than 100 feet.

At the Fayette, Missouri, lagoon,[41] odors were detected over a longer period because this experimental lagoon had six ponds in operation to determine the proper loading for its specific location. The ponds held within the recommended B. O. D. load limits did not produce odors. The more heavily loaded ponds produced odors detectable at some distance. Pond loadings ranged from 20 to 101 pounds per acre. Refer to Appendix C for statistical information. At the end of the testing period, a recommended loading for Fayette, Missouri, was determined to be 40 pounds B. O. D./acre/day.

As a result of these odor observations, it is obvious that the present requirements of some states prohibiting construction of lagoons at a distance ranging from 1/4 to 3/4 miles from the city limits or residential areas are overly restrictive.

The windfree site, that is, an area exposed to winds with no obstruction, is important in that the wind action upon the water agitates the water which serves to circulate the deposited solids throughout the lagoon, and by the same agitation process, mixes surface oxygen in with the water. The wind action is a very necessary part of the purifying process.

The effect of costs and expansion plans will be discussed at length in following sections.

The shape of all cells should be such as to produce a uniform perimeter. This eliminates islands, peninsulas or coves where solids could not circulate. Round, square or rectangular units with length not exceeding three times the width are considered most desirable.

Top soil is removed from lagoon sites, and the dikes are constructed from excavated material and compacted with earthmoving equipment. The soil formation should be relatively tight to avoid water losses through seepage. The Lebanon, Ohio, ponds(42) have worked with seepage problems and in one instance, because of extreme water losses, utilized a plastic membrane cover on the bottom of the pond. The specifications for the plastic cover was determined after reviewing Lauritzens' work on plastic membranes.(43)

Since the ability to maintain a permanent water level in the lagoon is a very important aspect of the lagoon design, it is necessary that the bottom and sides of the dikes should be thoroughly compacted to avoid seepage losses. In these studies, a small amount of seepage occurred in the initial stages of use, but this pond sealed itself through the effects of the settling solids.

The bottom of the pond should be level, and all plant life should be removed prior to filling with effluent. Weed growth can clog the lagoon and stop the circulation of solids. In addition, weed growth in the water and on the banks can create breeding places for mosquitoes. Greater depths may be required in summer than in winter to prevent weed growth.

The weeds can be controlled by several methods including weedicides, cutting, and sterilization of pond surfaces before filling the ponds. In the case of the Lebanon pond, the plastic covering prevented weed growth although Lauritzen(44) recommends covering the plastic bottom with soil.

The depth of the pond should be such as to allow an operating depth of two to five feet of liquid throughout the pond. A minimum water depth of two and one-half to three feet has been determined to be necessary to discourage the growth of rooted aquatic plants which encourage mosquito growth and propagation.

The inlet line should be constructed to discharge the influent upon a concrete pad to discourage bottom scouring and to locate the discharge in the center of the pond or lagoon. This location will be advantageous for the further dispersion of solids throughout the pond utilizing the wind action upon the pond.

The accumulation upon the pond bottom by sewage solids is negligible and estimates have been made indicating the pond or lagoon would require constant use for a period of over ninety years in order to fill the pond.[45]

In the construction of the dikes, attention should be given to the type of soil and the compaction of the soil in construction. The width of the dike should be enough to permit access of service vehicles. They should be seeded above the water lines with native shallow rooted grasses to prevent penetration that would allow seepage to occur in the dike.

The inside slope should range from a ratio of three or four (horizontal) to one (vertical) on smaller ponds and even flatter slopes for larger ponds. The freeboard should be sufficient to facilitate maintenance operation. Actual freeboard specifications are determined by the size of the lagoon because wave action on larger lagoons is more pronounced.

Maintenance problems of sewage lagoons divide themselves into five principal areas. They are:

1. Erosion control
2. Weed control
3. Burrowing animal control
4. Maintenance of water level control devices
5. Insect control.

However, it has been found that proper maintenance can be achieved by a single untrained city employee. Several cities utilize part time services of Park and Recreation employees.(46)

Finally, the lagoon should be surrounded by stock-type fences to prevent trespassing, and a sign signifying its use should be posted. This is to prevent its use by grazing animals as a watering hole, and also to prevent its use as a recreation area by children and adults.

SURVEY OF LAGOONS

As of June, 1959, a survey of 47 states conducted by Public Works Magazine showing those states where sewage lagoons are existing or were planned was completed and is included in Appendix B.

This survey lists the number of cities or towns using sewage lagoons together with the design data. The three states not surveyed are California, Alaska and Hawaii. Both California and Alaska are known to have sewage lagoons. Information was not received from Hawaii.

Of the forty-seven states surveyed, four do not allow lagoons; ten have not allowed any to date, but have not received requests; and the remaining thirty-three do allow lagoons under varying conditions. A total of 656 municipalities were using lagoons at the time of the survey.

North Dakota, South Dakota, and Texas have the largest number of lagoons, and the Dakota's have pioneered the development and use of lagoons since their inception with the lagoon at Fessenden.[47]

Three states require preliminary treatment prior to lagoon treatment, and B. O. D. loadings (raw sewage) are regulated in thirty states. These loading regulations of B. O. D. in pounds/acre/day vary from 15-20 pounds in Tennessee, to 60-80 pounds in Nevada. Two states required chlorination of effluent, and fourteen states gave indefinite answers, such as depends or sometimes, concerning the chlorination requirement. Only two states require fencing, Texas and Florida.

Correspondence with various State Health Departments revealed somewhat differing opinions concerning the future use of lagoons:

> We expect that the use of lagoons will increase materially in the future.(48)
>
> We believe that there are some locations in the state where waste stabilization (sewage lagoons) are the solution to the sewage problem; however, we do not feel that they can solve the needs of all communities.(49)
>
> We question whether this type of sewage disposal will be used very much in Ohio because of the extensive areas required for the ponds themselves and for isolation of the ponds.(50)

Of all states heard from, only Ohio strongly qualified acceptance of the use of sewage lagoons. This qualification, "the extensive areas required," will be discussed in detail in the following section.

The most encouraging reply was received from the Department of Health, North Dakota, which reported, "We have presently over 100 stabilization ponds or lagoons in operation in North Dakota treating waste from communities varying in size from 100 to 15,000 people designed according to our standards." This is especially significant because North Dakota is a state active in the use of lagoons, has a long history of their use, and has lower periods of solar radiation than many other states (see Appendix D).

In addition to the use of sewage lagoons solely by cities and towns for raw sewage, a great deal of consideration has been given to their use by industries for the treatment of industrial wastes.

The Public Health Service has studied this use and has published information on facilities used as the primary method of waste treatment.[51] A brief summary of these installations reveals that at least seven lagoons are used by pulp and paper industries, the most important example being located at Valdosta, Georgia.[52]

Five packing house waste lagoons were observed. Nine lagoons were reported treating dairy wastes, along with a variety of lagoons treating wastes ranging from chicken processing, canneries,[53] laundries, citrous packing plants, urea waste, petro-chemical plants and metal working plants.[54]

All of the lagoons reported satisfactory reductions. One pond handling creamery wastes reported a B. O. D. reduction of 90-95 percent after adding nitrate to maintain proper algal growths. Another plant[55] handling cannery waste reported using both an anaerobic and an aerobic pond which provided B. O. D. reductions up to 94 percent.

Because these plants for the most part have not kept performance records, they lack authoritative data relative to good design practices, but the same general factors applying to raw sewage ponds are likewise applicable to industrial waste ponds. It is expected that wastes lacking certain nutrients may interfere with conventional biological treatment and create problems, but with the addition of certain nutrients to support biological life, these problems could be overcome.

COSTS

One of the principal factors leading to the development of stabilization ponds or lagoons was the search for a low-cost method of sewage treatment. As in other forms of sewage treatment, accurate cost data are difficult to obtain. The United States Public Health Service has completed studies where the primary objectives were to provide a minimum cost method of sewage treatment with no specific concern for water reclamation. This report presented at the 29th Annual Meeting of the Federation of Sewage and Industrial Wastes Association in Los Angeles, October, 1956, listed a total of 105 ponds in North and South Dakota with their costs. This list is included in Appendix E. A table of per-capita costs average for the Dakotas have been compiled from this list. These figures are given in Table 2.

In a cost evaluation survey of 71 installations in the Missouri River Drainage Basin, the Public Health Service reported costs computed in the same manner, that is, excluding the cost of land, inlet structures and etc.[56] Here the costs ranged from $4.90 to $15.60 per capita. No average per-capita figures were given.

In addition to the Public Health Service cost evaluation studies, correspondence with various Water Pollution Boards contributed more cost data:

TABLE NO. 2

PER CAPITA COSTS FOR THE DAKOTAS

OCTOBER, 1956

State	No. Ponds	Range of Costs	Average
South Dakota	60	$4.27 - $37.94	$15.00
North Dakota	45	4.40 - 28.80	13.61

Note: Costs exclusive of pump stations, outfall sewers, and Eng. fees.

Source: W. W. Twone, A. F. Bartsch, and W. H. Davis, "Raw Sewage Stabilization Ponds in the Dakotas," Sewage and Industrial Wastes, XXIX, No. 4, (April, 1957).

In Missouri we have found that lagoons designed to serve communities of 500 to 10,000 people are constructed at an average cost of $9.84 (including land costs of $300 per acre) per capita, while comparable mechanical treatment plants are costing $41.58 per capita. During the past two years, 36 lagoons have been completed, and 40 are under construction or have been approved for construction. These lagoons are designed to serve a total population of 207,332.(57)

We do not have available tabulated costs of treatment, but as a rough estimate, we believe that raw sewage ponds can be constructed for $10 to $30 per capita, exclusive of land cost.(58)

Several states contributed more specific information regarding population served, area and costs of ponds. These figures have been tabulated in Table 3.

The following data has been submitted as a comparison of costs and treatment. In late 1958, the Public Health Service presented a study of per capita costs of constructing sewage treatment plants. This study gave gross figures for primary treatment, secondary treatment, and sewage lagoons, or stabilization ponds.

These estimates were designed to facilitate realistic engineering and financial planning by providing reliable norms for use by engineers, municipal officials, and water pollution control administrators.

There were a total of 553 projects involving new plant construction as of June 30, 1959. Only those projects were included for which the contract cost of the plant alone could be clearly identified, and only the contract cost is

TABLE NO. 3

PER CAPITA COSTS FOR SEWAGE LAGOONS

	Ripley	Belmont	Fayette	Palmyra*	Morristown**
	West Virginia		Missouri	Indiana	
Population	10,000	1,000	3,100	327	679
Area of pond (acres)	21.8	4.75	15	3.11	7.0
Cost of pond	$35,000	$30,803	$60,000	$7,672	$29,719
Per capita costs	$3.50	$20.80	$19.50	$23.46	$43.77

* Cost includes construction, fencing, 7 acres land plus easements.

** Costs include construction, lift station and Comminutor, force main pipes and 10.2 acres of land plus easements.

Source: Correspondence: Missouri, Indiana, West Virginia.

presented. The report notes that experience under the Federal Construction Grants program (Public Law 660) has demonstrated that construction contract costs represent about 80 percent of the total first cost of the sewage treatment plant. The variances of labor and material costs within the United States were correlated to a common base, the Engineering News-Record Construction Cost Index, which has received wide acceptance in the construction field. This procedure converts all data into 1913 dollars and accurately reflects the spatial differences.[59]

The conditions for this study established several standards. Primary treatment plants remove substantially all settleable solids with a B. O. D. reduction of approximately 30 to 40 percent; secondary treatment provides for the removal of substantially all settleable solids and a B. O. D. reduction of the final effluent in excess of 75 percent. A further note stated that stabilization ponds now comprise over 10 percent of the secondary type sewage treatment plants in the United States.

An additional study conducted by the Ohio Water Pollution Control Board contributes a more specific comparison as to costs and performance.

The average cost per capita for the construction of sewage treatment plants of the conventional type for villages in Ohio during the past three years has varied from

TABLE NO. 4

SEWAGE TREATMENT CONSTRUCTION COSTS

(UNITED STATES TOTAL ESTIMATED PER CAPITA COST IN 1913 DOLLARS)

	Pop. Size	Lower Limit	Exp. Value	Upper Limit	Valid Pop.Range	No. of Plants
Activated sludge	$10,100	0.83	$15.64	$22.58	500	37
	1,000	6.04	8.73	12.61		
	10,000	3.37	4.87	7.03		
	100,000	1.83	2.72	3.93	100,000	
Imhoff tanks	100	10.80	18.10	30.34	400	29
	1,000	3.64	6.10	10.22		
	10,000	1.21	2.03	3.40		
	100,000	.40	.68	1.14	10,000	
Primary settling	100	10.49	15.58	23.20	600	107
	1,000	4.99	7.42	11.05		
	10,000	2.38	3.53	5.26		
	100,000	1.13	1.68	2.50	100,000	
Trickling filters	100	11.80	17.19	25.03	500	186
	1,000	6.19	9.02	13.13		
	10,000	3.25	4.73	6.89		
	100,000	1.70	2.48	3.61	100,000	

TABLE 4--Continued

	Pop. Size	Lower Limit	Exp. Value	Upper Limit	Valid Pop.Range	No. of Plants
Trickling filters without sep.sludge digestion	100	$20.29	$27.24	$36.57	500	42
	1,000	6.38	8.57	11.50		
	10,000	2.01	2.70	3.62		
	100,000	.63	.85	1.14	25,000	
Stabilization ponds	100	1.72	3.05	5.41	200	152
	1,000	.95	1.69	3.00		
	10,000	.53	.94	1.67		
	100,000	.29	.52	.92	50,000	

Source: P. P. Rowan, K. H. Jenkins, and D. W. Butler, "Sewage Treatment Construction Costs," <u>Water Pollution Control Federation Journal</u>, XXXII, No. 6, (June, 1960).

$84.00 to $100.00 according to the degree of treatment needed to provide adequate protection to the receiving streams.

This table was based upon a study of cost records in 32 villages which have built sewage plants or started construction of plants during the 1957 to 1959 period. Costs are based on actual contracts, calculated on sewage treatment plants and do not include sewers.

TABLE NO. 5

PER CAPITA COSTS AND DEGREE OF TREATMENT
FOR CONVENTIONAL TREATMENT PLANTS

No. of Vlgs.	Per Capita Costs Range	Average	B. O. D. Reduction	Treatment
15	$59.00 - $256.00	$100.00	85 - 95%	Complete
4	75.00 - 124.00	91.00	60 - 70	Intermediate
13	48.00 - 165.00	84.00	approx. 35%	Primary

Source: Clean Waters for Ohio, Ohio Water Pollution Control Board, Columbus, Ohio, (Fall Edition, 1959).

The villages in the study above range in size from a population of 320 to 4,464. The actual costs of the various sewage plants ranged from $60,000 to $413,000, and the total costs of projects varied from $170,000 to $1,457,000.

When cost comparisons are made between septic tank systems and community treatment plants, it is not always clear why the community plant is not utilized more often. Studies by the United State Public Health Service report that the approximate average cost of septic tank installations will range from $150 to $500[60] and that average figures for community plants can be found frequently at comparable costs, although they may have a far larger cost range. However, if the community facility is more expensive in the short run, it can be designed to allow for future expansion and later adaptation to larger, more efficient systems. In addition, the peace of mind of the property owner connected to the community system should help to reduce the difference in the original costs.

As seen from the figures that have been presented reflecting the per capita costs of both conventional and lagoon methods of disposal, it is obvious that complete treatment can be achieved at lower per capita costs than that which is required for the conventional primary and/or secondary treatment plants.

A most important consideration must be given to operating costs. For the conventional plant, full time skilled technicians must be employed. Lagoons do require maintanance, but the duties required can be accomplished by a part time city worker.

Dependent upon prevailing conditions, lagoons for small cities and towns can be provided at a reasonable cost that is competitive with the septic tank and the conventional plant installation and provide equal if not superior treatment.

AESTHETICS

Large amounts of open space are essential to a well-ordered urban environment. In many forms, with many functions, open land serves people's physical and aesthetic needs. Neighborhood playgrounds, floodplains, parks, stream valleys, agricultural greenbelts and forest preserves are all important to the urban community.

Timing is the critical factor is preserving open land. No one who has tried to recover open land from more intensive use can doubt the necessity for earmarking and setting aside open spaces while they are still open. The most common methods of keeping land open are:

1. zoning for low density and intensity of use,
2. subdivision controls providing for dedication of open space,
3. purchase of development rights, a promising, but untried method of keeping land open through prevention of denser development, and
4. purchase in fee simple, a common and sure method of acquiring land for public uses.

All of these methods have been used or attempted for acquisition of open space for public use. It is suggested that the proper placement or the planned location of a sewage lagoon may well provide another means of preserving land for a future alternate use.

With proper landscaping, the lagoons can create a pleasing vista. The lagoon is not a place for active recreation, but it could provide a beautiful passive recreation area or open space to be enjoyed by its neighbors. With proper maintenance, the mowing of grass and etc., and with the placement of shrubs, bushes and small flowering trees, a lagoon can achieve an aesthetic amenity in the community. Properly fenced, it would present no hazard for children; and with some care in the design of the fence, it would appear to be a pleasantly landscaped pond, giving no indication of its true function.

The review of literature indicates that a widespread belief exists concerning odors and appearance that would make the lagoon undesirable as a neighbor. There are lagoons in operation that do emit odors periodically and may be unpleasant to observe at times, but many are in operation that have been property designed to prevent odors and properly landscaped to provide a pleasing appearance.

The photographs in Appendix A show that the Fayette, Missouri, pond offers an attractive view, and personal observation of this lagoon verifies the pleasing appearance. This lagoon utilizes a manually operated screen and a comminutor that prevents floating objects from entering the pond. The maintenance is provided by a part-time city employee who mows the grass and removes any floating objects or foam from the pond.

IV. URBAN PLANNING CONSIDERATION

Beginning at the turn of the century, when rural areas stopped growing and then began to diminish, the growth of urban areas increased at an accelerating rate. At first this growth was relatively slow, using land adjacent to the established community. But by 1950, the suburban movement was producing drastic changes in the pattern of city growth. Speculative housebuilding on new subdivisions were located in the suburbs to escape high costs and high taxes, but in recent years, the trend to locate in the suburbs has become almost a necessity.

A current inventory of vacant land would show that building plots within urban corporate limits are plentiful, but are often priced out, and in some cases, zoned out of the speculative market. There were nearly 13 million vacant lots of record in 1955, and according to the United States Census of Governments, in most cities the number of vacant lots are nearly twice that of those in use.

Increased population, better transportation, a higher standard of living, and a long period of prosperity, have brought about a major movement of the population out of the city into the suburbs. The Interstate Highway Program is also having a tremendous impact on cities and suburbs. The new roads permit commuting from greater distances, opening up new areas for development, and clearance in the rights of way has demolished thousands of homes, adding to the increased demand for buildable sites. It is paradoxical that some improvements in the city have made it easier for people to live in the suburbs.

The provision of adequate sanitary facilities for the locally dispersed development we are experiencing has caught our cities unprepared. The problem of sewage disposal alone is overwhelming. The lack of sewage disposal facilities has been designated the number two problem of more than 200 Pennsylvania cities and towns surveyed by R. A. Sigaffos of the Institute of Local Government at Pennsylvania State University,[61] surpassed only by the automobile and its associated ills.

Neither the large municipal system nor the individual household system of disposal has met the problem. With anticipated full urbanization, the filling in of all areas passed over by the initial suburban expansion, some method of disposal must be presented to fill the gap in the interstices between sparsely populated suburbs and the densely populated urban areas. This system should be able to handle the growth period from a few to a great number of people in the inevitable transition from farm land to suburb and from suburb to city. It would be desirable to design the elements of the collection system as the area is subdivided to provide for a final collection system to fit into the municipal area's planned major disposal plant.

THE LAGOON AS A PLANNING TOOL

Among the major physical facilities provided by a municipality that directly relates to City Planning are sewers and sewage treatment plants for disposing of sanitary sewage. These facilities are normally provided in response to existing or probable future development as determined by basic planning studies. Their design is determined by desired capacity, location, and needs of the anticipated population.

The provision of sewage lagoons can be a part of the planning or municipal policy designed to stimulate or inhibit development of selected areas.

The planner is vitally concerned with the implementation of the Master Plan that provides for the anticipated growth of his city. The principle means of implementation are the Zoning Ordinance, Building and Housing Codes, Urban Renewal, Capital Improvement Program, and Subdivision Regulations.

After determining the future land use plan for the community after exhaustive basic planning studies, the planner can determine where the expected population will be located. By population projections and density studies, the anticipated density of population can be estimated. To determine the needs of the expected population for a sewage disposal plant, Ernest W. Steel has developed a formula for determining the acreage requirements based upon gallons per day of settled sewage. According to the United States Geological Survey Circular 398, the average family with four persons contributes 445 gallons per day of sewage. The example given below would then be serving a population of 3500 persons.

> The required area for a city to treat 400,000 gallons/per/day of settled sewage having a 5 day B. O. D. of 13 ppm, the effluent may have a B. O. D. of 15 ppm. The loading is to be 40 pounds of 5 day B. O. D. per acre per day. The required area will be,
>
> $$\frac{400,000 \times 8.34 \times (130-15)}{1,000,000 \times 40} \doteq 9.6 \text{ acres.}$$ (62)

Although the loading will vary for communities located in various parts of the country, this formula can be used to determine the area required for a sewage lagoon tailored to existing or anticipated population. A proposed layout for a lagoon system that will enable the operation to be conducted on either a series or a parallel system is shown in Appendix F.

For the small community similar to Fayette, Missouri, with a population of approximately 14,000 persons, a single lagoon system will suffice as a permanent facility. The site for the lagoon would be selected primarily to satisfy the engineering requirements and good land use practices. The process of site selection must include a consideration of topography and a windswept area. If the

B. O. D. loadings are within the recommended limits for its particular location, the isolation of the lagoon need not present a problem as long as the lagoon is property maintained and operated. Fencing is recommended and together with proper landscaping, the lagoon would make a good neighbor for any type of land use.

In consideration of the larger cities with over 15,000 population, it must be anticipated that a sewage lagoon might eventually be replaced with a conventional treatment plant with sufficient capacity to service the entire municipal area. In this respect, planning for sewage lagoons may be developed on a subdivision basis.

Subdivision regulations provide standards for the subdivision of land within the communities planning jurisdiction. Normally the regulations specify minimum standards of development, with the requirement that all necessary improvements be installed and approved prior to the sale of lots within the subdivision. Some subdivision regulations require installation of sewage disposal systems and the dedication of "reasonable" acreages of land for public open spaces.

By using the subdivision regulations and the Capital Improvement Program, the city could require that a "reasonable" portion of land be set aside for public open spaces and for the development of a sewage lagoon. This site would be selected to conform with the Master Plan of development as well as with local topographic restrictions. By selecting the sites in this manner, a site of sufficient size may be obtained from several different subdivisions to serve the anticipated population without resorting to several small lagoon sites. For a large city, a long range plan for the sewer system would result in a smoother transition from the lagoon to a city-wide system and require fewer pumping stations and other accessory facilities.

Upon the event of obsolescence and conversion from the lagoon to a city-wide treatment system, when the conventional city system is expanded to include the area previously served by the lagoon, the lagoon could be eliminated. The land could be converted with little effort to its original form, retaining only enough land for the required pumping-station or sub-station. The remaining space would then provide sufficient area for parks, schools or other needed public facilities.

V. UTILIZATION OF WASTE LANDS

In order to overcome the objection that the proper use of lagoons requires an extensive area, it will be necessary to create an understanding of this country's existing land use situation.

In many of our communities, the spread of urban and industrial development into rural areas has been accompanied by a decline of arable acreage, uneconomically related land uses, inequities in the tax burden, excessive cost for public services, too much speculative development and a general instability of land use values.

An examination of our present land use reveals a large percentage of our cities and towns remain vacant for a variety of reasons. The vacant land exists in the form of vacant lots, land with poor drainage, land with steep slopes, land withheld for speculative reasons, land held due to title difficulties or proof of ownership, land with inflated tax rates and values, land unuseable due to poor zoning, and other waste lands. All of this vacant land, and in some cities it amounts to as much as 25% of the total developed area,[63] is very costly. The city suffers from tax losses, higher costs in providing utilities, loss of labor in time spent traveling, and a considerable intangible cost, both to the cities and their citizens.

This movement or trend of by-passing vacant areas within the city and moving out beyond present development creates many problems, both political and physical. It is suggested that, with proper study and design efforts, much of the passed-over area could be utilized by both private and public uses.

Some of the waste lands that can be utilized for sewage lagoons and other public uses are listed below:

1. Highways and their rights of way,
2. Airports and adjacent properties,
3. Floodplains,
4. Refuse disposal dumps, and
5. Abandoned strip mines.

Each type of "waste land" will be discussed separately.

HIGHWAYS AND THEIR RIGHTS OF WAYS

With our proposed 41,000 miles of super highway, averaging 300 feet of right of way and being constructed bit by bit, the land holdings in the right of way will eventually amount to approximately 2,330 square miles or 1,490,000 acres. This huge acreage will not be utilized except for two ribbons of concrete and its necessary accessory uses such as curbs, gutters, drainage ditches, and landscaping. It is conceivable that this vast amount of land could be used for the construction of sewage lagoons to serve the needs of adjoining communities.

There exists today a number of opportunities to establish public services and recreation areas along existing highways in urban and rural areas. In 1950, the United States Congress recognized the need and desirability of conserving the natural values of the roadsides and providing areas and facilities needed by the public for rest and recreation. This awareness on the part of Congress is reflected in Section 189 of Title 23 of the United States Code (as revised and enacted pursuant to the Act of August 27, 1958, 72 Stat. 885, 916):

> The construction of highways by the States with funds apportioned in accordance with Section 104 of this title may include such roadsides and landscape development, including such sanitary and other facilities as may be deemed reasonably necessary to provide for the suitable accomodation of the public, all within the highway R. O. W.

> and adjacent publicly owned or controlled rest and recreational areas of limited size and with provision for convenient and safe access thereto by pedestrian and vehicular traffic, as may be approved by the Secretary.

The intent of this statute is to provide needed public service to the populace who travel these roads. It is logical that this statute could be considered a precedent to obtaining highway right of way for use by cities for a sewage lagoon when sufficient highway right of way is available.

In reply to the question on the feasibility of a city's use of the right of way for its sewage lagoon, Mr. E. A. Stromberg, Bureau of Public Roads, wrote that:(64)

> Where Federal Aid has been used in paying part of the cost of R. O. W., no encroachment on the R. O. W. for highway use is permissible without consent of the Bureau of Public Roads. Generally speaking, the control of the R. O. W. rests with the State Highway Departments. It is possible that R. O. W. might be used for sewage lagoons as proposed in your letter. One element must be considered; impounding of water close to the highway is likely to result in a satureated roadbed which is damaging to highways. This can only be prevented by building an impervious wall or embankment.

In reference to the condition of an impervious wall or embankment, this condition can be designed into the lagoon. An earlier reference(65) to the waterproofing of lagoons by using a plastic membrane would satisfy the saturation problem under certain conditions. However, there are many areas of considerable acreage available in highway right of way where the distance from the paved highway would eliminate this problem. These areas are found most frequently in borrow pits, lowlands, between old and newly purchased right of way and in other areas unique to highway right of way purchases.

Depending upon individual state regulations concerning highway right of way, it is then possible that highway right of way could be utilized for sewage lagoons.

THE AIRPORT AND ITS ADJACENT PROPERTIES

The airport and its adjacent properties, by virtue of their function, must restrict the use of land in the aircraft approach zones for public safety. The sewage lagoon, with its need for space, its design which lends itself to flat areas, its ability to become an aesthetic asset, and the service it renders, could provide a very necessary complementary land use to the airport approach zone.

It has always been primarily the responsibility of the states and their local political subdivisions to effect the control of the use of land as may be necessary to ensure continued availability of airports to the public, and to prevent unnecessary interference with the rights and interests of the owners and the use of land in the vicinity of the airports as a result of airport operations.

The responsibility includes:[66]

1. protection of the aerial approaches against future obstruction,
2. removal of existing hazards in the vicinity of the airport,
3. to provide access to and from airports by air and ground,
4. to locate, develop and operate their airports to prevent their becoming private nuisances,

5. provide protection to persons on the ground from annoyance created by aircraft noise and lowflying aircraft.

For this purpose the C. A. A. has collaborated with the National Institute of Municipal Law Officers in drafting a Model State Airport Zoning Enabling Act. In addition, the C. A. A. while administering the federal air to airports program, is giving priority to projects involved in providing for the responsibilities listed above in the flight paths or clear zones. Federal aid to airports can contribute up to sixty-two and one-half percent of land acquisition costs that are involved in these projects.

FLOOD PLAINS

Because of recent attempts of cities to restrict the development of flood plains, the flood plains offer ideal sites for sewage lagoons by providing isolation, flat land, and being in an area to take full advantage of the natural drainage in the construction of the necessary sewers to serve the city.

Floods are consistently one of our greatest natural disasters. Each year, the flood damage is mounting, and each year more money is spent on flood control projects. This discrepancy is due to man's refusal to recognize the right of rivers to their flood plains.

One good answer to solving or halting the increase in flood damage is planning to ensure that the flood plains of our streams are used properly. This can be achieved by the use of zoning and subdivision regulations. Together, they provide an effective method of preventing the construction of dwellings in areas subject to flooding. Further restrictions would prohibit erection or construction of any structure that would impound running water, restrict the flow of water, or endanger human life. In effect, only those used which would not be extensively damaged by flood waters and those not endangering human life would be permitted to locate in the flood plain.

A logical use for this restricted area is the sewage lagoon. At periodic intervals when flooded, the pollution that would occur might be insignificant in comparison with the pollution created by the flood waters themselves. The construction of the lagoons could be either of a temporary nature if the area is frequently flooded, or of a more permanent nature if flooding is rare. Either way, the cost of periodic construction would be a very small price to pay for disposal services in comparison to the loss of life and the damages that would occur to permanent structures in the flood plain.

REFUSE DISPOSAL

Today's sanitation laws require most cities to have sanitary dumps. Because of the nature of refuse dumps, the surrounding land is commonly avoided by residential growth and other development. The sewage lagoon has proved to be a good neighbor to the refuse dump. The Fayette, Missouri, lagoon is adjacent to the refuse dump located on the same tract of city property.

There are several types of sanitary dumps. The most common sanitary dump is the sanitary land fill. It is common practice for many cities using this kind of facility to select low or swampy areas as sites and plan then to fill the dumps and later reclaim the land for other purposes.

In practice, the reclaimed land is not used for any purpose other than very small, light construction, parking areas, playgrounds, and similar uses. However, Nashville, Tennessee, has constructed a complete conventional sewage treatment over an old sanitary land fill.

The organic material in the landfill is undergoing slow decomposition, and no structure should be placed over the fill which might trap the escaping gases. In addition, a landfill dump remains very unstable for many years.

Depending upon the length of time the landfill has been completed, a sewage lagoon could be constructed over the site. Under certain conditions, a lagoon could be placed over a recent landfill with the proper precautions observed to provide adequate ventilation of escaping gases, and proper compaction of the landfill. The additional cost of providing ventilation may be warranted if the site is located at a strategic location in regards to the surrounding topography and population.

A decided economic advantage can be realized when the lagoon is operated in conjunction with the landfill process, thereby utilizing the same land tract for two separate municipal services.

ABANDONED STRIP MINES

Abandoned strip mine sites provide other potential sewage lagoon sites. In many areas of our country, there have been extensive strip mining operations that have left barren and ugly landscapes. These areas are not only aesthetic nightmares and non-productive but are unable to support any sort of plant life or ground cover for long periods of time. Although many states are now enforcing laws to force the present mine operators to leave the land in the condition it was found, many thousands of acres have already been worked and abandoned in this sterile state. Some are located in cities and suburbs; others are found in rural areas.

It is suggested that these lands when located at strategic sites be used for sewage lagoons. The site could be leveled and improved to create a system or series of lagonns for sewage disposal. Effluent from the lagoon could be utilized as irrigation water to irrigate a cover crop on the mined out area. Certain land cover crops are acid tolerant, such as certain varieties of pine trees. A crop such as this would serve a secondary purpose as a tree farm for a city beautification project.

A serious problem with abandoned strip mines is the damage that results from the exposure of these areas to air and water creating an acid drainage from the exposed areas.

This acid is the result of the mixture that occurs from air and water with sulfur compounds usually associated with coal deposits. However, the effluent from a sewage lagoon could not aggravate this condition, and the acid reaction within the pond could be prevented by using the plastic membrane liner discussed in a previous section.

This acid problem is usually associated with coal deposits; but many other minerals are also mined by this method; and many of these minerals, such as fire brick clays, do not have an associated acid problem.

Land rehabilitation by this method is a long term project and could be economically feasible even when the land is at some distance from the existing municipal limits and urbanized area.

In the examples given above, only the more obvious "waste lands" have been suggested. Each individual siting would necessarily require an exhaustive feasibility study of possible sites, costs, topography, etc. These waste lands are ordinarily found in most cities and towns, and since many communities have a need for lagoons, it should prove feasible to investigate the possibility of these sites for sewage lagoons. It is hoped that this discussion of waste lands will open the door to new ideas on the question of locating waste disposal facilities.

VI. PUBLIC HEALTH AND WATER POLLUTION CONTROL

Municipalities inherit the state laws pertaining to the welfare of the people. The municipality derives its powers from the state, and those powers are expressed in a charter. The charter establishes:

1. the form of government,
2. the powers that may be exercised, and
3. the general manner in which the powers granted may be exercised.

The charter also includes all state laws and judicial opinions that affect the structure, powers, or manner of exercising the powers of the corporation.[67]

Among the many laws that affect the citizens, and the one most directly related to the subject of sewage disposal, is that of the protection of the public health. The municipality must assume the responsibility of maintaining and protecting the health of its populace. This duty is set forth in federal and state laws, yet the compliance of the municipality is often not achieved.

By neglecting to provide adequate sewage treatment plants, the city is failing to live up to its moral obligations to its citizens and, in the case of the neighboring cities downstream, to its neighbors.

The primary function of the city is to provide a safe and healthy place to live; all other functions can only be secondary. The health and well being of the people are dependent in a large measure on effective waste disposal. This also applies to the health of those people who live downstream on the polluted stream.

It is unfortunate that sewers and disposal are not obviously or readily observed in most instances. It is always easier for an economy minded city council to completely ignore or minimize the operating budget or the necessary building funds for this facility. It is difficult for a city council to resist taking money from a department of which the public knows little and applying it to another which will produce more obvious results such as street repairs or public buildings. Perhaps it is because nothing is ever seen of the sewage system except the manhole covers, and some people may never realize that sewage disposal is a very important part of their everyday living. Yet the money which provides adequate sewage treatment could not be better spent. The health of the community cannot be purchased, only protected.

ENFORCEMENT OF ANTI-POLLUTION LAWS

There are many laws now existing that would prohibit water pollution on the state, interstate and federal levels. Most of these laws have never been rigidly enforced. Because violation is so widespread, the various state, interstate and federal agencies have been satisfied to suggest or ask for compliance rather than bring suit against the offenders. This procedure has met with some rewarding accomplishments:

> ....a decade ago, the Ohio River was everybody's repository for waste.....less than one percent of the 3½ million people along its banks provided sewage treatment. Today, 95 percent of the population is being served by treatment plants.(68)
>
> The number of Minnesota communities not providing sewage treatment has decreased from 113 to 73 since passage of pollution control in 1945. No new industry or no new sewer system has been built without provision for treatment facilities. Sewered communities have increased from 328 to 414.(69)

In spite of the voluntary compliance so evident in many areas, the growth of non-sewered communities and industries is increasing at an alarming rate. In view of this increase, the Department of Justice has sought a District Court injunction against the residents of a whole city for failure to clean up sewage discharges into the Missouri River. The suit was filed by the Department of Health, Education, and Welfare against St. Joseph, Missouri, whose citizens turned down a Department ordered bond issue to pay costs of preliminary engineering and construction of a sewage disposal plant. A great significance rests upon the outcome of this case, for if the Department of Health, Education, and Welfare's injunction is upheld, many communities who are now dragging their feet will be forced to speed up in compliance with existing laws.(70)

Not only has the federal government begun enforcement of the existing anti-pollution regulations, but the eight member states of the Ohio Valley Water Sanitation Commission has ordered seven Kentucky cities and two industries to set up timetables for completion of sewage disposal facilities. The Interstate Compact is binding since the agency was approved by eight state legislatures and ratified by congress.(71)

At the state level, another anti-pollution case now pending by a state agency is that of the Kentucky State Water Pollution Control Commission against the city of Maysville, Kentucky. Failure to comply with existing state legislation can result in large fines against the city.(72) In spite of the increasingly stringent enforcement procedures being brought to bear against our cities, it is obvious that many cities will not comply with existing legislation until they are forced to do so. This reluctance or inability to provide the needed facilities has reached a point of national disgrace. Surgeon General Leroy E. Burney stated that:[73]

> ....along some rivers, water supply intakes are so close to sewage outlets that one city takes its water chiefly from another city's waste.... on the Ohio River, where at times of low flow, the same water is used almost four times as it flows from Pennsylvania to Mississippi.

This situation poses a national health problem to this and future generations.

The Select Committee on National Water Resources has proposed a credo stating the moral obligations, rights, and privileges of all citizens and governments of this country. Adherence to this credo by all local governments would supplant the need for any legislation:[74]

> Users of water do not have an inherent right to pollute.
>
> Users of public waters have a responsibility for returning them as clean as technically possible.
>
> Prevention is as important as control of pollution.

VII. POSSIBLE LEGISLATIVE AIDS FOR LAGOON CONSTRUCTION

With the stricter enforcement of anti-pollution regulations against cities who are at present violating them, it is believed that a listing of the more important aid programs should be reviewed. The following assistance programs were selected for the acquisition of sites and construction of sewage lagoons.

The Federal Water Pollution Control Act (Public Law 660) provides funds in the form of grants to pay a portion of the construction cost of sewage treatment works.

The Housing and Home Finance Agency (HHFA) provides two sources of funds, the Community Facilities Administration and the Urban Renewal Administration. The CFA makes interest free advances to local public agencies for preparing preliminary and final plans for public non-federal works. Loans are then made available to local public agencies for the needed public facilities. The URA provides a number of aids to communities for the elimination of slums and blighted areas.

The Civil Aeronautics Administration makes grants, in-aid, generally on a 50-50 matching basis for public airport development, construction, and improvement. This includes preservation of safe areas within the flight paths.

The additional land for safety areas or approach zones could be used for lagoon sites.

Of the cited aid programs, only a few apply expressly for the purpose of sewage facilities. However, when properly planned in conjunction with airport expansion, highway planning and urban renewal, these federal aids can be realized in the planning and construction of sewage lagoons.

By using sites that can be provided by these means, the lagoon, with its high performance standards, its ability to incorporate landscaping benefits, and the advantage of not creating an obstruction or other hazard, could successfully be placed in certain areas at little or no site acquisition costs. This combination of low acquisition costs, low construction costs, and low maintenance costs, indicates a need for a new look by our cities at the sewage lagoon method of sewage disposal.

VIII. CONCLUSION

The need for sewage treatment is great, and the need is steadily increasing with our multiplying need for more and cleaner water. Because the nation's clean water supply is diminishing as a result of more people and more uses, it is only as a basic remedy that we begin to clean up our streams and ground waters so that we will eventually obtain a net increase in the amount of useable water from our streams and wells.

Many of our states have water pollution laws, and they are being enforced more rigidly each year. In addition to the individual state laws, there are in effect interstate compacts that have anti-pollution regulations. The United States Government, represented by the Department of Health, Education and Welfare, has also begun the enforcement of its laws (Public Law 660). With this pressure of law enforcement on the cities, our cities have begun to comply with the pollution laws. But in many instances, the community is unable to comply due to the cost of the needed plants, the inability to borrow due to the present debt load, because of other vitally needed civic improvements, or for other political reasons.

The increased emphasis on the public health aspects of water pollution may result in a more strict enforcement policy on existing legislation. For those cities who are reluctant to undertake the construction of the disposal plant for reasons other than financial inability, the increasing pressures from the enforcement of the existing legislation may provide the necessary impetus.

For those cities who are financially unable to provide sewage disposal facilities, the government is offering financial assistance in the form of planning loans, grants-in-aid, and long term loans.

With each consideration, the use of sewage lagoons seem to meet more and more of the requirements when the problems of the small city or suburban community are considered. The cost is relatively low; the efficiency of the lagoon is competitive; and the secondary benefits of the lagoon add greatly to the advantages for the community in later years.

Future dividends that can be realized are the abilities of the lagoon to fit into many areas now considered as waste lands, its ability to be converted at progressive stages into other uses at lower costs, the possibilities of financial gains through the utilization of lagoon sites for more than one purpose, and the ability of the lagoon to act as a planning tool in guiding the future growth of the community. The use of the lagoon may prove to be of substantial value to municipalities in terms of efficient land use and the preservation of open land for alternative future uses.

Although the sewage lagoon will not solve the needs of all cities, it can provide an economic, highly efficient disposal system for many cities.

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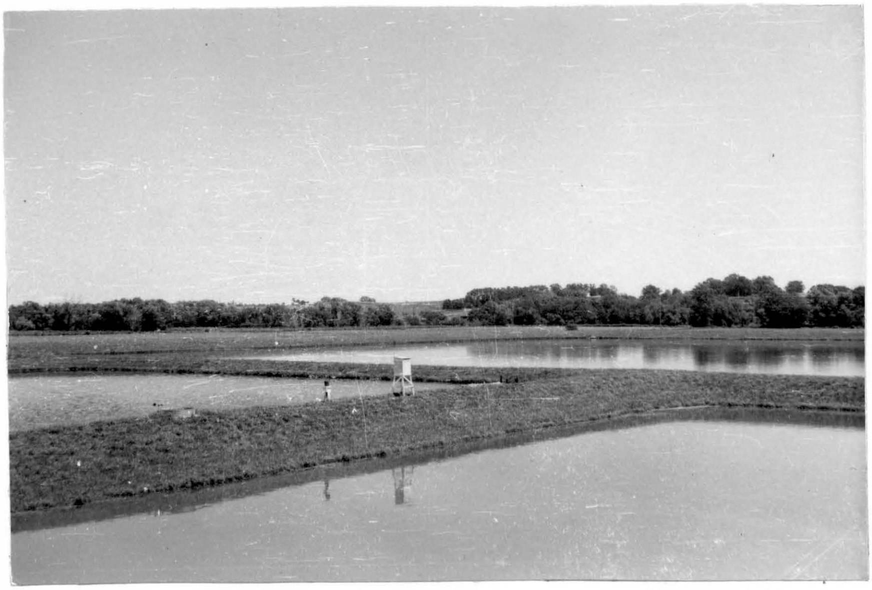
APPENDIX A

EXPERIMENTAL LAGOON AT FAYETTE, MISSOURI

1. VIEW ACROSS THE WIDTH OF THE FAYETTE SEWAGE LAGOON SYSTEM.

2. SMOKE IS FROM REFUSE DUMP IN BACKGROUND. ACCESS ROAD IS SHOWN ON DIKE.

EXPERIMENTAL LAGOON AT FAYETTE, MISSOURI



3. MEASURING GAUGES ARE PLACED ON A CENTRAL DIKE. MANHOLE COVERS INLET OPENING.

4. VIEW OF 15 ACRE POND, NOTE THE OVERALL APPEARANCE.

APPENDIX B

TABLE ________

SURVEY OF STATES
TO DETERMINE THE NUMBER AND THE DESIGN STANDARDS OF SEWAGE LAGOONS

				PRELIMINARY TREATMENT REQUIREMENTS			RAW SEWAGE LOADING PER ACRE		TREATED SEWAGE LOADING PER ACRE				
STATE	USE PERMITTED	NUMBER OF CITIES USING	SIZE LIMIT	SCREENING	COMMI-NUTION	SEDIMEN-TION	PERSONS	BOD LBS.	PERSONS	BOD LBS.	DEPTH IN FEET	CHLORI-NATION	FENCING
Alabama	Yes	2	No	No	No	No	300	50	450	50	3-5	No	Yes
Arizona	Yes	10	No	No	No	No	300	50	400	50	3 1/2-5	Sometimes	Yes
Arkansas	Yes	10	Yes	Yes	--	Yes	---	30	---	50	3-5	Sometimes	Yes
Colorado	Yes	29	No	No	No	No	100	--	---	50	3-5	No	Yes
Connecticut	No	(At least not as yet -- we are too densely populated for one thing.)								--	--	--	--
Delaware	Not so far		--	--	--	--	---	--	---	--	--	--	--
Florida	No	(Except after complete treatment.)				--	---	--	---	50	3-4	Yes	No
Georgia	Yes	None	No	No	No	No	200	35	---	--	3-5	Depends	Yes
Idaho	Yes	2	No	No	No	Depends	---	20-30	---	20-30	3-5	No	Yes
Illinois	Yes	17	No	No	No	No	120-150	20-25	180-230	20-25	3-5	Depends	Yes
Indiana	Yes	1	No	No	Desirable	No	100	20	130-140	--	2-5	Depends	Yes
Iowa	Yes	14	No	No	No	No	100	20	---	20	4-5	No	Yes
Kansas	Yes	14	No	No	No	No	---	25	---	25	3-5	No	Yes
Kentucky	Yes	None	No	(Not decided as yet)			(Standards not yet developed)				---	--	--
Louisiana	Yes	None	No	No	No	No	200	--	(Not established)		3-5	Depends	Yes
Maine	Possibly	None	--	--	--	--	---	--	---	--	--	--	--
Maryland	No specific requirement yet developed --					--	---	--	---	--	--	--	--
Massachusetts	No design standards adopted -- no such plants in use						---	--	---	--	--	--	--
Michigan	Yes	None	--	No	No	No	100	20	---	--	4-5	Depends	Yes
Minnesota	Yes	13	No	No	No	No	100	17-20	---	17-20	3-5	Depends	Yes
Mississippi	Yes	10	No	No	No	No	200	35	---	--	3-5	Depends	Yes
Missouri	Yes	--	No	No	No	No	200	34	---	34	3-5	No	Yes
Montana	Yes	38	No	No	No	No	200	18-20	(Not recommended)		5	No	Yes
Nebraska	Yes	34	No	No	No	No	150	25	250	25	3-5	No	Yes
Nevada	Yes	15	No	No	No	No	100	60-80	---	60-80	3-4 1/2	Sometimes	Yes
New Hampshire	Yes	2	Yes	No	No	No	100	17	---	--	3-5	--	Yes
New Jersey	None approved as yet			--	--	--	---	--	---	--	--	--	--
New Mexico	Yes	6	?	No	No	No	100-200	17-34	400	50	2 1/2- 3 1/2	Depends	Yes
New York	None approved as yet -- 10 state standards will be used							--	---	--	--	--	--
North Carolina	No	(Experimental unit now under trial.)				--	---	--	---	--	--	--	--
North Dakota	Yes	100	No	(This is discouraged)			---	20	---	20	3-5	No	Yes
Ohio	Not yet-	1	--	No	No	No	162	27.8	---	--	3 min.	Not yet	Yes
Oklahoma	Yes	51	Yes	No	No	No	200	30	300	30	4	No	Yes
Oregon	Yes	6	No	No	No	No	100	20	150	20	2-5	Depends	Yes
Pennsylvania	Under trial - 4 standards not yet developed.					--	---	--	---	--	--	--	--
Rhode Island	No requests received for approval.				--	--	---	--	---	--	--	--	--
South Carolina	Yes	None	No	No	No	No	300	50	---	--	3-5	No	Prefer
South Dakota	Yes	65	No	No	No	No	100	15-20	100	15-20	3-5	No	Yes
Tennessee	Yes	3	Yes	No	No	No	100	17	(No criteria)		3-5	Depends	Yes
Texas	Yes	152	No	Yes	--	Yes	(Not approved)		---	50	3-4	No	No
Utah	No	None	--	--	--	--	---	--	---	--	--	--	--
Vermont	No requests received for approval				--	--	---	--	---	--	--	--	--
Virginia	Yes	None	No	No	No	No	150	30	(No criteria)		3-5	Generally	Yes
Washington	Yes	15	No	No	No	No	350	60	---	60	3-5	Yes	Yes
West Virinia	Yes	None	No	No	No	Sometimes	200	34	300	34	3-5	No	Yes
Wisconsin	Yes	5	No	Yes	Preferred	Sometimes	100	17-20	135	17-20	3-5	No	Yes
Wyoming	Yes	27	No	No	No	No	---	30	---	30	3-5	No	Yes

• TABULATION, as of mid-1959, shows for 47 states the number of cities using Ponds and/or Lagoons, plus design data.

Source Public Works, December, 1959, Pg. 91

APPENDIX C

UNITED STATES PUBLIC HEALTH STUDY OF LAGOONS AT FAYETTE, MISSOURI

This is a brief resume of the overall results of the lagoon located in Fayette, Missouri. A more detailed description can be observed by referring to the Fayette Study which breaks down the entire operation, pond by pond.

The pilot plant consisted of five small ponds of approximately one acre each and a large pond of fifteen acres. The system was operated in series, the smaller ponds performing a primary treatment and the larger pond receiving the effluent for final treatment. Table 1 contains the average daily raw sewage load to the lagoons along with other pertinent data relative to the pilot plant.

The overall performance achieved can be determined by Table 2 which illustrates the reduction that occurred in the total system.

A tentative method for the determination of a preliminary loading figure based on solar radiation was presented, as a means of maintaining oxygen in lagoons receiving raw sewage in ice free areas. It suggests a minimum of 1.5 Langleys per day for each pound of B. O. D. per acre. To allow for a margin of safety, it is further suggested that the lowest daily average Langley figure per month be divided by two to arrive at a preliminary load estimate. It is pointed out that in areas of ice conditions, the intensity

TABLE 1

AVERAGE DAILY RAW SEWAGE LOAD TO LAGOONS

Cell	Area acres	Depth (ft)	Volume GPD Cell	Volume GPD Acre	Theoretical detention days	BOD (lbs) Planned Cell	BOD (lbs) Planned Acre	BOD (lbs) Realized Cell	BOD (lbs) Realized Acre
1.	0.75	2.5	7000	9000	87	15	20	15.2	20.3
2.	0.75	2.5	14000	18000	44	30	40	30.4	40.5
3.	0.75	2.5	21000	28000	29	45	60	45.6	60.8
4.	0.75	2.5	28000	37000	22	60	80	60.8	81.1
5.	0.75	2.5	35000	47000	17	75	100	76.0	101.3
6.	15.00	3.0	111000	7000	68	255	16	229.0	15.3

Source: Neel, J. K., McDermott, J. H., Monday, C. A., "Experimental Lagooning of Raw Sewage, Fayette, Missouri, Experimental Stabilization of Ponds, 1957-1958," (an unpublished report), United States Public Health Service, Region VI, Kansas City, Missouri, (1960).

TABLE 2

DEGREE OF TREATMENT

(PERCENT REDUCTION OF WASTE COMPONENTS)

ACHIEVED BY THE ENTIRE FACILITY

	Alk.	B.O.D.	Org. P	P04	Total P	Org. N	Nh3-n	Total N	MPN Coliforms
Avrg.	32	89	78	78	80	95	82	93	99.9996
Min.	21	86	66	68	68	90	56	84	99.9982
Max.	43	96	92	91	98	98	93	97	99.9999

Source: Neel, J. K., McDermott, J. H., Monday, C. A., "Experimental Lagooning of Raw Sewage, Fayette, Missouri, Experimental Stabilization of Ponds, 1957-1958," (an unpublished report), United States Public Health Service, Region VI, Kansas City, Missouri, (1960).

of solar radiation is an unreliable guide.

Odor conditions were recorded as follows:

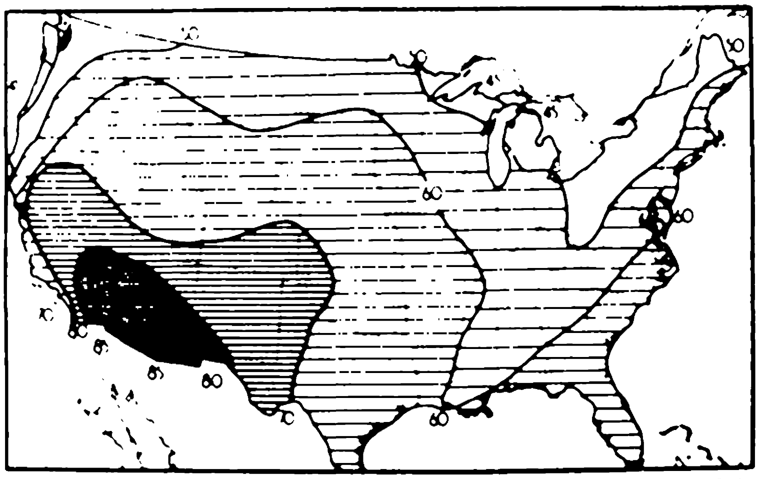
Five cells were loaded at the following rates:

Cell 1.	20	pounds/acre/day
2.	40.5	pounds/acre/day
3.	60.8	pounds/acre/day
4.	81.1	pounds/acre/day
5.	101.3	pounds/acre/day

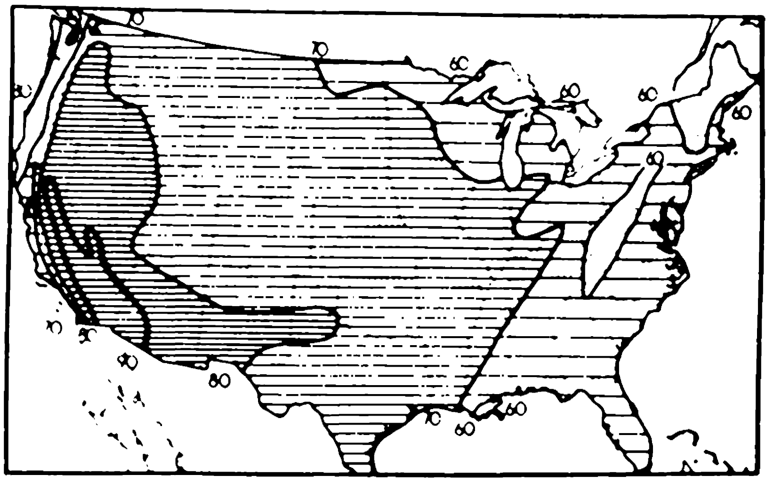
Odors were recorded as follows:

February	23	Slight odor in cells 4 and 5.
	26	Cells 3, 4, 5 produced odor detected 550 feet downwind.
	28	Cells 3, 4, 5 still detected odors 550 feet downwind.
March	2	Cells 3, 4, 5 could be detected 50 feet downwind.
	9	Cell 3 lost its odor.
	24	Cell 4 lost its odor.
	26	Cell 5 lost its odor.

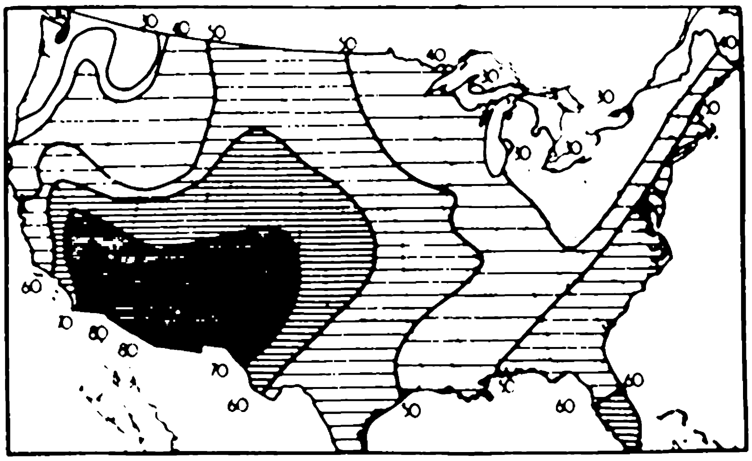
APPENDIX D



NORMAL ANNUAL SUNSHINE (% OF POSSIBLE)



NORMAL SUMMER SUNSHINE (% OF POSSIBLE)



NORMAL WINTER SUNSHINE (% OF POSSIBLE)

APPENDIX E

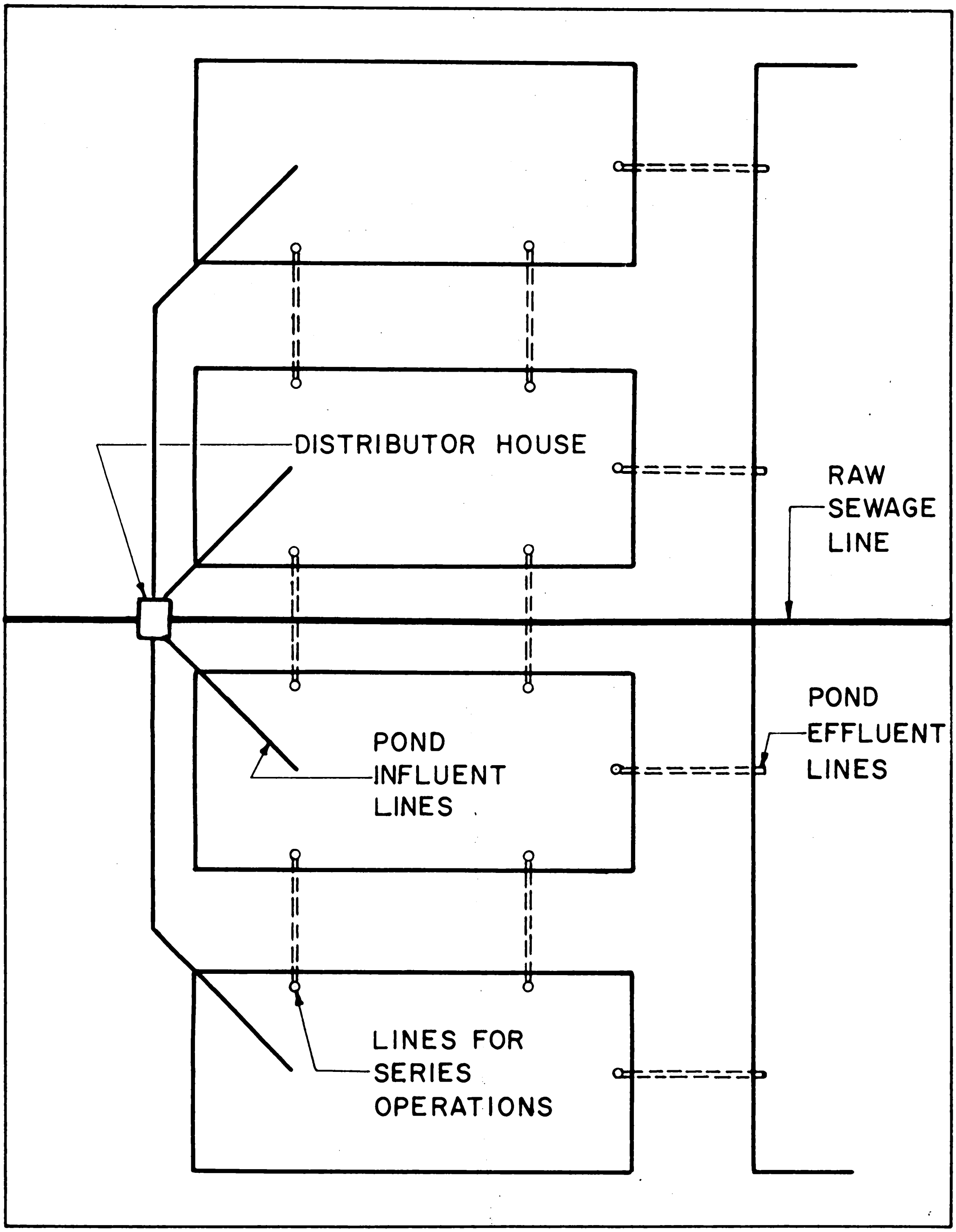
TABLE I.—Descriptive Data of Sewage Stabilization Ponds in the Dakotas, June, 1956

Sewage Source: Location	Sewage Source: Pop.	Applied Sewage: Kind	Applied Sewage: Pop. Equiv.	Pond: Date Constructed[1]	Pond: No. Cells	Pond: Area (acre)	Pond: Operation[2]	Inlet: Location[3]	Inlet: Type[4]	Outlet: Location[3]	Outlet: Type[5]	Costs ($) Pond Only: Total	Costs ($) Pond Only: Per Cap.	Costs ($) Pond + Lift Sta. and Force Main: Total	Costs ($) Pond + Lift Sta. and Force Main: Per Cap.
						(a) South Dakota									
Beresford	1,686	Raw	1,600	Su 1955	2	16.5	S	C	G	NW	O	17,265	10.24	—	—
Bison	457	Raw	300	F 1954	1	3.0	—	S	G	NE	O	—	—	None	None
Bonesteel	485	Raw	450	Su 1955	1	5.4	—	C	G	N	O	10,325	21.29	None	None
Bowdle	788	Raw	700	P	1	8.6	—	C	G	S	O	—	—	None	None
Burke	829	Im. effl.	975	F 1953	2	8.2	S	C	G	NE	O	12,000	14.48	None	None
Canton	2,530	Raw	2,400	P	2	30	S or P	C	P	SE	—	—	—	—	—
Cherry Creek[6]	5–60	Sep. tank	5–60	F 1953	2	0.34	S or P	S	G	SE	O	—	—	None	None
White Horse[6]	15–75	Sep. tank	5–60	Su 1953	2	0.36	S or P	S	G	E	O	—	—	None	None
Clear Lake	1,105	Raw	1,200	F 1955	1	12.0	—	C	G	SE	O	14,500	13.12	None	None
Freeman	944	Im. effl.	1,225	W 1955	1	9.0	—	C[7]	G	NE	O	12,425	13.16	None	None
Gettysburg	1,555	Raw	1,500	F 1955	2	20.0	S	C	G	W	O	23,764	15.30	None	None
Gettysburg (Air Force)	—[8]	Raw	—[8]	—	2	—[8]	S or P	—	—	—	—	—	—	—	—
Hayti	413	Raw	400	F 1953	2	5.0	S or P	C	P	NE, SE	O	15,670	37.94	85,338[9]	206.63
Isabel	511	Raw	475	Su 1955	1	2.7	—	C	G	NW	O	7,000	13.70	None	None
Kadoka	584	Raw	550[10]	F 1953	2	8.2	P	S, C	G	NW, SW	O	6,900	11.82	None	None
Langford	456	Raw	450	P	1	5.3	—	C	P	NE	O	—	—	—	—
Lemmon	2,760	Raw	2,600	Su 1951	1	27.1	—	C	G	SE	O	33,783	12.20	None	None
Murdo	739	Raw	730	Sp 1956	1	9.1	—	—[11]	G	SE	O	21,000	32.60	None	None
New Effington	367	Raw	200	Sp 1954	2	2.1, 1.6	S	C	P	NE	O	10,600	28.90	57,000[9]	156.30
Oahe Adm.	100–200	Raw	150	F 1954	2	0.44, 0.44	S or P	C	G	S	O	—	—	None	None
Philip[12]	810	Raw	750	Su 1953	2	5.7	S	C	P	E	O	5,276	6.52	39,000	48.15
Pierre[13]	503	Raw	500	Su 1955	1	5.1	—	C	P	SW	O	—	—	—	—
Pollock	395	Raw	350	Su 1955	2	2.3, 2.3	S	C	G	NE	O	10,122	25.60	None	None
Redfield	2,655	Raw	2,950	F 1955	1	30.2	—	C	P	SE	O	28,650	10.80	37,890	14.27
Rosebud Agency[13]	100–200	Sep. tank	—	Su 1954	4	0.78	S	C	P	—	O	—	—	—	—
Sisseton	2,871	Raw	3,000	Su 1955	2	16, 11	P	C	G	N	O	44,586	15.53	None	None
Tabor	373	Raw	350	Sp 1956	1	4.96	—	C	P	NE	O	—	—	—	—
USAF[14]	175	Raw	175	F 1955	2	0.7, 0.65	S or P	C	G	SW	O	—	—	None	None
Valley Springs	389	Raw	375	Su 1956	2	3.85, 2	S or P	C	G	NW	O	9,750	25.00	None	None
Veblen	476	Im. effl.	500	Su 1954	2	1.4, 1.1	S or P	—[15]	P	N	O	7,056	14.80	13,000	27.31
Wall	556	Raw	500[16]	F 1951	1	8.87	—	S	G	SE	O	11,000	19.80	None	None
Wasta[17]	144	Sep. tank	140	1953	1	0.5	—	S	G	—	N	—	—	None	None
Bethesda Home[18]	175	Raw	175	Su 1956	1	1.8	—	C	G	NE	O	—	—	None	None
Eagle Butte	375	Raw	—	—	1	8.4	—	—	—	—	—	—	—	—	—
Weaver[17]	50	Raw	—	1955	1	0.5	—	C	—	—	O	—	—	—	—
White River	465	—	—	P	1	5.0	—	C	—	—	O	—	—	—	—
Castlewood	500	Raw	1,100	P	2	7.6, 8.4	S or P	C	P	NW or SW	O	—	—	—	—
						(b) North Dakota									
Asc. Abbey[19]	260[20]	Raw	260[19]	F 1953	1	1.25	—	C	G	—	N	—	—	—	—
Beach	1,461	Raw	1,350	F 1953	2	7.1, 11.1	S	C	P	—	N	9,400	6.43	25,000	17.10
Bisbee	365	Raw	350	Su 1953	1	13.0	—	C	P	N	O	9,030	24.80	31,600	86.60
Butte	272	Raw	250	F 1951	1	1.03	—	C	G	N	O	3,400	12.50	None	None
Cavalier	1,459	Raw	1,450	F 1954	2	9.0, 8.0	S	C	P	—	N	28,510	19.50	77,550	53.10
Center	492	Raw	300	1954	1	4.5	—	C	P	S	O	3,500	7.10	14,500	29.50
Devils Lake[21]	6,427	Raw	11,650	Sp 1956	1	107	—	C	P	—	NP	48,000	7.47	200,000	31.20
Dunn Center	246	Raw	200	W 1955	1	3.0	—	C	P	SW	D	3,690	15.00	12,860	52.20
Dunseith[21]	713	Raw	700	Sp 1956	1	4.0	—	C	G,	S	O	10,900	15.30	None	None
Elgin	882	Raw	500	June 1954	2	6.0, 6.0	S	C	G	E, N	D, O	9,510	10.80	None	None
Fessenden	917	Raw	700	1928	1	12[22]	—	S	G	—	N	—	—	—	—
Flasher	413	Raw	300	Sp 1954	1	6.0	—	C	P	S	D	7,420	18.00	25,350	61.30
Flaxton	436	Raw	350	1953	2	3.0, 3.0	P	S	P	N	O	—	—	—	—
Fordville[21]	376	Raw	310	F 1955	1	4.0	—	C	P	SE	O	4,965	13.20	17,310	46.10
Fort Berthold:[23]															
West School	240	Raw	240	—	1	2	—	C	—	—	—	—	—	—	—
East School	240	Raw	240	—	1	1	—	C	—	—	—	—	—	—	—
South School	100	Raw	100	—	1	1	—	C	—	—	—	—	—	—	—
Golva	174	Raw	160	1953	1	1.9[24]	—	C	P	—	N	960	5.50	10,125	58.20
Grenora	525	Im. effl.	500	1949	1	3.0	—	S	—	—	—	—	—	—	—
Hazelton[21]	453	Raw	450	Sp 1956	1	—	—	C	G	N	O	7,100	15.70	None	None
Hope	470	Raw	475	1951	1	10[25]	—	C	P	—	N	—	—	—	—
Jamestown	10,697	Raw	12,550	F 1953	1	135	—	C	P	NW	O	100,000	9.40	500,000	46.80
Larimore	1,374	Raw	3,320	Sp 1953	1	9.0	—	C	P	—	N	9,000	6.55	38,000	27.60
Maddock[26]	741	Raw	1,750	1949	3	11.7, 12.3, 8.0	S	C	P	—	N	17,500	23.60	37,650	50.80
Max	465	Raw	400	1953	1	1.5	—	S	G	SW	O	2,500	4.40	None	None
Medina	564	Raw	500	F 1953	1	4.0	—	C	G	—	—	—	—	—	—
Minnewaukan	443	Raw	350	Dec. 1954	1	13.0	—	C	P	N	O	11,200	25.30	78,365	177.00
Minto	592	Raw	500	F 1954	1	7	—	C	P	W	D	5,200	8.80	44,900	75.90
Neche[27]	615	Raw	700	July 1955	1	16	—	C	P	NE	D	8,530	13.90	32,680	53.10
New England[21]	1,117	Raw	1,740	1954	1	13.0	—	C	P	E	D	11,060	9.90	29,366	26.30
New Salem[27]	942	Raw	890	1955	1	10.5	—	C	G	SW	D	14,300	15.80	None	None
New Town	1,300[28]	Raw	1,300[28]	June 1951	1	8	—	C	G	S	O	—	—	—	—
Northwood	1,182	Raw	1,110	1954–6	2	6, 6	S	C	P	—	N	—	—	—	—
Park River	1,692	Raw	1,600	1955	2	32.6	S	C	P	—	O, N	42,360	25.00	113,250	67.00
Plaza[27]	389	Raw	350	1955	1	5.0	—	C	P	E	O	8,100	20.80	30,075	77.30
Portland	641	Raw	800	1951–5	1	8.0,[29] 6.0	—	C	P	—	N	18,400	28.80	—	—
Rolette	451	Raw	400	F 1954	1	12.0	—	C	P	NW	D	8,550	19.00	40,710	90.30
Rolla	1,176	Raw	1,100	F 1954	1[30]	11.0	—	C	P	—	O	6,300	5.40	31,900	27.20
Scranton[21]	360	Raw	350	1956	1	4.0	—	C	P	SW	D	4,040	11.20	21,375	59.30
Stanley	1,486	Raw	—	1955	1	12	—	C	—	—	—	—	—	—	—
Watford City	1,371	Raw	1,300	1953–4	2	8.0, 2	S	C, C	G, P	E, E	D, D	14,119	10.30	18,219	13.50
				1955	1	2.0[27]	—	C	G	E	D	—	—	—	—
Wildrose	430	Raw	400	1954	1	10	—	C	—	—	—	—	—	—	—
Wishek[26]	1,241	Raw	1,490	1952	1	7.8	—	—[31]	G	NW	D	5,400	4.40	—	—
Zeeland	484	Im. effl.	500	1952	1	1.5	—	S	P	NW	O	4,000	8.30	37,000	76.40

[1] Sp = spring; Su = summer; F = fall; W = winter; P = planned.
[2] S = series; P = parallel.
[3] C = center; S = side.
[4] G = gravity; P = pumped.
[5] O = overflow; NP = none planned; D = drawdown; N = none.
[6] Cheyenne Indian Agency school.
[7] Two inlets.
[8] Classified.
[9] Includes new sewer system.
[10] Winter population; summer population = 850.
[11] 175 ft. from North end.
[12] Isotope flow study made here.
[13] Indian school.
[14] Weather station at Gettysburg.
[15] 30 ft. north of SE corner.
[16] Winter population; summer population = 1,000.
[17] Privately owned and operated.
[18] In Beresford.
[19] Private school.
[20] Winter population; summer population = 60.
[21] New.
[22] Former slough.
[23] Indian reservation.
[24] Being modified.
[25] Needs bottom seal.
[26] Included in seasonal research.
[27] Still filling.
[28] Estimated.
[29] First pond abandoned in 1955.
[30] Second pond planned for immediate construction.
[31] 25 ft. offshore.

APPENDIX F

PROPOSED SEWAGE LAGOON SYSTEM



THE SEWAGE LAGOON: ITS SOCIAL,
ECONOMIC, AND PLANNING IMPLICATIONS

Abstract

The basic objectives of this study were to determine: (1) the extent of water pollution contributed by our communities in the form of municipal and industrial wastes, (2) an investigation of the extent of use, performance characteristics, and costs of the sewage lagoon, (3) the planning aspects of the sewage lagoon, (4) the extent of anti-pollution law enforcement, and (5) the existing financial aid available to communities for the construction of sewage lagoons. The findings of this study indicate that:

1. The extensive contribution to the water pollution problem by municipalities and industry is serious. The projection of future water use based upon present standards of use and recovery indicates a very serious water problem in the near future. A need exists for an inexpensive method of sewage treatment.

2. Sewage lagoons are relatively new but are widely used. They have proved to be relatively inexpensive and are achieving a high standard of purification.

3. Possible secondary benefits resulting from the use of sewage lagoons may prove to be of substantial value

to municipalities in terms of efficient land use and the preservation of open land for alternate future uses.

4. The enforcement of the existing anti-pollution laws have been ineffectively enforced; however, new emphasis is being placed upon legal proceedings, rather than the voluntary compliance that has been practiced in the past.

5. With proper planning, a community can conceivably use several governmental programs for financial assistance both in grants-in-aid and long term loans for the construction of a sewage lagoon.