WASTE STABILIZATION LAGOONS
MICHIGAN APPLICATION

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JACK ROBERT SCHOON

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ABSTRACT

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For many years small communities have been plagued with the problem of sewage treatment. Many methods have been developed and utilized for the treatment of sewage. In 1960, the Michigan Department of Public Health accepted lagooning as a treatment method. Treatment by lagooning is based on natural processes of self-purification. The design and operation of lagoons have been based on empirical practices.

Waste stabilization lagoons have three major advantages: (1) lagooning is most favorable to small communities, (2) the treatment which wastes receive in lagoons is comparable to conventional secondary systems, and (3) the operating cost of lagooning is much less than conventional systems.

This study was designed to gather and compile data on stabilization lagoons in Michigan. The presentation of the material is arranged so that it may be used as a reference source or in total. The natural processes as well as the variables of light, temperature, and wind are discussed. An elaboration of the design criteria as well as the advantages and disadvantages of lagooning are presented. A summary is provided in place of a conclusion. This work helps bridge the information void concerning sewage lagoons in Michigan.

WASTE STABILIZATION LAGOONS

MICHIGAN APPLICATION

By

Jack Robert Schoon

A THESIS

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Jack Robert Schoon

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CHAPTER I

INTRODUCTION

Waste stabilization lagoons which have been used for municipal sewage treatment have only recently been accepted by the Michigan Department of Public Health as a workable sewage treatment method. Michigan's first stabilization lagoon, for the treatment of raw municipal sewage, was put into operation in 1961 in the community of Lawton. Today, 62 Michigan communities are using stabilization lagoons for sewage treatment. More than 130 other Michigan communities are considering or constructing stabilization lagoons.

Effective sewage treatment has three basic objectives--to protect the health of the general public, to avoid nuisance conditions, and to protect the high quality of natural waters. Sewage may be a nuisance to the health of the public because it contains pathogenic bacteria and other disease producing organisms. Untreated sewage is a nuisance as it is offensive aesthetically as well as to the senses.

Many methods have been found to minimize the objectionable properties of sewage. This paper will discuss one of the more elementary methods but complex systems for the treatment of sewage, namely stabilization lagoons. Lagoons are simply constructed and the basic operation is easily understood. However, there are complexities which result from the interactions that take place in the stabilization process.

Stabilization lagoons are shallow, diked structures used to receive raw sewage. The stabilization processes that are carried out in a lagoon are a combination of biological, chemical, and physical processes. The processes that take place in a lagoon are referred to as natural self-purification.

The purposeful addition of waste to ponds was probably begun in prehistoric times. It has continued until the present and still serves as a means of disposal. In Germany, purification of sewage in fish ponds has been practiced; however, in the United States such ponds have not been used. The first stabilization lagoon in the United States was built about the turn of the century but was designed for the sole purpose of excluding waste water from natural waterways. The resulting effluent from these ponds was found to be of a higher quality than the influent. The waste purification which results from inponding was gradually realized.

> It is now widely recognized that when properly designed and operated, stabilization ponds will develop a population of organisms which will degrade organic matter and subsequently convert the low-energy products of degradation into high-energy algal cells. . . . it may be said that whereas the normal treatment

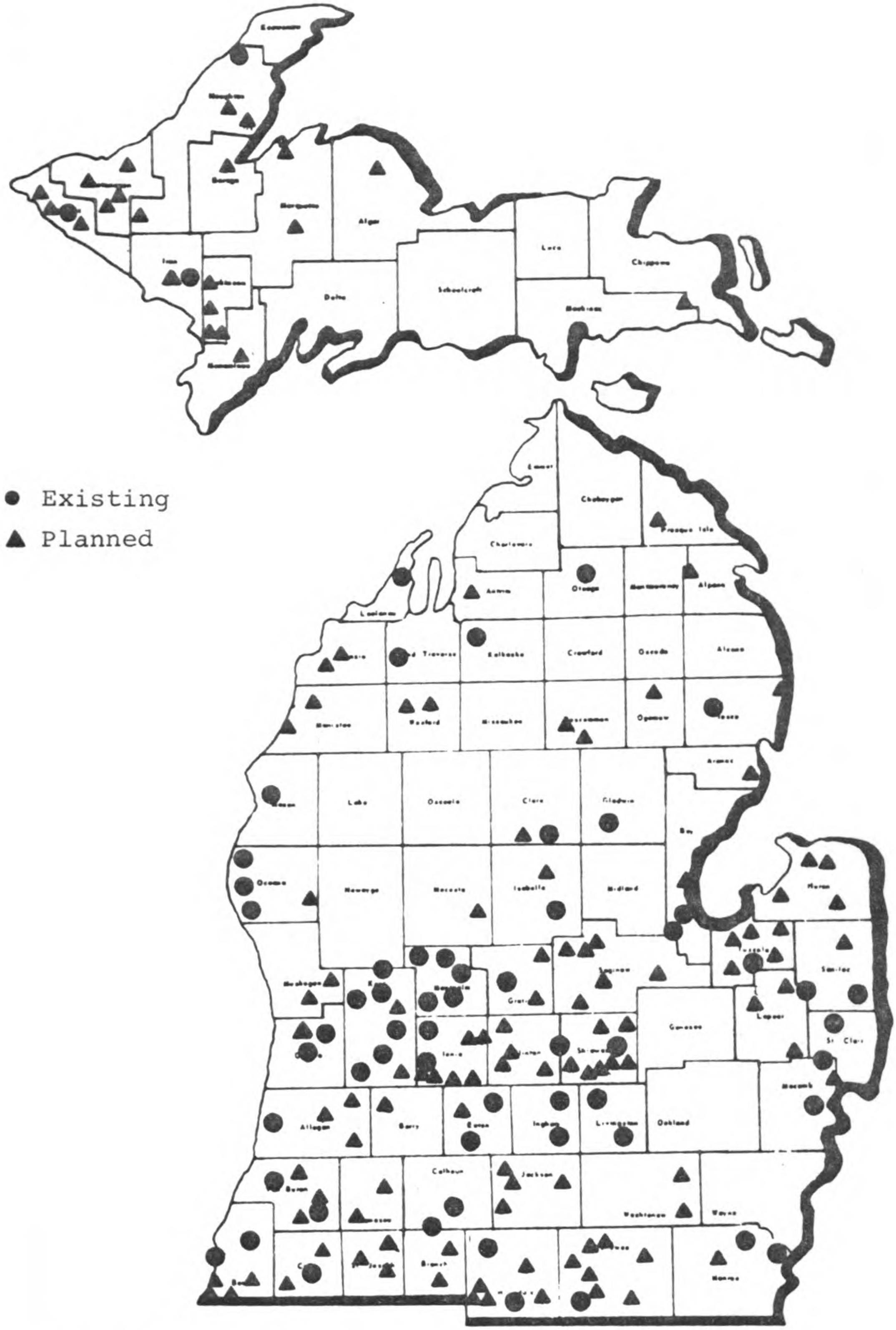

Figure 1.--Stabilization Lagoons in Michigan, June, 1970.

Source: Michigan Department of Public Health.

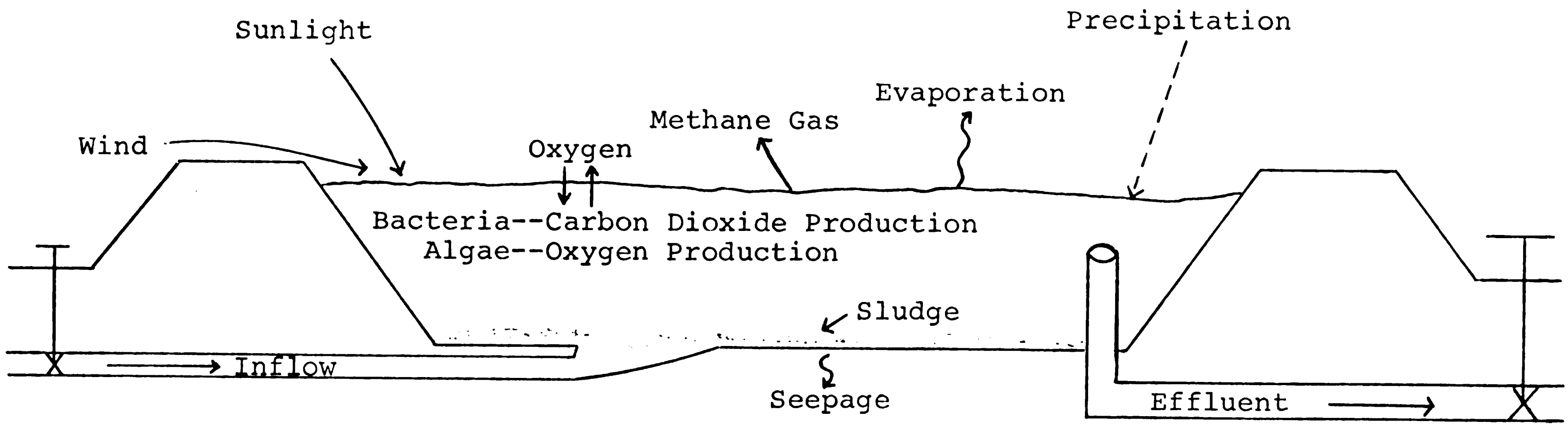

Figure 2.--Waste Stabilization Lagoon.

> system degrades organic matter to stable fertilizer compounds which remain in the water without exerting an oxygen demand, the pond system goes further to pick up a large fraction of these fertilizers and incorporate them into living cells again.[1]

It is the objective of this paper to present, in a meaningful way, Michigan's application of stabilization lagoons. Only the municipal application of sewage lagoons in Michigan will be considered in this work.

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[1]P. H. McGauley, Engineering Management of Water Quality (New York: McGraw-Hill, 1968), p. 210.

CHAPTER II

THEORY OF OPERATION

To facilitate a better understanding of the theory of operation each component is discussed separately. The characteristics of sewage are first discussed. Next the major activities of the treatment process are discussed. However, the activities of the treatment process take place together and ultimately affect each other.

Characteristics of Sewage

Before the processes of treatment which are carried out in a stabilization pond are discussed, a working knowledge of the nature of the material being treated is necessary. Human excreta is the principal source of organic wastes which are treated in lagoons. On a per capita per day average, excreta is composed of 83g of feces and 970g of urine. The wastes are composed of large amounts of water, some organic (putrified) matter which amounts to approximately twenty percent of the feces and two and one half percent of the urine and small amounts of nitrogen, phosphoric acid and sulfur as well as other organic compounds. When diluted with water to form sewage, the solid content of the waste becomes minimal.

Present per capita dilution rates range from 30 gallons to 120 gallons per day. About three-eighths of the solids are in suspension and what remains is in solution. Even though there are extremely small amounts of organic matter in sewage, it does possess the ability to become very odoriferous. The more important treatment aspect of sewage is that it contains many organisms which may cause disease.

Human waste is not the only waste of which sewage is composed. Waste water from laundry, kitchen and bathing as well as from garbage grinders may be incorporated with the human waste. Many other forms of waste may be incorporated in the sewage.

Operational Theory

The operational theory of waste treatment in oxidation ponds is understood by few. Ross McKinney, one of the best known sanitary engineering microbiologists, points out in his book that: "One of the most confused items in biological waste treatment is the theory behind oxidation ponds. Very few engineers really understand how and why an oxidation pond works and what results can be obtained."[2] A review of the more recent works in the field also indicates a lack in the communication of basic operational theory.

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[2]Ross E. McKinney, Microbiology for Sanitary Engineers (New York: McGraw-Hill, 1962), p. 239.

Bacteria

The actual stabilization of organic matter is carried on primarily by bacteria, with certain flagellated protozoa to assist. Bacteria are typically unicellular microorganisms which do not have chlorophyll. Bacteria are classified by the habitat in which they live. Anaerobic bacteria are bacteria that live in the absence of oxygen. Aerobic bacteria live in the presence of oxygen. Bacteria which can function with or without oxygen are termed facultative. Under anaerobic conditions, bacteria form organic acid and under aerobic conditions carbon dioxide and water are produced.

Anaerobic Bacteria

Anaerobic bacteria is found in the lower levels of the lagoon. As the decomposition of carbonaceous matter takes place, carbon dioxide, organic acids, and methane are produced. From the proteins and other nitrogenous matter, ammonia and sulfur compounds are produced. The sulfur compounds are further reduced to hydrogen sulfide and a few other compounds. The hydrogen sulfide and other compounds are unpleasantly odorous; however, the solid stabilized material remaining after decomposition has little or no odor.

Aerobic Bacteria

Aerobic bacteria are located near the surface where dissolved oxygen is available. The aerobic bacteria

stabilize waste materials wholly through aerobic oxidation. In this metabolic process of aerobic bacteria, carbon dioxide is the resulting end product.

In a facultative system, effort is made to keep the pond principally aerobic. "Since the B.O.D. of the effluent will be low only when carbon dioxide and water are the end products of metabolism, efforts are made to keep the system aerobic."[3]

Algae

Algae are a group of plants which contain chlorophyll and have no roots, stems or leaves. During the synthesis of protoplasm, the energy of the sun is used in the photosynthetic process to combine carbon dioxide and water. As a by-product of this process, oxygen is produced.

> It has been felt by many engineers that the release of oxygen by the algae supplied the necessary oxygen for aerobic stabilization of the organic matter by the bacteria. Actually, the algae cannot produce enough oxygen to meet the demand of the bacteria and the protozoa unless they have another source of nutrients than that from the wastes being metabolized by the bacteria.[4]

Sedimentation

Inert solids, which are not biologically metabolized, as well as many microorganisms, settle to the bottom of the pond. The rate of settling is dependent on specific gravity which indicates whether settling will occur and the

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[3] _Ibid._, p. 240.

[4] _Ibid._

rate at which it will occur. Size and shape also affect the settling rate. The solids which settle out produce a thin sludge layer. Sedimentation is a very important component in that the materials do not leave the pond.

pH

The value pH has a definite influence on the efficiency of biological activities in a lagoon system. The symbol pH represents the logarithm of the reciprocal of the hydrogen ion concentration and pH is used to indicate acidity or alkalinity. A pH of seven indicates a neutral condition. Values of less than seven indicate acidity and values greater than seven indicate alkalinity.

For algal photosynthesis, an energy source, mineral nutrients and a good source of carbon dioxide are required. The available dissolved carbon dioxide which results from bacteriological activities is soon exhausted during photosynthesis. To have continued photosynthesis another source of carbon dioxide must be used. The carbonate buffer system then serves as a source of carbon dioxide. However, algae found commonly in lagoons cannot use bicarbonate directly; therefore they "must rely on carbon dioxide made available by the following reaction: $2HCO_3^- \rightarrow CO_2 + CO_3^= + H_2O$. This reaction is accompanied by a shift in the monocarbonate-bicarbonate rise in pH."[5] The above reaction makes a supply

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[5]Dorell L. King and Arliss D. Ray, "New Concepts for Design, Operation and Management of Stabilization Ponds," International Conference on Water For Peace, Vol. 4 (Washington, D. C.: U. S. Government Printing Office, 1967), p. 275.

of carbon dioxide available for photosynthesis until an alkalinity pH value of 9.2 is reached. At this level carbon dioxide becomes limited for photosynthesis and resulting oxygen production.

After dark pH drops rapidly from the daytime high. The rapid drop in pH is the result of a build up of carbon dioxide created by respiring organisms. The increased carbon dioxide replaces the carbon dioxide used by the carbonate buffer system. This results in a lowering of the pH value until it reaches its original value. The original pH value of the system is very similar to the pH value found in the incoming sewage. The pH fluctuation described above is a daily occurrence with values reaching a maximum in the afternoon and a minimum in the early morning. The rather marked similarity of daily variation of available dissolved oxygen and pH shows a direct interrelationship.

Observation of pH values indicate, "When the influent pH is greater than 7.2 increasing detention period increases B.O.D. removal; but when influent pH is 7.2 or less, the converse phenomenon is observed."[6] Research indicates that an increase in pH roughly corresponds to the intensity of the incidence of light. All organisms seem to have their own tolerance range for pH where metabolic activities are least affected. Lagoons should be designed

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[6] Wesley O. Pipes, "pH Variation and B.O.D. Removal in Stabilization Ponds," Water Pollution Control Federation Journal, 34 (November, 1962), p. 1149.

to operate at the optimum pH for the desired organisms. It has been found that higher pH values tend to favor a more rapid absorption of carbon dioxide from the atmosphere. From the above discussion it can be concluded that sudden variations in pH are not desirable.

Summarization

McKinney summarizes the stabilization process in the following manner:

> In essence, all that has happened is conversion of the organic matter from one form to another form. In the presence of sunlight the algae do not have a demand for oxygen since the sun supplies their necessary energy; but at night without sunlight, the algae would demand oxygen in the same manner as the bacteria for endogenous metabolism. The oxygen demand of the protoplasm formed is less than the oxygen demand by the cells forming the waste so that the rate of oxygen demand has been reduced by this conversion.[7]

The theory of oxidation was summed up quite adequately by Floyd L. Matthew in his article in the Water and Wastes Engineering Journal entitled "Operation and Maintenance of Aerobic Stabilization Ponds."

> A stabilization pond is nothing more than a manmade facility in which natural purification processes occur under controlled conditions while the wastewater is still on the owner's property. The putrescible material in the wastewater is food upon which microorganisms thrive if the proper conditions exist. The process of stabilization can be compared to trash burning. The trash is stabilized and reduced to an inoffensive "ash" by combining it with oxygen in the burning process. In the stabilization pond, bacteria biochemically "burn" the organic, putrescible materials in the wastewater by combining organics with oxygen. The stable "ash" falls to the

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[7] McKinney, Microbiology, p. 241.

bottom or is carried out in the effluent. Hence, the name "stabilization pond." Most of the pathogenic bacteria are also removed by predators, sunlight, and other purifying effects.[8]

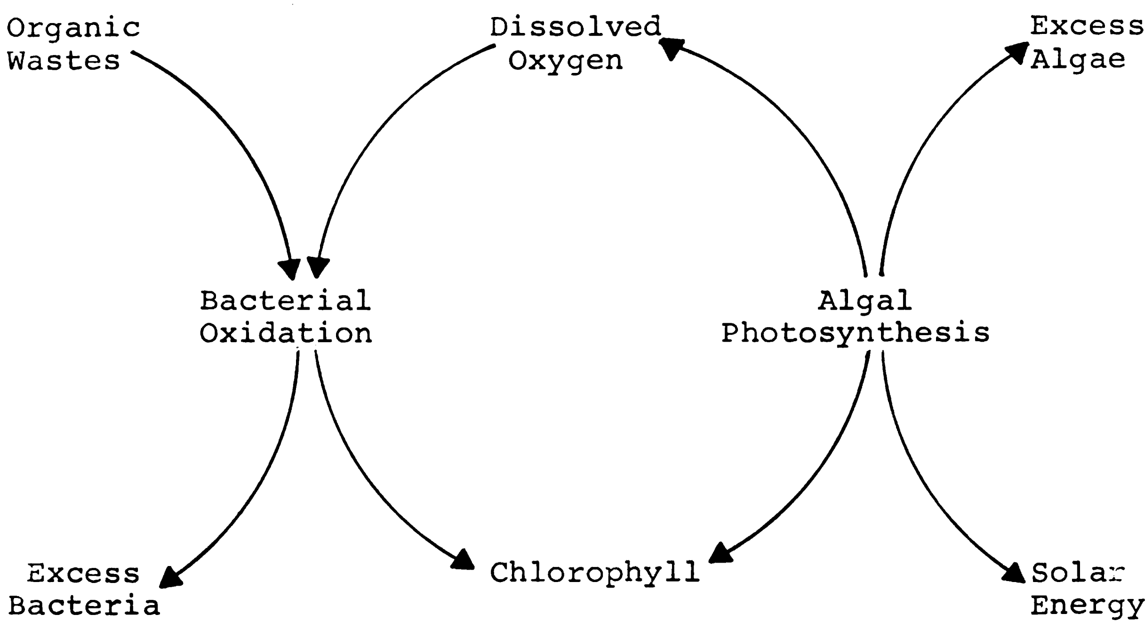

Fig. 3.--Stabilization of Organic Matter in Lagoons.

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[8] Floyd L. Matthew, "Operation and Maintenance of Aerobic Stabilization Ponds," Water and Waste Engineering, 5 (July, 1968), p. 64.

CHAPTER III

VARIABLES

The sewage treatment which results from lagooning is accomplished through natural processes. The natural processes are influenced and affected by many variables.

Location

The location of the lagoon system is probably the most important decision a community will make concerning its treatment facility. Since a lagoon system is a sewage treatment facility, it should be located in a place where there is a minimal possibility of health problems. Past experience indicates that the lagoon should be away from residential areas and the site should not be easily accessible by the public. Michigan's regulations read that "A pond site should be as far as practicable from habitation or any area which may be built up within a reasonable future period."[9] Due to Michigan's discharge policy, sites should be located relatively close to the discharge waterway.

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[9]Great Lakes-Upper Mississippi Board of State Sanitary Engineers, Recommended Standards for Sewage Works (Albany, N. Y.: Health Education Service, 1968), p. 94.

Other factors concerning location include: economic consideration, ground water, surface runoff and prevailing winds. These particular factors are discussed in other sections of the thesis.

Climatic Consideration

In Michigan, summers are warm while winters are moderately cold. Precipitation is rather well distributed throughout the year. Generally, precipitation is greater during the growing season. Precipitation ranges from 26 to 36 inches per year throughout the state. The state's average is 31 inches per year. During the winter, snow is expected throughout the state. The depth of snow varies from 30 inches in the southeastern section of the lower peninsula to over 150 inches in the western portion of the upper peninsula.

Light

Light is without a doubt the most important variable in the stabilization processes carried out in lagoons (King, Arliss 1967) (Porges, Mackenthun 1963). Oxygen is necessary in the continuous stabilization process. Algae produces oxygen as a by-product of its photosynthetic process.

A large amount of research has been done on the effects of light on sewage lagoons (Varma, Wilcomb 1963). Light penetration in lagoons is usually limited to the upper two feet of the lagoon. The saturation level for photosynthesis in algae seems to be about 400-600 foot candles. At this point photosynthetic oxygen production is equivalent to total respiration.

The amount of light that reaches a lagoon varies from day to day and hour to hour. Turbid conditions, as well as floating solids, hamper effective light penetration. All light that reaches the liquid surface does not penetrate. Some light is reflected back to the atmosphere. Prevailing atmospheric conditions also influence the amount of light available for photosynthesis. Ice cover greatly reduces the incidence of light.

Intensity of light determines the amount of photosynthetic activity that algae cells will have. The higher the light intensity the greater the photosynthetic activity. Conversely, at lower light intensities the photosynthetic rate will decrease. Research does indicate that algae can use short flashes of light as efficiently as continuous light. Light is only needed for initial activation and excitation of the photosynthetic process. Due to algae's need of light, it is established in the zone of light penetration. It therefore follows that most available oxygen is found in this zone.

Temperature

As light, temperature is very important in waste stabilization ponds. Temperature has a definite effect on

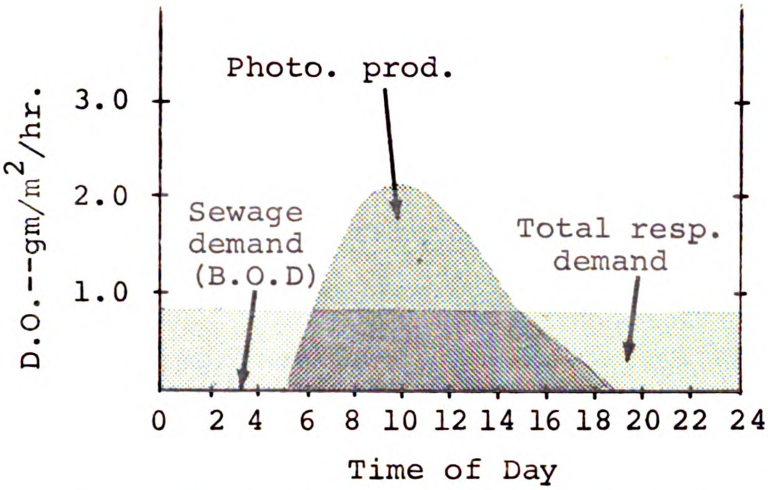

Figure 4.--Oxygen Relations in a Typical Raw Sewage Pond.

Source: U. S. Department of the Interior, Federal Water Pollution Control Administration, Biology of Water Pollution--A Collection of Selected Papers on Stream Pollution, Waste Water and Water Treatment (Washington D. C.: U. S. Government Printing Office, 1967), p. 265.

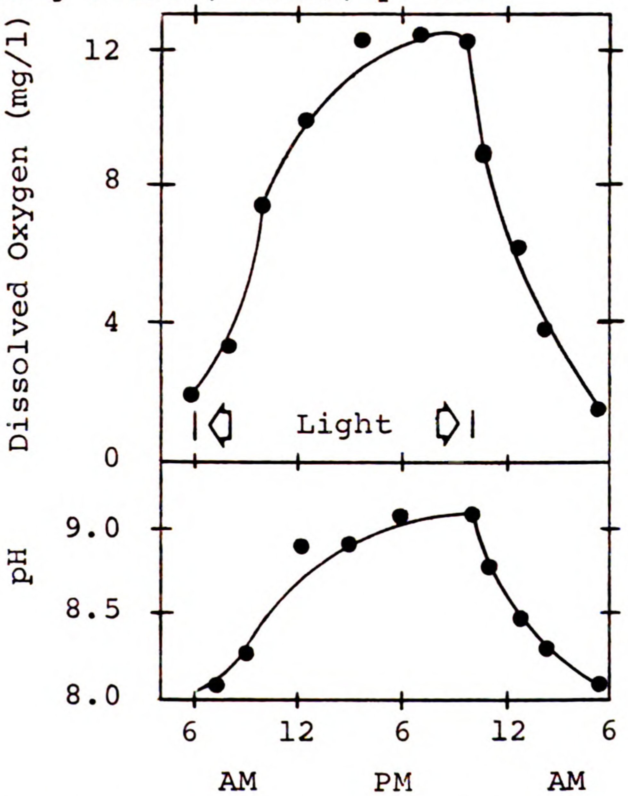

Figure 5.--Diurnal Variation in pH and Dissolved Oxygen Within the Aerobic Zone of a Facultative Lagoon.

Source: Dorell L. King and Arliss D. Ray, "New Concepts for Design, Operation and Management of Stabilization Ponds," International Conference on Water for Peace, Vol. 4 (Washington D. C.: U. S. Government Printing Office, 1967), p. 275.

photosynthetic oxygen production. Optimum production of oxygen is about 20°C. Limiting temperature values are about 4°C. and 35°C. As with lagoons, the solubility of oxygen in fresh-water is a function of temperature. With an increase in temperature, the solubility of oxygen in fresh-water is decreased from an average of 14.5 mg/l at 0°C to 7.5 mg/l at 30°C.

Temperature affects the stabilization process by influencing the rate of decomposition. Every microorganism which has been studied has a definite temperature range for optimum activity. If the temperature range of an organism is greatly varied or if there is a sudden temperature change, death of the organism may result. For sound operation of a stabilization pond extreme and sudden variations of temperature should be avoided. Metabolic activities of organisms are said to have a direct correlation with temperature. The van't Hoff-Arrhenius relationship states that for each 10°C increase in temperature there is an approximate doubling of the rate of metabolic activity. It can be concluded that for the maximum stabilization process to occur, temperature should be at the optimum for the desired microorganisms.

During Michigan's winters, temperatures of below 0°C are common as well as ice. Ice cover does have a direct influence on light intensity as well as penetration. As indicated previously a drop in temperature decreases tak

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metabolic activity. During the winter, metabolic activity is almost stopped. Aerobic activity ceases due to surface sealing and the exclusion of light. As a result of this, there is a lack in oxygen production. Some anaerobic activity does take place but at a reduced rate. This results in the production of gas which is trapped below the ice. During the spring ice break up, objectionable odors may be emitted. The odors are the result of septic conditions which are eliminated when the algae again produce oxygen. Facultative conditions may take several weeks to become established.

Wind

Wind action around a pond is very important in three basic ways: aids in surface aeration, disperses odors, and aids in mixing.

Surface aeration is the process in which oxygen from the air is transferred to the water surface. This supply of oxygen is very limited in that very little actual water surface area is available for atmospheric transfer. Since wind action increases mixing, more water surface is available for aeration. Surface aeration is limited because oxygen transfer cannot take place during surface saturation conditions. The water temperature determines what the saturation level will be at a particular time.

Wind also serves another valuable function when it dilutes and carries away odoriferous gases. Dissipation of odoriferous gases is dependent on air movement which aids in dilution of gases. Due to this very important function of wind, lagoons should be located downwind from inhabited areas.

Wind also acts as a mixing agent. As wind velocities increase, surface movement is increased resulting in upwelling and therefore increased mixing. Increased wind not only aids in mixing but may be destructive to lagoons. Embankments and dikes are subject to wave erosion resulting from wind action.

Maintenance

A lagoon needs very little maintenance, but to keep the facility in top working order with a minimum of cost and labor, a regular maintenance program should be followed. The amount of maintenance usually necessary is dependent on the size of the installation. The facility should be checked as often as needed; however, once a week is the very minimum. Inspection should include checking the dike for erosion, damage from burrowing animals, materials suspended on the surface and the need for mowing. Other maintenance which is indicated from the visit should be noted. In Michigan daily inspection during the working week is usually practiced.

Mowing the grass which surrounds the lagoon should be a monthly occurrence. This mowing schedule is designed to keep the grass down to a three to six inch level which helps control insects as well as maintains the appearance of the facility.

Monthly checks of valves and other control equipment should be made to see that the equipment is in proper working order. Repairs should be made when necessary.

The best guide to lagoon maintenance is common sense. When something is in need of repair, it should be taken care of as soon as possible. Short cuts in the maintenance program may not show up right away, but the price of neglect seems to compound itself.

CHAPTER IV

DESIGN CRITERIA

Michigan design criteria is taken from the Recommended Standards for Sewage Works. The standards have been modified by the Michigan Department of Public Health (January, 1970). This section is an elaboration and expansion of the design criteria which the Michigan Department of Public Health follows.

Land Acquisition

Enough land should be acquired to meet the present needs of the community. In purchasing land it must be remembered that the land will be used for a sewage treatment facility. The amount of land purchased should be adequate for possible future expansion and to provide a buffer zone between the lagoon and adjacent development.

Cell Configuration

The shape that a pond takes is the result of satisfying two criteria. For effective treatment, the incoming sewage must be mixed and rapidly distributed throughout the pond. Secondly, a uniform flow of effluent is necessary for effective treatment. Therefore, the pond shoreline should be regular with an absence of coves and peninsulas.

Islands within the pond are considered an interference to good mixing and flow and therefore are prohibited by Michigan regulations. The regular shape of the pond may take the form of a square, circle or rectangle. The square and rectangular shaped ponds should have rounded corners. The length of rectangular shaped ponds should not exceed three times the width.

With an irregularly shaped pond, good mixing and adequate circulation cannot take place. Therefore, local septic conditions result and the overall efficiency of the pond is lowered. Within irregularly shaped ponds, floating materials as well as wind-blown trash collect in coves. The accumulated material limits light penetration and also acts as an insect breeding area.

A study carried out by Shindala and Murphy (1969) shows that rectangular shaped lagoons indicate a more uniform load distribution than lagoons of other shapes.

Regularly shaped lagoons are required in Michigan. The actual shape a lagoon takes is dictated by topographical features as well as sound engineering principles.

Size of Lagoon Installations

The installation size in Michigan is dictated by the size of the community to be served by the system. Michigan's regulations state that for every 100 persons served by the system there must be one acre of water surface area. The regulation only serves as a minimum for size. Maximum size is dic

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is dictated by foreseeable population growth, hydraulic underloading and/or economic considerations.

In Michigan the lagoon systems are usually designed for either annual or semi-annual discharge. Therefore, the system must be of adequate size for the storage volume necessary.

<u>Embankments (dikes)</u>

Embankments should be as steep as possible in order to minimize the amount of shallow water where aquatic plants can grow, but not so steep as to cause mowing or erosion problems. The area on which the dike is to be constructed should be stripped of vegetation and other organic material should be removed. Pockets of sand and gravel should be removed before the dike is actually constructed. Embankments should be constructed of compacted impervious clay material. Material removed from the bottom area may be used to dress the outer slope providing vegetation and organic materials are removed.

Michigan's regulations state that the maximum slope of the inner and outer face of the dikes is not to exceed three horizontal to one vertical. Minimum slope on the inner banks should not be flatter than four horizontal to one vertical. Special considerations may be given to larger installations (twenty acres or more) because of wave action. The outer bank can be of any slope providing it is not greater than the maximum slope permitted. Surface run-off from adjacent land to the lagoon is not permitted.

The dikes should be of adequate height to allow for a minimum of two feet of freeboard above the high water line. The freeboard has been found necessary to contain waves which may develop, and the freeboard acts as a safety barrier. On very small installations (two acres or less) a reduction in the freeboard requirement may be considered by Michigan's regulatory agencies.

The top of the dike is to be at least eight feet in width. Ten feet are recommended for ease of access by maintenance vehicles. Maintenance vehicles should be able to travel around the complete installation on top of the dikes.

Embankments should be seeded from the outside toe to one foot above the high water line on the dikes. Low growing perennial type grasses which will withstand erosion and can be mowed are sought. Alfalfa and other long-rooted crops should not be used since their roots impair the water holding efficiency of the dikes. The County Agricultural Extension Agent or Soil Conservation Agent can usually advise as to locally suitable permanent grass varieties.

Pond Bottom

Great care should be exercised in constructing the bottom of the pond. "The ability to maintain a satisfactory water level in the ponds is one of the most important aspects of design."[10] It is imperative that all vegetation

[10] *Ibid.*, p. 94.

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and other organic material be removed from the bottom. If the organic material was not removed, it would place an additional demand on the decomposition mechanism. The removal of relatively porous topsoil is recommended. The remaining subsoil should be compacted and pockets of sand and gravel should be replaced with clay or other tightly structured soils. To prevent ground water contamination, soils of a relatively tight structure are sought for bottom material.

Areas of limestone and highly fissured or fractured rock should not be considered for a lagoon site. Loosely structure soils composed of a large portion of sand and gravel should be avoided if possible. If a lagoon system is constructed on loosely structured soil, additional methods of sealing should be sought. A clay blanket, bentonite or other sealing material may be used. Some sealing does result from bottom deposits during operation, but the amount of sealing may be considered negligible.

In Michigan a minimum amount of infiltration is considered desirable. The infiltration potential can be determined by having a percolation test made on the bottom material.

The bottom should be relatively level. Some authorities state that the bottom should not vary more than three inches of grade. In Michigan a slight downgrading towards the outflow area is permitted. This is done to facilitate pond

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pond drainage. A relatively flat bottom does not allow a build up of sludge, which may result in local septic conditions.

Pond Depth

Several factors determine optimum lagoon depth. The ability of light to penetrate the water area is probably the foremost condition. Without adequate penetration, the algae could not carry out their function of oxygen production. On the basis of oxygen production, the optimum depth would be about two feet. Temperature also has a bearing on liquid depth. Shallow liquid depths cause the temperature to fluctuate greatly, which is not suitable for optimum biological activity. In Michigan, ice cover can be expected. Therefore, greater depth is required to prevent solid freeze-up or ice damage to piping and embankments.

Aquatic vegetation growth also influences the depth requirement of the ponds. It has been found that 18 to 24 inches of liquid depth discourages emergent aquatic vegetational growth. Aquatic vegetation is undesirable because it interferes with pond circulation and acts as a habitat for insects. In Michigan a depth of two feet is considered minimum for any cell. In the raw sewage cell (primary) maximum depth is six feet which results in an effective storage of four feet. The secondary cells may be a maximum of eight feet while tertiary and subsequent cells are not to exceed ten feet in depth.

Surface Runoff

Ponds in Michigan are designed to exclude surface runoff. If water is added to a functioning pond, it only increases hydraulic loading and serves no worthwhile purpose. However, in beginning a pond additional hydraulic loading is sought; and, therefore, surface runoff may be considered an advantage. If surface runoff is used in prefilling a pond, adequate safeguards must be used to minimize erosion. Precautions must also be taken to trap trash before it enters the pond.

Influent Lines

Any generally accepted material used in sewer construction will be given consideration as an influent line material in Michigan. The piping material selected should be adapted to local conditions. Manholes are required to be installed at the terminus of the outfall line or the force main and shall be located as close to the embankment as topography permits. "Influent lines should be located along the bottom of the pond so that the top of the pipe is just below the average elevation of the pond bottom."[11] In practice the influent line is located 18 to 24 inches below the pond floor grade. This is done so the piping will not be damaged during the required compaction of the pond bottom. The use of the dike to carry the influent

[11] Ibid., p. 95.

line is not allowed. This practice has been found to impede pond circulation.

Discharge to a single cell shall be essentially center oriented. In multicelled installations operated in parallel, near center discharge is recommended. In multicelled installations operated in series interconnecting piping is used. Influent lines of rectangular cells should be terminated at the approximate third point furthest from the outlet structure. Third point locating seems to provide adequate circulation with a minimum of short-circuiting. The influent is to be discharged into a saucer shaped depression which should not extend below the pond bottom more than one foot plus the pipe diameter. The dish shaped depression should be made of concrete. The end of the influent line should rest on a concrete apron of dimensions greater than two feet square. The saucer shape depression and apron are employed to minimize erosion.

Detention Time

With Michigan's relatively high quality waterways and intensified recreational use, pond discharge is limited to twice annually and in some situations only once a year. The lagoons are discharged in the early spring and late fall. Effluent from the fall discharge may be of a higher quality than spring effluent. The two discharge periods correspond with maximum stream flow and minimum stream use. During maximum flow, increased dilution provides a greater safet

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safety factor. The total detention during times of peak use and minimum flow decreases the possibility of lowering the quality of the receiving waterway.

Effluent Outlets

Michigan requires at least two cells to be equipped with outlet structures to permit independent emergency dewatering of the system. Outlet capacity should be one foot per day from all cells through all available outlets. Devices to control effluent discharge should be so designed to allow pond depth to vary from two feet to the maximum depth. To avoid picking up bottom deposits and creating eroding velocities, draw off should be at least twelve inches above the bottom. It has been found that the highest quality effluent comes from several inches below the liquid surface. Subsurface draw off not only provides the best effluent but insures retention of floating solids. Consideration may be given to a baffling system for excluding floating materials.

Many designs for effluent draw off mechanisms have proven satisfactory. Individual preference determines which system will be used. The draw off valves and other necessary mechanical devices should be inclosed and provided with a locking mechanism to prevent unauthorized access to the draw off control facilities.

Each cell must be equipped with a mechanism for completely draining the pond. When possible the outlet str

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structure should be located on the windward side of the cell to prevent short-circuiting. Consideration in the design of the outflow mechanism should be given for ice damage and freezing under winter conditions.

Interconnecting Piping

Interconnecting piping enables adjacent cells to be operated in series. Interconnecting piping must be fitted with valves, or other arrangements must be made to regulate flow between the cells and permit flexibility in depth control. Michigan requires piping between cells to discharge horizontally near the bottom to eliminate the need for erosion control measures. Piping should be of cast iron or corrugated metal of ample size to handle liquid transfer.

Fencing

The pond area should be adequately fenced to exclude domestic animals and discourage trespassing. Michigan requires fence to be of a woven nature, sturdy and at least six feet in height. Two or three strands of barbed wire along the top of the fence are encouraged. Woven fence does collect wind-blown material which, to preserve the well kept appearance of the lagoon, will require disposal. The fence should be equipped with a gate which is wide enough to permit maintenance vehicles access to the facility. Each gate is required to have a locking mechanism.

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Warning Signs

Appropriate signs denoting the nature of the facility and advising against trespassing should be located around the facility. Intervals of 100 to 200 feet along the perimeter of the fence seem to be adequate.

Multicelled Operation

Michigan requires that multiple cells be used and designed to be operated in both series and parallel. This flexibility permits regulation of liquid depth as well as loading. If maintenance is required on a particular cell, this flexibility permits continual operation. Series operation produces an effluent of higher quality than parallel operation and should be used when a higher level of B.O.D. or coliform removal is required. Each subsequent pond in series operation acts as a clarifier for the effluent of the previous pond. When installations are operated in series, the loading is calculated only on the first cell not the total pond area. During parallel operation, the raw sewage is divided among the cells resulting in equal distribution of waste to each cell.

Testing and Records

One of the most important aspects of lagooning is knowing what has been accomplished. This knowledge of operations is gathered through testing and observation and is retained in records. Records are valuable in that they may thre

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be used to coordinate past with present results as well as aid in the making of future decisions. Records will help in budget planning and will aid in design of improvements. Records also give a composite view of how the lagoon is functioning.

The Michigan Department of Public Health requires three basic types of records. Each working day the operator is required to fill out a record sheet indicating physical and environmental factors. The physical and environmental factors include: maximum and minimum daily temperature, weather type, wind speed, precipitation, flow in million gallons per day, liquid depth, dissolved oxygen, percentage of ice cover, odors and other remarks. The information is submitted to the state health department on a monthly basis.

A second information sheet is used at the time of discharge and a portion is used on a weekly basis. Periodically the raw sewage should be analyzed for pH, B.O.D. and suspended solids (Total and Volatile). This analysis should be carried out by a reliable laboratory. On a daily basis during discharge, the above tests are performed as well as tests for the following: ammonia, nitrates, phosphorus and coliform bacteria. This last group of tests is performed by the Michigan Department of Public Health.

The third record sheet that the state health department requires is a supplemental remarks sheet. On this form

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form flow diagrams are provided where the operator is to indicate which flow pattern has been followed and for what length of time. This sheet is to be submitted to the Michigan Department of Public Health monthly. (Examples of the record sheets presently used will be found in Appendix A.)

The two major criteria which are used to measure lagoon efficiency are B.O.D. and coliform bacteria. The B.O.D. test is used to determine the organic strength of sewage and effluent. The biological oxygen demand test is the actual measurement of the oxygen used in stabilizing the organic matter by microorganisms over a period of five days at a constant temperature of 20°C. Studies by the United States Department of Health indicate that B.O.D. reduction accomplished in lagoons range from a minimum of 43.6 percent which was recorded under ice conditions to a maximum of 98.4 percent. The average reduction range for B.O.D. is 75 to 85 percent.

The majority of coliform bacteria are harmless organisms which are used as indicators. The coliform organisms have their origin in the intestinal tract of humans as well as the soil. They are used as a pollution indicator. Coliform removal by lagooning varies, however removal usually approach 100 percent.

During discharge, dissolved oxygen testing is performed at least three times daily at the site. Lagoon per

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performance can be measured by testing for dissolved oxygen. Since a facultative lagoon is primarily aerobic, a lack of dissolved oxygen or a low reading may be indicative of possible problems. Dissolved oxygen does affect the quality of the receiving waterway. It is desirable to have a dissolved oxygen concentration of greater than 4 mg/l. If the effluent has a concentration below 4 mg/l of dissolved oxygen, discharging should be discontinued until the lagoon recovers.

Michigan regulations state that a raw flow meter and recorder are required for all lagoon systems. The health department prefers a pump station location for the meter because of the need for continuous accessibility and service. An effluent measuring device is also required.

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CHAPTER V

DISADVANTAGES--PROBLEMS

Waste stabilization lagoons are not the panacea of waste treatment. Problems may arise, but with an awareness of potential problems many may be minimized.

Ground Water

The possibility of ground water contamination must be considered when a lagoon is designed. When designing a lagoon system, knowledge of the geology and hydrology is needed to determine what the subsoil conditions are. The information gathered on subsoil conditions should include the local soil type, depth and direction of ground water flow and the infiltration rate. A lagoon should not be deep enough to contact the ground water table.

Two important axioms hold when ground water contamination is considered. First, the better sealed a lagoon the less chance there is for ground water contamination. It has been found that lagoons constructed on materials composed of clay and silt are better insulated against possible ground water contamination than lagoons constructed on other soil materials. Second, the farther the contamination travels through the soil, the less the chance for

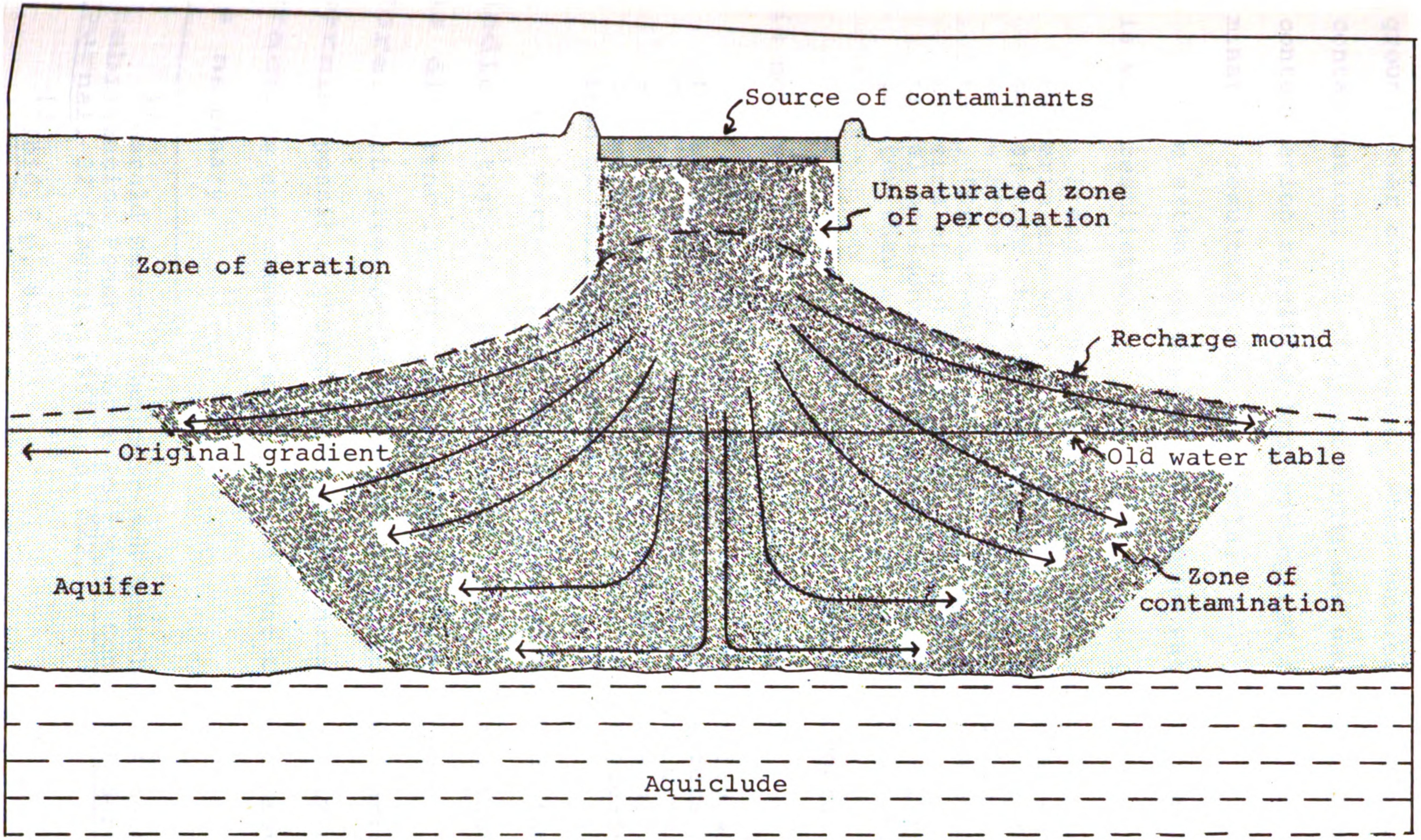

Figure 6.--Schematic Diagram Showing Percolation of Contaminants Through the Zone of Aeration.

Source: Gerald Meyer, "Geologic and Hydrologic Aspects of Stabilization Ponds," <u>Water Pollution Control Federation Journal</u>, 32 (August, 1960), p. 821.

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ground water contamination. When considering ground water contamination, two distinct forms are usually indicated--contamination resulting from biological sources and contamination resulting from chemicals.

The extent of biological ground water contamination is very restricted.

> Stead (6) has pointed out that very few sewage bacteria are able to survive in ground water environments; more than 99 percent die within two or three weeks after exposure to this environment. He states that, "Ground-water velocities vary but are usually in terms of not more than a few feet per day, so that travel horizontally of sewage bacteria for distances greater than a few hundred feet is extremely rare."[12]

The extent and persistence of chemical contamination is not as limited as biological contamination.

> These inorganic liquids are not readily affected by the "filtering" effect that aquifers have on biological contaminants. Dilution with ground water is slow, so that heavy concentrations of chemical waste may travel distances many times greater than bacterial contaminants.[13]

All wirters concerned with ground water contamination indicate that more field data are needed. Each installation is different in hydrologic and geological aspects. Therefore, each site should be evaluated on its own merit concerning possible ground water contamination. Only empirical practices and common sense dictate what type of protection is necessary.

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[12] Gerald Meyer, "Geologic and Hydrologic Aspects of Stabilization Ponds," Water Pollution Control Federation Journal, 32 (August, 1960), p. 822.

[13] Ibid., p. 823.

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Erosion Control

There are three basic types of erosion which may develop in a lagoon system. First, and probably the most frequent, is erosion of the dikes which is created by water moving over exposed soil. This type of ercsion is known as rill and may develop into gully erosion if not stopped. Rill erosion may be easily prevented by the planting of a vegetational cover. Short stem perennial grass with a relatively tight root system has proven very effective. If bare sports in the grass develop, they should either be reseeded or replaced by sod. If drought conditions develop, it may be necessary to artificially water the grass ways.

The second type of erosion that may develop is that caused by waves. The waves which are created by high winds hit the dikes with great force causing a loosening of the soil and an eventual downward movement of the soil particles. The wave action erosion continues until either the bank reaches the angle of repose or some preventive measure is taken. If the waves are left to erode until the angle of repose is reached, an increase in aquatic vegetation results around the dike. Also the structural soundness of the embankment is reduced. If the establishment of grassed banks does not prevent this erosion, some form of riprap, usually pit run gravel is applied. Large rocks, concrete as well as asphalt, have been used for embankment protection. Baffles may also be used to lessen wave action. The mos

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most unusual material used was fiberglass matting which was reported to be very effective.

The third form of erosion is caused by the rapid movement of water. This form of erosion is usually found near the inlet or outlet structures as well as near the interconnecting piping. The erosion is the result of moving water which tends to undermine the bottom matter resulting in suspension and later sedimentation or being carried out to the receiving waterway. Concrete is the most widely used material to prevent this form of erosion. At the inlet pipe a concrete pad as well as a basin is provided for dispersion. The concrete serves to absorb or reflect the energy of the moving water. The same type of protection may be used at the discharge end of the interconnecting piping. To eliminate eroding velocities at the effluent discharge, the effluent is not taken from the bottom but at a minimum depth of one foot.

Odors

Odors result from two principal sources--decaying material and anaerobic decomposition. Odors resulting from anaerobic decomposition are by far the most severe.

During anaerobic conditions, bacteria decompose organic material. This decomposition results in the production of carbon dioxide, water and organic acids. Under extended anaerobic conditions, the organic acids are further reduced to methane, hydrogen sulfide and other gases. The hydrogen sulfide which is produced creates a very objectionable odor which is sometimes referred to as rotten egg gas or septic conditions. It is the objective of facultative lagoons to operate primarily under aerobic conditions which result in little odor. The predominance of aerobic conditions cannot be maintained in Michigan. Therefore, in Michigan there is an extended period of anaerobic conditions. During the winter the gas which results from anaerobic conditions cannot escape to the atmosphere because of ice sealing. During the spring ice breakup, the gases which escape from the lagoon may cause objectionable odors. The septic conditions which result from the spring ice breakup cannot be avoided in Michigan, but the duration as well as the intensity of the odor can be modified.

As soon as the lagoon assumes a facultative condition the odors are minimized. Several methods have been found useful in speeding up the transition period. Where there is relatively little ice build up, the breaking up of the ice helps in venting the gas as well as encouraging surface aeration. It has been found that the period of anaerobic dominance can be lessened by artificially inducing oxygen into the system. Oxygen has been induced by the addition of sodium nitrate which adds available oxygen directly to the lagoon.

Other methods used to reduce the odors which result from anaerobic decomposition include the use of masking compounds. Masking compounds do nothing to the odor or its source. They simply make the odor less offensive, just as perfumes do. Their use has been limited. By regulating the depth of the pond, the duration of odors can be reduced. If the pond level is lowered, the total amount of B.O.D. is reduced. Before the action of discharge is undertaken the Michigan State Department of Public Health must be consulted.

Odors which result from decay are much less intense than odors resulting from anaerobic action. The odors of decay result when organic materials are accumulated on the surface of the pond. By the disposal of the accumulated surface organic material, odors can be eliminated.

Research indicated that high concentrations of sulfates in the water supply may aid in odor production. Two theories have been put forth concerning high sulfate content in the water supply. First, sulfates serve as a supply of sulfur for the formation of odor-producing sulfide gas. The other theory postulates that the presence of sulfate retards biological activity. In either case the prevalence of high sulfate concentrations (more than 500 mg/l) may warrant special considerations.

Insects

Insects are seldom a problem on well maintained lagoons. Federal research has indicated that insect production is directly related to the amount of weed growth.

As with other treatment facilities, the close proximity to human habitation increases the possibility of disease transmission by insects. The possibility of disease transmission is even greater from open ponds. Due care must be taken to minimize the possibility of a health hazard. Mosquitoes are usually the prevalent group of insects associated with lagoons. Some variaties of mosquitoes found in Michigan are associated with the transmission of encephalitis.

It has been found that the destruction of breeding areas is the most effective control of insects. Insecticides have been found very beneficial in the control of insects, but great care must be exercised due to possible toxic effects. Minnows, as well as other aquatic predators, have been used to control insects.

Weeds

Aquatic vegetational growth interferes with the treatment process carried on in lagoons by hindering circulation, reducing sunlight penetration and overloading with organic material as the vegetation dies. The vegetation also provides areas for insect breeding.

Aquatic plants grow in the water with their roots attached to the bottom or along the shore line. Aquatic plants typical to lagoons include cattails, rushes and pond weed. Control of aquatic plants includes mechanical cutting, hand pulling and the use of selective herbicides.

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The fore-mentioned controls should not be needed if an adequate water depth can be maintained in the lagoon (two to two and one-half feet).

Terrestrial weed growth on and around the dikes can be minimized by a regular maintenance program which includes mowing. Some of the more common terrestrial weeds include sunflowers, chickweeds, thistle and ragweed. Terrestrial weeds act as a breeding area for insects, interfere with air movement and subtract from the well kept look of the lagoon.

A weed may be defined as a plant out of place. With this definition any plant with long roots growing on the dikes of the lagoon is considered a weed. Plants with long root structures such as alfalfa, shrubs, willows and cottonwood trees should be destroyed. These long rooted plants impair the waterholding capacity of the dikes.

Ice Cover

In Michigan during the winter ice formation on the lagoons is a common occurrence. Michigan can expect to have ice cover on its lagoons for up to four months. Ice cover conditions create two basic problems.

First, ice cover excludes wind, air and sunlight which are necessary for aerobic conditions. Under ice cover conditions the anaerobic bacteria are the only active microorganisms. The gases which are produced by the anaerobic bacteria are trapped below the ice cover and are

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not vented until the spring ice breakup. As mentioned above at the time of ice breakup, very objectionable odors may be emitted to the air. If ice conditions could be eliminated, odors could be minimized. Ice cover affects both the rate of decomposition and the ventilation of odorous gases.

Secondly, ice tends to cause problems with embankments, piping and control devices. As ice forms, it expands with great force resulting in damage to the forementioned areas. With proper water depth in the lagoons and constructional consideration for ice conditions, the damage resulting under ice conditions can be minimized.

Animals

During lagoon operation animals sometimes create problems. The fence is used not only to exclude humans but to keep domestic and wild animals away from the lagoon. Diseases could be carried by animals allowed around the lagoons. There are two major groups of animals which should be considered.

Burrowing animals can cause extensive damage to lagoon installations. Some of the more common burrowing animals include muskrats, badgers, gophers and beavers. They may cause failure to dikes which is costly because of flood damage and possible health hazards. The tunnels which these animals create weaken the embankments.

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Recently Michigan has experienced problems with muskrats. In the information bulletin "Muskrat Control," the Michigan Department of Public Health outlines several control measures. Trapping during the muskrat season is advised. If satisfactory control is not achieved, a special out of season permit should be sought from the local conservation officer. If control is still not achieved, shooting and use of an appropriate rodenticide is recommended. Due to the migratory habits of the muskrat, repeating the controls through the spring on a yearly basis is recommended. The department of health recommends that they, as well as the local conservation officer, be contacted before a control program is put into operation.

Waterfowl also frequent the lagoon installations in Michigan. The possibility of contamination of the meat of the wildfowl is greatly increased when waterfowl frequent the lagoons. They may also carry bacteria and virus attached to their feathers. However, to date, the Michigan Department of Public Health has not received any complaints concerning waterfowl.

The total effect of lagoons on wildlife is not known. Limited research on the various forms of wildlife which visit lagoons has been conducted.

Animals which may benefit the stabilization process also deserve mention. First, turtles and other aquatic animal life are sometimes mentioned in lagoon literature as stabilizing agents. In some countries lagoons are used to rear fish.

Land Area Required

Very small communities may need less land for lagoons than for conventional waste treatment facilities. This, however, is usually not the case. Michigan's criteria calls for one surface acre for each 100 persons. Therefore, for the average community of 3,000 people being served by a lagoon, a minimum of 30 acres of surface area is required. Dikes and a buffer zone may increase the land requirement to 90 to 100 acres for the total lagoon facility. However, typical sites in Michigan are of about 50 acres. The land area requirements of conventional sewage treatment facilities are usually less than those for lagoons.

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CHAPTER VI

ADVANTAGES

Stabilization lagoons have many advantages for small communities. For an evaluation of an installation, advantages as well as disadvantages should be considered.

Flexibility

Lagoons have more flexibility than other forms of sewage treatment. Operational flexibility is one of the major advantages of lagoons. The loading rate of each cell can be controlled. Series operation usually results in a high quality effluent while parallel operation allows a higher loading rate. With the fore-mentioned flexibility one cell can be taken out of service without halting operation or an appreciable lowering of the effluent quality.

A lagoon system can be built in stages as needed. Construction time is much less than any other sewage treatment system. Some lagoon installations are considered temporary and are only utilized until the population is considered large enough to construct a conventional sewage treatment plant. Lagoons are also used temporarily while interceptor sewers are being constructed.

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Flexibility of size is another advantage of the lagoon system. Lagoons can be constructed in a variety of sizes depending on the community's needs. Lagoons have been used by communities ranging in size from 100 to 125,000 people. (The larger lagoon is in Australia.)

Lagoons have been used for primary, secondary and in some cases tertiary treatment. The life expectancy of a lagoon system is dependent on the maintenance program. Some writers indicate that bottom deposits will only amount to three to six inches in 100 years. (The amount of bottom deposits depends on the quality of inflow, clay, sand, silt, etc.) Many lagoon modifications have been tried and tested. Some have been put into operation. As long as the basic operational theory is followed many new modifications will be found and used.

Cost

A large portion of the literature reviewed indicated economic considerations to be a major advantage of lagoons. However, very little data was supplied to support this supposition. Initial or construction costs as well as operational costs are the two major cost considerations associated with lagoons.

Construction costs of lagoons and conventional treatment facilities are very difficult to compare. No two communities have the same treatment needs or identical locations, therefore construction costs vary. There are three basic ways in which cost comparisons can be made of initial costs. A per capita cost is sometimes used. However, this form of comparison has proven unrealistic in that economy of scale is not considered. The federal government also reports on construction costs. They use a national average on a per capita basis. This data are of little value when only considering Michigan.

Sometimes comparisons of initial costs are made among various treatment facilities already in operation. This form of comparison has proven unsatisfactory in that needs and prevailing conditions are not the same and are very difficult to adjust for.

A third type of comparison which is used is bid estimation. When a project is approved, bids are sought for the cost of the installation. If a particular treatment system is not indicated, several treatment systems are considered each with its own estimated cost. When several construction firms bid on the project each providing its own alternative bid, some form of comparison may be made. However, these bids are not actual cost but only a representative estimate of cost. Each firm has its own preference as to facilities and the bids which are submitted indicate this. Bid estimation is probably the best method to use in making a decision as to which type of facility will cost least. The type of facility chosen will depend on the degree of treatment desired.

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As can be seen from the preceding, initial cost comparison is very difficult to evaluate. The size population that is to be served and land acquisition costs are the two major considerations which determine construction costs.

Lagoons do have a major advantage over conventional treatment facilities in that the operational costs are much less. Lagoons need only a part time inspector and occasional maintenance personnel, while conventional facilities need a full time certified operator and often require round the clock manning. The majority of actual maintenance a lagoon requires is occasional dike repair and monthly mowing, while a conventional plant requires daily maintenance.

In operating lagoons very little special equipment is needed. The needs can usually be supplied from existing supplies. The part time personnel may also be supplied from an existing governmental department. At time of discharge, when special knowledge is necessary, the state health department supplies specially trained personnel. In Michigan post chlorination is not practiced on lagoons, while at conventional treatment plants post chlorination is required by Michigan regulations. This adds to the cost of operation. Average operational costs of lagoons in Michigan are without a doubt less than present day conventional costs.

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Salvage Value

The relatively high salvage value of the lagoon site is another advantage. Lagoons are usually constructed of earthen materials which can be easily reclaimed through the use of earth moving equipment. At a conventional treatment plant, moving or abolishing the facility is much more expensive and time consuming. A lagoon system may be built as a temporary structure where salvage of the land is anticipated, while conventional plants are usually considered permanent structures.

Construction Benefits

The length of time that it takes to construct a lagoon system is usually much less than that for a conventional plant. The major construction activity is associated with earth moving which can be done very rapidly with present day equipment. The lagoons need considerably less piping and controls than conventional plants which results in less installation time.

Results of Stabilization

The results of the stabilization process carried out in lagoons are very good. Many authorities indicate that the effluent of lagoons is comparable to or superior to the effluent of secondary plants. A limited testing program carried out by the Michigan Department of Public Health on streams receiving lagoon effluent supported the fact that effluent is equal and in some cases superior to secondary effluent.

CHAPTER VII

SUMMARY

The three objectives of sewage treatment can be met through treatment in stabilization lagoons. In properly operated lagoon systems, protection of the public health, avoidance of nuisance conditions, and the protection of high quality natural waters are all achieved.

The preparation of the thesis in individual sections to facilitate use as a reference has one major drawback, it does not adequately handle the interactions of sectors. A lagoon system is not made up of static sectors but is a dynamic whole composed of many variables.

Costs are usually the determining factor in a community's decision as to treatment method used. The land aquisition costs are a major consideration in lagooning while with conventional systems this is not the case. In most cases lagooning maintenance costs are substantially less than in conventional treatment facilities.

Lagooning is not the panacea of waste treatment. However, it does deserve attention as a treatment system. The application of lagooning in Michigan has been limited to small communities. The simplicity of operation as well as economic considerations are usually favorable. A lagoon system may create problems and may be the object of community criticism. However, the majority of potential problems associated with lagoons may be either eliminated or minimized by conforming to the Michigan criteria, following an adequate maintenance program and using good sound management practices.

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APPENDICES

APPENDIX A

MICHIGAN DEPARTMENT OF PUBLIC HEALTH

RECORD SHEETS

MDPH
D-4.10

OPERATION REPORT OF WASTE STABILIZATION LAGOONS

____________________, Michigan

Analyst ____________________

____________________, 19 ______

Laboratory ____________________

DATE	FLOW – MGD		INFLUENT				EFFLUENT									REMARKS
	Inf.	Eff.	PH	MG/L			PH	MG/L						COLI–MPN or MF		
				BOD	SUSP. SOLIDS			BOD	SUSP. SOLIDS		NH_3	NO_3	P	TOTAL	FECAL	
					TOTAL	VOL.			TOTAL	VOL.						
1																
2																
3																
4																
5																
6																
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28																
29																
30																
31																
Total																
Arith Mean																

D-4.9 – INSTRUCTIONS

Weather – Report Daily

Temp. – Data should be from a reliable source in community. Data must be from a maximum-minimum thermometer.

Precip. (inches) – Data should be from a reliable source in the community, either at the plant or elsewhere. Do not use general area data. For information regarding official weather stations, write State Climatologist, Room 202, Manly Miles Building, 1405 South Harrison, East Lansing, Michigan 48823. If no reliable source is available install a precipitation gage as recommended by the State Climatologist.

Flow (MGD) – Report Daily

The raw sewage flow should be reported in million gallons per day (MGD), for example:

70,000 gallons per day as 0.07 MGD.
375,000 gallons per day as 0.38 MGD.
3,750,000 gallons per day as 3.75 MGD.

Use no more than three figures.

Power – Report Daily

Report the power consumed for pumping at the major pump station in kilowatt hours (KWH).

Liquid Depth – Report at Least Weekly

The depth to the nearest one-half foot in each of the lagoon cells, for example:

2 foot 2 inches as 2 ft.
4 foot 7 inches as 4½ ft.
5 foot 10 inches as 6 ft.

Dissolved Oxygen

Report time when a dissolved oxygen sample is taken. The dissolved oxygen concentration should be reported at least once a week in each cell during the period when the lagoon is not being discharged and once a day during discharge on the cell being discharged, recording the minimum D.O. value of at least three samples taken during the day (morning, noon and evening).

Ice Cover – Report at Least Weekly

Report the percentage of the lagoon system covered with ice. If measurements of ice and snow depths are taken report these results in remarks column.

Odors

Report odor condition as noted on form. If odors are not detectable indicate with dashed line in appropriate space. Discuss any unusual circumstances concerning odors in remarks column.

Remarks

This space should be reserved for any observations and information not included in other parts of this form. Observations on algae concentrations (both suspended and floating) color and turbidity in the lagoon along with comments on efforts to control rodents, insects and weeds should be reported. Problems with industrial waste, storm water or infiltration should also be noted. If additional space is necessary, please use Supplemental Remarks Sheet.

Flow Pattern

Indicate by brief sketches on Supplemental Remarks Sheet (MDPH – D-4.9a) the pattern (or route) of flow through the lagoon system.

MDPH
D-4.9

OPERATION REPORT OF WASTE STABILIZATION LAGOONS

________________________, Michigan

Month ____________ 19 ____ Operator ____________

DATE	WEATHER					Flow MGD	Power KWH	LIQUID DEPTH-Ft.			D. O. Mg/l				% ICE COVER	ODORS c	REMARKS
	TEMP. °F		a	b	Precip. inches			CELL			TIME	CELL					
	Max.	Min.	Type	Wind				1	2	3		1	2	3			
1																	
2																	
3																	
4																	
5																	
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28																	
29																	
30																	
31																	
TOTAL																	

a. Weather Type – C- Clear CL- Cloudy R- Rain W- Windy CA- Calm
b. Wind – Indicate strength and direction – S- Strong M- Med. W- Weak
c. Odors – S- Slight M- Moderate O- Offensive C- Complaints

INSTRUCTION FOR D-4.10

Date Record all data and analysis results on line corresponding to day of sample collection.

Flow (M.G.D.) Record influent and effluent flows in million gallons per day using three figures.

Example: 37,000 gallons per day as 0.04 MGD
Example: 168,000 gallons per day as 0.17 MGD

The volume of flow is recorded on MDPH form D-4.9 but should also be recorded here to aid in quick evaluation of lagoon or receiving stream loadings.

Influent (Laboratory Data) Periodic analysis of raw waste flows should be performed by a reliable laboratory to determine the waste load tributary to the lagoon system. Analysis should be performed for:

pH A measure of the acidity or alkalinity of the waste.

BOD Biochemical Oxygen Demand, measured in milligrams per liter; a measurement of the strength of the waste material in terms of the oxygen required to biologically stabilize or "treat" the wastes.

Suspended Solids (Total and Volatile) Measured in milligrams per liter; a measurement of the total amount of solid materials in the waste which may be filtered out of the sample and the portion of those solids which are volatile and may be subject to organic decomposition.

Effluent (Laboratory Data) Each weekday during lagoon discharge a composite sample of effluent flow should be collected and delivered to a reliable laboratory for analysis to determine the quality of effluent discharged to the receiving stream. pH, BOD, and Suspended Solids (Total and Volatile) are as noted above. By comparison with representative influent flow analyses these results indicate the degree of treatment provided. Results from each individual composite sample indicate the loading on the receiving stream for that day.

The remaining analyses will be performed by the Michigan Department of Public Health and the results will be reported to the operator for recording on the report form. These tests will include:

NH_3 Ammonia

NO_3 Nitrate

P Total Phosphorus reported as P.

Coli Coliform Bacteria M.F. (membrane filter count per 100 ml) or M.P.N. (most probable number as determined by the multiple tube method, per 100 ml). Indicate test method used.

Remarks Note any unusual conditions relative to factors affecting analysis results.

Total Flow Record total volume of influent and/or effluent flow for the month.

Arith. Mean (Average) Calculate arithmetic mean values for all columns (except Coliform) by adding all values in each column and dividing by the number of data entries in the column.

MDPH
D-4.9a

WASTE STABILIZATION LAGOONS

SUPPLEMENTAL REMARKS SHEET

________________________, Michigan

Month ________________________ 19 _____ Operator ____

FLOW PATTERN (Sketch flow pattern in space provided below, indicating dates during month. If more than one pattern was used make an additional sketch for each period.)

From ______________________________ To ______________________________
(Date) (Date)

From ______________________________ To ______________________________
(Date) (Date)

From ______________________________ To ______________________________
(Date) (Date)

REMARKS

____
____
____
____
____
____
____
____

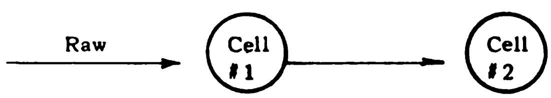
D-4.9a - INSTRUCTIONS

Flow Pattern

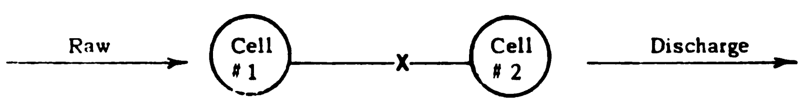
Indicate by brief sketches on Supplemental Remarks Sheet (MDPH - 4.9a) the pattern (or route) of flow through the lagoon system.

Examples:

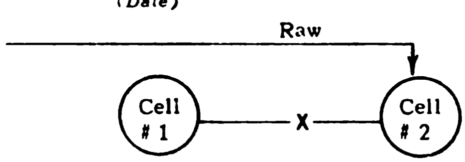
From October 1, 1968 (Date) To October 4, 1968 (Date)



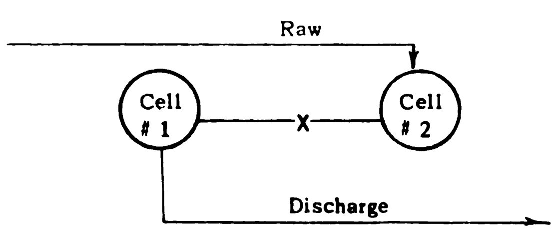
From October 5, 1968 (Date) To October 13, 1968 (Date)



From October 14, 1968 (Date) To October 22, 1968 (Date)



From October 23, 1968 (Date) To October 31, 1968 (Date)



APPENDIX B

ECONOMIC COMPARISONS

TWO MICHIGAN COMMUNITIES--COSTS COMPARISON DATA

Beulah

Consideration for additional treatment to a primary treatment plant.

100 people for 100,000 gallons.

Sand filtration	$48,000
Trickling filter	69,600
Activated sludge	74,400
Sewage lagoon	56,000

1965

Dryden

Projections--not in operation or under construction.

600 people.

	Prefabricated	Lagoon
Construction	$82,000	$35,000
Operating	9,500	2,000

1965

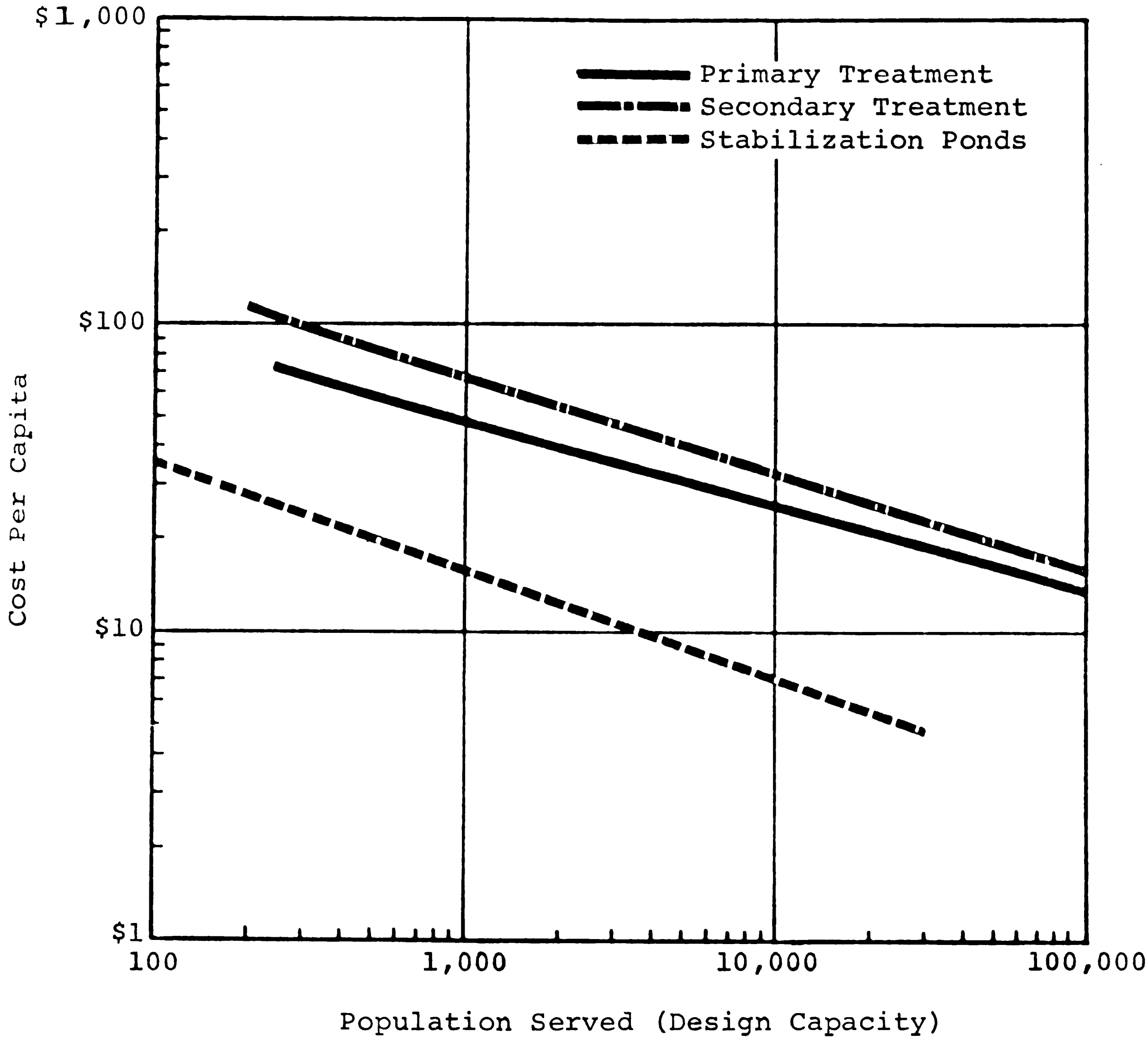
Source: Michigan Department of Public Health

CONSTRUCTION COST COMPARISONS OF ILLINOIS SEWAGE TREATMENT PLANTS FOR 1957-1959 BASE

Type of Treatment plant	Total cost for design PE's of						Cost ratio* for design PE's of					
	500	1000	2000	5000	10,000	30,000	500	1000	2000	5000	10,000	30,000
Primary--digester			183,000	287,000	403,700	696.900			1.50	1.27	1.12	0.92
Primary--vacuum filter			80,900	145,300	226,000	456,000			0.66	0.64	0.63	0.61
Trickling filter--digester		95,100	149,900	272,000	426,900	872,400		1.24	1.23	1.20	1.19	1.16
Trickling filter--Imhoff	48,000	76,600	122,100	226,100	360,200	753,900	1.00	1.00	1.00	1.00	1.00	1.00
Activated sludge, constructed in place		124,900	176,000	293,200	397,800	1,081,000		1.63	1.44	1.30	1.10	1.43
Activated sludge, factory built	53,500	81,000	122,600	212,200	321,200		1.11	1.06	1.00	0.94	0.89	
Trickling filter additions	63,250	96,200	146,400	254,900	387,700	753,900	1.32	1.26	1.19	1.13	1.08	1.00
Activated sludge additions	77,500	119,500	184,300	326,850	504,000	1,002,000	1.61	1.56	1.50	1.45	1.40	1.33
Oxidation lagoon without land cost	25,400	41,000	66,200	124,000	201,000		0.53	0.54	0.54	0.55	0.56	
Oxidation lagoon with land cost	30,600	50,500	83,600	162,800	272,300		0.64	0.66	0.68	0.72	0.76	

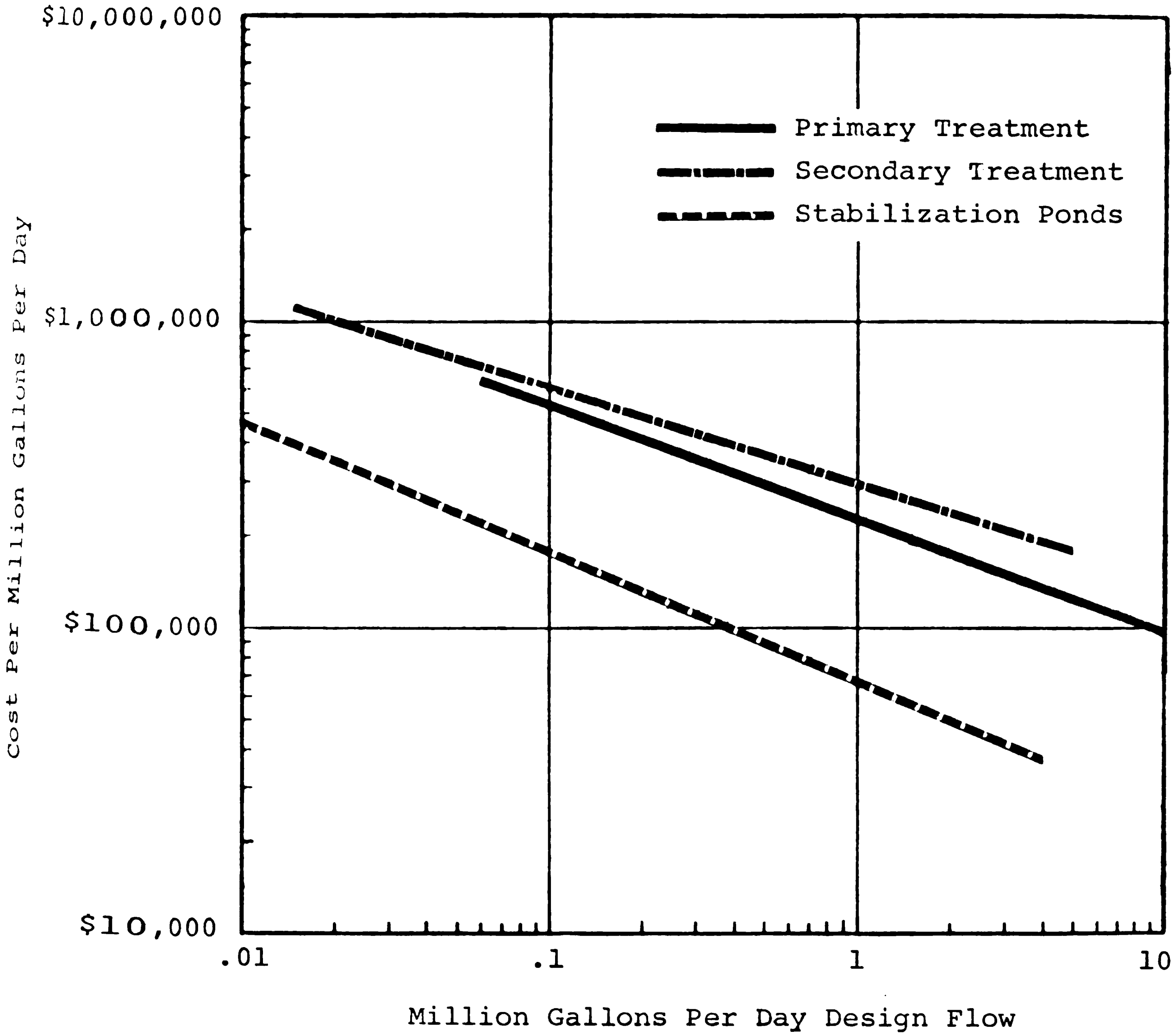
*Ratio of construction costs to trickling filter-Imhoff costs.

Source: Illinois State Department of Public Health.



Construction Cost per Capita--Composite Comparison by Types of Treatment.

Source: U. S. Department of Health, Education, and Welfare, Public Health Services--Division of Water Supply and Pollution Control, <u>Modern Sewage Treatment Plants--How Much Do They Cost?</u> (Washington, D. C.: U. S. Government Printing Office, 1964), p. 33.



Construction Cost per Unit Flow--Cost Comparison by Types of Treatment

Source: U. S. Department of Health, Education, and Welfare, Public Health Services--Division of Water Supply and Pollution Control, Modern Sewage Treatment Plants--How Much Do They Cost? (Washington, D. C.: U. S. Government Printing Office, 1964), p. 18.

APPENDIX C

CASE STUDIES

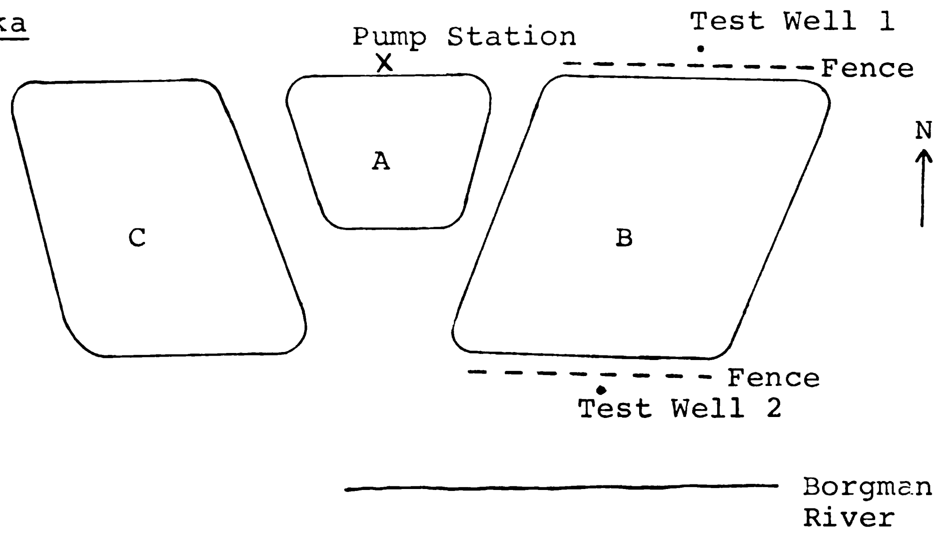
CASE STUDIES

To aid in understanding this thesis, four municipal lagoons were selected at random as case studies. The author did not visit these sites or talk with the operating personnel until a preliminary draft of the thesis was prepared. This was done for two reasons. It did not give a bias when writing the thesis and the completed preliminary draft served as a guideline for discussion with operating personnel.

The interviews which were conducted were private and were usually held before visiting the actual lagoon site. Each operator had his own method of explaining how the lagoon functioned.

In visiting the various lagoon sites, one can gain an appreciation for the reasons that Michigan's regulatory agencies have only a general guideline and evaluate each system on its own merit. The shape and size of each lagoon can be expected to vary due to individual community needs. Methods of operations, maintenance, and testing vary greatly from lagoon to lagoon; however, all operators indicated satisfactory lagoon operation.

Kalkaska



The community of Kalkaska is located in the northern portion of the lower peninsula, east of Traverse City on the Borgman River. The lagoon site is located down river from the community and one-half mile away from the river and community. Only one cell of the three celled structure is being used (cell B). Cell A had been used as a primary cell; but due to overloading, odors were created and use of cell A was discontinued.

Kalkaska is a community of about 1,500 people. The community is built on soil which is made up principally of sand. At the time of construction a clay blanket was applied to each cell to aid in sealing.

The operation of the lagoon system has created few problems. The establishment of a ground cover has been very difficult. Odors have been a problem to the nearest resident, who is located one-half mile down wind from the lagoon. However, operating personnel indicate odors to be minimal.

To increase the knowledge concerning ground water contamination, a very limited testing program was carried out on July 17, 1970. The following are the results of the testing program:

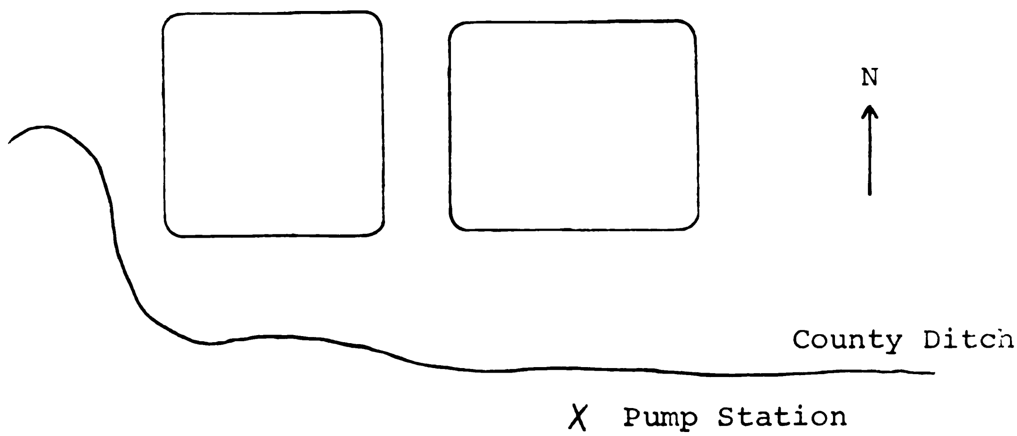
Testing

July 17, 1970
Analysis: July 20, 1970
Method of analysis: Quick Hack Method

Location	Depth	Sodium Cloride	Total N (Nitrates)	Ortho-Phosphate
1. 100 ft. North end	19' 2-1/2"	50 PPM	10 PPM	0 PPM
2. 100 ft.+ South end	6'	50 PPM	12 PPM	0 PPM
Inlet		200 PPM	5 PPM	10 PPM
Outlet		150 PPM	6 PPM	10 PPM

Testing performed by Sejed M. Usman.

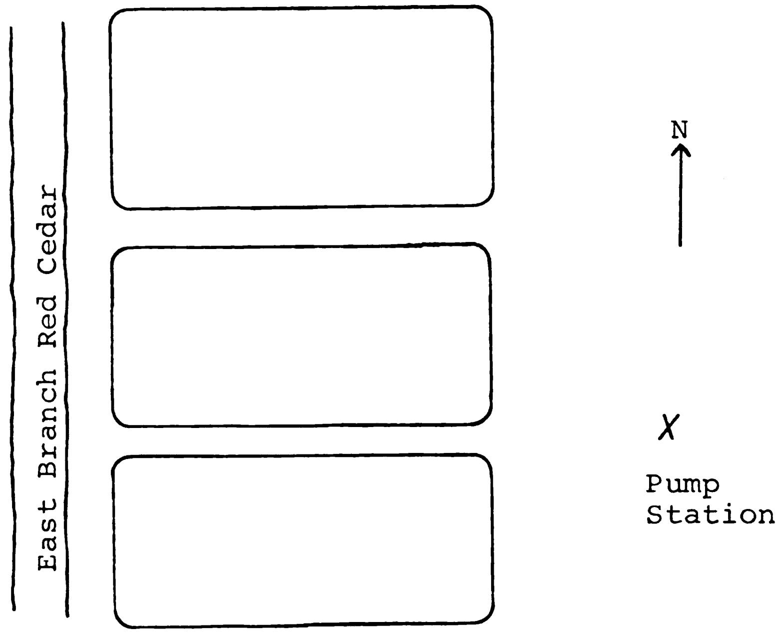
Potterville



The community of Potterville is located in the lower half of the lower peninsula of Michigan directly west of Lansing. The community has a population of about 1,250 and is using a two celled structure which is located about one-half mile northwest of town. The lagoons will be discharged into an open ditch owned by the county which is located 200 feet from the installation.

The community has been using the lagoon system for 14 months. A weed problem had developed but has been remedied by manual removal. No odor problem has been indicated. However, muskrats are being trapped. The site is 28 acres in size and the lagoon surface is a little less than 15 acres. The lagoon is checked daily, and a weekly testing for dissolved oxygen is carried out. Due to the high precipitation this year, mowing has proven a problem.

Fowlerville

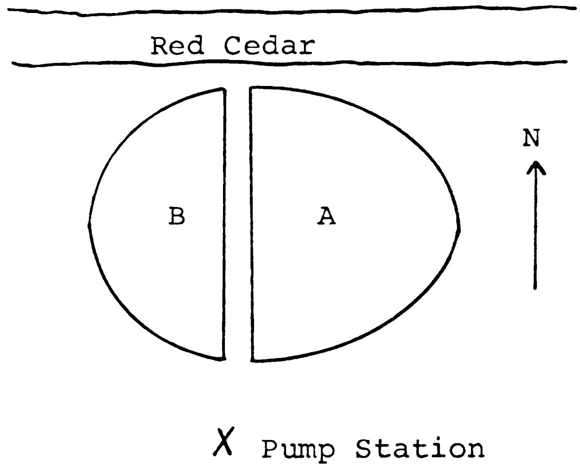


Fowlerville is located southeast of Lansing. Since 1962 the lagoon system has been used by the community. About 2,000 people are now served by the three celled structure which is located on a 72 acre site of which 32 acres are pond area.

In being one of the first communities to use lagoons, Fowlerville has had many problems. The site is on the flood plain of the east branch of the Red Cedar River. It is located in a marsh area. This year it has been too wet to mow. Aquatic weeds have been a major problem. They are now mechanically removed. The nearest resident is 1,500 feet away from the installation, and recently a new municipal well located 1,200 feet away was put into operation. Dispersion of floating solids has been necessary for odor control.

The lagoon site is checked two or three times a week. There is no testing program carried out. The operator did indicate that the community was satisfied with its operation.

Webberville



Webberville is located southeast of Lansing. The population is about 700. The lagoon has been in operation only one year. Only one of the two cells are being used. The lagoon will be discharged into the Red Cedar River which is located about one quarter mile north of the lagoons. The lagoons are located north of the community. The 40 acre site of which 12 acres are pond has the appearance of a well kept pond area. The lagoons have been sealed with bentonite clay. The operator did indicate that muskrats have proven to be a problem.

Conclusion

Each lagoon site conformed quite closely to the design standards which are followed in Michigan. The only exception would be the lagoon serving the community of Fowlerville.

The four lagoon installations which were visited had several things in common. For each community the lagoon system in use was the first community sewage treatment system. All fencing was of the agricultural page wire variety with a single strand of barbed wire. Each operator contacted indicated that in his own opinion the lagooning method was satisfactory for his community.

APPENDIX D

WASTE STABILIZATION LAGOONS IN MICHIGAN

WASTE STABILIZATION LAGOONS IN MICHIGAN*

(As of May, 1969)

Community	Population Estimate	River Basin
Ada Township		Grand
Auburn	1497	Kawkawlin
Bangor	2109	Lake Michigan
Beaverton	926	Tittabawassee
Belding	5000	Grand
Bridgman	1454	Lake Michigan
Brown City	993	Black
Brownstown Township	17200	Huron
Capac	1235	Belle
Carleton	1379	Lake Erie
Cassopolis	2027	St. Joseph
Cedar Springs	1768	Grand
Chesterfield Township	4000	Lake St. Clair
Crystal Falls	2500	Paint
Eau Claire	562	St. Joseph
Edmore	1234	Grand
Fennville	705	Kalamazoo
Fowlerville	1674	Grand
Gaylord	2700	No Outlet
Harrison Township		Clinton
Hart	1900	Lake Michigan
Howard City	1004	Muskegon
Ithaca	2900	Shiawassee
Kalkaska	1321	Boardman
Kent City	617	Grand
Byron Center		Grand
Kent Co. Airport	5000	Grand

Community	Population Estimate	River Basin
Lakeview	1126	Muskegon
Lawton	1402	Paw Paw
Lexington	722	Lake Huron
Memphis	996	Belle
Midmichigan Airport	3150	Saginaw
Morenci	2053	Tiffin
Olivet	1185	Kalamazoo
Ottawa County		Grand
Ovid	1505	Grand Maple
Pentwater	1030	Lake Michigan
Plainfield Township	1481	Augres
Potterville	1028	Grand
Sand Lake	400	Grand
Scottville	1245	Pere Marquette
Shepherd	1293	Tittabawassee
Stanton	1139	Grand Flat
Stockbridge	1097	Huron
Suttons Bay	421	Lake Michigan
Union City	1669	St. Joseph
Vernon	754	Shiawassee
Wakefield	3000	Black
Webberville	664	Grand
Yale	1621	Black

*Source: Michigan Department of Public Health.