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ENVIRONMENTAL IMPACT STATEMENT

DRAFT

Part II Organic Solids Reuse Plan and Environmental Assessment

Prepared by Madison Metropolitan Sewerage District,
Dane County, Wisconsin

ORGANIC SOLIDS REUSE PLAN

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INTRODUCTION 1

Chapter 1
INTRODUCTION

This report is in partial fulfillment of an agreement dated 28 January 1975 between the Madison Metropolitan Sewerage District (MMSD) and CH2M HILL to furnish engineering services to MMSD for an Advanced Waste Treatment (AWT) Facilities Plan and an Organic Solids (sludge) Reuse Program for the Nine Springs Sewage Treatment Works. Described herein are the investigation of alternatives and the recommended Sludge Reuse Program. The AWT Facilities Plan by CH2M HILL is reported separately. Another engineering consultant, O'Brien and Gere, has been retained by MMSD to develop the long-term wastewater discharge strategy. These studies are in compliance with Wisconsin Pollutant Discharge Elimination System (WPDES) Permit No. WI-0024597 received by MMSD on 27 September 1974. The permit requires completion of a facilities plan prior to further work on advanced treatment, sludge disposal, and final effluent disposal.

This report on sludge reuse precedes completion of the discharge strategy and facilities plans so that the recommended reuse plan can be more quickly implemented. Therefore, certain estimates of the character and quantity of sludge to be reused had to be made for this report. The reuse program is flexible so that it can be modified upon completion of new facilities or changes in the treatment plant operation to allow for different organic solids character and quantity.

1.1 SCOPE OF STUDY

The work tasks required to prepare this report consisted of the following:

- Review and analyze previous efforts related to organic solids disposal.
- Determine present character and volume of sludge and estimate future character and volume of sludge.
- Review local, state, and Federal regulations regarding distribution and application of sludge on land.

- Perform a study of potential sludge application sites including a soils survey, a ground-water survey, and a review of current farming practices.

- Determine permissible organic solids loading rates.

- Determine the probable extent of public and farm community participation or concern in an agricultural reuse program.

- Evaluate alternative reuse programs based on potential sites for facilities and application, ownership of sites, timing of organic solids application, methods of distribution and application, and management of application sites.

- Recommend a reuse program.

- Develop a public information and/or marketing program.

- Outline a monitoring program which will assure the success and safety of the reuse program.

1.2 HISTORY OF SLUDGE DISPOSAL AT NINE SPRINGS TREATMENT WORKS

The Madison Metropolitan Sewerage District initiated the practice of recycling sludge about 40 years ago. From the early 1930's until World War II, the digested sludge produced at the Nine Springs Sewage Treatment Works was dewatered on sand drying beds and sold or given to the public for fertilizing lawns and gardens. This recycling program was stopped at the beginning of World War II because the manpower required to continually load and clean the drying beds was no longer available.

In 1942 the District constructed a 45-acre sludge disposal lagoon east of the Nine Springs Works. This disposal system was relatively easy to maintain and resulted in low sludge handling costs over the next 25 years. When the original lagoon began approaching capacity in the 1960's, a second, 85-acre lagoon was constructed just east of the first lagoon. The lagoon disposal system continued without problems until April 1970 when a portion of the dike enclosing the second lagoon broke. The resultant spill of approximately 85,000,000 gallons of lagoon supernatant into Nine Springs

Creek was cited as the cause of a large fish kill. The State of Wisconsin brought suit against the District for the fish kill. The suit was settled when the District paid for damages and entered into a stipulation assuring timely work to achieve a more reliable sludge disposal method. The District repaired the dike system and installed a pump and pipeline to return supernatant from the east lagoon to the plant for treatment. This was done to lower the water level in the lagoons and to help prevent further dike failures. The dikes have since been continuously maintained and raised as needed.

In November 1973 another section of the second lagoon dike began to fail. Extensive repair efforts prevented any large supernatant spills. The decision was made in late December 1973 to discontinue using the second lagoon unless the first lagoon filled to a level of potential failure. In order to allow for continued use of the first lagoon, the District began dredging sludge from it to make room for the 180,000 gallons of sludge discharged from the treatment plant each day. This then began the existing system of using the first lagoon for sludge storage and settling out the solids. The supernatant is returned to the plant for treatment and eventual discharge to Badfish Creek. The solids are periodically dredged from the lagoon bottom and hauled by truck to land of requesting farmers for recycle as fertilizer and soil conditioner.

1.3 PAST REPORTS ON SLUDGE DISPOSAL

The 1970 lagoon dike failure prompted MMSD to seek more reliable methods of sludge disposal. An investigation by Warzyn Engineering and Service Company, Inc., showed that the lagoon dikes were built on peat and silt with very little bearing strength and would require extensive repair to prevent further failures. In March 1971 Greeley and Hansen Engineers finished a *Report on Sewage Treatment-Additions to the Nine Springs Sewage Treatment Works* which included possible courses of action for sludge handling and disposal. The Wisconsin Department of Natural Resources (DNR) reviewed the report and issued a pollution abatement order which, among other things, required that MMSD provide for the satisfactory disposal of sludge from the Nine Springs Sewage Works and that the operation shall include provision for the abandonment of the present method of disposal of liquid sludge in the Nine Springs Marsh.

In a report to DNR in January 1972 the District outlined actions taken to arrive at an acceptable sludge disposal solution and indicated the methods under consideration and their associated costs. DNR replied that the following sludge disposal methods would be acceptable: (a) spreading of liquid digested sludge on farmland, (b) composting, (c) vacuum filtration of digested sludge and disposal of cake on land, and (d) vacuum filtration of undigested sludge followed by incineration. During 1972 the District corresponded with the City of Madison regarding composting the City's solid waste with the District's sludge. Difficulty in coordinating with the various organizations and communities affected inhibited further investigation of this alternative.

The District consulted the U. S. Soil Conservation Service as to suitable areas for disposal of liquid sludge on lands in Dane County. In July 1972 MMSD received a letter report describing nine possible disposal sites. The nine sites were selected on the basis of the soil's ability to filter describing nine possible disposal sites. The nine sites were selected on the basis of the soil's ability to filter the leachate. In June 1973 MMSD retained Roy F. Weston, Inc., Environmental Scientists and Engineers, to conduct a study of appropriate methods for sludge handling and disposal. The Weston report recommended that the District pursue liquid digested sludge application on farmland as the method of disposal. The District staff prepared an addendum to the Weston report which examined several treatment and disposal alternatives not considered in the Weston report. A more detailed discussion of the alternatives considered in the Greeley and Hansen and Weston reports is contained in Chapter 2.

Several proposals from commercial firms have been made to MMSD for disposal of their sludge since the first dike break in 1970. These include the Livingston Irrigation and Chemical Company, Buhler Bros., Ltd., Browning-Ferris Industries, Inc., and Enviro-Systems of Wisconsin. The proposals were studied by the District and were either rejected or not acted upon.

2.1 GREELEY AND HANSEN REPORT

2.2 WESTON REPORT

2.3 MMSD ADDENDUM TO WESTON REPORT

2.4 MMSD DECISION

REVIEW OF SLUDGE DISPOSAL ALTERNATIVES CONSIDERED 2

Chapter 2
REVIEW OF SLUDGE DISPOSAL ALTERNATIVES CONSIDERED

Alternative methods of sludge disposal have been studied in detail by Greeley and Hansen, Engineers, and Roy F. Weston, Inc., Environmental Scientists and Engineers.

2.1 GREELEY AND HANSEN REPORT

The Greeley and Hansen March 1971 *Report on Sewage Treatment Additions to the Nine Springs Sewage Treatment Works* includes a description of five alternative sludge handling and disposal methods. The alternatives consist of the following: (A) spread dried digested sludge on land; (B) incinerate digested sludge; (C) incinerate raw sludge; (D) heat treat and landfill digested sludge; (E) apply liquid digested sludge to land. Economic analysis of these five alternatives indicated that Alternative E, liquid sludge application to land with 25-mile pipeline transport was the most cost effective. The cost estimated for Alternative E treatment, disposal, and transportation was about $23.00 per ton dry solids. The costs for Alternative E with rail transportation was estimated somewhat higher at about $30.00 per ton dry solids. The estimated costs for the other alternatives including 25-mile truck transport, were as follows: (A) spread dried digested sludge on land, $66.00 per ton dry solids; (B) incinerate digested sludge, $82.00 per ton; (C) incinerate raw sludge, $75.00 per ton; and (D) heat treat and landfill digested sludge, $91.00 per dry ton. These costs were based upon an Engineering News Record (ENR) Cost Index of 1450 and a sewage flow of 57 million gallons per day (mgd).

2.2 WESTON REPORT

The Weston report, *Nine Springs Sewage Treatment Works Sludge Disposal Study*, investigated several sludge disposal methods. Subsurface placement disposal was rejected because DNR stated that they would not approve of the method. The alternative of continued lagoon disposal was eliminated because of the recent lagoon dike failure and because it would not receive support of public officials. Marketing for land application of dried sludge in a form like Milorganite was rejected because of lack of a suitable market.

Incineration was also investigated in the Weston report. Sludge dewatering, chemical addition, or use of supplemental fuel to support combustion were considered necessary for incineration. Mechanical dewatering was investigated, but the moisture content of the cakes was so high that the heat value of the cake was not adequate to support combustion. Chemical additions, used to help achieve lower moisture in mechanical dewatering, consumed so much heat in the recalcination process that again the sludge would not support combustion. Sandbed drying and lagooning could be used to dewater the sludge, but would not meet the requirement of continuous sludge feed to an incinerator. It was therefore determined that incineration could not be used without supplemental fuel. The alternative of incineration was abandoned because of the limited future fuel supply.

Three remaining alternatives for sludge disposal, sanitary landfill, land application of liquid sludge, and land application of compost, were found to be suitable and were analyzed on the basis of costs. The estimated 1975 costs per ton dry solids for a disposal rate of 10,676 tons per year were as follows: Sanitary landfill system, $95.00; land application of sludge-solid waste compost, $196.00; land application of sludge-wood chip compost, $140,00; and land application of liquid sludge system, $63.00. The alternative of land application of liquid digested sludge was found to be most economical and was recommended for implementation.

2.3 MMSD ADDENDUM TO WESTON REPORT

The MMSD staff prepared an addendum to the Weston report in April 1974 which included additional sludge disposal alternatives. Seven alternatives were selected for further study, three of which were eliminated. Alternatives 1B and 1C which included heat treatment of thickened raw sludge followed by thickening, mechanical dewatering, and trucking to land trench were both eliminated because of the poor quality of thickener overflow and vacuum centrate following the heat treatment process. Alternative 2B, anaerobic digestion of sludge, followed by trucking to a lagoon and land irrigation, was eliminated because of the high cost of trucking the sludge.

Four remaining MMSD proposed alternatives and their estimated costs per ton dry solids are as follows:

- Alternative 1A--Chemical conditioning of thickened raw sludge followed by trucking to land trench, $50.00.

- Alternative 2A--Anaerobic digestion of thickened raw sludge, followed by pipeline transport to a lagoon and land irrigation, $41.00.
- Alternative 3A--Anaerobic digestion of thickened raw sludge followed by chemical conditioning, centrifugation, trucking to a mixing site, mixing with milled refuse, and landfill disposal, $79.00.
- Alternative 3B--Anaerobic digestion of thickened raw sludge followed by chemical conditioning, centrifugation, trucking to disposal site, and land spreading, $60.00.

Alternative 2A was found to be the least costly.

2.4 MMSD DECISION

The three aforementioned studies on methods of disposal of sludge from the MMSD Nine Springs Sewage Treatment Works all came to the same conclusion: Land application of liquid digested sludge is the most economical and acceptable method for sludge disposal. In June 1974 the MMSD Commission resolved that liquid digested sludge from the Nine Springs Treatment Works be handled through the process of application on land. This report therefore deals solely with land application as the disposal method. The other methods--incineration, composting, mechanical dewatering--were found to be technically unfeasible or less economical.

3.1 GENERAL

3.2 EXISTING SYSTEMS

3.3 RESEARCH AND REPORTS

3.4 SUMMARY

LAND APPLICATION OF SLUDGE STATE OF THE ART 3

Chapter 3
LAND APPLICATION OF SLUDGE
STATE OF THE ART

3.1 GENERAL

In reviewing what has been done throughout this country and in Great Britain on the reuse of organic solids (sludge) three basic levels of reuse came to light--fertilization, high-rate fertilization and disposal. Table 3-1 illustrates these three basic reuse levels.

The reuse of organic materials for "fertilization" as shown on Table 3-1 utilizes low loading rates (less than 20 tons dried material per acre per year) depending on sludge characteristics, soil, and crop grown. The objective is the maximization of crop production by full use of the nutrients present in the organic materials. Almost any soil suitable for high-rate agricultural production is suitable for this type of operation. The key feature of this system is that a balance between the nutrients added and the nutrients removed with the crops is maintained. Only the amount of organic material required to maximize crop production is applied.

TABLE 3-1

THREE BASIC CATEGORIES FOR WASTE ORGANICS APPLICATION TO LAND
MADISON METROPOLITAN SEWERAGE DISTRICT

METHOD	LOADING RATES: ANNUAL	LOADING RATES: MAXIMUM ACCUMULATION	OBJECTIVE	SUITABLE SOILS	IMPACT ON QUALITY: SOIL	IMPACT ON QUALITY: WATER
FERTILIZER	Less than 1-20 tons/ac depending on waste organics characteristic, soil and crop grown.	100-1,000 tons/ac. prevent excess accumulation of heavy metals or other pollutants in soil	Maximize crop production by use of fertilizer value to supply part or all of primary and/or micro nutrients	Any soil which is suitable for high agricultural production	Improves soil fertility and organics improve soil structure No detrimental effects.	With a well-managed system, there would be no harmful effect on ground water or surface water
HIGH-RATE FERTILIZER	Less than 5 to more than 75 tons/ac.	400-1,000 tons/ac. to prevent toxic accumulations of pollutants in the soil	Apply organics to cropped soil Maintain crop while maximizing organics applications	Generally fine-textured soils with a high capacity to adsorb or precipitate large quantities of heavy metals or other pollutants	May reduce soil usefulness for some crops or uses soil that would probably be improved at lighter loadings Accumulation of pollutants in soil must be monitored.	Possibly would result in excess nitrogen which could be leached to ground water Proper management of surface runoff would protect surface waters
DISPOSAL (LANDFILL)	5 to several hundred tons/ac.	Several hundred to 1,000 or more tons/ac.	To dispose of organics by incorporation in soil A crop may or may not be grown between applications	Generally fine-textured soils with a high capacity to adsorb or precipitate large quantities of heavy metals or other pollutants.	Soil usefulness will likely be greatly reduced Accumulation of pollutants in soil should be monitored	Excess nitrogen could be leached to ground water Proper management would minimize potential for pollution from other materials.

The "high-rate fertilizer" system uses higher loading rates (up to 75 tons per acre per year). The objective is to maximize the amount of organic materials applied with crop production secondary in importance. Soils suitable for this type of operation should be fine textured with a high capacity to absorb or precipitate large quantities of heavy metals. Eventually, continued unbalanced applications of organic materials may reduce the soil's usefulness to grow certain crops because of accumulations of heavy metals or salts. The application of the nitrogen contained in the organic materials would not be balanced by crop removal or natural denitrification, and accumulation of nitrogen in the soil would probably occur. Nitrogen compounds could eventually reach the ground water or surface system if proper precautions are not taken.

The third general method of operation involves "disposal" at very high loading rates (up to several hundred tons of organic materials applied per acre per year). The objective is to dispose of as much organic material as possible by incorporation into the soil with little or no emphasis on crop production. Fine textured soils will precipitate large quantities of heavy metals or other pollutants and are suitable for this type of operation. The end result of continued operation using the "disposal" method is the potential impairment of the soil due to accumulation of salts, heavy metals, and nitrates in the soil. Leaching of nitrates, salts, and heavy metals from the soil into the ground water or carrying of these materials into the surface water regime are a potential hazard that must be designed for.

3.2 EXISTING SYSTEMS

This review of the "State of the Art" was not intended to be all inclusive, for to do so would require a voluminous compilation of material. Pertinent examples of the general types of systems presently in operation are presented.

Metropolitan Sanitary District of Greater Chicago (MSD)

The Metropolitan Sanitary District of Greater Chicago (MSD) operates two organic solids sites utilizing land disposal and/or incorporation techniques. At Arcola, Illinois, a subcontracted system is operated by SEMCO (Soil Enrichment Materials Company). In Fulton County, Illinois, MSD operates an ambitious reclamation project to reclaim abandoned strip mined land for agricultural production.

SEMCO Project-Arcola. SEMCO (Soil Enrichment Materials Company) is under contract with MSD to clean out several of the District's existing sludge storage lagoons. The State of Illinois Environmental Protection Agency has jurisdiction over the operation and has issued a permit allowing application of 150 dry tons of organic material per acre per year to the land.

For several years up through 1974, SEMCO used about 300 acres of owned and leased land for organic solids application. In 1973, they grew corn on 34 acres. The remainder of the site was used solely for application of organics with no cropping. In 1974, they grew corn and soybeans on about half of the site and applied organics on the remaining half.

SEMCO has recently started selling the organics to farmers and hauling it to them in trucks which also spread the material. This method was begun because the site at Arcola could not be enlarged.

The organic materials were incorporated into the top 14 inches of the soil and spread by a tractor drawing an incorporation mechanism. There had been public objections to application of the organics by sprinkler irrigation because of wind carry of the spray and odor problems. Because of public objections, subsurface application has become the dominant method of application.

The Illinois EPA has required construction of a berm around the field to provide protection from the 100-year flood. Runoff from precipitation and snowmelt is allowed to collect behind the berm and stand for evaporation and percolation.

Because of the high application rates on the Arcola site and the lack of continuous cropping of the majority of the area, this site could be classified as a "disposal" site. Continued monitoring of heavy metals buildup, nitrogen, phosphorus, and coliform counts are presently being undertaken on the Arcola site. As operating experience is obtained, these data will be useful in judging the potential for pollution of the ground water and the surrounding environment from this type operation. The effects of the SEMCO operation on the environment outside of the site appears to be minimal.

Fulton County Site. The Fulton County project site is owned and operated by the Metropolitan Sanitary District of Greater Chicago. The site is an abandoned strip mine encompassing almost 750 acres. It is necessary to note that all this land was acquired without the need to obtain a conditional land-use permit. The obtaining of such permits can become a major political stumbling block to the implementation of organic solids systems. Fulton County had no solids waste ordinance at the time of land acquisition. They now have such an ordinance along with all the traditional land-use restrictions machinery and are currently negotiating with the District on the location of additional storage basins.

The operation begins by barging the liquid organic material 200 miles down the Illinois River from the treatment plant to the unloading docks in Fulton County. From there, it is pumped overland about 11 miles through a pipeline to the project site near Canton, Illinois, where it is stored in four large lagoons. The total capacity of these lagoons is approximately 8 million cubic yards. The lagoons encompass an area of 260 acres at an average depth of 32 feet.

From the lagoons, the organic material is distributed to the various fields through an overland piping system. In the past, the material was applied to land using mainly self-propelled big gun sprinklers. Presently, the main method of sludge application is by tractor-drawn moldboard or chisel plows. These soil incorporation systems are fed 3.5-4.0 percent solids content sludge by a flexible hose which is dragged behind the plow. Sprinkler application is now used only on certain sites which have adequate buffer areas.

The surface runoff from the site is collected, and if not detrimental to the receiving stream, it is discharged. If the runoff is found to be detrimental, it is reapplied to the fields.

The organic materials are spread by the Sanitary District personnel as previously described. The farming operations are all accomplished by contract. The contracted farmer plants, cultivates, applies herbicides, and harvests and crops for a price determined through competitive bidding. The crop belongs to the District. Bidding interest has been low, but the MSD personnel indicated that they have been able to count on at least two bidders for each contract. The cost of the farming operations appears to be about double the going rate in the area. The reason is believed to be the presence of the contract document with its long list of legalities and specifications. Despite this markup, the value of the crop has been paying for the farming operations.

The Fulton County project currently has a permit to apply 75 tons of dry organics per acre for the first year, 60 tons per acre the second year, and so on down to 20 tons per acre during the fifth year. After this period, the permit will be reviewed. To this date, they have only been able to apply 5 tons per acre due to equipment limitations. They will apply heavier loadings when they are capable.

The most significant observation made during our visits to the Fulton County operation was the apparent lack of concern over what we have come to consider in our studies as heavy loadings. The crop grown on the project site is corn, and only the grain portion of the corn is removed from the field. The stalk and all the other foliage are left in the field and thus the nitrogen contained therein is recycled back to the soil. The net removal of nitrogen from the site is much less than the amount applied each year.

The Fulton County operation can be classified as a "high-rate fertilizer" system. The main objective is to maximize organics application with the cropping of the site being somewhat secondary to this end. MSD has recently come under pressure from the U.S. EPA to change this operation because of odor problems.

West Hertfordshire Main Drainage Authority, Great Britain

The West Hertfordshire Main Drainage Authority in Rickmansworth, Great Britain (HERTS) was visited to determine how their program, which has been widely publicized by the EPA, has actually operated.

The HERTS treatment works serves a total population of 550,000 plus several industries which produce a waste equivalent to about 700,000 people. Total flow of the plant is about 35 mgd (US). The plant provides secondary treatment utilizing the activated sludge process. Waste activated sludge and primary sludge are anaerobically digested and hauled as a liquid to consenting farmers. They have more requests for the organic materials than they can satisfy.

Several years ago, the HERTS Authority purchased 1,200 acres of land for the purpose of "demonstrating the value of the sludge as a fertilizer." The land was operated as a farm, but the farmers never really accepted the system. They viewed it as a disposal operation and would not accept the use of the organic materials on their private farmlands.

About 6 years ago, the Authority hired a marketing manager whose job was to develop a market for organic materials. To accomplish this task, he made several major changes in the Authority's operation. The changes made were all in the area of improving public relations. The Drainage Authority's management acknowledges these changes as the key element to their present success.

The changes made in the Drainage Authority's operation were as follows:

1. The organic materials were given a name. The name, "HYDIG," was established and enabled the Authority to use a name other than "sewage sludge" or "waste organic materials" in all of their literature. Everyone in the vicinity of the Authority's operation knows what HYDIG is, but they are not reminded so blatantly that the material is "sewage sludge." HYDIG is a much less descriptive and more acceptable name for the product.

2. The public and the farmers were told explicitly what HYDIG is. HERTS has published a pamphlet describing in very basic language the operation of the treatment plant, the origin and treatment of HYDIG, the fertilizer value of HYDIG, and some documentation on its benefit as a fertilizer.

3. A strong monitoring program was instituted. A policy was developed by which organics would not be applied to any land until samples of soil were analyzed for heavy metals content. Once the soil data are recorded, organics are applied according to a predetermined program. A sample of the organics is also analyzed prior to application to the farmer's land.

   The basis of control is the "zinc equivalent" wherein the metals concentrations are related by their relative toxicity to the toxicity of zinc.

   The British admit that they are not sure they are recording the correct data or if the data will be of use in the future. They are sure, however, that it is important to the farmer to know that someone is watching over his land to make sure it is not damaged.

4. The farmer is given the quantity of material that he wants when he wants it and where he wants it. The British have gone out of their way to please the farmer. In addition to trucking and spreading the materials, they also provide free spraying, if desired. Portable pumps and irrigation equipment are used during the winter when the fields are too wet to get a truck on the land.

5. The image of the truck driver was changed. The truck drivers are first and foremost the ambassadors of the Authority. The public and farmers see more of the drivers than any other individuals.

   The drivers travel about 100-120 miles per day in about eight trips. They spread organics, lay pipe, or do anything else to speed up the operation.

   They take samples as required and also keep a log of all activities. They also must keep their trucks clean. It was noted that it takes a great deal of supervision to maintain a crew of drivers that will adhere to this code of conduct. While good conduct was lavishly recognized, bad conduct resulted in immediate dismissal.

With the foregoing public relations program, the Authority has been able to dispose of their entire supply of organic materials on public farmlands.

The HERTS Authority currently operates a fleet of 22 tank trucks ranging in size from 1,200 U. S. gallons to 6,000 U. S. gallons. They also have two portable pumps and associated irrigation equipment. In the summer, about 85 percent of the organics is truck spread and 15 percent is spray irrigated. In the winter, about 85 percent is spray irrigated and 15 percent is truck spread. They currently deliver to about 70 farmers who own an average of 100 acres each, or a total of 7,000 acres. Standard application rates are about 12,000 U. S. gallons of 4 percent organic material per acre per year. This is quivalent to a dry solids loading of about 2.0 tons per acre per year. This is considerably lower than the 20-75-ton loading at the Chicago Fulton County site. The HERTS Authority now puts organics on their own land only for the purpose of maintaining current research programs.

The cost to the Authority for utilizing their organic materials in this manner is about $3.25 per ton of dry solids. This includes all costs from the time the material leaves the secondary digester until it is on the fields (including the cost of management). This compares to $12.50 per ton for estuarine or ocean disposal, which is the major means of disposal in Great Britain.

The HERTS application is a most notable example of the "fertilizer" category of organics application shown in Table 3-1. The organic material is utilized mainly as a source of fertilizer for growing crops, and the growth of crops is optimized by the individual farmers. The disposal of organic material by the farmers is a secondary consideration with maximizing of crop production being primary in their minds.

Los Angeles County Sanitary District Composting System

Representatives of CH2M HILL visited the Los Angeles County Joint Wastewater Treatment Facility in Willmington, California, where air drying and composting of organic materials is presently practiced.

The plant is a 350-mgd primary plant with single-stage anaerobic digestion. No solids-liquid separation takes place in the digesters, and the digested sludge is centrifuged in solid bowl centrifuges. Centrifuged sludge at approximately 70 percent moisture is applied to the composting system.

Approximately 100-120 tons of dry solids per day are composted by constant turning in long windrows approximately 4.5 feet high. The final product is approximately 30 percent moisture. Temperatures of 140°-150°F are reached within the windrow during the composting and curing operation which takes approximately 20 days in the summer and 40 days in the winter.

The composting operation is extremely dependent on having dry weather for successful operation. If prolonged periods of rainfall occur, the entire composting operation must be stopped and the organic material removed and buried. During such periods, strong odors can occur. During normal operation, the process is relatively odor free.

The composted end product is sold to a fertilizer company located on county land adjacent to the composting operation. The fertilizer company bags the compost without additives and sells it for home garden use. They are able to market all of the composted organic material that is produced by this plant and are currently allocating it to selected customers.

City of Boulder, Colorado

James L. Smith, Associate Professor of Agricultural Engineering at the Colorado State University in Fort Collins, Colorado, has been working with the City of Boulder, Colorado, to develop a system of subsurface injection for their organic materials. The subsurface injection system developed by Smith requires relative low power inputs and mixes the sludge with the top layers of the soil (at depths as shallow as 3-5 inches). With this type of injection plow, 1,000-1,500 gallons per minute of 4-5 percent solid material can be injected below the surface of the soil.

One significant result achieved by Smith's work is the fact that the injector can be used to achieve high loading rates at low cost. Several of his test plots have received a total of nine injections of organic material; an application rate of 280,000 gallons per acre. The average solids content of this material was 3.8 percent and resulted in a loading rate of 45 dry tons per acre. Most of the plots were injected weekly during October and November.

Smith anticipates that because of the high performance characteristics of this machine, it would be possible to inject organic material during wet weather or with snow on the ground and still obtain satisfactory results. The injector has been operated successfully when the ground was frozen 2 inches deep.

At Boulder, the organic material is delivered to the operating tractor and plow through a buried pipeline to various connection points throughout the injection field. A 660-foot 6-inch-diameter rubber hose connects the plow to the distribution points.

Metropolitan Denver Sewage District No. 1

In early 1971, the Metropolitan Denver Sewage Disposal District No. 1 made a commitment to develop a long-term beneficial sludge reuse system to replace an interim sludge recycle system at the Lowry Bombing Range. An investigation of alternative systems indicated that agricultural reuse of anaerobically digested wastewater treatment plant sludge is the most economically and environmentally desirable solids handling system for the District. Digested sludge used as fertilizer has shown strong indications of being a valuable resource. In a preliminary marketing effort, the District has already located some potential users for its digested sludge.

Design has now begun on an agricultural reuse system which is expected to begin operation in early 1977. The proposed site of this new agricultural reuse system will be located approximately 25 miles east of the Central Plant and will initially encompass 2,000 acres. The site will serve as a sludge drying and distribution center. Sludge treatment will be accomplished by anaerobic digestion at the Central Plant in Commerce City. The liquid sludge will then be delivered from the plant to the distribution site through a system of force mains and a booster pumping station. The drying and distribution site will include approximately 600 acres of drying basins for open air drying of the sludge, a storage area for stockpiling the dried material prior to distribution to the users, an area of subsurface injection of the sludge, demonstration plots, and miscellaneous site facilities necessary for operation and maintenance. The sludge material will be available for agricultural reuse in both dry and liquid form. The dried sludge produced by the open air drying process will be stored at the distribution center for marketing. The liquid sludge will be distributed to the farmers from the Central Plant, the booster pump station, or the distribution center.

City of Salem, Oregon

A fertilizer rate reuse program has recently been started at Salem, Oregon. This program was patterned after the HYDIG system used in England. The sludge has been given a trade name, BIOGRO, a brochure has been prepared and distributed which describes BIOGRO and the reuse program, and a public relations manager has been appointed. The City has been truck hauling and applying 45,000-60,000 gallons of sludge to farmland each day. The program has been an immediate success with more than 20 farmers requesting sludge for their land.

Other Locations

Table 3-2 briefly describes several other selected sludge reuse programs.

TABLE 3-2

OTHER SLUDGE REUSE PROGRAMS
MADISON METROPOLITAN SEWERAGE DISTRICT

LOCATION	METHODS
Springfield, Illinois	Sprinkler application on 66 acres Began in 1965
Ottawa, Illinois	Surface irrigation on 37 acres Reclamation of *silica sand site*
Shawnee National Forest, Illinois	Land application on 190 acres Reclamation of barren strip-mined land
Blue Plains, D C	Plow or disk sludge into soil Trench in up to 500 tons per acre Presently 240 wet tons per day are being processed into dried pellitized fertilizer for sale Land application for reclamation, soil conditioner, or fertilizer at various places using different methods since 1938
San Diego, California	Reclamation of Mission Bay Park began in 1951.
St Mary's, Pennsylvania	Hauled in 1,500 gallon capacity trucks, applied with portable irrigation system. Used on farmland.
Piqua, Ohio	Hauled and applied on 380 acres with 5,000 gallon capacity tanker
Montgomery County, Ohio	Liquid sludge hauled and applied with 3,800 and 6,300 gallon capacity trucks Filter cake also used Sludge applied on county and private farms
Kankankee, Illinois	Apply liquid sludge on 8,000 acre ranch Began in 1965
England	About 40% of municipal treatment works recycle sludge to land
Marshall, Missouri	Switched from drying beds to liquid sludge recycle in early 1950's Used on farmland
Milwaukee, Wisconsin	Sludge is mechanically dried, bagged, and marketed as fertilizer and soil conditioner Marketed under trade name of "Milorganite"
Grand Rapids, Michigan	Sludge is mechanically dried and marketed as a fertilizer and soil conditioner Marketed under trade name of "Rapidgro" Operated since 1932.
28 Cities in Southeast	Recycled on land as soil conditioner and fertilizer in towns in Alabama, Arkansas, Florida, Kentucky, South Carolina, and Tennessee.

3.3 RESEARCH AND REPORTS

University of Wisconsin Research

The College of Agricultural and Life Sciences, University of Wisconsin, Madison, has been actively involved in research on land application of sludges for several years. Their research has shown that rye, corn, and sorghum-sudan yields increased with moderate sludge applications (Kelling, et al, 1974). Up to 20 cm of liquid digested sewage sludge were applied with no detrimental effect on yields. They did notice that where sludge or water is spread by tank truck on established alfalfa, crown survival through the winter and yields were markedly reduced. They also found that liquid sludge provides residual fertility and its greatest benefit may be improvement of the long-term fertility status of soils.

Research on phytotoxic effects of heavy metals in sludge was reported by Cunningham in 1974. This, as most of the research reported on by the University of Wisconsin, was performed at Arlington and Janesville, Wisconsin. These studies indicated that the cadmium application should be limited to 2 pounds Cd per acre each year and 20 pounds Cd per acre over the life of the site. Ryan and others in 1973 and 1975 reported on nitrogen transformations and availability in sludge-amended soils.

Other Major Reports

The current sludge handling technology is covered in many publications. Among the more recent are the Proceedings of the Second National Conference on Municipal Sludge Management and Disposal which was held in August 1975, and the Process Design Manual for Sewage Sludge Treatment and Disposal (EPA, 1974). Burd in 1968 reported on the status of the sludge handling art.

3.4 SUMMARY

Several important principles can be derived from the "State of the Art" review reported herein. If a true recycle system is to be established and the organic materials truly utilized for beneficial purposes, then it becomes evident that cooperation of the local farming community is essential. Experience of the HERTS Authority in Great Britain emphasizes that the importance of a well-managed distribution operation cannot be overstated.

4.1 CHARACTER OF SLUDGE PRESENTLY PRODUCED

4.2 CHARACTER OF SLUDGE PRODUCED IN THE FUTURE

TREATMENT PLANT SLUDGE CHARACTERIZATION 4

Chapter 4
TREATMENT PLANT SLUDGE CHARACTERIZATION

The Nine Springs Sewage Treatment Works' sludge character and quantity were required for the basis of the land application rates. The existing sludge characteristics were determined by sampling and analyzing the digested sludge produced by the Nine Springs Works. The future sludge character may change due to changes in the sewage input or because of changes in the operation or equipment of the treatment works. Since this study precedes the final results of the advanced waste treatment study, the expected changes in the sludge character and volume had to be estimated for the treatment alternatives considered.

4.1 CHARACTER OF SLUDGE PRESENTLY PRODUCED

The character of the sludge produced under the existing conditions was determined by a sampling and chemical analysis program and by comparison to data supplied by MMSD.

Sampling and Analysis Procedures

Analyses were performed on grab samples collected at the digested sludge inlet pipe to the small lagoon.

The sampling procedures and analytical tests performed on both the treatment plant sludge and lagoon deposit samples collected during the study were in accordance with the following publications:

- EPA: *Methods for Chemical Analysis of Water and Wastes* (1974).
- APHA, AWWA, WPCF: *Standard Methods* (1971).
- Roberts, S., Vodraska, R. V., Kauffman, M. D., and Gardner, E. H.: *Methods of Soil Analysis Used in the Soil Testing Laboratory at Oregon State University* (Special Report No. 321, April 1971). Agricultural Experiment Station, Oregon State University, Corvallis.

- EPA: Great Lakes Region Committee on Analytical Methods: *Chemistry Laboratory Manual--Bottom Sediments* (December 1969).

The treatment plant sludge samples were analyzed for the following constituents: total solids, total volatile solids, total soluble salts, pH, potassium, iron, zinc, copper, titanium, lead, barium, chromium, manganese, nickel, tin, cadmium, molybdenum, cobalt, aluminum, arsenic, boron, selenium, mercury, sulfate, alkalinity, calcium, magnesium, total Kjeldahl nitrogen, ammonia nitrogen, and total phosphorus.

Results of Analysis

The results of the analysis performed for this study and in the recent past by Warf Institute for MMSD are shown in Table 4-1. Because there was some question about the validity of the analysis for nitrogen, extra analyses were performed by CH2M HILL and MMSD. These results are shown with results of analysis by the University of Wisconsin Soils Laboratory in Table 4-2.

TABLE 4-1

CHARACTERIZATION OF TREATMENT PLANT ORGANIC SOLIDS
MADISON METROPOLITAN SEWERAGE DISTRICT

PARAMETER	CH2M HILL			WARF INSTITUTE					AVERAGE	TYPICAL DIGESTED SLUDGES(2)
	2-21-75	3-10-75	4-11-75	4-30-74	5-22-74	5-31-74	6-6-74	6-14-74		
Total Solids, %(3)	2.3	2.2	2.5	2.92	2.41	2.21	2.28	1.88	2.34	4 – 6
Total Volatile Solids, %(3)	1.6	1.6	1.6						1.6	
Total Soluble Salts (EC), µmhos/cm	6,380	7,220	7,840						7,150	
pH	8.11	8.12	8.11						8.11	
Potassium, mg/kg	9,100	9,100	4,820						7,670	12,000 – 19,000
Iron, mg/kg	10,800	6,800	8,950						8,850	8,000 – 78,000
Zinc, mg/kg	1,600	2,200	1,910	2,192	2,448	3,032	2,877	2,712	2,370	490 – 12,200
Copper, mg/kg	500	570	505						525	140 – 10,000
Titanium, mg/kg	<90	<90							<90	
Lead, mg/kg	640	380	175	188	245	177	246	234	286	40 – 4,600
Barium, mg/kg	1,820	1,000	600						1,140	530 – 1,340
Chromium, mg/kg	290	100	312						234	50 – 32,000
Manganese, mg/kg	200	170	198						189	180 – 1,130
Nickel, mg/kg	270	60	50.5	55	45.6	54.3	61.4	53.2	81	15 – 1,700
Tin, mg/kg	<10	<10							<10	
Cadmium, mg/kg	<40	160	60.3	37.7	62.2	63.3	87.7	69	73	5 – 400
Molybdenum, mg/kg	<10	<10							<10	
Cobalt, mg/kg	40	<20							30	
Aluminum, mg/kg	2,640	3,100							2,870	3,600 – 12,000
Arsenic, mg/kg	14	<14							14	
Boron (hot water soluble), mg/kg	4.0	394	500						300	150 – 750
Selenium, mg/kg	<4	<4							<4	
Mercury, mg/kg	6.2	6.5	4.8	10.3	10.7	17.2	19.3	17.6	11 6	0.6 – 31
SO_4-S (soluble), mg/kg	470	200							335	
Alkalinity as $CaCO_3$ pH 4.5, mg/kg	5,800	6,100							5,950	
Alkalinity as $CaCO_3$ pH 4.2, mg/kg	6,300	6,600							6,450	
Calcium, mg/kg	13,400	62,300	77,900						51,200	42,000 –180,000
Magnesium, mg/kg	6,600	7,400	12,900						8,970	8,000 – 12,000
Total Phosphorus, mg/kg	6,000	9,100	26,800						13,970	27,000 – 61,000

(1) Results are shown on dry weight basis, except as noted, for various sampling dates.

(2) As reported by Konrad and Kleinert.

(3) Percent of sample volume.

TABLE 4-2

SUMMARY OF NITROGEN ANALYSIS[1] OF MMSD DIGESTED SLUDGE
MADISON METROPOLITAN SEWERAGE DISTRICT

DATE	ANALYZED BY	TOTAL NITROGEN (%)	AMMONIA (%)	ORGANIC (%)
5-16-74	U of W Soils Lab	8.2	3.9	4.3[2]
5-23-74	U of W Soils Lab	9.1	4.8	4.3[2]
5-30-74	U of W Soils Lab	9.3	4.9	4.4[2]
6-06-74	U of W Soils Lab	9.6	5.2	4.5[2]
6-20-74	U of W Soils Lab	9.0	4.3	4.7[2]
6-27-74	U of W Soils Lab	9.3	4.6	4.8[2]
2-21-75	CH2M HILL	11.4	6.9	4.5
3-10-75	CH2M HILL	14.8	7.9	6.9
4-11-75	CH2M HILL	12.3	6.6	5.7
6-29-75	CH2M HILL	12.1	6.3	5.8
6-03-75	MMSD	10.4	5.7	4.7
Average MMSD Digested Sludge		10.5	5.5	5.0
Average MMSD Lagoon Sludge		5.9	1.2	4.7
Typical Digested Sludge		5.0	1.6	3.4

(1) Unless otherwise noted all samples were analyzed on a wet weight and reported on dry weight basis

(2) These samples were oven dried before analysis for total nitrogen. Therefore the results are only an estimate of the organic nitrogen. The total nitrogen content is the sum of the ammonia plus an estimate of the organic.

The sludge analysis also indicated a high level of cadmium. Therefore, in an attempt to find major cadmium sources, effluent samples from five service area industries, Ray-O-Vac, Ohio Medical Labs, Kipp Corporation, Mautz Paint Company, and Northern Plating, were collected and analyzed. This survey did not find any significant single source of cadmium. Of an estimated cadmium inflow to the plant of about 2.9 pounds per day, less than 0.15 pound per day could be attributed to the five sampled industries.

Discussion of Results

Most of the sludge constituents, with the exception of ammonia nitrogen and solids content, are within or near the range of values for typical digested sludges. The high ammonia nitrogen may be creating a problem of ammonia toxicity in the digesters. Under normal operating conditions, which should be achieved in future modifications to the treatment plant, the ammonia nitrogen content is expected to be nearer to the typical 1.6 percent. Lagoon aging of the sludge for a few months has also been shown to be effective in reducing the nitrogen content to normal levels. The high nitrogen content of the sludge, while being a benefit to the farmer, creates a problem for the District in that more farmland would be required for sludge application.

The solids content is lower than typical for digested sewage sludge. This low solids content results in about twice as much liquid to be handled as would be required with a typical 4- to 6-percent solids sludge.

The cadmium to zinc ratio of the treatment plant sludge averages 3.1 percent. This may present a problem for land application of the sludge because of a possible health hazard. This problem is discussed further in Chapter 6. Possible sources of the relatively high cadmium content include the electroplating industries, pigments and chemicals, alloys, and automobile radiators and batteries. The District should perform an industrial waste survey to identify the point sources and require that cadmium be removed before discharging to sewers.

4.2 CHARACTER OF SLUDGE PRODUCED IN THE FUTURE

The character of the sludge produced in the future will depend on the discharge strategy ultimately selected for the project. Several discharge strategies have been considered for this project which require a wide range of effluent qualities and, therefore, a wide range of degrees of treatment. Since the quality and quantity of sludge produced is dependent on the degree of treatment, it is necessary to define what levels of treatment are being considered so that the impact on the reuse program can be assessed.

At this time, several discharge strategy alternatives have been eliminated. Those remaining for detailed study require the following effluent qualities or degrees of treatment.

- Effluent I: Less than 30 mg/l of BOD and suspended solids; less than 2.0 mg/l ammonia nitrogen.
- Effluent II: Less than 10 mg/l of BOD and suspended solids; less than 0.2 mg/l of ammonia nitrogen.
- Effluent III (for industrial reuse): Less than 100 mg/l of total hardness; less than 1,000 mg/l of total dissolved solids; less than 0.2 mg/l ammonia nitrogen.

The qualities required for Effluents I and II can be accomplished with conventional biological treatment processes. The quality required for Effluent III will require a lime softening treatment of the effluent from a biological treatment process. A discussion follows on how these effluent quality requirements will affect the future quality and quantity of sludge produced at the Nine Springs Works.

Quality of Sludge

Organic Sludges. The quality of the organic sludges is expected to improve with the anticipated modifications and expansions required to meet the effluent qualities under consideration. The current high ammonia content and low solids concentration may be improved by a modification of the digester operation. This is currently under study as a part of the AWT study. If this study fails to find an acceptable solution, another solution would be to age the sludge by lagoon storage. Aging the sludge would accomplish two things; first, a portion of the ammonia will be lost by volatilization and second, the sludge will go through a natural freeze-thaw cycle which has proven to be effective in improving the settleability and dewaterability of the sludge.

Lime Softening Sludges. As stated earlier, Effluent III will require lime softening of a high quality effluent to make it acceptable for industrial reuse. This process will produce large quantities of lime sludge in addition to the organic sludges if this effluent is required. We again will recommend that these sludges be handled separately. Depending on the quality of the lime sludge, it may be suitable for land application to maintain a proper pH in the soil. If the lime sludge is of poor quality, we will recommend landfill as the ultimate method of disposal. In the event industrial reuse is selected as the recommended discharge strategy, we will investigate the ultimate disposal methods in more detail.

Quantity of Sludge

The quantity of organic sludges is, for most cases, expected to increase with the implementation of the proposed modifications and expansions to the Nine Springs Sewage Treatment Works.

The 1974 level of sludge production was estimated, based upon MMSD data, to be about 5,350 tons dry solids per year. This is expected to increase in proportion to the volume of flow treated until 1977 when the Fifth Addition goes on line. The sludge production is then expected to increase markedly to about 6,000 tons dry solids per year due to more effective BOD removal. The sludge production is again expected to increase in direct proportion to the volume treated until 1981 when the advanced waste treatment (AWT) facilities are expected to go on line. The sludge production with AWT will depend upon the level of treatment provided and the treatment process selected.

There are currently several processes under consideration to produce the levels of treatment required. One of these processes will eliminate the need to digest and recycle secondary waste activated sludge. It is a biophysical treatment process* which utilizes activated carbon in the aeration basin to absorb nonbiodegradable organics. During the process of regenerating the spent carbon, the waste activated sludge is converted (destroyed) to an inert ash. This ash can then be handled separately and placed in a landfill or it may be returned to the head of the plant and handled with the primary sludge. If this process is selected, there will be a significant reduction of organic sludge to handle as there will be no waste secondary sludge. Only primary sludge would then be available for anaerobic digestion and land application.

Implications of a Future Phosphorus Removal Requirement

At the present time, the discharge strategies being considered in detail do not require phosphorus removal. However, in the event future effluent quality requirements demand phosphorus removal, we would recommend that a chemical treatment system be employed. The effect of a chemical phosphorus removal system on the quantity and quality of sludge produced will depend upon the specific process employed which, in turn, will depend upon the phosphorus removal requirement.

The two most common phosphorus removal systems employed today are:

1. Addition of alum or ferric chloride to the activated sludge aeration basins and

2. Addition of alum, ferric chloride, or lime in a separate tertiary treatment system.

At the present time, these systems also appear to be the most promising alternatives for future phosphorus removal at Nine Springs.

*Developed and marketed by Zimpro, Inc.

The addition of alum or ferric chloride to the activated sludge system will result in the production of a combined biological-chemical sludge. Experience with anaerobic digestion of combined biological-chemical sludges has shown that the digestion process is generally not impaired. Achievement of 80-90 percent phosphorus removal at the Nine Springs plant, however, would increase the quantity of digested solids requiring disposal by 50 percent or more. More important, the quality of organic solids would be severely impaired by the presence of a high concentration of aluminum or iron. Based upon irrigation water quality criteria discussed in Section 6.3, these biological-chemical sludges would not be suitable for land application.

Tertiary chemical treatment for phosphorus removal with alum, ferric chloride, or lime would result in production of a chemical sludge. We would recommend that such purely chemical sludges be handled separately from the organic solids. As stated earlier, lime sludge may be suitable for land application to acid soils to maintain a proper soil pH. Chemical sludge resulting from the addition of alum or ferric chloride would have few beneficial qualities for land application. Consequently, dewatering and landfill would be appropriate for alum and iron sludges and for lime sludge which could not be land applied.

Summary

Tables 4-3 and 4-4 summarize the quality and quantity of the treatment plant sludge (organic solids) to be used for the remainder of the report.

TABLE 4-3

SUMMARY OF EXPECTED TREATMENT PLANT ORGANIC SOLIDS QUALITY
MADISON METROPOLITAN SEWERAGE DISTRICT

PARAMETER(1)	EXISTING	5TH ADDITION ON LINE 1977	AWT ON LINE 1981
Total Solids, %	2.3	2.3	5(2)
Nitrogen, %	10.5	10.5	5(2)
Phosphorus, mg/kg	13,970	13,970	13,970
Potassium, mg/kg	7,670	7,670	7,670
Cadmium, mg/kg	73	50(3)	20(3)
Zinc, mg/kg	2,370	2,370	2,370
Copper, mg/kg	525	525	525
Nickel, mg/kg	81	81	81

(1) All results, except total solids are reported on dry weight basis.

(2) Improved quality expected due to modifications in plant operation

(3) Improved quality expected due to source removal program

TABLE 4-4

SUMMARY OF EXPECTED TREATMENT PLANT
ORGANIC SOLIDS QUANTITY(1)
MADISON METROPOLITAN SEWERAGE DISTRICT

YEAR	LEVEL I 30/30(2)	LEVEL II 10/10	LEVEL II 10/10 WITH BIOPHYSICAL	LEVEL III 10/10 WITH LIME SOFTENING
1981	5,870	6,730	2,890	6,730 +Lime Sludge
1990	6,560	7,500	3,230	7,500 +Lime Sludge
2000	7,460	8,520	3,660	8,520 +Lime Sludge

(1) Tons of dry solids per year.

(2) Indicates an effluent with 30 mg/l of BOD and 30 mg/l of suspended solids.

The solids content is expected to be increased to about 5 percent and the high nitrogen content is expected to be reduced to a more typical 5 percent with the addition of AWT facilities in 1981 or by lagoon aging. A program to find the major cadmium point sources and remove or reduce them should be implemented as soon as possible. If successful, the cadmium should be reduced to at least 20 mg/kg. This would reduce the cadmium to zinc ratio to less than 1 percent.

The quantities of sludge expected for the various effluent qualities and processes are shown in Table 4-4. We have used the quantities indicated by Effluent II without bio-physical sludge processing in preparing the remainder of this report.

SLUDGE LAGOON STUDY 5

Chapter 5
SLUDGE LAGOON STUDY

5.1 BACKGROUND

The sludge disposal lagoons at the MMSD Nine Springs Sewage Treatment Works are located just east of the treatment plant as shown on Figure 5-1. There are two lagoons, one approximately 45 acres in size, and one approximately 85 acres. The smaller west lagoon (Lagoon 1) was constructed in about 1942, while the dikes for the larger east lagoon (Lagoon 2) were installed in 1967.

The dikes were constructed on the westerly edge of an extensive grass-sedge marsh area. The underlying surficial soils are primarily peat and organic silts. These soils have low bearing capacity, and consequently the dike sections of Lagoon 2 have failed twice since their construction. The two areas of embankment failure are shown on Figure 5-1. The first failure, along the north dike in April 1970, resulted in a supernatant spill of approximately 85 million gallons and a large fish kill. The second failure, along the south dike in November 1973, was contained with a major fill hauling effort. A program of maintaining the lagoon dikes, of pumping lagoon supernatant back to the treatment plant, and of hauling sludge from the lagoon to farmland has been initiated by MMSD in an effort to prevent future dike failures.

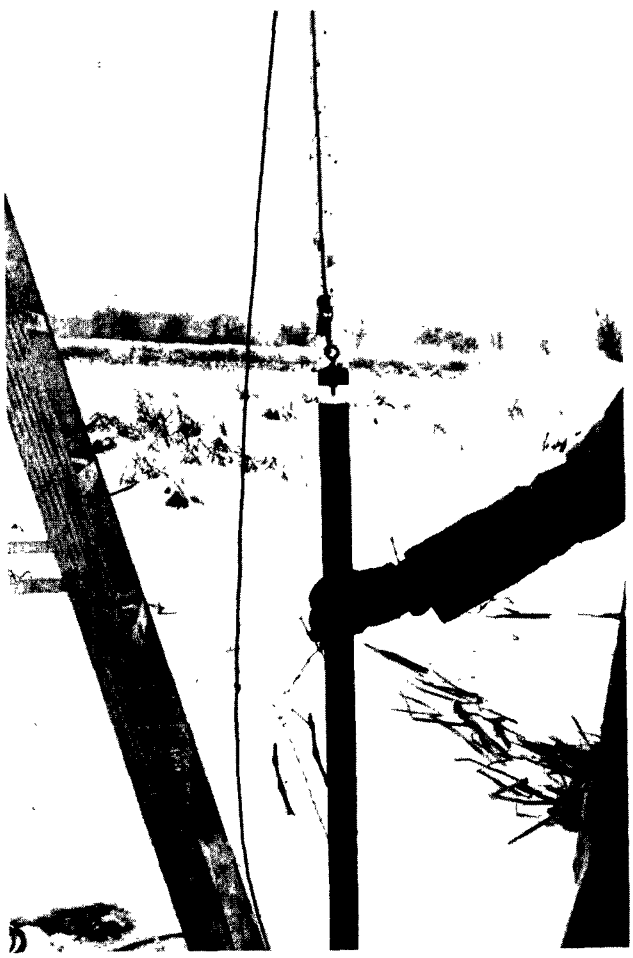
As a result of the 1970 dike failure, WDNR required that MMSD abandon the present method of sludge disposal and take measures to prevent the recurrence of discharges to the state waters. This order initiated several studies, most notably those by Greeley and Hansen Engineers and Roy F. Weston, Inc., which resulted in the recommendations to dispose of the sludge on land. To complement the sludge reuse program, CH2M HILL's study was to include evaluation of the lagoon problem. As background for this, a lagoon sampling program was used to provide an assessment of the environmental impacts of lagoon abandonment alternatives and of the suitability of the lagoon solids for reuse on land. Also, the lagoon dikes were investigated to determine their condition and need for stabilization.

5.2 DESCRIPTION OF LAGOONS AND DEPOSITS

The lagoon deposits were characterized by sampling and analysis at 48 locations in the two lagoons. The field program tasks consisted of (1) determining physical dimensions of each lagoon for sludge deposit quantification, and (2) collecting samples for physical and chemical characterization of the lagoon deposits and bed material. A preliminary field study revealed the lagoon bed material to consist of a peat layer overlying a marl layer.

Field Work Methodologies

A systematic sampling station grid network was established in each lagoon to provide sufficient areal coverage and detailed characterization of the two lagoons and their deposits. Eighteen stations were located in a rectangular pattern in Lagoon 1, and 30 stations were similarly located in Lagoon 2. Location of each sampling station is shown on Figure 5-1.



TYPICAL SLUDGE CORE

The field sampling was performed in March 1975 while the lagoons were frozen. Sampling consisted of boring through the ice with an ice auger and measuring the ice thickness. Ice samples were collected at selected stations and placed in plastic containers. Sludge samples were then obtained by coring with clear plastic pipes fitted with an adjustable rubber stopper attached to a nylon cord as shown on Figure 5-2. With the stopper end of the pipe touching the sludge surface, the pipe was slowly pushed into the sludge until a solid bottom was felt. The stopper was kept at the surface of the lagoon by the taut line as the pipe was pushed down. This created a vacuum for recovering the liquid sludge in the pipe. When the more resistant lagoon bottom was reached, a measurement of the empty portion of pipe was made and subtracted from its length (8 feet) to yield the depth of the sludge layer. The pipe was then pushed into the bottom to obtain a peat bottom plug, and the additional length of pipe pushed into the peat was measured and recorded. The core was then retrieved, capped, and numbered. With the core in an upright position, measurement and identification of the layered masses (peat, sludge, marl) were then made.

At stations where a peat plug could not be obtained due to the solidness of the sludge, the location of the peat mass was determined with a commercial peat sampler.

COLLECTING SAMPLE FROM PEAT SAMPLER

At selected stations, peat and marl samples were taken with the peat sampler. Peat samples were taken at 3-foot intervals until the marl layer was reached. Samples were placed

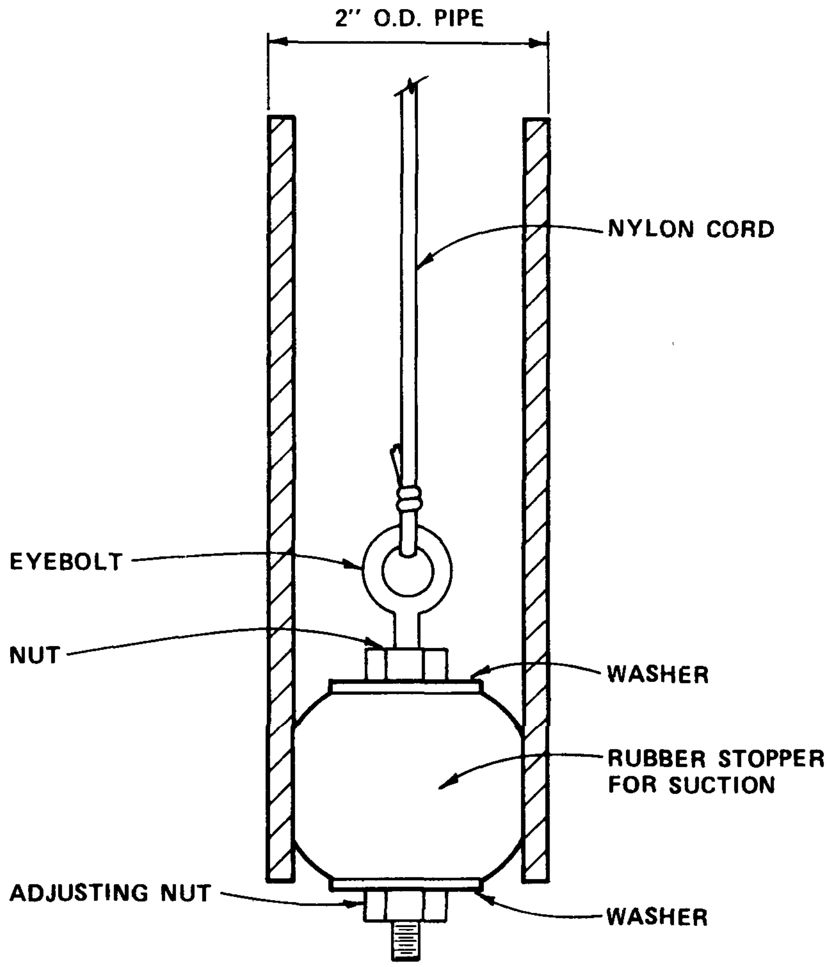


FIGURE 5-2

CORING APPARATUS

MADISON METROPOLITAN
SEWERAGE DISTRICT
MADISON, WISCONSIN

CH2M HILL

S9166.0

in plastic containers as shown in photo. Background samples were taken from the nearby swamp by shovelling with the ice auger and with the peat sampler.

All sludge cores were frozen in the upright position and packed in insulated crates with dry ice for air freight delivery to the laboratory. Ice, peat, and marl samples were frozen and shipped with the sludge cores for analysis.

Results of Field Work

Depth of Sludge. The sludge depths in Lagoon 1 decreased from west to east and ranged from 2-7.1 feet as shown on Figure 5-3. This may be attributed to the contour and slope of the bed and the settling of solids near the sludge discharge pipe on the west dike wall. Cores taken from Stations 1 through 4 had the consistency of a dry paste as opposed to sludge cores of lesser viscosity taken progressively eastward. In general, the vertical profile of the lagoon consisted of an ice-soil mass mixed with shallow rooted vegetation approximately 1 foot thick, the sludge layer, 2-7 feet thick, and a peat bed at least 5 feet thick overlying a marl layer. Peat and soil layers were entrapped between the sludge layer at Stations 2 and 10.

The sludge depths in Lagoon 2 ranged from 3.9 feet to 17.2 feet, as shown on Figure 5-3. However, the 17-foot depth occurred only at Station 48 and was the result of dredging the peat bed for dike reinforcement at the southeast corner several years ago. The sludge samples from Lagoon 2 were less viscous than those taken from Lagoon 1. A 1- to 4-foot-thick layer of peat mixed with sludge overlays the peat bed at Stations 32, 36, 39, and 42. The vertical profile was similar to that of Lagoon 1, and layers of a peat-sludge mixture were entrapped within the sludge at Stations 32, 36, 39, 42, and 44.

Volume of Lagoon Deposits. The lagoon volumes were calculated with the aid of a computer using the sludge depth data and the aerial photographs for dimensions and by making assumptions of the sludge depths along the dike walls. The results indicate Lagoon 1 has a sludge volume of over 449,000 cubic yards (90,700,000 gallons) and Lagoon 2 over 594,000 cubic yards (120 million gallons).

The average percent dry solids analyses were 12.9 and 8.2 for Lagoons 1 and 2, respectively. This is calculated to 48,700 dry tons of sludge in Lagoon 1 and 41,000 dry tons of sludge in Lagoon 2, for a combined total of 89,700 dry tons of sludge material.

5.3 CHEMICAL ANALYSES OF FIELD SAMPLES

In addition to physically describing the lagoon contents, several chemical analyses were performed to characterize the quality of the lagoon contents and to determine if any of the constituents of the lagoon sludge were leaching from the lagoon and entering the ground water.

Fourteen lagoon sludge samples were evenly divided and analyzed in two different CH2M HILL laboratories for mercury, copper, and zinc. The analytical results were cross-checked as part of a quality assurance program. There was close agreement between the laboratories' results.

Characterization of Lagoon Sludge

To characterize the sludge in each lagoon, several selected cores were composited and analyzed for zinc, copper, cadmium, nickel, mercury, potassium, total phosphate phosphorus, total Kjeldahl nitrogen, ammonia nitrogen, and total soluble salts. The remaining cores from both lagoons were composited and analyzed for total solids. The analysis of each sample was performed on the "as received" sample, and the results were reported on a dry weight basis. A summary of the results is presented in Table 5-1.

Discussion of Results

The lagoon deposits analyses vary significantly only in respect to percent of solids. Lagoon 1 has an average solids content of 12.9 percent while Lagoon 2 has 8.9 percent. Since Lagoon 1 is closer to the discharge pipe and has been used for 25 years longer so the higher average solids content was expected. The solids contents measured for the two lagoons agrees well with the 10-percent average solids content estimated in the Weston report.

The ammonia nitrogen content of the lagoon sludge is much lower than that of the treatment plant sludge. This can be explained by the fact that ammonia is lost by volatilization from the lagoon surface.

The cadmium to zinc ratio of the lagoon sludge is about 1.3 percent. This is slightly over the of 1.0 percent recommended in the Federal Guidelines for sludge applied to agricultural land. The cadmium to zinc ratio is also significantly lower in the lagoon than in the treatment plant sludge. Increased industrial discharge of cadmium in recent years would explain why the treatment plant sludge has higher cadmium content.

TABLE 5-1

CHARACTERIZATION OF LAGOON SLUDGE[1]

MADISON METROPOLITAN SEWERAGE DISTRICT

STATION	DEPTH OF SLUDGE (ft)	SOLIDS CONTENT[2] TOTAL SOLIDS (%)	VOLATILE SOLIDS (%)	PRIMARY NUTRIENTS TOTAL N (%)	NH_4 N (%)	TOTAL P (%)	TOTAL K (%)	HEAVY METALS Zn (mg/kg)	Cu (mg/kg)	Cd (mg/kg)	Ni (mg/kg)	Hg (mg/kg)	TOTAL SOLUBLE SALTS as EC (μmhos/cm)
LAGOON 1													
1	6 9	19 4											
2	7 1	18.3	9 8	4.46	1.14	1 39	0 12	3,200	470	30	50	21.0	2,670
3	7 1	24 1											
4	6 5	19 2											
5	6.0	14 1											
6	5 2	11 6		5 94	1.22								
7	6 1	3.1											
8	5 5	13 2		7 55	1.85								
9	6 7	13 8		2 74	0.81	1.59	0.12	2,145	476	37.5	60.3	21.7	4,010
10	2 0	8 3											
11	5.5	8 2		6.20	1.80								
12	5.9	7.4											
13	5 3	9 8		3.86	1 27	2.67	0.20	3,456	490	39.1	60.1	19.4	4,430
14	5 4	11.8		9.23	1 03								
15	5 7	16.0											
16	5 3	10.8											
17	6.1	12.9											
18	5 1	10.2											
MIN.	2 0	3 1		2 74	0.81	1 39	0.12	2,145	470	30.0	50.0	19.4	2,670
MAX	7 1	24 1		9.23	1 85	2.67	0.20	3,456	490	39.1	60.3	21.7	4,430
MEAN	5 74	12 90	9 8	5.71	1 30	1 88	0.15	2,934	479	35.5	56.8	20.7	3,703
LAGOON 2													
19	3.9	9 7											
20	4 8	8 6											
21	4 9	9.3		8.66	1 36								
22	4.8	12.7		4.36	0 75	0.73	0.07	2,012	541	33.3	55.5	17.3	3,590
23	5.5	10.3											
24	5 2	9.0											
25	5.7	7.2		6.07	1.88								
26	4 7	8.9											
27	4.6	7.8											
28	4.2	11 8											
29	5.4	6.7											
30	5.9	5.9											
31	4.2	10.0											
32	4.6	7 7											
33	4.3	8.2											
34	5.6	4.5											
35	4.3	8 7											
36	4.5	7.5		4.16	1.15		0 16		259				2,740
37	5.0			6.91	1.81	1.41	0.31	2,080	459	25.3	50.7	26.9	4,730
38	2.7	8.0											
39	4.7	9.9											
40	5 0	4.2											
41	4.4	5.0											
42	4 0	5 7											
43	4.5	10.5											
44	6 2	7.0											
45	5.1	4.6											
46	9.0	10.8		6 16	0.50								
47	4.0	6.8											
48	17.2	10 7											
MIN.	2.7	4.2		4.16	0.50	0.73	0.07	2,012	259	25.3	50.7	17.3	2,740
MAX.	17.2	12.7		8.66	1.88	1.41	0.31	2,080	541	33.3	55.5	26.9	4,730
MEAN	5 30	8.20		5.98	1.16	1.07	0.18	2,046	420	29.3	53.1	22.1	3,687
AVERAGE CHARACTER OF LAGOON SLUDGE	5 52	10 55	9 8	5 84	1.23	1 48	0 165	2,490	450	32.4	55 0	21 4	3,695

(1) Analyses performed on an as-received composite of entire core and results reported on a dry weight basis. Exceptions are cores 2 and 36, in which the listed values are an average for several individual segments

(2) Percent of sample volume

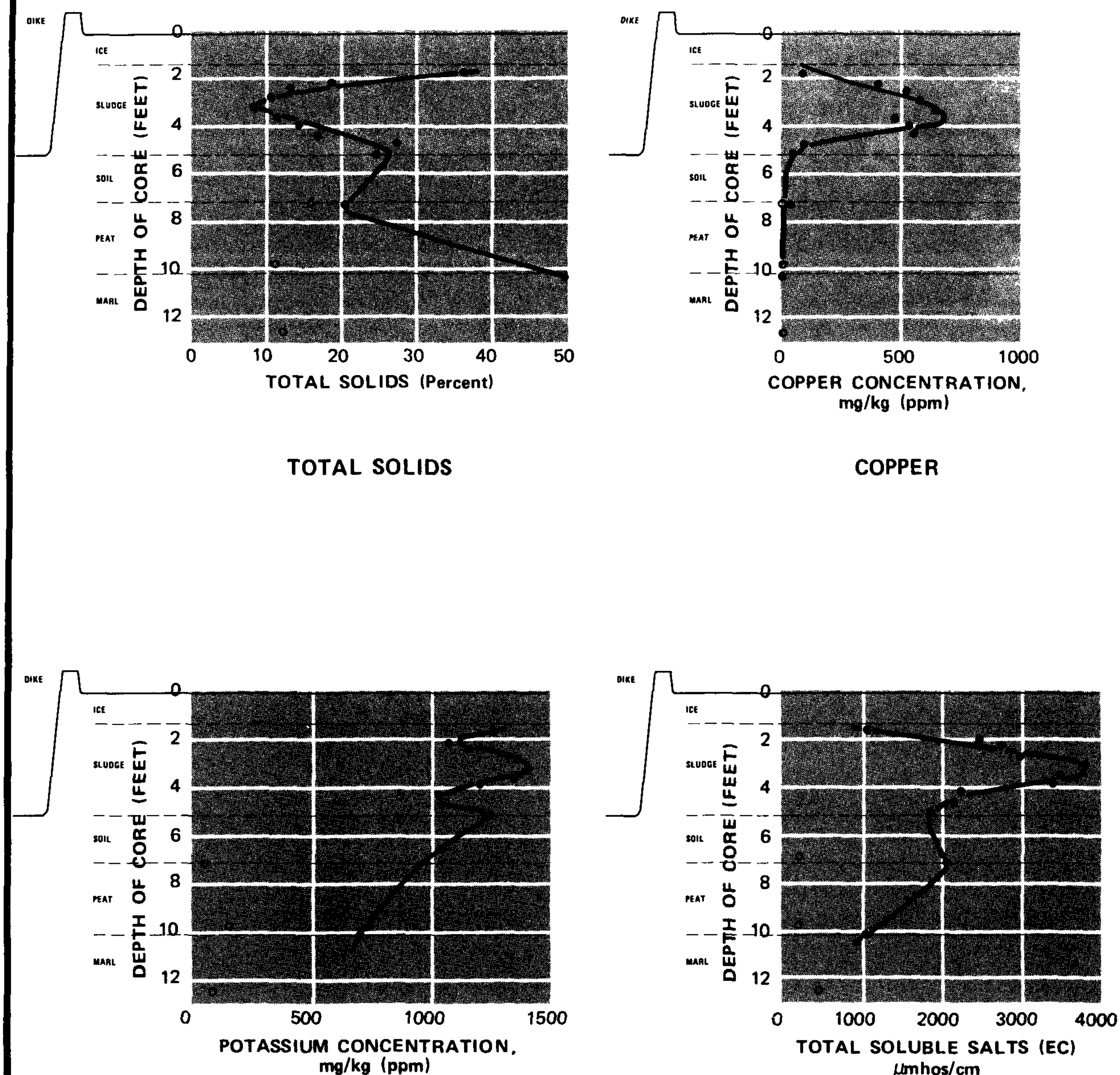
Leaching of Lagoon Constituents

The presence of the sludge lagoon represents a potential threat of ground-water contamination. To determine if this threat is real, several core samples were selected for detailed chemical profile tests. The sludge cores selected were from Station 2 in Lagoon 1 and Station 36 in Lagoon 2. Each of these sludge cores was then segmented into 4.5-inch sections for analysis. In addition to the sludge samples, deeper grab samples of peat and marl were collected with the peat sampler at Stations 2 and 36 and also at the background Stations N-1 and N-2 located in the uncontaminated marsh north of the lagoons. Each of these samples was then analyzed for several selected chemical constituents, and the results were plotted as a function of depth. Concentration profile plots for four selected constituents for Lagoon 1 are presented on Figure 5-4. The profile plots for Lagoon 2 are presented on Figure 5-5. Additional plots for Lagoon 1 are included in Appendix A. The lagoon deposits were analyzed for tin, molybdenum, cobalt, and selenium, but none were detected.

The results of these plots indicate that there is little or no leaching of the sludge constituents past the first 1 foot of the peat-soil layer. The concentration of constituents typically reach a peak about midway through the sludge blanket. The concentration is then rapidly reduced and approaches the background concentration about 6 inches to 1 foot below the peat-sludge interface.

The potential for leaching of lagoon constituents through the dikes was also evaluated. Hydrogeologic investigations by Stephenson and Hennings (1972) indicate that seepage losses through the dikes may be on the order of 0.001 to 0.01 cubic foot per second (cfs) on the perimeter of Lagoon 2. This seepage water is very much diluted in the estimated annual average flow in Nine Springs Creek of about 5.8 cfs. The factor of dilution will be about 1 part seepage water in 600-6,000 parts watershed drainage water.

The District's program of monitoring the streams around the lagoons also indicates that leaching of polluted water through the dikes is not a problem. Two water quality sampling stations have been established on Nine Springs Creek; one upstream from the lagoons, the other downstream. Monitoring of the ammonia content of the stream indicates that there is no significant increase in ammonia as the stream passes the lagoons.



TOTAL SOLIDS

COPPER

POTASSIUM

TOTAL SOLUBLE SALTS (EC)

LEGEND

- • CORE SAMPLE NUMBER 2 FROM LAGOON 1
- ∘ CONTROL SAMPLE N-2 TAKEN OUTSIDE LAGOON

FIGURE 5-4

LAGOON 1
PHYSICAL AND CHEMICAL DEPTH PROFILE

MADISON METROPOLITAN
SEWERAGE DISTRICT
MADISON, WISCONSIN

CH2M HILL

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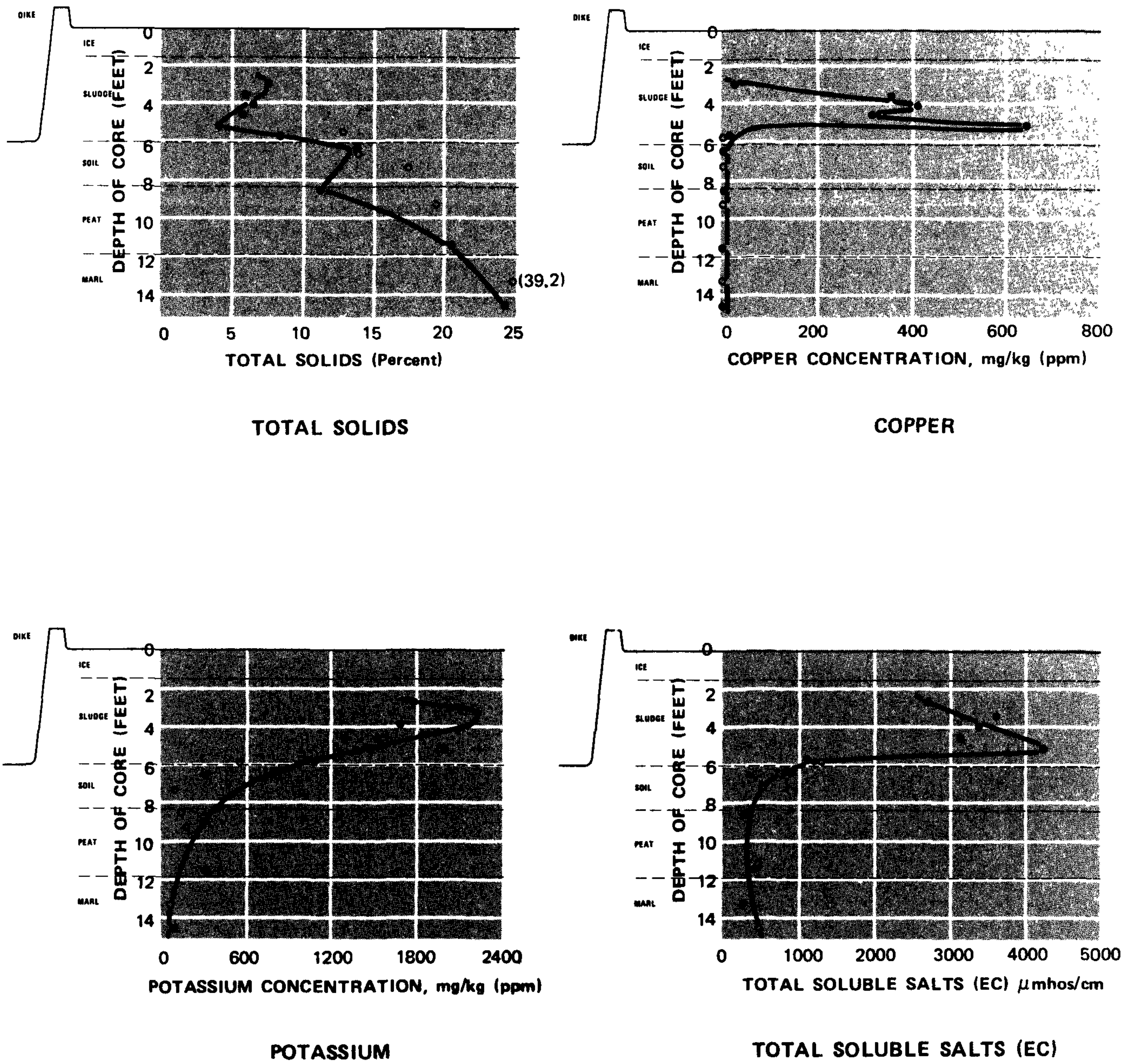


LEGEND

- • CORE SAMPLE NUMBER 36 FROM LAGOON 2
- ∘ CONTROL SAMPLE N-1 TAKEN OUTSIDE LAGOON

FIGURE 5-5

LAGOON 2
PHYSICAL AND CHEMICAL
DEPTH PROFILE

MADISON METROPOLITAN
SEWERAGE DISTRICT
MADISON, WISCONSIN

CH2M HILL

S9166.0

Summary

TABLE 5-2

SUMMARY LAGOON ORGANIC SOLIDS CHARACTER AND QUANTITY*
MADISON METROPOLITAN SEWERAGE DISTRICT

PARAMETER	CONTENT
Quantity, tons dry solids	89,700
Total Solids, %	10.55
Nitrogen, %	5.84
Phosphorus, mg/kg	14,800
Potassium, mg/kg	1,650
Cadmium, mg/kg	32.4
Zinc, mg/kg	2,490
Copper, mg/kg	450
Nickel, mg/kg	55

*All results, except quantity and total solids, are reported on a dry weight basis.

Table 5-2 summarizes the lagoon deposits character and volume. The quantity may have changed slightly since it was measured in March 1975 because sludge has been continuously discharged into the lagoons and the District has also hauled some sludge to farmers.

5.4 LAGOON EMBANKMENT EVALUATION

In July 1975, we presented a special report to MMSD entitled *Geotechnical Evaluation of Sludge Lagoon Embankments*. This report included a detailed discussion of the lagoon history and physical conditions, past embankment failures, and past geotechnical investigations. The existing condition of the dikes was visually inspected by a geotechnical engineer from CH2M HILL in April 1975. Based upon this inspection and the results of previous investigations, a stability analysis was performed. Alternatives for embankment stabilization were prepared when it became evident that more dike failures were imminent. Listed below are the major conclusions and recommendations of the special report.

Conclusions

Relative to the sludge lagoon embankments, CH2M HILL's visual inspection and evaluation of record information led to the following conclusions:

- Certain reaches of the sludge lagoon embankments are unstable.
- Failures and possible damaging spills are imminent, and in the case of the south dike of Lagoon 2, incipient.
- Regardless of the disposition of the sludge in the lagoons, the unstable reaches must be repaired as soon as possible.

- The present method of sludge removal by dragline from the dikes contributes to embankment stability problems by removing counterweight (surcharge) material.

Recommendations

CH2M HILL recommended that the Madison Metropolitan Sewerage District take the following action:

- Stabilize the south dike of Lagoon 2 and portions of the north and west dikes of Lagoon 2 as soon as possible.
- Stabilize the reaches recommended by replacing the existing dikes with embankments constructed by corduroy and berm techniques.
- Terminate the present method of sludge removal as soon as possible.
- Continue to return supernatant to the plant to maintain freeboard.
- Adopt a schedule which would result in the dikes being stabilized by July 1976.

In their meeting of 8 September 1975, the District accepted the findings of the special report and decided to proceed with the recommended dike stabilization program.

Later Investigations

In early 1976 test borings performed in the dike stabilization program were used to provide data for detailed evaluation of Lagoon 1 dikes. Engineering analysis using measured soil strengths and compressibility indicated that the dikes surrounding the westerly half of Lagoon 1 possess an adequate factor of safety against failure and could continue to be used as a sludge storage facility.

5.5 LAGOON ABANDONMENT

A program is required for abandoning the current method of sludge disposal so that no lagoon contents will spill into waters of the State. There are four general abandonment options available.

1. Treatment plant sludge; continue discharge to existing lagoons or discontinue discharge and build new lagoons.

2. Lagoon sludge; remove and apply to farmland or leave in lagoons.

3. Lagoon supernatant; remove and return to treatment plant or leave in lagoons.

4. Lagoon dikes; stabilize and maintain or leave as they are.

The four general abandonment options were each examined separately. The cost estimating and calculating procedures used in comparing lagoon abandonment alternatives and in planning this sludge reuse program are discussed in Appendix B.

Option 1--Storage of Treatment Plant Sludge

The advantage of continuing discharge of treatment plant sludge to the existing lagoons is that the facilities, the pipeline and lagoons, already exist. If discharge to the existing lagoons is discontinued, a new lagoon must be built for sludge storage. Both options are viable, but continuing discharge to the existing lagoons would be less costly than building a new lagoon. Also, it would be difficult to obtain a site for a large sludge storage facility. As will be shown later in this report, the required seasonal sludge storage capacity will be about 150 acre-feet. The estimated cost to construct and acquire land for this lagoon is $607,000. The detailed cost estimate for the new 150-acre-foot capacity sludge lagoon is presented in Table 1 of Appendix B.

Option 2--Removal of Lagoon Sludge

Two major factors regarding removal of the lagoon sludge are removal methods and effects of leaving the sludge in the lagoons.

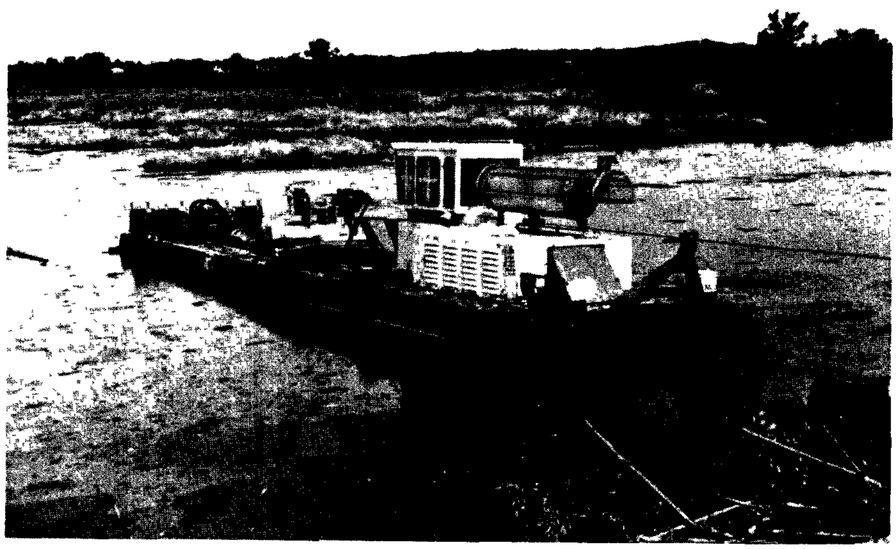
Lagoon Sludge Removal. Several alternative sludge removal methods, including those used by the District, were investigated for technical feasibility, reliability, and costs. In 1973 and 1974, the District used a crane dragline to remove lagoon solids for use on farmland when the lagoon began to fill to danger of dike failure. One dragline kept four trucks busy and was able to remove about 100 dry tons of lagoon deposits per day. This method of dragline cleaning costs about $3.55 per dry ton as determined by MMSD for 1974. Two problems with this method make it infeasible for future use. First, we noted that the dragline bucket sinks below the sludge and picks up peat from the lagoon bottom. While this accomplishes storage volume recovery, it does not fully accomplish sludge removal. Second, the operator is able to swing the bucket out into the lagoon only 50-75 feet. After once or twice around Lagoon 1 in 1974, the draglined strip had filled with mostly treatment plant sludge because the higher solids content sludge from the center of the lagoons failed to flow toward the dikes. In order to continue this method of sludge removal, about 7.8 miles of finger dikes, placed about 125 feet apart, would be required to clean both lagoons. At an estimated $5.00 per lineal foot, the finger dike construction would cost approximately $205,000. Another problem with this method is that sludge removal by dragline from the dikes contributes to embankment stability problems by removing counterweight (surcharge) material.

In August 1975, the District began using a small Sauerman type dragline to drag sludge toward the dikes. This type of dragline allowed the District to reach farther and minimize dike stability problems. The sludge was then removed by clamshell and loaded onto trucks. This method of dragging the heavier solids toward the dikes appeared to be working satisfactorily. They were able to increase their reach to about 300 feet but still not enough to reach the middle of the lagoons.

As an alternative to the dragline methods presently used, we corresponded with Sauerman Bros. of Bellwood, Illinois, who build large slackline cableway dragscrapers. This equipment would operate from large stationary towers and drag lagoon deposits toward the tower where it would be deposited at a pump or conveyor. Due to the instability of the lagoon area soils, considerable expense would be required to install equipment of this type capable of cleaning the entire lagoon. The cost of the extra foundation work alone would be an estimated $50,000. The total cost of such a system would be between $300,000 to $400,000. Experience with the small dragline presently used indicates that the bucket tends to sink through the liquid sludge to the bottom of the lagoon, picking up some peat while leaving the more liquid sludge. Another factor which also makes this type of equipment infeasible is that it tends to remove dike counterweight material, contributing to embankment instability. Due to the high cost and poor technical feasibility, this system is not suitable for the Nine Springs Lagoons.

Use of stationary sludge or mud pumps in place of dragline was also considered but felt to be unsatisfactory because the high solids content deposits will not flow toward the pump, and consequently, the pump would soon deplete its source and have to be moved.

Other methods of lagoon deposits removal which were considered were by helicopter and by dewatering the lagoon. A helicopter operation with bucket, as used to scoop water from lakes and dump onto wildfires, was abandoned as being too expensive. Dewatering by pumping with a pump located on the dikes and then going in with loaders on pads to clean out the remainder was also abandoned as being unproven.



MUD CAT ON NINE SPRINGS LAGOON

A small portable dredge which would slurry the sludge prior to pumping is felt to be the most feasible method of cleaning the lagoons. Mud Cat, manufactured by National Car Rental, is a small floating dredge which is self-propelled and can move into sludge to be pumped. A Mud Cat demonstration was held on the Nine Springs Lagoons on 4 September 1975. The machine demonstrated that it could pick up and pump 3 percent solids sludge at a rate of 2,200 gallons per minute or 10 percent solids sludge at 700 gallons per minute. At a pumping rate of 700 gallons per minute and operating efficiency of 70 percent, about 900 8-hour days would be required to remove the 210 million gallons of lagoon deposits. The Mud Cat will require about 2 feet of liquid to float on for maneuverability. Therefore, after removing sludge for a time, water may need to be left in the lagoons to provide flotation and improve discharge pipe maneuverability.

The cost of cleaning the lagoons with a small floating dredge like Mud Cat is estimated to be about $3.90 per ton of dry solids or a present worth of $270,000. This includes the capital costs of a dredge like Mud Cat, the pipeline to a wet well, and a wet well. This does not include transportation and land application of the sludge. The life of the machine is expected to be 10 years. It is estimated that it would remove an average of 10,000 tons of sludge per year for 9 years. An extra year of operation was included in the cost estimate to be used in slurrying the sludge and to assist in weed mat removal. The cost estimates also include the expense of applying a herbicide which would slow weed growth and allow easier sludge removal. The development of the cost estimates for lagoon sludge removal is detailed in Appendix B, Table 2.

Other Considerations for Option 2. If the lagoons are cleaned, the marsh could be allowed to return to its natural state, and the threat of sludge spilling into the lakes would be eliminated. If the sludge is left in the lagoons, there would be no cost of removing the sludge, but since supernatant and rainfall are expected to accumulate, there would be the cost of returning this supernatant to the treatment plant until it becomes nontoxic to fish. To determine how long supernatant would have to be returned and treated before it becomes nontoxic, a brief analysis was made of the time required to dilute the ammonia-nitrogen content of the lagoon supernatant with rainwater to the level of 1.0 mg/l. This dilution analysis indicated that it would take several hundred years. The reason for such a long time is that ammonia nitrogen is continually mineralized from the very large reservoir of organic nitrogen in the sludge. Based upon this estimate, supernatant would have to be pumped back every year. At the end of the planning period of this study, the year 2000, very little improvement would have been accomplished to the present lagoon situation. The lagoons would still exist as a threat to the lakes, and the supernatant quality will have improved very little.

Option 3--Lagoon Supernatant Removal

As stated earlier, it is anticipated that supernatant from rain, snowfall, and sludge will accumulate in the lagoons. If left to accumulate, the supernatant will overtop the dikes. Since it is toxic to fish, it must not be allowed to spill, but rather it must be returned to the treatment plant for BOD and ammonia removal before discharge. At the present time, the impact of the supernatant on the treatment process and the effluent is minimal. However, when the treatment plant is upgraded to meet more stringent effluent standards, the impact on the treatment process and effluent could be significant.

Based on the discharge strategies currently under consideration, it is highly probable that ammonia removal facilities will be required to meet the required effluent quality. If this is required, the ammonia content of the supernatant will have the most impact on the treatment process design.

Under the present operation of the lagoons, sludge and supernatant accumulate over the winter months. During this period, there is minimal supernatant return due to ice cover and there is also an increase in ammonia concentration also due to ice cover.

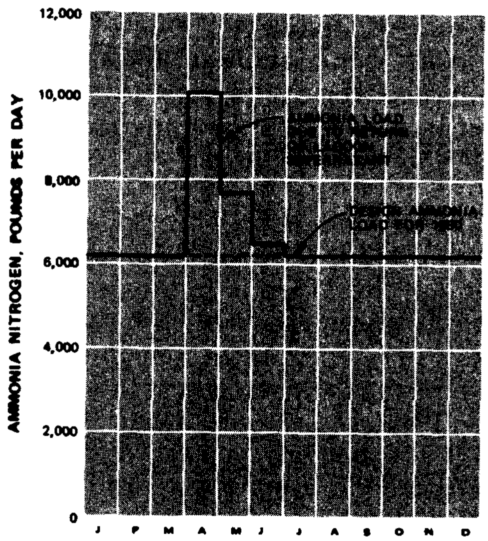


FIGURE 5-6

IMPACT OF LAGOON SUPERNATANT ON AMMONIA CONTENT OF TREATMENT PLANT INFLUENT

MADISON METROPOLITAN SEWERAGE DISTRICT
MADISON, WISCONSIN

In the spring, shortly after thaw, there is an urgent need to pump the supernatant back to the plant to avoid a spill of supernatant over the dikes. This pumping results in a large flow (2 mgd) of supernatant, very high in ammonia (250 mg/l), back to the plant during April of each year. As the season progresses, the flow and concentration diminish very quickly; however, the ammonia load to the plant during April adds another 65 percent to the design ammonia load for the treatment plant based on the domestic contributions during 1980. The impact of the supernatant ammonia load on the plant design is illustrated on Figure 5-6.

As shown previously, if the sludge is not removed from the lagoons, the supernatant must be returned and treated for more than 100 years. If the sludge is removed, the supernatant must be handled for about 10-15 years.

Cost of Treating Supernatant. Several alternatives are available for the removal of ammonia from the lagoon supernatant. Due to the relatively small volume and high strength, it can be effectively treated in a separate unit process. This would relieve the treatment plant of a major seasonal recycle load. On the other hand, if compatible, the supernatant can be returned to the treatment plant and be treated within the available capacity of the plant. The selected mode of treatment is dependent on which one provides the least cost of operation.

To provide a cost estimate for separate treatment, the Ammonia Removal and Recovery Process (ARRP) was selected. The ARRP is an ammonia stripping absorption process in which ammonia is recovered as a byproduct that can be used as an ammonia-based fertilizer. The ARRP has recently been applied to only small, concentrated streams of ammonia such as anaerobic digester supernatant and the ammonia-rich brine produced in ion-exchange regeneration. The ARRP is schematically shown on Figure 5-7.

A major factor to consider in the design of such a process is that if the sludge is not removed, there will be extra freeboard on the lagoons to store the supernatant. The supernatant treatment facilities must then be sized to handle the very high peak ammonia concentration and flow rate which occurs when the lagoons thaw in the spring as shown on Figure 5-6. If sludge is removed from the lagoons, freeboard will become available, and the supernatant treatment facilities can be sized to handle a smaller load over a longer duration. For this analysis, both cases were evaluated.

The estimated present worth to construct and operate the treatment facilities for the high peak load for 20 years is $3,872,000. If some sludge is removed by 1981 so that freeboard storage area is available, and if all sludge could be removed, the facilities would have to treat lagoon supernatant at a lower flow rate for only about 10 years. The present worth in this case is estimated to be about $1,469,000. The detailed costs of treating the supernatant with the ARRP are presented in Table B-4 of Appendix B.

Cost estimates for treatment of the supernatant within the plant were based on year-round nitrification utilizing the rotating biological contactors. To achieve year-round nitrification, it is necessary to design the nitrification process to operate during the critical low temperature winter months since the growth of nitrifying organisms is

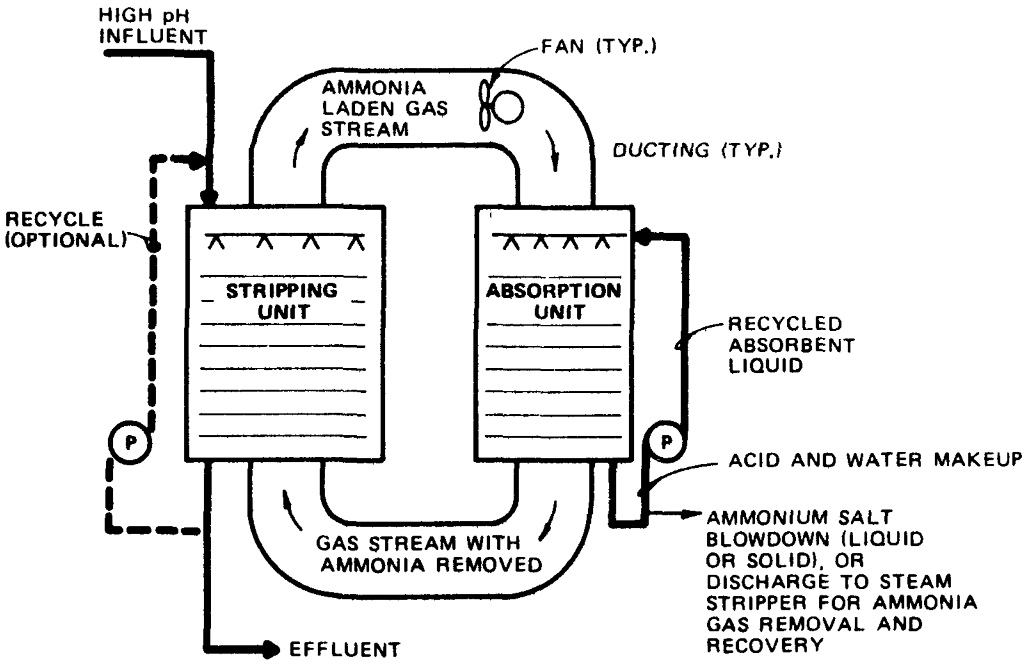


FIGURE 5-7

AMMONIA REMOVAL AND RECOVERY PROCESS (ARRP)

MADISON METROPOLITAN
SEWERAGE DISTRICT
MADISON, WISCONSIN

CH2M HILL

S9166.0

very temperature sensitive. At low temperatures, the growth rate of nitrifiers is reduced substantially below that observed at high temperatures. This requires additional treatment capacity during the winter to accumulate the volume of organisms required to achieve nitrification. Therefore, since the system must achieve wintertime nitrification, there is, in effect, additional unused capacity during the warmer spring and summer months.

As shown on Figure 5-6, the supernatant is typically returned to the plant during the spring months of April, May, and June. Based on the temperature of the wastewater during this period and the volume and strength of the supernatant, it has been determined that the supernatant ammonia can be treated within the unused warm weather capacity of the proposed nitrification facility. This mode of operation would not require any additional construction costs, but there will be some operation and maintenance costs. These costs include power to supply air to satisfy the oxygen demands of the additional BOD and ammonia, power to pump the supernatant back to the plant, maintenance of the pump, and labor ot operate and maintain the pumping system. The annual cost to treat supernatant in this manner is estimated to be $33,800 per year as shown in Table B-4 of Appendix B. The present worth of this annual cost over 10 years is $250,000. If no lagoon sludge is removed, this cost would probably occur over the next 100 years, in which case the present worth would be $600,000. Based on the preceding analysis and the cost comparison shown in Table B-4, it appears most cost-effective to continue returning lagoon supernatant to the treatment plant.

Option 4--Stabilization of Lagoon Dikes

As stated earlier, we have recommended stabilization of the existing dikes. These recommendations are based on findings of our special report to the commissioners, *Geotechnical Evaluation of Sludge Lagoon Embankments*. In developing our recommendations, we considered the options of doing nothing which might result in an accidental spill on breaching the dikes and causing a spill. Under these options, it was presumed that it would be more economical to replant a fish kill than to invest large sums of money in embankment stabilization or lagoon cleanout. However, if the sludge was released, it would introduce oxygen-depleting organics, taste and odor producing constituents, toxic substances and heavy metal ions, release tremendous amounts of nutrients, increase the color and turbidity, increase suspended and dissolved solids, and introduce potentially pathogenic wastes to the receiving waters. The environmental consequences would be manifested by the deposition of sludge beds in streams, the stimulation of excessive growths of weeds and algae, particularly attached algae, deterioration of water quality, the killing and prohibition of the existence of certain species of fish and aquatic life, and the devaluation of the aesthetic and recreational values of the affected waters.

Causing or allowing the lagoon deposits to enter the streams and lakes would also be contrary to the purpose and success of the present diversion of sewage effluent and wastes around the Madison lakes to retard lake degradation. Allowing the lagoon deposits to enter the lakes and streams would eliminate the past accomplishments in improving the water quality of the lower Madison lakes. In the event of a spill, replanting fish alone will not be sufficient in restoring any ecological balance. The excessive algae growth will become so luxuriant that chemical treatment and mechanical aquatic plant harvesting would be necessitated. And finally, the public's displeasure over the condition of a polluted Lake Waubesa and Kegonsa may bring legal action against the parties reponsible.

Based upon the preceding analysis and the dike investigations presented in the special report, the dikes should be stabilized as soon as possible to prevent continued failures.

5.6 ALTERNATIVE ABANDONMENT PROGRAMS

Based on the foregoing examination of the options available, the following abandonment programs were considered to be environmentally sound and were investigated and compared to select the most feasible.

1. Discontinue discharging sludge to lagoon and build a new lagoon, do not remove the sludge, return supernatant until it becomes nontoxic.

2. Discontinue discharging sludge to lagoon and build a new lagoon, remove sludge, return supernatant until it becomes nontoxic.

3. Continue discharging sludge to a portion of existing lagoon, remove sludge, return supernatant.

Common requirements of each alternative abandonment program are that the dikes be maintained or stabilized and supernatant be returned. Dike stabilization has been implemented, and the cost and effects will be the same for each alternative.

Abandonment Program 1

Abandonment Program 1 consists of discontinuing discharge of sludge to the lagoons, leaving the sludge in the lagoons, and returning the supernatant for treatment.

The main advantage of this alternative stems from the stipulation that the sludge would not be removed from the lagoons. This would save the expense of handling the sludge and the need to find land on which to apply it.

However, this abandonment program has several disadvantages. A new storage lagoon would be needed. This would require major construction and acquisition of land, which is a major problem in itself. People simply do not want a "sewage lagoon" located near them and would oppose and delay construction. The concept of farmers accepting sludge for agricultural reuse requires favorable farm community attitudes which may be lost in areas near a new large sludge lagoon. Another disadvantage of Abandonment Program 1 is that the sludge filled lagoons will continue to be a source of odor and will remain a potential source of contaminants to the surrounding swamp and waterways.

Lagoon Abandonment Program 1 will have three major costs. One will be the direct cost of stabilizing and maintaining the dikes. This will be a continual periodic cost lasting for the more than 100 years estimated necessary for the lagoons to naturally return to an environmentally safe condition. Another major expense would be the cost of returning the supernatant to the treatment plant and making it safe for discharge. The construction and operation of supernatant treatment facilities for 20 years has an estimated present worth of $430,000 as shown in discussion of Option 3. A major indirect expense would be the cost of land acquisition for and construction of a new storage lagoon. This was estimated to cost $607,000.

Abandonment Program 2

Abandonment Program 2 consists of discontinuing discharge of sludge to the lagoons, removing the sludge, and returning the supernatant for treatment.

Removing sludge from the lagoons will cause some temporary environmental disturbances, but these will be outweighed by the overall improvement of the lagoon situation.

The major environmental disturbances from the sludge removal action would be noise, dust, and odors. The lagoons' appearance now approaches that of the surrounding marsh in summer with lush plant growth in the lagoons and on the dikes. Removal of the sludge would change the lagoon appearance back to that of a sludge lagoon with the black liquid sludge readily apparent. After the cleanout operation was completed and the lagoons left to return to a natural state, they would again take the appearance of the surrounding marsh. Removing sludge from the lagoons will lessen the degree, and may even eliminate potential environmental hazards presently existing from the lagoon deposits.

In abiding by the MMSD Commission's resolution to dispose of sludge on land, the sludge removed from the lagoons should be applied to land. It would be most practical to remove sludge from the lagoons at the same rate at which it could be applied to farmland rather than all at once. This would eliminate intermediate handling and construction of another large lagoon for the lagoon deposits; however, a small lagoon will be required for seasonal storage of the treatment plant sludge as in Abandonment Program 1.

The allowable rates of land application of sludge are discussed in Chapter 6. The annual lagoon sludge application rate is about 3.0 tons dry solids per acre. The total allowable sludge application can be about 120 tons sludge per acre. If a single parcel of land is to accept all of the sludge at a rate of 3.0 tons per acre per year, the application would have to be spread out over 40 years. This is not a suitable method due to the long time requirement. If all of the sludge were removed in 1 year and applied to land at the rate of 3.0 tons per acre, 30,000 acres of land would be required. This also is not suitable since it would be infeasible to obtain the use of such a large amount of land and not practical to gear up for such a large sludge handling operation for a single year.

The time frame for removal of the sludge from the lagoons depends upon the amount of land available for sludge application. An analysis of farmer acceptance of sludge is included in Chapter 6. Based upon that analysis, it is expected that enough farmers will want sludge that the District could empty the lagoons in 8-14 years. Net removal of sludge from the lagoons cannot begin until more than enough land becomes available for reuse of the treatment plant sludge. Due to the expected gradual farmer acceptance of sludge reuse, 1-3 years may be required before a full lagoon cleanout operation could be started. With the above time frames for lagoon cleanout, the sludge removal method must be capable of removing between 7,000-14,000 dry tons per year. A rate of 10,000 dry tons per year, for 9 years, was used as a basis of comparing the lagoon abandonment programs.

After the lagoon is cleaned out, the annual precipitation into the lagoon may accumulate. This supernatant should be monitored, and if found to be of good quality, be allowed to drain into the marsh. If not of good quality, it should be collected and pumped back to the treatment plant. Achieving good quality supernatant depends upon how well the sludge is cleaned from the lagoon and how much of the precipitation and nutrients weeds will use.

The time expected for the supernatant to become nontoxic is, in any case, much less than if the lagoons were not cleaned out; and when it does become nontoxic, the treatment plant will be relieved of a major contaminant recycle stream.

Several factors must be investigated at the time the lagoons are emptied to determine the supernatant quality required for drainage into the marsh. This would include a determination of the amount of runoff from the lagoon area and the effect of various water quality parameters on the creek and lake environment. A preliminary analysis indicates that a supernatant with 8 mg/l of ammonia could be discharged to Nine Springs Creek with a resultant increase in the present average ammonia concentration from 0.5-0.6 mg/l. If the creek ammonia concentration is allowed to be increased to 1.0 mg/l, the supernatant ammonia concentration could be 38 mg/l.

Lagoon Abandonment Program 2 will have the major costs of stabilizing and maintaining the dikes for 10-15 years, the cost of removing the sludge from the lagoons, $270,000; the problems and costs of building a new treatment plant sludge storage lagoon, $607,000; and the cost of returning the supernatant to the plant and treating it for 10 years, $210,000. The cost of transporting and applying the sludge to farmland must also be considered. At an estimated $25.00 per dry ton, this would be $2,250,000.

Abandonment Program 3

Abandonment Program 3 consists of continuing discharge of sludge to the lagoons, removing sludge from the lagoons, and returning the supernatant for treatment.

This program is different from Program 2 only in that MMSD would use the west half of Lagoon 1 for seasonal storage and aging of the treatment plant sludge. This would eliminate the need to construct another storage lagoon. The sludge in the remaining half of Lagoon 1 and all of Lagoon 2 would be removed.

The environmental impacts at Nine Springs Marsh of this abandonment program would be greater than for Program 2, because a portion of the area would continue to be used for seasonal sludge storage. However, the overall environmental impacts will be the same because Program 2 will require construction of a similarly sized lagoon elsewhere. Also, the time period for cleaning the lagoons would be the same as for Program 2. A major economic advantage of this program over Programs 1 and 2 is that the District would not need to construct a new lagoon to store the treatment plant sludge in periods when it cannot be applied to land.

A Mud Cat or similar device, as described earlier, is also recommended for lagoon sludge removal in this program. It would be required to handle the treatment plant sludge in addition to the lagoon deposits. The major cost items of Program 3 would be dike stabilization and maintenance, lagoon sludge removal, $270,000; construction of a dike across Lagoon 1 to form the seasonal storage lagoon, $234,000; supernatant return and treatment, $211,000; and transporation and land application of the sludge, $2,250,000. The costs and basis for construction of a seasonal storage lagoon in Lagoon 1 are given in Table B-3 of Appendix B.

Comparison of Lagoon Abandonment Programs

Table 5-3 lists a comparison of the three abandonment programs. They are compared on the basis of potential for sludge spill and environmental damage and dike stabilization and maintenance requirements. They are also compared on the basis of the costs of providing sludge storage, removing sludge from the lagoons, reusing the sludge, and returning and treating the supernatant. Based on the economic comparison, Program 1 would be best because it has the lowest cost, followed by Program 3, and with Program 2 having the greatest cost. However, Program 1 has a lasting potential for severe environmental degradation in the event of a dike failure. Also, the costs of continually maintaining the dikes, which were not included in Table 5-3 because they could not be reasonably estimated, could reduce or eliminate the economic advantage of Program 1. Therefore, Lagoon Abandonment Program 3 is recommended for implementation.

5.7 RECOMMENDED LAGOON ABANDONMENT PROGRAM

General Description

The recommended program consists of removing all sludge from Lagoon 2 and from approximately the east half of Lagoon 1. Treatment plant sludge will be discharged to the west

TABLE 5-3

COMPARISON OF LAGOON ABANDONMENT PROGRAMS
MADISON METROPOLITAN SEWERAGE DISTRICT

	PROGRAM 1	PROGRAM 2	PROGRAM 3
Description	Discontinue sludge discharge to lagoons, do not remove sludge, return supernatant.	Discontinue sludge discharge to lagoons, remove sludge, return supernatant.	Continue sludge discharge to lagoon, remove sludge, return supernatant
Potential for Sludge Spill and Environmental Damage	Lasting Potential	None after lagoons emptied.	None after lagoons emptied.
Dike Stabilization and Maintenances	For over 100 years	For about 15 years	For about 15 years
Seasonal Sludge Storage	Build new lagoon	Build new lagoon	Use west half of Lagoon 1 after about 1984
Construction Cost (1)	$ 607,000	$ 607,000	$ 136,000
Land Acquisition Cost (1)	23,000	23,000	0
Sludge Removal Cost (1)	None removed 0	Remove all $ 270,000	Remove all $ 270,000
Sludge Reuse Cost (1)	Not reused 0	Applied to land $2,250,000	Applied to land $2,250,000
Return and Treat Supernatant	For over 100 years	For about 10 years	For about 10 years
Cost (1)	$ 430,000	$ 211,000	$ 211,000
Less Value of Sludge (2)	0	$1,350,000	$1,350,000
Total Present Worth (1)	$1,060,000	$2,011,000	$1,517,000
Total Comparative Annual Cost (3)	$ 92,500	$ 175,500	$ 132,000

(1) These costs are the present worth on January 1, 1976 of capital, operation, and maintenance costs incurred during the study period.

(2) Value of sludge is $15.00 per dry ton.

(3) Total present worth amortized over the study period.

half of Lagoon 1 when required for storage. All of the treatment plant sludge may be aged in the lagoons before agricultural reuse. The lagoon sludge and treatment plant sludge will be removed and applied to farmland as required to meet farmer demand. The supernatant in the lagoons will be returned to the Nine Springs Plant for treatment and discharge whenever it begins to accumulate to an unsafe depth. The lagoon dikes will be stabilized in the ongoing rehabilitation program. The dikes must be maintained for about 15 years or as long as there is sludge or toxic supernatant in the lagoons.

Implementation

Sludge Removal. Lagoon 2 should be cleaned first because its dikes are the most unstable. Some sludge should also be removed from Lagoon 1 each year to keep from overtopping the dikes. It is likely that there will not be a net removal of sludge from the lagoons in at least the first year, and possibly the first 3 years, because the market for sludge will take some time to develop. The first years should be utilized to break up or remove the thick mat of weeds which now covers the lagoons. A herbicide could be used to slow or stop weed growth on the lagoons to make weed mat removal easier. This should be done on small areas so that the weed mat is removed or broken up before the weeds can become reestablished. The herbicide could be applied from the floating dredge, from a small boat, or from the dikes. The herbicide manufacturer's recommended procedures for use should be followed closely to prevent damage to the marsh surrounding the lagoons. The sludge removal dredge with weed-cutter attachment could chew up and slurry the weed mat. The contents should also be slurried; otherwise, the more liquid portion would be removed first, leaving behind the heavier consistency sludge. If a Mud Cat type of dredge is used, it may be necessary to leave water in the lagoons to provide flotation and increase its mobility when the lagoons are nearly cleaned.

Supernatant Handling. The District must continue removing supernatant when they can. Once some freeboard is obtained by sludge removal, the supernatant return could be spread out over spring through fall, rather than at a high peak rate after the spring lagoon ice thaw. After several years of sludge removal, the supernatant might possibly be mixed in with the lagoon deposits and handled with the sludge applied to farmland.

Equipment Requirements. We recommend that MMSD purchase one standard Model MC-10 Mud Cat, or equivalent, to remove sludge from the lagoon. One machine operating about 100 days per year could remove 10,000 tons of lagoon sludge. This would leave at least another 100 days per year to handle treatment plant sludge. During peak sludge use periods, two or three 8-hour shifts may be required each day.

Several appurtenances which should be purchased with the dredge are float-supported pipeline, a small rowboat to provide transportation to the dredge, and pipeline to transport the sludge to a wet well. A wet well should be constructed with its top no higher than the dike top into which the dredge can discharge the sludge. The wet well should be low so that the dredge pumping rate would not be reduced. The sludge would be pumped into a loading dock, into trucks, or through a pipeline to farmland from the wet well. Two men will be required for the lagoon cleanout operation: one to operate the dredge and the other to move the pipe and guide cables.

Seasonal Sludge Storage Lagoon. A dike should be constructed across Lagoon 1 to form a storage area in the west half with a capacity of about 150 acre-feet. The remainder of Lagoon 1 would be allowed to return to a natural state like the surrounding marsh. This work should not be done until Lagoon 1 is partially empty in order to minimize construction problems. Also, Lagoon 1 can serve as the seasonal sludge storage area until the dike is built in about 1984. The storage capacity requirement should be refined at that time, based upon experience of operating the sludge reuse program. Detailed investigations of the embankment foundation should also be performed at that time as the basis for designing and building the new dike section.

Lagoon Cleanout Schedule. An estimated total of about 10 years will be required to remove all the sludge from the lagoons. This allows 1 year for weed mat removal and 9 years to remove the estimated 89,700 dry tons of sludge at a rate of 10,000 dry tons per year. A major unpredictable variable which could change the time required is the farm community demand for sludge.

Program Cost. The estimated total present worth to remove the sludge from the lagoons and apply it to land, and to provide seasonal storage for the treatment plant sludge is $1,517,000. This estimate includes the following: construction of a dike across Lagoon 1, removal of sludge from the lagoon, agricultural reuse of the sludge, treatment of the supernatant, and the value of the sludge as a fertilizer. On a unit basis, the cost is about $16.90 per dry ton.

Accomplishments. This abandonment program would end the disposal of sludge in the Nine Springs Marsh and protect the streams and lakes from a sludge spill. The estimated 89,700 tons of lagoon sludge, estimated to have a fertilizer value of about $15.00 per ton, or $1.35 million total, would be made available for agricultural reuse. Also, most of the existing lagoon area would be returned to a natural condition, and seasonal treatment plant sludge storage would be provided. We believe this plan will meet the WDNR directives asking for abandonment of the present method of sludge disposal.

5.8 SUMMARY

The quantity and quality of the sludge in the Nine Springs Lagoons were determined by extensive field sampling and laboratory analyses. The depth of sludge in the 135 acres of lagoons ranges generally from 2-7.1 feet in Lagoon 1 and 3.9-6.2 feet in Lagoon 2. The percent dry solids content averages 12.9 and 8.2 in Lagoons 1 and 2, respectively. The total sludge quantity in the lagoons was calculated to be 89,700 dry tons.

The quality of the lagoon sludge, as shown in Table 5-1, indicates its suitability for agricultural reuse. The sludge sampling investigation included gathering samples of the underlying peat and marl to determine leaching of sludge constituents and indicated that there is little or no leaching past the first 1 foot of the peat-soil layer.

The condition of the lagoon embankments was studied in detail and a special report was presented to MMSD which concluded that failures and possible sludge spills are imminent and recommended that the dikes be stabilized. The District has proceeded with the recommended dike stabilization program.

A program for abandonment of the present method of sludge disposal in the Nine Springs Lagoons was prepared as required by the Wisconsin Department of Natural Resources. The recommended program consists of removing all sludge from Lagoon 2 and from approximately the east half of Lagoon 1. The west half of Lagoon 1 will be used for seasonal storage of the treatment plant sludge. The estimated present worth to remove the sludge from the lagoons and to provide seasonal storage for the treatment plant sludge is $1,517,000, or about $16.90 per dry ton.

CONSIDERATIONS FOR AGRICULTURAL REUSE OF SLUDGE 6

Chapter 6
CONSIDERATIONS FOR AGRICULTURAL REUSE OF SLUDGE

This chapter discusses the study area, regulations regarding land application of sludge, sludge application rates, application sites, and other considerations for agricultural reuse of sludge. All of these factors must be investigated to ensure that the reuse program is acceptable to the public, that it is environmentally safe, and that the sludge will be successfully recycled into agriculture.

6.1 STUDY AREA DESCRIPTION

A study area consisting of the land within a 10-mile radius of the Nine Springs Sewage Treatment Works was delineated as a basis for discussion. This study area is located within Dane County, mostly south of Madison. It consists of about 91,000 acres of farmland and could accept all of the MMSD sludge for many years to come.

Agriculture

The major crops grown in the study area are field corn, 40,000 acres; small grains (including oats, barley, and wheat), 5,600 acres; and alfalfa, 15,000 acres. The field corn consists of about 75 percent grain corn and 25 percent silage corn. Other crops commonly grown include soybeans, potatoes, tobacco, processing peas, sweet corn, hay other than alfalfa, and pasture or greenchop grass and legumes. There are approximately 550 farms in the study area, covering 91,000 acres or about 165 acres each (Wisconsin Statistical Reporting Service, 1974).

Dane County ranks high in agricultural production in Wisconsin. In 1973 Dane County led production in grain corn, silage corn, alfalfa hay; and was a major producer of processing peas, livestock and dairy products. Dane County's outstanding agricultural production is further emphasized by Wisconsin's No. 1 nationwide ranking in production of dairy cattle, milk, cheese, corn silage, all hay, and green peas for processing (Walters 1974). The grain crops are fed to the farmer's own cattle or sold on grain markets. The dairy cattle are increasingly kept on feedlots. Forage is either in the form of dried hay or greenchop rather than pasture. The weather and prices paid for crops play a very important part in determining the types and amounts of crops planted. A late wet spring, for instance, may cause substitution of the types of crops planted.

Climate

TABLE 6-1

NORMAL STUDY AREA TEMPERATURE AND PRECIPITATION*
MADISON METROPOLITAN SEWERAGE DISTRICT

MONTH	TEMPERATURE (°F)	PRECIPITATION (inches)
January	17.5	1 40
February	19 5	1 13
March	29.1	1.84
April	44 4	2 57
May	56.1	3 34
June	66 1	3 95
July	71 1	3 58
August	69 5	3 37
September	61 0	3 32
October	49 9	2 21
November	34 0	2 14
December	22 1	1 31
YEAR	45 0	30 16

* Data are standard normals (1931-1960) for Madison, Wisconsin, Truax Field, gathered and reported by U S Department of Commerce Weather Bureau

The study area climate is typically midwestern with most of the precipitation coming in summer when crops need it most. The area climate is also affected by the Great Lakes (Wisconsin Statistical Reporting Service 1967). Few areas are irrigated and most rely on natural precipitation to supply the crop water requirements. Many areas suffer some minor effects of drought most years, but the advantages of irrigation do not offset the cost. The monthly normal temperature and precipitation are listed in Table 6-1.

The summer months are characterized as being hot and muggy with frequent thunderstorms, whereas winters are cold and relatively dry. Normally, the ground is frozen from mid-December through mid-March, with the frost depth reaching below 20 inches at times. The ground is often snow covered from December through mid-March (Wisconsin Statistical Reporting Service 1970).

Ground Water

Geology. The strata from which Dane County obtains its ground-water supply are sandstones, dolomites, and shales of Cambrian and Ordovician ages and sand and gravel deposits of Quaternary age. The Cambrian rocks, which are the major source of water and the overlying dolomite of the Prairie du Chien Group of Ordovician age, were deposited in a shallow sea environment. Following a long period of emergence, erosion, and then submergence, the remaining rocks of Ordovician age were deposited. Subsequent uplift and erosion has left an irregular bedrock surface having a maximum relief of about 1,000 feet.

In the more recent Pleistocene time, glaciers moved across the eastern two-thirds of the county from northeast to southwest, transporting large quantities of rock debris frozen in the ice. This unconsolidated material (drift) was dumped on the land surface by the melting glaciers, and thus formed the present day surface that contains glacial features and that is poorly drained.

Glacial drift covers most of the bedrock except in the westerly one-third of Dane County. In this area, glacial outwash deposits and Recent alluvial deposits occur in the valleys. In addition, this area is thinly blanketed by loess (Cline 1965).

Occurrence. Ground water occurs under water-table and artesian conditions in Dane County. Glacial till partially confines ground water in many places in the eastern two-thirds of the county, whereas water-table conditions prevail in the western part of the county. Ground water in the sandstones of Cambrian age generally is partially confined.

Permeability of rocks and movement of ground water in Dane County are generally greater parallel to than perpendicular to the rock's bedding. Rock strata having low permeability--such as clay, shale, and dolomite--retard the vertical movement of water. Rock fractures or joints provide paths for ground-water movement in the less permeable rocks or zones.

Vertical movement of water through the St. Peter Sandstone is generally good, except in the basal part where shale and poorly sorted material retard the movement of water. In places where the St. Peter Sandstone rests directly on the Cambrian rocks, circulation of ground water between the two units is more rapid than in places where the Prairie du Chien Group is present.

Circulation of water through the Platteville-Galena unit is poor and occurs principally through fractures and solution channels.

The outwash and alluvium are generally excellent sources of ground water and yield small to large quantities of water. Ground-water movement through outwash and alluvium is generally good as well as the circulation between the outwash and alluvium and adjacent bedrock.

Ground water moves through the principal aquifers from areas of recharge to points of discharge, such as springs, streams, lakes, wells, and drainage ditches. The direction of ground-water movement in the deep aquifers is shown by arrows on Figure 6-1. The arrows run normal to lines of equal elevation on the piezometric surface, which is the surface to which water will rise if the aquifer below the confining layer is tapped. Locally, where there are no confining layers, the piezometric surface is representative of the water table surface.

The direction of ground-water movement is nearly coincident with the direction of surface drainage. Generally, this will indicate a gain in streamflow due to ground-water seepage into the stream. Conversely, when the direction of ground-water movement runs across the surface drainage there will be a loss from stream flow.

Ground-water movement under natural conditions is extremely slow. As shown on Figure 6-1, the effective velocity of ground-water movement within the deeper aquifers ranges between about 0.04 feet per day and 3.1 feet per day, the difference in velocity being attributable to differences in rock permeabilities and hydraulic gradient.

Quality. The ground water in Dane County is for the most part of excellent chemical quality. Generally, the ground water quality is poor only where man has added a pollutant. One report (Holt and Skinner 1973) listed the results of water quality measurements taken in many municipal and private wells. Of 106 wells tested for dissolved solids, only six were above the 500 mg/l limit for drinking water recommended by the U.S. Public Health Service (USPHS). Of 84 wells tested for nitrate, three had levels above 45 mg/l which is the safe limit suggested by the USPHS. The source of the high concentration of nitrogen appears to be localized contamination from feedlots and other manure sources (Water Resources Task Group 1971). Improper wastewater and sludge disposal and excess fertilizer applications may also cause a buildup of ground-water nitrate. Since the study area ground water is generally safe for drinking, the sludge reuse program must be designed to protect the ground water from contamination.

Land Use

The majority of the land in the study area is used for agriculture. However, the area is being encroached upon by many housing developments, with some developments approaching a quarter section in size. The area also contains, or is bordered by, the villages of Oregon, Stoughton, McFarland, Brooklyn, and Verona. There are several large marshes in the study area which can be used only for wildlife and recreation.

6.2 REGULATIONS

Local, state, and Federal regulations regarding distribution and application to land of liquid sewage sludge were investigated to ensure that the recommended reuse program conforms to all applicable requirements and guidelines.

Local Regulations

Applicable local regulatory agencies in the study area were contacted for regulations regarding land application of sludge. The agencies and persons contacted consisted of the following: Dane County Regional Planning Commission, Dane County Zoning Administrator, City of Madison Environmental Health Public Health Department, City of Madison City Planning, City of Monona Clerk, Village of Verona Clerk, Village of Brooklyn Clerk, Village of Belleville Clerk, Village of Oregon Clerk, City of Stoughton Clerk, Village of Cottage Grove Clerk, and City of Middleton Clerk. This investigation indicated that the various agencies would rely on the state requirements for sludge application to land.

State Regulations

The Wisconsin Department of Natural Resources (WDNR) has recently prepared "Guidelines for the Application of Wastewater Sludge to Agricultural Land in Wisconsin," Technical Bulletin No. 88, dated 1975. This report provides working guidelines which may be revised as new information becomes available in the future. This report is one of the most comprehensive of its kind in the United States. It will be used to assist WDNR personnel in granting discharge permits.

The WDNR guidelines contain detailed explanations of methods to determine acceptable annual and total sludge application rates. It also contains guidelines for program management and operation and site selection. The following list is a summary of recommendations from the WDNR guidelines:

- Raw sludge should not be applied to agricultural land.

- Sludges should be applied to soils consistent with the nitrogen needs of the crops being grown.

- At least 2 feet and preferably greater than 4 feet of soil should exist between the sludge application zone and bedrock, any impermeable layer, or the water table.

- Sludge should not be applied to soil in the year the area is used for any root crops or other vegetables which are consumed uncooked.

- If sludge is surface applied to sloping land, runoff should be minimized by use of contour strips, terraces and border areas. Also, runoff can be reduced by injection or immediate incorporation of the sludge.

- Pasture land (or crops which are harvested green) should not be used for milk cow feeding for 2 months following sludge application. Other animals should not graze pasture land or be fed greenchop material for at least 2 weeks after sludge application.

- Metal loadings must be kept within acceptable limits to minimize the potential of crop damage or food chain accumulation. The soil pH must be maintained at 6.5 or greater.

- Application systems must be such that they minimize the runoff potential and odor problems while remaining cost-effective.

- Sludge application sites should be at least 500 feet from the nearest residence. If the sludge is injected or incorporated into the soil, a reduction in this distance may be possible.

- Site management must be such that nutrient deficiency and soil acidity problems do not occur, public access is limited, and crop yields are maximized.

- Site monitoring should be the responsibility of the municipality. If sludge additions consistent with nitrogen requirements are used, monitoring needs include only sludge and plant analyses as well as routine soil testing. If higher rates, on dedicated land, are used, comprehensive groundwater monitoring must be included.

- To ensure adequate protection of water supplies, the sludge application site should be a minimum of 1,000 feet from the nearest public water supply well and 500 feet from the nearest private water supply well.

The last list item which recommends a 500-foot radius (18 acres) buffer area around all private water supply wells may be too stringent. In the study area, where most farm homes will have a private well, this requirement alone will prevent sludge application on about 15 percent of the area. This will also create an inconvenience for the farmer in that he would need to use an alternate fertilizer method in the large buffer area. Section NR 112.07 (k) of the Wisconsin Administrative Code on Well Construction and Pump Installation Standards and Related Information, by WDNR, requires 200 feet between any well and any sludge disposal area if that well is used to supply ground water for human consumption or for preparation of food products. We have recommended a 200-foot buffer radius and periodic ground-water monitoring for nitrates.

Federal Regulations

The U.S. Environmental Protection Agency (U.S. EPA) is completing a supplement to be entitled, "Municipal Sludge Management: Environmental Factors" to the *Federal Guidelines: Design, Operation, and Maintenance of Wastewater Treatment Facilities*, which includes guidelines for land application of sludge. The U.S. EPA guidelines, which must be used by Federal grant applicants, are summarized in the following list:

- The sludge nutrient value, heavy metals and other constituents which may economically recycle or cause environmental damage should be determined.
- The site soils should be tested for cation exchange capacity (C.E.C.), pH, and background heavy metals.
- The soils and ground-water conditions should be investigated at each site.
- Sludge must be stabilized before land application.
- Pathogen reduction may be required in some projects.
- The suitability of the crop for sludge amended soils must be determined.
- The project should be designed so that ground water will be protected from pollution.
- Surface water runoff must be controlled.

- The annual application rate must be such that the amount of plant available nitrogen added is not greater than twice the nitrogen requirement of the crop.

- The grant applicant must show the capability to manage and operate the system.

- The grant applicant must develop and implement a monitoring program. The monitoring data must be periodically reviewed.

- The sludge heavy metal additions calculated as zinc equivalent must not exceed 10 percent of the CEC of the unsludged soil.

- The soil pH must be maintained at 6.5 or greater for a period of at least 2 years after sludge application.

- Sludge having a cadmium content greater than 1 percent of its zinc content should not be applied to cropland except under certain specified conditions.

- Special precautions should be taken when sludge is applied to pasture.

- The facility plans should be reviewed by the U.S. Department of Agriculture (USDA) and Food and Drug Administration (FDA).

- Products in the human food chain grown on sludge amended land should be monitored for heavy metals, persistent organics, and pathogens.

6.3 SLUDGE APPLICATION RATE DEVELOPMENT

Three major factors are required to determine sludge application rates. These are the sludge characteristics, the soil suitability for sludge application, and the types of crops grown. The character of the treatment plant sludge and the lagoon deposits were reported in Chapters 4 and 5.

Soil Suitability for Sludge Application

Seven soil parameters; erosion hazard, depth to ground water, depth to bedrock, flood hazard, soil texture, soil permeability, and cation exchange capacity were investigated to determine soil suitability for sludge application. Each parameter was given a point rating. The ratings were then combined to classify each soil series and phase. The source of information was the interim soil survey for Dane County titled, *Soil Interpretations, A Guide to Land Use and Conservation Planning*, by the Soil Conservation Service (SCS), 1970.

Erosion Hazard. Soil erosion is a potential source of pollution through runoff and sediment loading of surface waterways. Soil erodibility was evaluated and each soil assigned an erosion hazard of none, slight, moderate, or severe from values calculated from known K (soil erodibility factor) and T (permissible soil loss, ton per acre per year). The K and T factors are listed for each soil in the interim soil survey. The Universal Soil Loss equation was used to calculate the estimated soil loss in tons per acre per year. In addition to the known K value, this equation considers the variables (L) length of slope, (S) slope gradient, (C) cropping management, (P) erosion protection practices, and (R) rainfall index where A (soil loss) = K x L x S x C x P x R. Values for L, S, C, P, and R were taken from USDA Handbook 282 and information supplied by the State SCS Agronomist in Madison.

The estimated soil loss in tons per acre per year was calculated by assuming several values for each variable. These A values were compared to the individual T (permissible soil loss) value for each soil. Each soil was assigned an erosion hazard classification point rating according to the following:

No erosion hazard	----	1.00
Slight erosion hazard	----	.90
Moderate erosion hazard	----	.80
Severe erosion hazard	----	.60

Slopes greater than 12% were given a zero (unsuitable) rating. A particular soil may show more than one erosion hazard rating as a result of a difference in management conditions.

Depth to Ground Water. A fluctuating water table may cause a flushing action on the chemical constituents and increase weathering within the soil profile. Any soil with a seasonal high-water table within 3 feet of the surface was eliminated by a zero rating due to possible ground-water contamination from nitrates and soluble salts. The DNR guidelines suggest at least 2 feet and preferably 4 feet to ground water. Three feet is used here because the soils are mapped for either 3 or 5 feet rather than 4 feet. Setting the limit at

5 feet would be too restrictive for the study area. The soils were evaluated and given a point rating for depth to ground water as follows:

>5 feet	----	1.00
3-5 feet	----	.70
<3 feet	----	0

Depth to Bedrock. The soil has a finite capacity to absorb heavy metals, store nutrients for plant uptake, and hold pathogens until they are biologically inert. The deeper the soil, the greater the soil mass for removal of possible pollutants. Shallow soils over bedrock, or other impermeable layer, have a seriously reduced ability to remove possible sources of pollution; therefore, any soil with bedrock within 3.5 feet of the surface was eliminated by a zero rating. All other soils were evaluated and given a point rating according to the depth to bedrock as follows:

>5 feet	----	1.00
3.5-5 feet	----	.45
<3.5 feet	----	0

The DNR guidelines suggest at least 2 feet and preferably 4 feet to bedrock or other impermeable layer. This depth is mapped mostly according to 20, 40, or 60 inches in Dane County. Therefore, 40 inches, 3.5 feet, was used as the cutoff point.

Flood Hazard. Soils that are subject to frequent flooding were eliminated due to possible pollution hazards. Pathogens, heavy metals, and sediments may be introduced into surface waters from soils that are flooded. A point rating was assigned according to the flood frequency as follows:

None	----	1.00
Rare (less than once in 20 years)	----	.80
Occasional (less than once in 5 years)	----	.40
Frequent (more than once in 5 years)	----	0

Soil Texture and Permeability. Texture and permeability are two closely related soil characteristics that must be considered in an evaluation of the soil. Both characteristics are important in determining the movement of moisture and nutrients into and through the soil profile. With sludge applications on sandy soils, there is concern about the rapid movement of nitrates and other potential pollutants into the ground water. With fine-textured soils, there is concern about slow water movement and the possibility of surface runoff or ponding.

The soil textures are grouped in accordance with USDA Soil Taxonomy textural classes with the control section generally from 10-40 inches. Contrasting textural classes within the control section are indicated. Soil textures were evaluated and given a point rating as follows:

Fine loamy or fine silty	----	.90-1.00
Loamy	----	.70-1.00
Fine (clayey)	----	.80- .95
Coarse loamy or coarse silty	----	.70- .90
Sandy (sands)	----	.65- .85
Sandy (skeletal)	----	.50- .70

A variable point rating has been established because in certain textural classes, particle size percentages are grouped within a specified range; i.e., coarse loamy contains less than 18 percent clay and more than 15 percent sand.

Soil permeabilities are listed by USDA permeability classes in inches per hour. Soil permeabilities were evaluated and given a point rating according to the following:

Slow (0.06-0.2 in.hr)	----	.80
Moderately Slow (0.2-0.6 in./hr)	----	.95
Moderate (0.6-2.0 9n./hr)	----	1.00
Moderately Rapid (2.0-6.0 in./hr)	----	.95
Rapid (6.0-2.0 in./hr)	----	.85

Cation Exchange Capacity. Cation exchange capacity (CEC) is a measure of the soil's ability to exchange and adsorb cations, thereby reducing the cation mobility within the soil. This soil characteristic is important in determining the heavy metal loading rates for each soil.

Cation exchange information was obtained from USDA-SCS Soil Survey Investigations Report No. 17, Wisconsin; No. 19, Illinois; and No. 18, Indiana. CEC information from soils in adjoining states is assumed to be valid for the same series mapped in Wisconsin. Additional pertinent information was provided by Dr. Leo Walsh of the University of Wisconsin, Madison.

Soils were grouped by soil taxonomic classification so that similar soils could be assigned comparable CEC when no other information was available. Soils were evaluated and given a point rating according to their CEC as follows:

>16 meq/100 grams	----	1.00
10-16 meq/100 grams	----	.80
6-10 meq/100 grams	----	.60
4-6 meq/100 grams	----	.40
<4 meq/100 grams	----	.20

Computations. A numerical rating from 0 to 1.00 was computed for each soil series and phase by multiplying all individual item points together. The suitability classification for sludge application was prepared based on the following numerical rating system:

Class 1	.66-1.00
Class 2	.35- .65
Class 3	.01- .34
Class 4	0

Class 1 soils are the most suitable for sludge application. Class 2 soils are suitable with minor limitations. Class 3 soils should be used only if enough Class 1 and 2 soil areas are not available. Class 4 soils are not suitable for sludge application.

Summary of Suitability Classes. The properties and suitability for sludge application of the Dane County soils are summarized in Appendix C. Class 1 soils have ground water at a depth of more than 5 feet, bedrock at 5 feet or more, no flood hazard, and a cation exchange capacity equal to or greater than 15 meq/100 grams.

Many of the Class 2 soils are the steeper phases of the Class 1 soils with at least one additional major limitation. Most of these soils have a combination of limitations which are not severe enough to place them in a lower class. All of the Class 2 soils have bedrock at greater than 5 feet depth and ground water at greater than 3 feet depth.

The Class 3 soils often represent steeper phases of Class 1 and 2 soils with additional major limitations. All but four of the Class 3 soils have bedrock at greater than 5 feet. The four that have bedrock at 3.5 to 5 feet have ground water at greater than 5 feet.

Class 4 soils have major limitations making them unsuitable for sludge application. Any soil factor evaluated with a zero rating places the soil into Class 4.

A comparison of this suitability classification with the Wisconsin DNR guidelines shows the following: Class 1 and Class 2 are equivalent to soils having slight limitations; Class 3 soils are similar to soils with moderate limitations; and Class 4 soils correspond to soils having moderate to severe limitations. This soil suitability classification system is very restrictive. Of over 200 soil series and phases investigated, only 83 were placed in suitability Classes 1 and 2.

Crop Suitability for Sludge Application

Dane County crops were studied to determine their annual nitrogen fertilizer requirement, cultural practices, and their use. The annual nitrogen requirement is important in determining the annual sludge application rate. The crop type and use is important in determining the allowable method, time, and total quantity of sludge application. The planting and harvesting dates and restrictions for sludge use on common Dane County crops are shown in Table 6-2.

TABLE 6-2

CROP PLANTING AND HARVESTING DATES AND RESTRICTIONS FOR SLUDGE REUSE
MADISON METROPOLITAN SEWERAGE DISTRICT

CROP	PLANTED	HARVESTED	SLUDGE REUSE RESTRICTIONS
Grain Corn	May	late Sept.-Nov.	General*
Silage Corn	May	Aug.-Sept.	No foliage application within 2 months before harvest.
Small Grains			
Spring	Apr.	Aug.	General
Winter	Sept.	mid-July-early Aug.	General
Soybeans	May	Oct.-mid-Nov.	General
Sweet Corn	May	Aug.-Sept.	No foliage application, no application within 2 months before harvest. Reduce total application by one-fourth
Processing Peas	Apr.	late June	No application after planting. Reduce total application by one-fourth
Tobacco	May	July-Sept	No application after planting Reduce total application by one-fourth
Vegetables cooked before consumption	Apr.-June	July-Sept	No application before harvest in calendar year crop is grown Reduce total application by one-fourth for general crop, by one-half for leaf vegetables
Vegetables eaten raw	Apr.-June	July-Sept	No application within 3 years before crop is grown Reduce total application by one-fourth for general crops, by one-half for leaf vegetables
Alfalfa	Perennial		No application within 2 months before harvesting for lactating cow feed, 2 weeks required for nonlactating animal feed No application in fall while soil is wet
Forage Grasses	Perennial		No application within 2 months before grazing or harvesting for lactating cows, 2 weeks for nonlactating animals.

* General restrictions apply to all crops and include no application 1 month before harvest, during pollination, or within 2 weeks of planting

TABLE 6-3

ANNUAL FERTILIZER REQUIREMENTS
(pounds of element per acre)
MADISON METROPOLITAN SEWERAGE DISTRICT

CROP	NITROGEN	PHOSPHORUS	POTASSIUM
Grain Corn	125	35	40
Silage Corn	175	35	40
Oats	35	20	50
Barley	35	20	50
Rye	35	20	50
Wheat	35	20	50
Sorghum	100	40	160
Soybeans	5*	20	50
Alfalfa	0*	35	400
Pasture	75	25	50
Processing Peas	5*	20	50
Sweet Corn	75	35	40
Tobacco	100	40	75
Potatoes	160	85	160
Other Vegetables	100-200	15-60	130-250

*Legumes can get most of their nitrogen from the air, but they will also use soil nitrogen when readily available.

NOTE. The crops are listed with their planting and harvest dates and restrictions for sludge reuse in Table 6-2. The local crop management practices were determined by discussions with Dane County Agricultural Extension personnel and local farmers.

Fertilizer requirements for crops grown in the study are shown in Table 6-3. These values are based upon general literature and discussions with local agricultural extension personnel. The fertilizer requirements vary from field to field and from year to year in a single field depending upon natural soil fertility, past cropping and fertilizer applications, and crop management. The fertilizer values in Table 6-3 are meant only to be used as a basis of determining general study area sludge application rates.

Annual Sludge Application Limits

In general, the annual sludge application rates will be limited by the nitrogen application rate. If the amount of applied nitrogen that becomes available to crops is greater than that which the crop can use, the excess could be leached into the ground water where it could be a health hazard. Ideally, the applied nitrogen which becomes available to the crop should equal the crop nitrogen requirement. Not all of the nitrogen in the sludge is available to crops in the year it is applied. Most nitrogen used by crops is in the nitrate form. Since the nitrogen in the sludge is mainly in the ammonia and organic forms, it must be converted or mineralized into the nitrate form which crops can use.

Ammonia nitrogen is rapidly mineralized. It is estimated that about 90 percent of the applied ammonia nitrogen which is not lost by volatilization will become available in the year applied. The remainder should become available in the second year. The amount of ammonia nitrogen lost by volatization to the atmosphere will depend upon the method of application to land.

The organic nitrogen requires a longer period for mineralization. It is estimated that about 20 percent of the applied organic nitrogen will become available to plants in the year it is applied. In the second year, 6 percent of the remaining organic nitrogen should become available. In the third year, about 4 percent will become available. In the fourth year and each year thereafter, about 2 percent of the remaining soil organic nitrogen should become available to plants. These organic nitrogen mineralization rates are based upon University of Wisconsin research (Walsh 1975).

The annual sludge application rates will vary for the treatment plant and lagoon sludges because the nitrogen contents, especially ammonia nitrogen, are different. The annual application rates required to achieve a certain amount of available nitrogen must be reduced to allow for the mineralization of organic nitrogen applied in previous years. The yearly decrease in the treatment plant and lagoon sludge annual application rates are shown on Figures 6-2 and 6-3. The treatment plant sludge annual application rates could change considerably depending upon future plant operation.

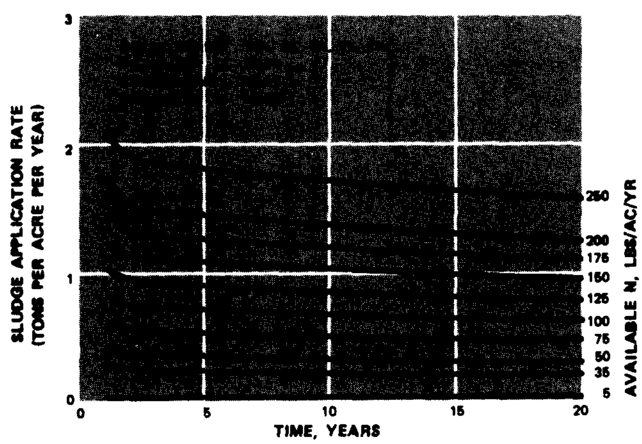


FIGURE 6-2

ANNUAL TREATMENT PLANT SLUDGE APPLICATION RATES FOR DIFFERENT AVAILABLE NITROGEN REQUIREMENTS

MADISON METROPOLITAN SEWERAGE DISTRICT
MADISON, WISCONSIN

The annual sludge application rate for Class 3 soils should be reduced by one-third because the soils in this class are generally less capable of supporting crops which could utilize a full nitrogen application. These less suitable soils also may have shallow depths to ground water and bedrock. Reducing the annual sludge application is recommended as an added precaution against ground-water pollution.

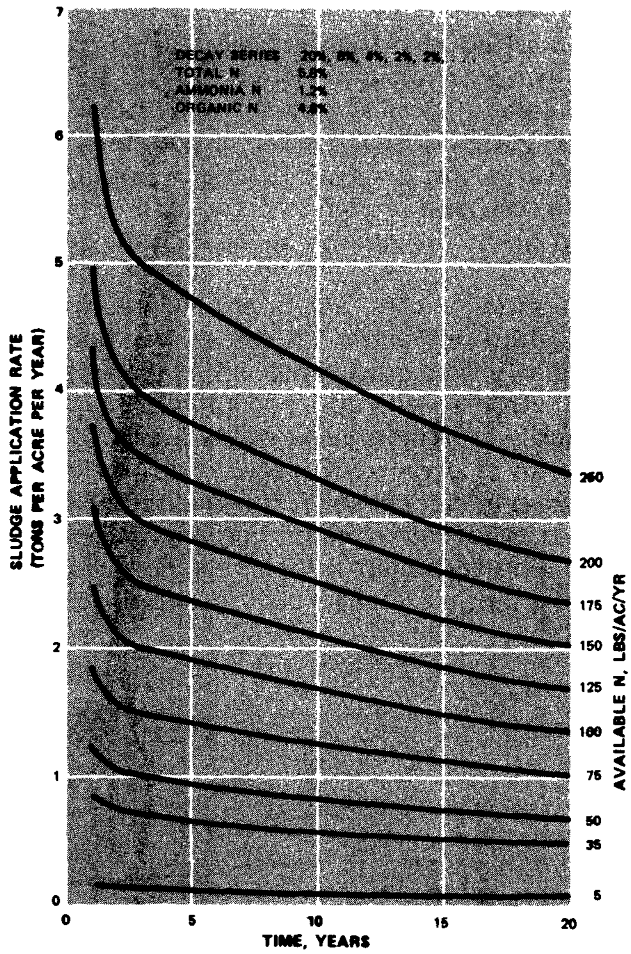


FIGURE 6-3

ANNUAL LAGOON SLUDGE
APPLICATION RATES FOR DIFFERENT
AVAILABLE NITROGEN REQUIREMENTS

MADISON METROPOLITAN SEWERAGE DISTRICT
MADISON, WISCONSIN

The WDNR guidelines for sludge reuse recommends limiting the annual cadmium (Cd) application to 2 pounds per acre per year. For the treatment plant sludge, the annual application is limited by Cd to 14 tons per acre per year. Cadmium limits the lagoon sludge annual application to 31 tons/acre/year. Nitrogen will control the annual sludge application rates because it is more limiting than cadmium.

Total Sludge Application Limits

The limits set for total sludge application are based upon constituents which accumulate in the soil. Heavy metals will generally be the limiting constituents.

Heavy Metals. Heavy metals have been shown to be phytotoxic to crops when applied to soil in large amounts. Heavy metals, when accumulated in plants, may also be toxic to humans and animals (Page 1974). If the metals are retained in the soil, unavailable for uptake by roots, they will not be a problem. The mechanisms which cause soil retention of heavy metals are numerous, complex, and interrelated. The sludge application rates recommended are conservative, based upon the best information currently available.

Several empirical methods have been used to estimate total safe metal loadings. The "zinc equivalent" method, developed in England and recommended by U.S. EPA and WDNR guidelines, limits the total metal loading calculated as "zinc equivalent" to 10 percent of the soil cation exchange capacity. This limits the combined zinc, copper, and nickel additions below phytotoxic levels. The equation used to compute total allowable sludge application is

$$\text{Total sludge} = \frac{32{,}700 \times \text{CEC}}{\text{ppm Zn} + 2(\text{ppm Cu}) + 4(\text{ppm Ni})}$$

Total sludge - tons dry solids/acre
CEC - cation exchange capacity of the unsludged soil in meq/100 g
ppm - mg/kg dry wt. of sludge

The calculated allowable total application rates for the treatment plant and lagoon sludges both equal about 140 tons for Class 1 soils, 90 tons for Class 2 soils, and 60 tons dry solids per acre for the Class 3 soils. These were computed using CEC's of 15, 10, and 6 meq/100 g, respectively.

The WDNR guidelines suggest limiting the total cadmium application to less than 20 pounds per acre because of potential health hazards. This is based in part upon the research performed by the University of Wisconsin. For the treatment plant sludge, this equals about 137 tons of sludge per acre. For the lagoon sludge, this equals 308 tons of sludge per acre.

There are other heavy metals which may also be of concern. As yet no standards have been developed for these based upon sludge application. The University of California, however, has developed guidelines for irrigation water quality criteria (Ayers and Branson 1975). Using this, the allowable loading rates were computed for metals other than zinc, copper, nickel, and cadmium. This method bases the total loading rate for individual heavy metals on the amount which would be applied with 3 acre-feet per acre of irrigation water each year for 20 years at the limiting quality criteria. Table 6-4 lists the sludge application limits imposed by metals other than Zn, Cu, Ni, and Cd. According to this method, iron may be a problem with lagoon sludge applications over 120 tons dry solids per acre.

TABLE 6-4

TOTAL SLUDGE APPLICATION BASED ON IRRIGATION WATER QUALITY CRITERIA
MADISON METROPOLITAN SEWERAGE DISTRICT

	CONCENTRATION IN SLUDGE		WATER QUALTIY CRITERIA		SLUDGE APPLICATION LIMIT	
ELEMENT	TREATMENT PLANT (mg/kg)	LAGOONS (mg/kg)	CONCEN-TRATION (mg/l)	QUANTITY IN 60 AC.-FT. (lb/ac)	TREATMENT PLANT SLUDGE (ton/ac)	LAGOON SLUDGE (ton/ac)
Aluminum	2,870	5,850	20 0	3,260	570	279
Arsenic	14	11	2 0	326	11,600	14,800
Boron	300	75	2.0	326	543	2,170
Chromium	234	200	1 0	163	348	408
Cobalt	30	ND	5 0	816	13,600	-
Iron	8,850	13,980	20 0	3,260	184	116
Lead	286	520	10 0	1,630	2,850	1,570
Manganese	189	350	10 0	1,630	4,310	2,330

ND means not detectable

Mercury was investigated individually because it accumulates in animals and can be toxic. Plants are not very sensitive to mercury and exclude it at the soil-root interface. Therefore, at the low sludge application rates we have recommended it should not accumulate in the plants or be magnified in the food chain.

Phosphorus. Ground water is usually protected from phosphorus contamination because soil has a very high degree of retention capacity for phosphorus. However, the phosphorus fixating capacity is limited and must not be exceeded. Methods for estimating the phosphorus sorption capacity are now being developed. When perfected, these procedures could be used for site evaluation (Ellis 1973 and Schneider and Erickson 1972). Meanwhile, the total phosphorus application should be limited to about 5,000 pounds per acre, or 180 dry tons sludge per acre.

Salts. The dissolved salts in the sludge should not cause salinity problems to crops. The major study area field crops, corn, grain, and alfalfa are tolerant of soil saturation extract salt content (ECe) of about 3.3, 4.7, and 2.0 mmhos/cm of salt, respectively (Ayers and Branson 1975). More than 26 tons per acre of treatment plant sludge and 230

230 tons per acre lagoon sludge would be required to increase the ECe of the soil by even 1 mmho/cm. The total salts in the sludge will not contribute to soil salinity since over time, some salts will be precipitated, others will be removed by crops, and still others will be leached below the root zone. Ammonium salts, for example, will be nitrified and over a period of time be consumed by plants or be lost by leaching or denitrification. If it is assumed that half of the applied salts do not contribute to soil salinity and that the soil is now low in salts, over 170 tons of sludge could be added over a period of several years with no detrimental accumulation of salts in the soil. Salt accumulation in soils is easily monitored and therefore controlled with good sludge reuse management.

Total Sludge Application Rates Summary. The total sludge application rates based upon the zinc equivalent, cadmium, water quality, phosphorus, and salts were compared to determine recommended rates. The total recommended treatment plant sludge application is 140 tons per acre for Class 1 soils. This corresponds to the limits set by both the zinc equivalent and cadmium criteria. The recommended total for lagoon sludge on Class 1 soils is 120 tons per acre. This is due to the iron limitation as determined by the irrigation water quality criteria. The water quality criteria were determined for the arid west where the soils are seldom, if ever, flushed out by excess water moving through the soil as they are in the midwest. Therefore, the irrigation water quality criteria are very conservative for Madison. The total recommended sludge application for the Class 2 soils is 90 tons per acre as determined by the zinc equivalent method. The total recommended sludge application limit for the soil Class 3 should be 60 tons per acre as determined by the zinc equivalent method.

The total sludge applications should be reduced by at least one-quarter for all direct human consumption vegetables such as processing peas and sweet corn. The total loading should be reduced for land which will be used for leaf vegetables, such as lettuce, by one-half because cadmium tends to accumulate in the leaves.

Summary of Sludge Application Rates

The annual and total sludge application rates according to soil class and crop type are shown in Tables 6-5 and 6-6 for the treatment plant sludge and the lagoon sludge, respectively.

TABLE 6-5

TREATMENT PLANT ORGANIC SOLIDS ANNUAL AND TOTAL APPLICATION RATES(1) ACCORDING TO SOIL CLASS AND CROP TYPE

(tons dry solids per acre)

MADISON METROPOLITAN SEWERAGE DISTRICT

	ANNUAL AVAILABLE NITROGEN REQUIREMENT (lb/ac)													
	(2)	(2)	5	5	35	50	75	75	100	125	150	175	200	250
SOIL CLASS	VEGETABLES LEAF	ROOT	SOYBEANS	PROCESSING PEAS	SMALL GRAINS		FORAGE GRASS	SWEET CORN	TOBACCO	GRAIN CORN		SILAGE CORN		
1	(2)/70	(3)/105	0.05/140	0.05/105	0 3/140	0 4/140	0 6/140	0.6/105	0 9/105	1 1/140	1 3/140	1.5/140	1 7/140	2 1/140
2	(2)/45	(3)/70	0 05/90	0 05/70	0 3/90	0.4/90	0.6/90	0.6/70	0 9/90	1 1/90	1 3/90	1 5/90	1 7/90	2 1/90
3	(2)/30	(3)/45	0 03/60	0 03/45	0.2/60	0.3/60	0 4/60	0 4/45	0 6/45	0.7/60	0.9/60	1 0/60	1 1/60	1 4/60
4	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE

(1) Application rates shown as annual/total, annual rate shown for first year applicaton.
Rates shown are for sludge which has not been aged.

(2) Wide variation in annual nitrogen requirements.

(3) Waste organics should not be applied in year crop is grown.

TABLE 6-6

LAGOON ORGANIC SOLIDS ANNUAL AND TOTAL APPLICATION RATES(1) ACCORDING TO SOIL CLASS AND CROP TYPE

(tons dry solids per acre)

MADISON METROPOLITAN SEWERAGE DISTRICT

	ANNUAL AVAILABLE NITROGEN REQUIREMENT (lb/ac)													
	(2)	(2)	5	5	35	50	75	75	100	125	150	175	200	250
SOIL CLASS	VEGETABLES LEAF	ROOT	SOYBEANS	PROCESSING PEAS	SMALL GRAINS		FORAGE GRASS	SWEET CORN	TOBACCO	GRAIN CORN		SILAGE CORN		
1	(2)/60	(3)/90	0 1/120	0.1/90	0 9/120	1.3/120	1 9/120	1 9/90	2 5/120	3 1/120	3.7/150	4 4/120	5 0/120	6 2 120
2	(2)/45	(3)/ 70	0 1/90	0 1/70	0.9/90	1.3/90	1.9/90	1.9/70	2.5/90	3.1/90	3.7/90	4 4/90	5 0/90	6.2/90
3	(2)/30	(3)/45	0.06/60	0 06/45	0.6/60	0.9/60	1 3/60	1.3/45	1.7/60	2.1/60	2.5/60	2 9/60	3 3 60	4.1/60
4	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE

(1) Applicaton rates shown as annual/total, annual rate shown for first year application

(2) Wide variation in annual nitrogen requirements.

(3) Sludge should not be applied in year crop is grown.

The application rate values shown in Tables 6-5 and 6-6 are presented as an estimate and should not be used until verified in the field. The CEC of the unsludged soil and the other factors used to determine the soil classification should be checked on each site before sludge is applied. The annual application rates will vary because the cropping patterns will change and because soil organic matter will also change, depending upon site management. The total application rate will be determined by monitoring each site. The sludge character, which has a direct influence upon application rates, may change and must be monitored also. The loading rate tables presented will be used as the basis of land requirements for this report.

6.4 OTHER CONSIDERATIONS FOR AGRICULTURAL REUSE

Fertilizer Market

The fertilizer market situation will have great impact upon how willing the farm community is to accept sludge as a substitute for commercial fertilizers. The fertilizer industry has recently experienced a shortage of the natural resources and energy necessary to produce fertilizers while the demand for fertilizer has grown tremendously in certain areas of the country. These factors have resulted in greatly increased prices for nitrogen and phosphorus fertilizers all across the United States.

In Wisconsin, about 594,000 tons of fertilizer mixtures and materials were used in the year ended June 30, 1965. By 1972, seven years later, fertilizer use had grown to 942,000 tons per year. About 11,300 tons of natural organic fertilizers were sold in 1972 (Crop Reporting Board, USDA 1973).

With the high prices of fertilizers, farmers have reduced their use of commercial fertilizer somewhat and have begun to use available natural organic sources. As long as the fertilizer prices stay high, the farm community is expected to use natural organics, including sludge, as lower cost nutrient sources. The decreased use of fertilizer has resulted in some increase in fertilizer producers' inventories in the last year. Supply should not be as great a problem in the next few years as it has been in the recent past (Chemical Week, August 1975), but natural resources and energy shortages are expected to keep prices high.

Reuse of sludge should have little impact on the commercial fertilizer market in the Madison area. It is estimated that the Nine Springs Sewage Treatment Works sludge could supply only about 3 percent of the study area nitrogen requirement. This should assure a high demand because of the apparent limited supply.

Farm Community Acceptance of Sludge Reuse

It was necessary to estimate the number of farmers which will want to use sludge to determine if a program based upon farmers wanting sludge will succeed. Two public meetings, to which the farm community was invited, were held to determine their interest in the program. These meetings were also used to inform the farmers about the requirements of sludge reuse and to show them how sludge can be used and applied and how the program could operate. Feedback from the farmers was used in developing the reuse program wherever possible.

Eighteen farmers, representing about 3,000 acres, who attended the meetings and returned questionnaires, all said they would use sludge. Several want it as soon as they can get it. Based upon MMSD records on those who have already used sludge and the results of a MMSD letter and questionnaire sent to farmers on 2 August 1974, there are now about 26 farmers, representing about 5,000 acres, who apparently are willing to use sludge. The District has also been approached by several other farmers in the area who want sludge. Based upon the preceding, the District already has a strong potential market for sludge reuse represented by more than 5,000 acres of land.

Land Ownership

The farmland in the study area is presently about 80 percent owner operated and 20 percent leased. The trend is toward fewer, larger landowners and operators. Small farms simply are not large enough for most efficient and economical operation. Many small farms (less than 100 acres) are leased to persons operating combined areas of over 100 acres. The cost of farmland in the study area has been rising rapidly in the last year. It now varies from about $700 per acre for medium to poor land several miles from cities up to $2,500 per acre in areas under pressure of subdivision and land speculation. This cost includes the value of improvements such as the farmhouse, barns, and fencing. The cost of leasing or renting farmland is normally about $50 per acre per year.

Public ownership of the land required for sludge application would be a distinct advantage to the District because it would then be assured of a place to apply the sludge. The land availability would not be affected by public attitudes or variations in the economy as could happen if the sludge is applied on privately controlled farmland. However, private ownership has several advantages which, in this case, outweigh public ownership.

Acquisition of several hundred or thousand acres of land by the District would be a major institutional and economic problem. Many families would need to be displaced from land that in many cases may have been in the family for generations. Long and expensive condemnation proceedings would most likely be required if MMSD were to attempt to purchase any large land areas for sludge application. Neighbors to a large sludge application site would most likely complain about environmental conditions, whereas relatively small, widespread sludge reuse areas in private ownership would cause much less concern by neighbors to the sites.

Other problems of public ownership are that a public institution would become engaged in the production of crops for competitive markets, and the land could be removed from the tax rolls. The adverse effects of these factors could be minimized if the farming operation were leased to a local farmer and if the District elected to make a payment in lieu of taxes.

The cost to the District to own and operate an application site would be very high; about $1,250 to $1,600 per acre or $21 to $26 per dry ton of sludge applied. This is the present worth cost of owning and operating an application site for 20 years. The analysis considered the cost of the land; taxes or payment in lieu of; cost of condemnation; potential revenue from the crops; the salvage value at the end of the 20-year operating period, and the potential savings in transporting, applying and monitoring the sludge at a District-owned site.

A similar analysis was performed for the marketing alternative (see Section 7.2). The estimated cost to the District to operate this type of program is expected to range from $500 to $1,200 per acre, or $8 to $20 per dry ton of sludge applied. The high range assumes no revenue from the sale of sludge, and the low range assumes receiving revenue equal to one-half its value as a commercial fertilizer.

Sludge Application Periods

Several factors will control the periods during which sludge can be applied to land. These include cultural practices, crop growth stages, weather, application equipment capabilities, and animal and human health protection.

Cultural Practices. Sludge application should not interfere with cultural practices. Certain practices must generally be performed at specific times to maximize crop production and to minimize farming expenses. Sludge application should be scheduled around seedbed preparation, planting, harvest, and fertilizer, herbicide, and pesticide application. These cultural practices vary from crop to crop and year to year.

Crop Growth Stages. Crops go through several growth stages where sludge application could be detrimental. Liquid sludge is high in soluble salts which may inhibit seed germination. Therefore, sludge must not, in general, be applied within 2 weeks before or after planting. If the soil is dry, the required buffer period may be more than 2 weeks to allow sufficient time for the soluble salts to dissipate before planting. Sludge should not be applied to crop foliage within 2 weeks before or after the pollination period to prevent washing off pollen or disturbing pollen-carrying insects. Application on growing plants could result in injury to the leaves. Application in fall could result in less efficient nitrogen use due to denitrification or nitrate leaching.

Weather. The weather in Dane County is a significant factor which must be considered in sludge application. The climate is typically midwestern with much of the precipitation falling during the summer. Sludge should not be applied onto saturated or frozen sloping ground because subsequent precipitation or thawing could cause surface runoff. The ground is generally frozen from about mid-December to mid-March.

Equipment. The time of sludge application will be limited to that which the application equipment can effectively operate without causing rutting or excessive soil compaction. Heavy equipment such as trucks or farm tractors are not usable while the ground is wet and soft. Subsurface injection is not usable in wet, hard, or frozen soil.

Health. To protect the public and animal health in use of the crop, sludge must be applied so that it will not contaminate the harvested portions of the crop. In general, sludge must not be applied within 1 month before harvest. Rains will wash sludge from the crop but cannot always be depended upon. Sludge must not be applied to pasture or forage crops within 2 months before the crop is grazed or harvested. The major method of dairy cow feeding in the study area is greenchopping and hauling it to feedlots. This is performed about every 5 weeks, so sludge application on greenchop land will not be permitted during the summer months. Grazing animals should not be allowed on pasture until the sludge is removed from the plant by rain or other method; this can be determined visually. The minimum time between sludge application and feeding should be 2 weeks for general livestock. Sludge should not be applied to land used to grow vegetables within the calendar year before harvest.

TABLE 6-7

ESTIMATED MONTHLY DISTRIBUTION OF SLUDGE USE ON PRIVATE FARMLAND
MADISON METROPOLITAN SEWERAGE DISTRICT

MONTH	PERCENT OF ANNUAL TOTAL
January	0
February	0
March	0
April	30
May	15
June	10
July	5
August	5
September	10
October	15
November	10
December	0

The foregoing factors affecting the time of sludge application were considered for each crop grown in the study area. Based on the period of sludge application for each crop, and the relative amount of sludge applied to each crop, an overall monthly distribution of sludge application on private farmland was determined and is shown in Table 6-7.

Soil Wetting Effect of Sludge

The time required for soil to dry is important to a farmer who is waiting to plant his crops in the spring. The amount of water applied with a 3-ton-solids per acre sludge application is about 0.5 inch depth. This amount of moisture is not a significant problem in drying the soil. However, if the sludge is spread on the surface and not then incorporated into the soil, a film may form which can delay soil drying time considerably. University of Wisconsin researchers have noticed that the time for a soil to dry with sludge applied can be about twice as long as required where an equivalent amount of water was applied. Therefore, whenever soil wetness could be a problem, the sludge should be incorporated into the soil directly after spreading or at least harrowed and broken up when dried sludge film forms.

Odors

Well-digested liquid sewage sludge will emit a faint tar-like odor immediately after application which is not objectionable to most people and which dissipates rapidly. When air dried, sludge has an earthy odor. The odors caused by well-digested sludge can be minimized or made undetectable by subsurface application or incorporation into the soil. Incompletely digested sludge or sludge from an upset digester, however, can be very malodorous and should not be applied to land. It should first be stored or treated to reduce the odor.

The odors experienced by passersby or neighbors to the land application site should be less than the magnitude of odor caused by manure spreading. The fact that it is sewage sludge, though, may cause them to imagine that the odor is stronger or more offensive than manure. Where complaints have been received, or could be in the future, such as near major roads or subdivisions, the sludge odor should be minimized by applying only by subsurface methods or when it can be incorporated into the soil within 2 days. The wind direction while surface applying should also be considered and application be made only while adverse effect would be minimized.

Insects

Flies and other nuisance insects can be a problem if careful management is not used. Sludge which has been lagooned will have fewer insect problems because it is more stabilized than fresh digested sludge. Insects should not be a problem where good housekeeping is practiced. Sludge handling equipment should be kept clean, and spillage onto roads, into ditches, etc., must not be allowed. Liquid sludge should not be allowed to drain into low wet spots in fields as insects will breed in ponded areas. Incorporation into the soil during or soon after application will prevent insect problems.

Weeds

Most weed seeds will not survive the sludge digestion process. Tomatoes and melons are the most common exception and will sprout in sludge applied to fields. These plants can easily be controlled by herbicides or cultivation and generally are not considered a problem by farmers. Plants normally considered to be noxious weeds by farmers do not enter the sludge with the sewage because they are not part of the waste normally put into sewers. Sludge which is stored in open lagoons will collect weed seeds just as farmland does by natural processes. These weed seeds should be minimized by controlling weed growth around lagoons.

Farmers who have used MMSD sludge report that they need to apply more herbicide than normal to sludged land. This is because the sludge additions add organic matter to the soil which buffers the effect of herbicides and, consequently, more herbicide must be applied. Also, the lagoon sludge contains many weed seeds. Some farmers report that 10-20 percent more herbicide is required.

Public Health Aspects

Sludge reuse on agricultural land must be done with caution because digestion does not remove all pathogens. Research on Nine Springs Sewage Treatment Works digested sludge (Cliver 1975) showed viruses to be present. Bacteria, protozoans, and intestinal worms are also found in processed sludges (Burge 1974). Anaerobic digestion, which is presently used at Nine Springs, has been shown to be very effective in reducing pathogens (MSDG Chicago 1974; Malina et al. 1974; Ewing and Dick 1970; and Dean and Smith 1973). Prolonged storage of sludge, such as the lagoon solids have received, has also been shown to be an effective method for pathogen reduction (MSDG Chicago 1974). Pathogens which are applied with sludge to land are readily removed by soil through the mechanics of filtration and sorption-inactivation and by die off. Pathogens usually do not move more than a few feet in soil unless the soil is very coarse textured or contains cracks or channels.

The question still to be answered by research is not whether or not there are pathogens in sludge, but rather, what levels are required to constitute a health haazard. There have been no cases reported of a health hazard being traced to digested sewage sludge (Ewing and Dick 1970). Sludge can be disinfected by pasteurization, composting, heat drying, and lime treatment. These procedures are all expensive, but if required as a means to protect public health, should be investigated and utilized. The following list of criteria, if adhered to, should prevent any health hazard:

- Sludge must be stabilized by anaerobic digestion or equivalent before being applied to agricultural land.

- The depth of soil between zone of sludge application and bedrock should be at least 2 feet and preferably 4 feet.

- Sludge should not be applied to soil in the year the area is used for any root crops or other vegetables which are cooked or processed. Sludge-treated land should not be used for human food crops to be eaten raw until 3 years after sludge application.

- If sludge is surface applied to sloping land, runoff to streams or lakes should be prevented by use of contour strips, terraces, or border areas.

- Pasture land and harvested forage should not be used for milk cow feeding for 2 months following sludge application. Other animals should not graze pasture land or be fed greenchop material for at least 2 weeks after sludge application.

- Public access must be limited in areas of sludge application.

Heavy metals in the food chain are another potential public health problem that must be controlled. Cadmium, in particular, is mobile in the soil and not excluded by plants. Therefore, it can enter the food chain. Cadmium can accumulate in the human body and has deleterious effects on the kidneys and liver (Page and Bingham 1973). Public health problems can be prevented by limiting the cadmium application rate and monitoring crop tissue for cadmium content.

In this reuse program the cadmium application rate will be limited to 2 pounds per acre per year and 20 pounds per acre total over the life of the site. These limits are as recommended in the DNR guidelines and are based upon research at the University of Wisconsin (Kenney et al. 1975). Also, crop tissue will be monitored to detect increases in cadmium and other trace elements.

Sludge Drying Considerations

Drying the digested sludge was studied but found unfeasible as a means to reduce the volume of sludge to be handled. Mechanical drying, as the Weston report discussed, is not feasible because of the poor dewatering characteristics of the Nine Springs Treatment Works sludge.

Nebiker (1967) has performed research on open air drying of sludge. He notes that the rate of drying would initially be approximately equal to the evaporation from a free water surface. After a certain solids content is reached, the free water surface in the sludge will be lost, and drying will slow greatly.

On an annual basis, the evaporation exceeds the precipitation by only about 5 inches. During May through October, the net evaporation is about 15 inches. Application to drying beds on a year-round basis would not be feasible due to the small amount of drying which could be achieved. About 100 acres of drying bed area and 6 months sludge storage capacity would be required. Due to the extensive facilities required and the fact that one heavy rainstorm late in the summer could rewet all the sludge, air drying is considered infeasible.

Nitrogen Losses During Application

Research reported by Ryan and Keeney (1975) indicates that when wastewater sludge is surface applied, between 11-60 percent of the applied ammonia nitrogen can be lost by volatilization. The amount lost depends on the type of soil, the rate of application, and the length of time before the sludge is incorporated into the soil. When surface application methods are used, the sludge application rate should be adjusted upward to account for ammonia losses. The WDNR guidelines suggest using an average 50 percent ammonia loss.

6.5 SLUDGE APPLICATION SITE INVESTIGATION

The study area was investigated to determine how much farmland is suitable for sludge reuse and where it is located. This was then compared to the amount of land required to determine the potential for success of a sludge reuse program.

Land Requirement for Sludge Reuse

The amount of land required was estimated based upon an average sludge application of 3 tons dry solids per acre per year. In the first year of the reuse program, it is expected that only the amount of sludge produced by the treatment plant, about 5,800 tons, could be used on farmland. The lagoon weed mat removal program, other startup problems, and arranging for farmers to use sludge is expected to prevent large-scale use of sludge in the first year. The land requirement for the first year will therefore be about 1,930 acres. In succeeding years much more land will be required to accept an estimated 10,000 tons of lagoon sludge each year, plus the annual treatment plant production. The land requirement is expected to be between 5,200 and 5,700 acres until the lagoon is emptied. After the lagoon is emptied, about 1986, only the treatment plant sludge will need disposing. The land requirement is then expected to be from 2,400 to 3,000 acres each year.

If the same farmland is used every year, the amount of sludge applied would not exceed about 72 tons of sludge by the year 2000. This is well below total application limits for the Class 1 and 2 soils. It is most likely that many different parcels of land will have sludge applied rather than the same land every year.

Site Suitability Criteria

Previous sections of this report have explained many of the requirements for safe agricultural reuse of sludge. Those requirements and several others relating to site suitability are listed below:

- Sludge should not be applied within 1,000 feet of public water supply wells or within 200 feet from private water supply wells.

- Sludge should not be applied anywhere that it could be carried by runoff to surface waters. A buffer strip of at least 300 feet is recommended unless it can be shown by site inspection that a specific site has characteristics which would allow a lower limit (between 300 and 100 feet) without runoff or contamination problems.

- Sludge should not be used where it would endanger rare and endangered plants or animals.

- Sludge application should be limited to sites which are actively farmed.

- Sludge application sites should be at least 500 feet from concentrated population areas, urban and suburban housing tracts, rural subdivisions, commercial areas, recreation spots, or schools if the sludge is surface-applied. If it is subsurface injected, the buffer shall be a minimum of 300 feet.

- Sludge may not be applied within 300 feet of rural homes and gardens unless the District first contacts affected residents, explains the program, and obtains their permission to apply sludge closer. The minimum buffer distance may be 200 feet if the sludge is surface applied or 100 feet if subsurface injected. Sludge must not be applied where it could be carried by runoff onto the farmstead.

- Sludge lagoons, sprinkler application systems, and other unsightly facilities or operations shall be located so as to be screened from major public view.

- Sites subject to occasional or frequent flooding, more than once in 20 years, are not suitable for sludge application. Areas subject to rare flooding, less than once in 20 years, will have the requirement that sludge be applied and mixed into the soil at least 2 months before any potential flood season.

- Sludge application sites must have depth to seasonally high ground-water table of at least 3 feet and preferably 5 feet.

- Sludge application sites must have depth to bedrock or other impermeable layer of at least 3.5 feet and preferably 5 feet. Areas with bedrock less than 5 feet shall be used only if better sites are not available.

- Sites with both bedrock and ground-water depths less than 5 feet are not suitable for sludge application.

- Sites with slopes greater than 12 percent are not suitable for sludge application unless special measures are taken to prevent erosion.

- All District-owned sites and facilities should be located within Dane County.

Land Available for Sludge Reuse

Soil suitability and land use are the two major factors of land availability for sludge reuse. These two factors were mapped to determine their extent.

Soils. The soils in the study area were mapped by sludge application suitability class on the detailed soils maps of Dane County. The detailed maps were used as the basis of determining amounts and locations of suitable soils. Due to the size and detail of the detailed soils maps, they could not be incorporated into this report. Therefore, a more general soil suitability map was prepared. This general map of soil suitability for sludge application appears on Figure 6-4. The general soils map groups are comprised of the following soil classes. General Soil Group A is about 75 percent Class 1 and up to 25 percent Classes 2, 3, and 4. General Soil Group B is about 75 percent Classes 2 and 3 with up to 25 percent of Classes 1 and 4. General Soil Group C is about 75 percent Class 4 soils and up to 25 percent of Classes 1, 2, and 3. The general soil map is meant for illustrative purposes only. The detailed soil survey maps must be used when looking at individual farms.

Land Use. Areas of land unsuited for sludge reuse including cities, population centers, recreational areas, schools, subdivisions, commercial, and industrial areas, are shown on Figure 6-5. These areas must be avoided for sludge reuse as much as possible. Figure 6-5 also indicates the locations and densities of rural homes. Areas with many clustered homes should also be avoided.

The soils and land use maps were overlain together to determine the amount of land suitable for sludge reuse. About 40,000 acres, or 44 percent of the 91,000 acres of cropland, in the study area can be used for sludge reuse. In comparing this to the highest expected land requirement of less than 6,000 acres, it is apparent that more than enough land is available in the study area.

6.6 SUMMARY

This chapter has discussed the many factors related to agricultural reuse of sludge. A study area consisting of the land within a 10-mile radius of the Nine Springs Sewage Treatment Works was delineated as a basis for discussion. The study area contains about 91,000 acres of very productive farmland. Its soils, land use, and ground-water conditions were investigated for their suitability for sludge reuse. Based upon the site investigations, it was determined that about 44 percent of the study area, or 40,000 acres, is suitable for sludge application. Farmers representing more than 5,000 acres of farmland have already shown a strong interest in having sludge applied to their land. The amount of farmland available for sludge reuse is expected to increase rapidly after the reuse program is started.

The amount of land required for reuse of all the Nine Springs Sewage Treatment Works sludge will be between 5,200 and 5,700 acres until the lagoons are emptied. Thereafter, only about 2,400 to 3,000 acres will be needed each year. The land area requirement is based upon recommended annual and total sludge application rates which were developed in this chapter. The sludge application rates were set to guard against potentially harmful overapplication of crop nutrients and heavy metals.

This chapter also included criteria for determining the suitability of particular sites for sludge application and site management necessary to protect the surrounding environment.

SLUDGE REUSE PROGRAMS 7

Chapter 7
SLUDGE REUSE PROGRAMS

An organized program will be required to ensure successful and safe sludge reuse. The program must outline procedures for management and for distribution and land application of sludge. Management considerations include the application rate categories of fertilizer rate, high-rate fertilizer, and disposal. For distribution and application, the reuse program considerations include District-owned land, land leased by District, and farmer-owned and controlled land.

7.1 CRITERIA FOR PROGRAM SELECTION

Program Criteria

To choose between the many possible alternative systems for recycling sludge, it is necessary to first determine criteria which the reuse program must meet. The criteria are as follows:

- The program must be able to handle all of the annual treatment plant sludge production plus the sludge to be removed from the lagoons.
- The program must recycle the sludge back into agriculture.
- The program must be flexible.
- The program must be acceptable to the farm community.
- There must be no pollution of ground or surface waters.
- There must be minimum detriment to other environmental factors.
- The program must be cost effective.

- Reuse Program 1--Market all sludge to farmers.
- Reuse Program 2--Lease land for short periods for sludge application.
- Reuse Program 3--Combination marketing and land leasing.

Reuse Program 1--Market All Sludge

Description. The District would make sludge available to area farmers as they request it for fertilizer rate application to their farmland. A public relations program would be developed to aid in marketing the sludge. The farmer would have complete control over his land. He would contact MMSD when he wanted sludge, then he and a District representative would determine the suitable time, location, and application rates for sludge application.

Facilities Requirements. In this program, sludge demand is expected to be high during April and May and again in September through November, whereas the supply of sludge is uniform each month. Therefore, facilities for sludge storage and high seasonal sludge distribution and application will be required.

The storage requirement for Program 1 was calculated based upon the monthly use shown in Table 6-7 and upon the estimated uniform sludge production each month. The calculated storage capacity required is 33.4 percent of annual treatment plant production. The recommended design storage capacity is 75 percent of annual production (150 acre-feet) to allow 5 months extra capacity in case adverse weather delays or prevents spring sludge use. The sludge would be stored in Nine Springs Lagoon 1, in small on-farm lagoons, or at distribution centers. Lagoon 2 will be abandoned as recommended in Chapter 5. The storage facilities would be filled during the winter months of no sludge use and the midsummer months of expected low sludge use. All storage should be emptied by about November each year.

In addition to providing some seasonal sludge storage, on-farm lagoons would relieve some of the peak season distribution requirements. The District would need to obtain a commitment from the farmer to accept sludge for several years before helping to build a small lagoon. A 3-5 acre-foot-capacity lagoon would be required to hold enough sludge for application to 100 acres.

The sludge handling facilities should be sized to distribute and apply, in 1 month, 35 percent of the amount of sludge used in the year. This is based upon Table 6-7 which indicates that the peak month use will be about 30 percent of annual use. An extra 5 percent was added for contingency. If the distribution and application system fails to meet demand for even one season, many farmers may stop using sludge because they may feel they cannot rely on the system to meet their needs.

Distribution centers could be used after strong sludge reuse market areas develop. These would serve as a central point from which sludge would be supplied to surrounding farmers. Sludge would be pumped via pipeline from the Nine Springs Works as used or be stored at the distribution center until used. The advantage of using a pipeline is that, in general, it will be more economical to transport the sludge longer distances by pipeline than by truck. The distribution center could also be used for research, demonstration, and monitoring. The storage capacity at a distribution center would depend upon the size of the market served from it. Strong interest has been shown for a sludge distribution center in the Cottage Grove area. The area around Oregon may also be suitable for a distribution point. The District should wait until a strong market is developed in an area before locating distribution centers. Potentially strong market areas cannot be determined with enough reliability to select sites at this time.

The land application sites would be located wherever a farmer wanted sludge applied, as limited by the site selection criteria. Farms nearer to the Nine Springs plant should be given first preference as this will reduce the District's transportation costs.

Program Management. The District must appoint a person to manage the sludge reuse program. Duties of this manager would include scheduling distribution and application, answering farmers' questions, reviewing requested sites and application rates, directing the monitoring program, and marketing sludge for reuse. This person should be capable of talking to farmers in their terms, be familiar with the local agriculture, and be enthusiastic about the project.

Marketing Program. In order for the concept of farmers asking for sludge to become reality, the District must develop a strong community involvement program. This has already been started by the District staff and has been continued with the farm community meetings which were a part of this planning study. This should be continued by the use of educational programs sponsored by MMSD.

The public's view of the sludge reuse facilities and operation must be carefully maintained by the District. For instance, the truck drivers should be considered as ambassadors of the District because they are in everyday contact with the farmers and rural public. Clean trucks and courteous, helpful operators can be very important in achieving a successful program.

Another marketing concept that should be used is an attractive informational brochure which would explain to the public what sludge is, how it is beneficial to agriculture, and how farmers can contact MMSD and arrange to get sludge applied on their land. Also, the sludge should be given a trade name such as HYDIG or BIOGRO. This would eliminate the need for calling it sewage sludge, which admittedly is a negative term. The farm community knows that it is sludge, but they need not be continually reminded.

Monitoring Program. The District must implement a program to monitor the effects of sludge reuse for two reasons: (1) it is required by State and Federal regulations and, just as important, (2) the farmers will feel more confident using sludge if they are assured that someone competent is guarding their soil and crop production.

Reuse Program 2--Lease Land for Sludge Application

Description. In this program, the District would lease or rent land from farmers for sludge application. Since sludge would be applied during the growing season, no crops would be grown that year. The lease cost, therefore, would have to offset the net returns the farmer would have otherwise received from a crop plus the fixed costs of equipment and land ownership.

The amount of leased land and consequently the program cost could be reduced by applying enough sludge to satisfy the crop nutrient requirements for more than 1 year. U. S. EPA guidelines limit available nitrogen application to twice the crop nitrogen requirement in a single year. Only heavy, moderate to slow permeability soils are suitable for this program because they would not allow the excess nitrogen to be leached below the root zone in the first year. The cost of leasing land for this program is estimated to be $38.60 per acre or $5.68 per dry ton of sludge applied where

2 years of sludge is applied in 1 year. The basis of the land lease cost is shown in Table B-5. The lease cost would be reviewed each year to allow for different farming costs and crop sale values.

Two purposes for obtaining leases for the land are (1) the District would be assured of land for sludge application for some period in advance, and (2) sludge application could be scheduled evenly throughout the summer, thereby reducing peak handling requirements. The farmer would benefit from knowing he would not be hurt by crop failure, fertilizer would be applied onto his land, and he would not need to farm the land for one season. Depending upon the interest in this program, the leases could be procured by competitive bidding or by the program manager approaching individual landowners with the program.

Facilities Required. The facilities would be set up to supply sludge to land according to a schedule set up by the District. If weather permits, sludge would be applied evenly over the 8-month period, April through November. This results in 12.5 percent of the annual sludge reused being applied in each month. The handling facilities should be sized to handle an extra 5 percent to allow for contingency.

The total storage capacity should be designed for 75 percent of annual treatment plant sludge production. This is based on the same estimates as used for Reuse Program 1. Workable storage locations would be in the Nine Springs Lagoon 1 and at one or more central distribution points as described for Reuse Program 1.

In a leased land program, it is likely that the application sites would be smaller and more widely scattered than as in Reuse Program 1 because an actively farming landowner would be reluctant to lease all of his land to MMSD for 1 year. Rather, he would likely lease a small portion 1 year, a different portion the next year, etc.

Program Management. As in Reuse Program 1, the District should appoint a program manager. His duties would include finding and arranging land leases in addition to scheduling sludge handling, talking to farmers, reviewing sites and on-farm management, directing monitoring, and marketing the sludge.

Marketing and Monitoring Programs. The District will need to both market the sludge and monitor the reuse as in Reuse Program 1. The success of this program depends upon making farmers aware of the program, how it works, and showing them the benefits. The program must be monitored to satisfy regulatory agency requirements and, more important, to show the farmer that MMSD cares about their crops and land.

Reuse Program 3--Combination Sludge Marketing and Land Leasing

This program would be set up to market sludge to farmers for use on their land as in Reuse Program 1, plus it would include provisions for MMSD leasing land as in Program 2. MMSD-leased land would be used to apply sludge during the low-use months of July and August. This would spread the application period out more evenly over the year and thus reduce peak sludge handling requirements. The amount of land leased versus that kept in private management would depend upon the farm community.

The sludge storage capacity, the program management, and the marketing and monitoring programs would be the same as described for Reuse Programs 1 and 2. The capacity of the sludge distribution and application facilities would be between the estimated requirements for Reuse Programs 1 and 2.

7.3 SLUDGE HANDLING CONTINGENCY PLAN

A contingency plan must be available for sludge handling in the event that the sludge reuse market is suddenly lost. A marked decrease in the number of farmers requesting sludge could be caused by a reduction in the price of commercial fertilizer, a publicity scare, or a change in the sludge character. If a problem does develop, the District's first effort should be to find the cause of the problem and correct it. In the case of lower commercial fertilizer prices, the District must simply make sludge reuse more economically attractive by lowering or cutting out any cost to the farmer, or maybe even paying them to take sludge.

A continuing public relations and educational program must be used to prevent the farmers from being frightened of sludge reuse by unfounded claims. If the sludge character changes, making it undesirable for agricultural reuse, the reason for the change should be found and corrected. If, for instance, a particularly high toxic metal concentration occurs in the sludge, the source should be found and removed.

In the event that it is not possible to prevent loss of the sludge market, an alternative temporary sludge handling and disposal method should be available. The sludge handling alternative should be able to handle the sludge for about 3 years until the sludge market can be restored or until another disposal method could be developed. Possible alternative temporary programs would be to (1) have several thousand acres of District-owned or option-to-control land available for sludge application, (2) have facilities for incineration or dewatering and landfill available for sludge disposal, or (3) have capacity to store sludge for 3 years. The first and second alternatives are not feasible because of the high cost and impracticability. The third alternative is recommended: store the sludge until a permanent solution can be found. The west half of the Lagoon 1 storage area will have capacity to store 75 percent of 1 year's sludge production at 2.3 percent solids. With concentration to 10 percent solids, as is currently achieved after a freeze-thaw cycle, this storage area could hold 3 years' treatment plant sludge production. Also, the dikes surrounding the east half of Lagoon 1 should be left intact, except as required to allow drainage, after the sludge is removed. This area would then, with minor rehabilitation, be suitable for storage of an additional 3 years' sludge production in an emergency. The Mud Cat and supernatant return and treatment facilities will be available to concentrate the lagoon solids.

If loss of a sludge reuse market is to occur, it will most likely happen in the first years of the program before sludge reuse becomes a common, well-accepted practice. After many years of sludge reuse, the chance of losing the sludge market would be very remote. Sludge marketing is a vital element of the sludge reuse program, and all should be done, especially by way of public education, to assure the program's success.

7.4 PRESENT METHOD OF SLUDGE REUSE

The present method of sludge reuse is a form of Reuse Program 1. The farmers, upon hearing that MMSD had sludge to dispose of, asked for it, and the District hauled and applied it for them. The present program includes monitoring of streams near sludge application sites.

The present method of handling and disposing of the anaerobically digested sludge produced at the Nine Springs Treatment Plant consists of two steps. First, the sludge is piped from the digesters to Lagoon 1. The average rate for the last 4 months of 1974 was 184,000 gallons per day. A dragline is then used to remove sludge from the lagoons. The sludge is put into trucks which haul it to nearby farms where it is dumped into piles. The piles are then spread by a grader.

In 1974 6,682 tons of sludge were removed from the lagoons and hauled to farmland or on-site stockpile. Sludge was hauled for 29 days between 23 January and 4 March and for another 37 days between 21 October and 31 December. Sludge was also hauled until early February 1975 and again in the fall. The application rates during 1974 ranged from 2.8 dry tons to 28.2 dry tons per acre.

The District estimated that the cost of the dragline and trucking operation in 1974 was $9.06 per dry ton. To this we added an estimate of the cost of spreading, supervision, and sampling and testing. This produced an estimated total cost for sludge reuse in 1974 of about $11 per dry ton.

The District takes care while loading sludge into the trucks so that none will spill onto roads. There are some problems, though, with the present method of sludge disposal. It was noted on one farm in February 1975 that large frozen pieces of sludge lay on top of the frozen soil. When the spring thaw came, this sludge was apparently washed down a draw past several homes toward Lake Waubesa. This caused some complaints from residents located between the fields and the lake. Also, the sludge application rates used on some fields are considerably higher than required to meet the nitrogen requirements of the crops.

7.5 FUTURE SLUDGE HANDLING FACILITIES CONSIDERED

The sludge handling facilities, namely the transport, storage, and application methods, and their costs must be determined in order to select the best sludge reuse program. All sludge handling facilities were compared using a 3.0 dry tons per acre application of 5 percent solids sludge. This is equivalent to a liquid application of 14,400 gallons per acre or 0.53 acre-inch of liquid per acre.

Transport Facilities

The two most feasible methods of transporting the liquid sludge are by pipeline and tanker truck. Rail transportation may be feasible in some instances, but was not studied in detail here.

LAGOON CLEAN-OUT OPERATION AND TRUCK-LOADING FACILITY

The source of sludge at the Nine Springs Works will be a transfer-loading-pumping facility to which both the lagoon and digester sludge will be pumped or drained to. The digester sludge will normally be routed through the lagoon for storage, and because lagoon aging and/or dewatering may be desirable or necessary before land application of the sludge.

Truck Transport. Trucks with closed tanks would be used to prevent sludge spillage. They would be filled by either pumping directly into the tank or by first pumping to a loading dock and then discharging into the truck tank. The trucks could be filled at the Nine Springs site or at a remote loading dock fed by a pipeline. The tanker trucks would transport the liquid sludge to fields or temporary storage facilities for eventual land application by other equipment. Special on-off road trucks which can transport and apply sludge have also been developed; in this report they are considered in the sludge application methods discussions.

Many of the county and town roads in the study area are posted with reduced load limits in spring because of soft conditions resulting from thawing of the ground. This occurs mostly in March through May and has to be considered in studying truck transport of sludge. The trucks should be equipped with aluminum tanks and any other cost effective weight reducing designs. The tank capacity should be limited to 5,000 gallons maximum. If the trucks are kept on Class A county roads or better, 6,000-gallon tanks could be used. The cost for 5-mile transport with a 5,000-gallon tanker truck is estimated to be $2.69 per dry ton-mile. One truck could haul about 50,000 gallons per 8-hour day. See Table B-6 for the cost and capacity development. The cost of a loading dock capable of holding three truckloads of liquid sludge is about $50,000.

Pipeline Transport. A 5-mile transportation distance was also used in considering a pipeline to make the costs comparable to truck transportation. The pipeline transport cost development is given in Table B-7 and is for a 500-gallon-per-minute capacity system. The cost is estimated to be $1.57 per dry ton-mile. This system would include a pump station and buried pipeline. The cost could change, depending upon the designed capacity, pipeline route, and discharge point elevation. A higher-capacity system will generally have a lower per ton-mile cost, whereas a lower capacity system will normally be more costly. The 500-gpm system capacity used here is about four times as great as the average sewage treatment plant output. This excess capacity will be required during peak sludge use periods and to handle the lagoon sludge.

Pipeline transportation has the advantage of being more cost effective than truck transportation. Also, if possible, it should be routed to serve some farmers along its length. A major disadvantage of a pipeline is that it can serve only areas which it passes over or borders on, and its use at all depends upon the market area served by it. The end point and location of the pipeline cannot be determined until a reliable market for sludge large enough to make a pipeline cost effective is developed.

Sludge Storage Facilities

Intermediate sludge storage facilities may be useful between the transportation and application systems to increase the efficiency of those systems. For instance, small on-farm storage ponds, which would be filled by tanker truck during the off season, could supply sludge for land application when needed. This would reduce the peak period sludge transportation requirement. Another intermediate sludge handling system would be to use portable nurse tanks in fields to provide a continuous supply of sludge to the application equipment. The nurse tanks would be intermittently filled by tanker trucks.

Storage of the treatment plant sludge will be provided in Lagoon 1 as recommended in Chapter 5 of this report.

On-Farm Storage Lagoons. A lagoon with about 4.5 acre-feet of storage capacity would be required to hold enough 5 percent solids sludge for application to 100 acres. This is about the size that would be required by most farmers. On large farms with several hundred acres, several lagoons would be placed in different locations to serve separate fields.

The on-farm lagoons should be located away from shallow ground water and bedrock, out of frequent public view, where they could be reached by tanker truck or pipeline source, and where they could effectively serve the fields. A qualified District representative would perform the necessary site investigations and select a lagoon site that would conform to District requirements and be acceptable to the landowner and WDNR. Figure 7-1 shows the design considerations for an on-farm lagoon. The lagoons must be designed to ensure that they would not leak and have stable dikes. The lagoons should be built by the District to assure proper construction. Concrete ramps and other necessary appurtenances would be provided so that the lagoons can be maintained.

The sludge solids will probably settle out in the lagoons after some time as experience has shown in the Nine Springs Lagoons. Therefore, the sludge may require slurrying before removal for application to land. The District should supply a portable slurrying pump, as commonly available for manure pits, to slurry the lagooned sludge. One such pump can slurry the sludge in a pond within 1 day's time and therefore be able to handle all of the small on-farm lagoons. District ownership of the slurry pump and the pumps to remove sludge

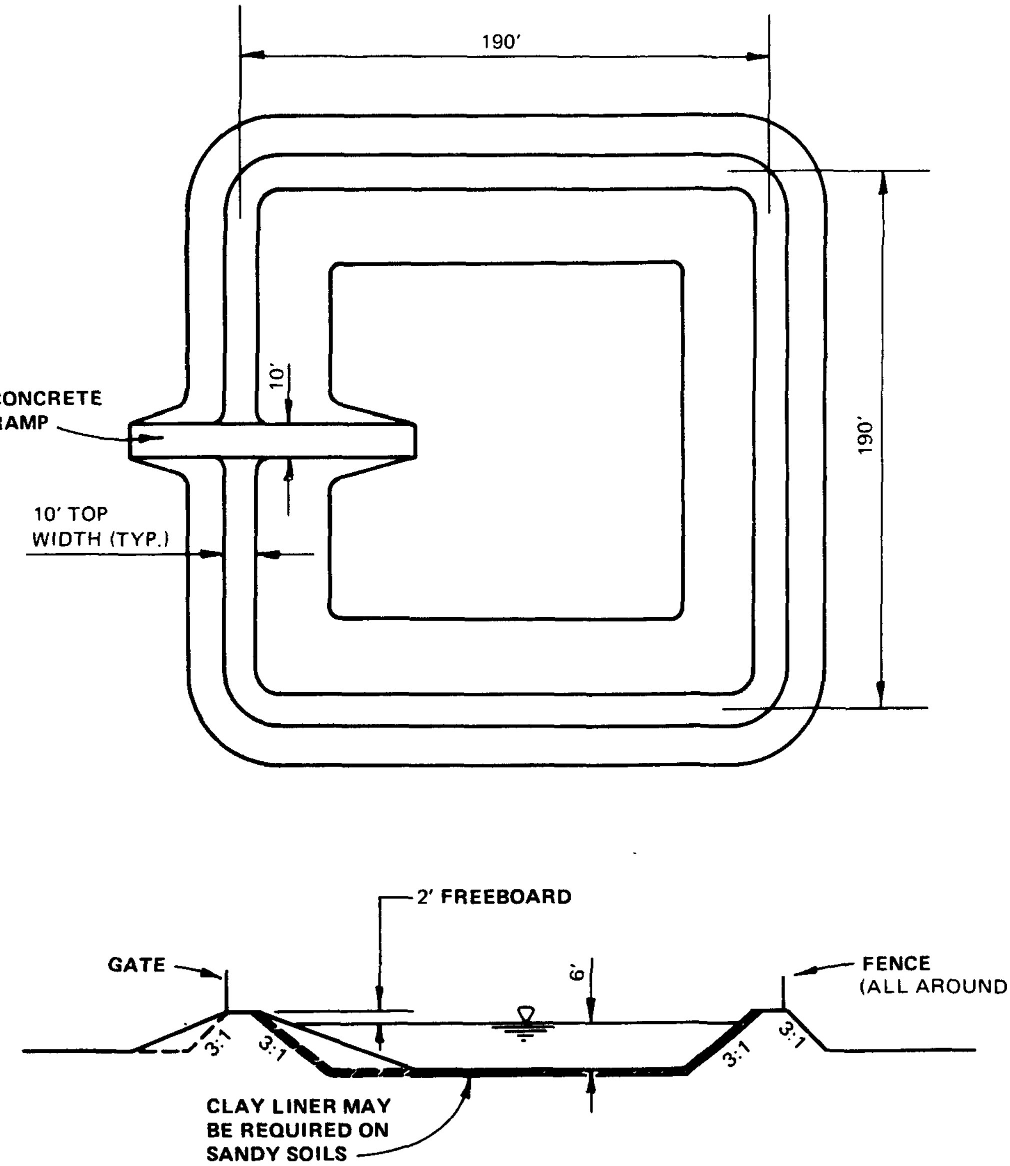


FIGURE 7-1

ON-FARM
LAGOON DESIGN CONSIDERATIONS

MADISON METROPOLITAN
SEWERAGE DISTRICT
MADISON, WISCONSIN

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from the lagoons would assure District involvement in the application of the sludge.

The District would need to obtain a commitment from a farmer to accept sludge for many years before constructing a lagoon or any permanent facility on the farmer's land. The question as to whether farmers would accept such an arrangement was asked by questionnaire at the 2 October 1975 meeting with the farm community. Four out of six respondents to the question said they would. The other farmers at the meeting showed positive interest in such an arrangement but did not state so on a questionnaire. After the farmers have used sludge for a few years, it is expected that many more will want permanent facilities on their land. They would benefit from permanent facilities by being assured of sludge on a priority basis and possibly at less cost than other farmers.

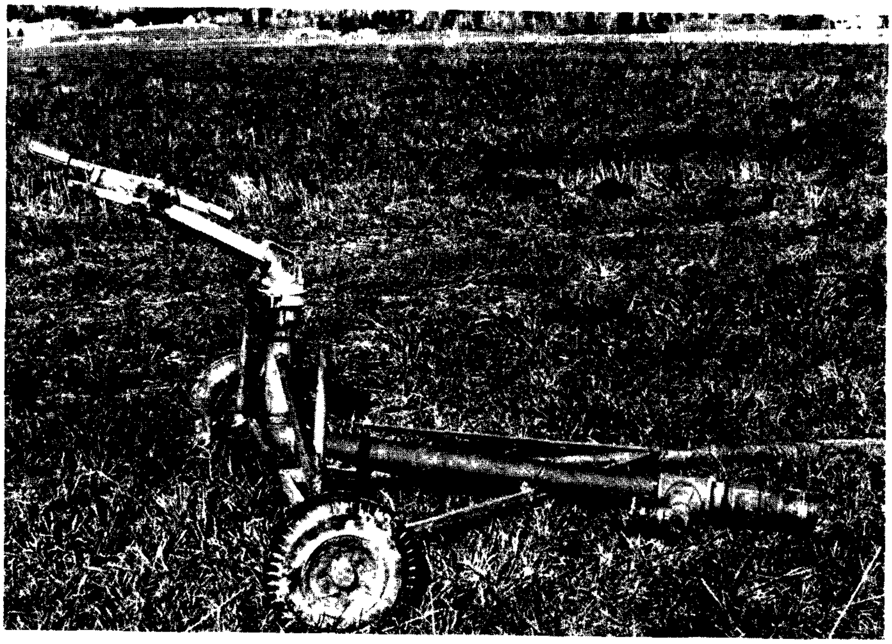
As shown in Table B-8, the cost of a small 4.5-acre-foot capacity on-farm lagoon has been estimated to be $8,500 for average site conditions.

Nurse Tank. A nurse tank could be used to provide a continuous supply of sludge to application equipment where a pipeline or lagoon source is not located close by. This nurse tank could be the trailer from a tractor-trailer tanker truck or a very large capacity tank on wheels. The very large nurse tank could have a capacity of over 15,000 gallons when filled and would be towed to the field empty. It would be filled by tanker truck, whereas an empty trailer tank would be exchanged for a full trailer when empty. The estimated cost of either type of nurse tank would be about $15,000.

Sludge Application Methods

Four methods of liquid sludge application were investigated: sprinkler application, soil injection, truck spreading, and tractor spreading. These were studied to determine their cost, ground coverage rate, effects on the fields, and farmer and public acceptance.

Sprinkler Application. Big gun sprinklers are required rather than the smaller sprinkler systems in order to spray the large sized particles in sludge. Big gun sprinkler systems have been used successfully for sludge application. The system would consist of a source which could provide a continuous supply of sludge such as an on-farm lagoon, nurse tank, or main sludge pipeline. An on-farm lagoon or nurse



HAND MOVEABLE BIG GUN SPRINKLER

PORTABLE SLUDGE PUMP

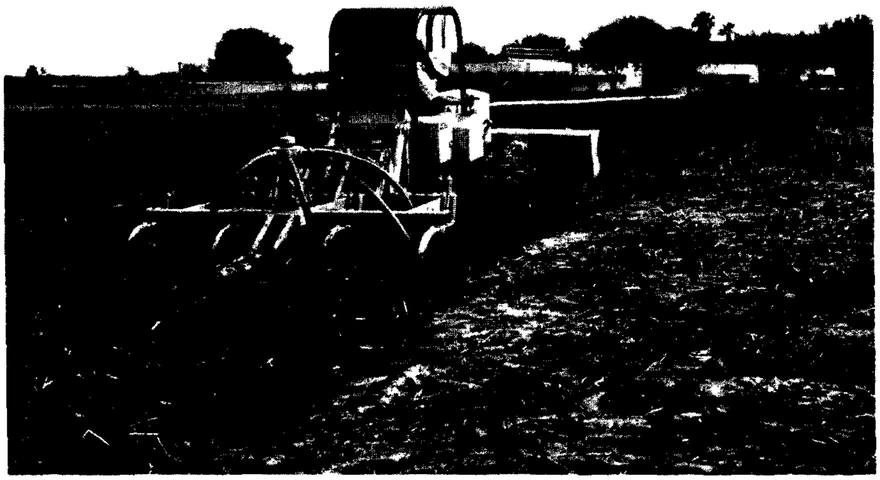
tank would require a portable pump. The pipeline from the source to the sprinkler could be either hand-move irrigation pipe or a permanent buried lateral.

A major advantage of the sprinkler method over other application methods is that the system could be used on growing grain crops and while the soil is too soft for heavy equipment. A hand-movable sprinkler was used for this analysis, but a self-propelled big gun system could also be used. Other advantages of a big gun sprinkler system are that it will cause little or no soil compaction, it is suitable on soft soils, and continuous feed is possible. Continuous feed allows much more efficient operation of the application equipment than a system where the equipment must travel across the field to fill up, then return to where it was working for a short period until it empties again.

Two major disadvantages of this system are its adverse visual impact and soil sealing effect. This system could not be used close to roads or homes where easily seen by the public. The sight of black sludge being sprayed several hundred feet across a field is certain to cause complaints. These complaints would be for imagined or real odors and/or wind-carried aerosols. Also, when sludge is sprayed onto soil, it will form a thin crust or seal when it dries. This seal is a problem in that it slows soil drying and could cause excessive rainfall runoff and washoff of sludge in a rainstorm. The sludge film should be broken up by soil incorporation or harrowing as soon as possible after application.

A big gun sprinkler application system, as shown in Table B-9, could cover about 6.0 acres per 8-hour day. The cost is estimated to be about $3.56 per ton dry solids. The farmer could provide the labor to operate the system.

Soil Injection. Many types of soil or subsurface injection systems have been developed and used. A commercially available system developed at Colorado State University was used in this discussion because it is designed to mix the sludge with the soil better and has a faster application rate than most other systems.



DEEP-SIX INJECTOR

Flexible hose supply systems, which were originally perfected for traveling big gun sprinklers, have been adapted to provide a continuous supply to sludge application systems. A soil injection system works very efficiently with this type of supply line. Up to 15 acres can be covered with a single hookup with a typical 660-foot-long flexible hose as shown on Figure 7-2. The sludge source could again be an on-farm lagoon, nurse tank, or pipeline. A pump would be required if a lagoon or nurse tank source is used. Hand-movable irrigation pipe or a permanent buried pipeline could be used to carry sludge from the source to the flexible hose feed line. A method to anchor the pipeline where the flexible hose is attached would be required with movable pipe.

Injectors till the soil and therefore need a tractor with considerable power to pull them. A 40-hp crawler tractor or 60-hp wheel tractor will generally be required to pull a five- or seven-sweep injector. It is assumed that the District would need to provide the tractor and injector for the farmer to use. The equipment could be transported to the field on a loboy trailer. The farmer could operate the soil injection application equipment after some instruction. Many farmers would not allow someone unfamiliar with farming to operate this type of equipment on their land.

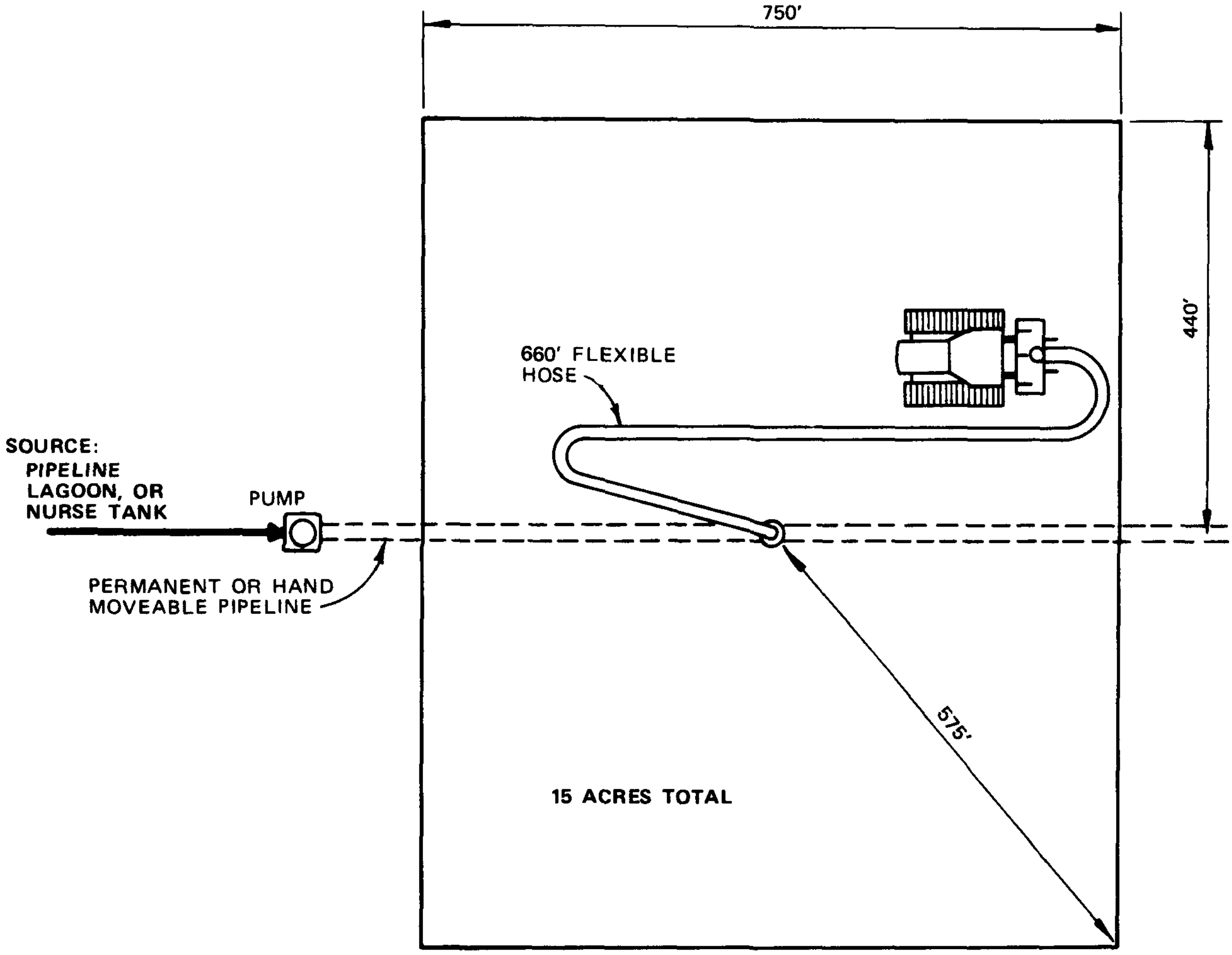


FIGURE 7-2

FLEXIBLE HOSE SLUDGE SUPPLY SYSTEM WITH SUBSURFACE INJECTOR

MADISON METROPOLITAN
SEWERAGE DISTRICT
MADISON, WISCONSIN

CH2M HILL

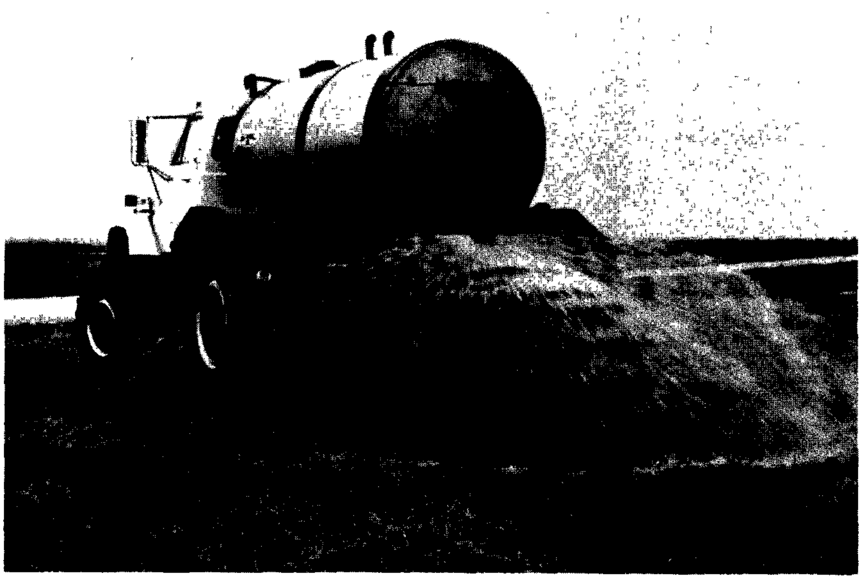
S9166.0

ON-FARM LAGOON, SPRINKLER APPLICATION, AND SOIL INJECTION

Soil injection is the best application method in terms of effects on the environment and the public. The sludge is placed beneath the soil surface and would not be visible to the public. Subsoil placement also prevents the loss of any nutrients and washing of the sludge from the surface. It will be permissible to use soil injection closer to housing and other such developed areas than would be allowed with other sludge application methods. Subsurface injection cannot be used on cropped land because the injector sweeps would cut the crop roots and tear out plants.

A subsurface injection system can cover about 9 acres in an 8-hour day. The cost would be about $5.93 per ton solids. The land coverage rate and costs are developed in Table B-10.

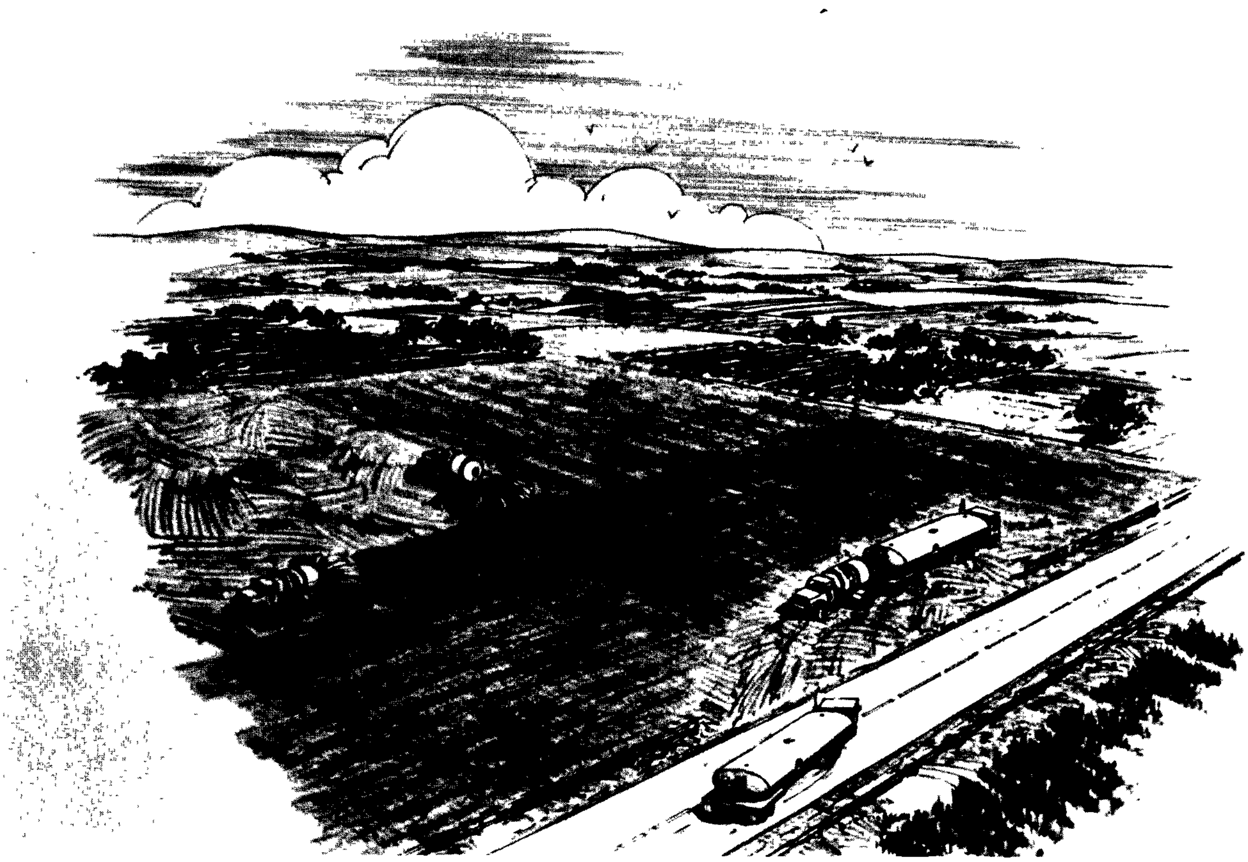
Truck Spreader. This system would consist of a truck capable of hauling a 1,500- to 2,500-gallon tank of liquid sludge in the fields. The sludge is spread across a 10- to 30-foot-wide strip behind the truck by pumping at low pressure against a deflector plate or through a large nozzle. Two or three passes may be required to apply one-half inch of liquid sludge without causing it to run off and pond. The truck can empty itself in a matter of a few minutes, which requires that it spend a great deal of time traveling back and forth across the field to be filled. Some commercially available units are also capable of traveling on the highway to transport the sludge. A 1,600-gallon capacity Big Wheels brand liquid sludge spreader truck as demonstrated at the Nine Springs Works on 30 May 1975 was used as the basis of the costs and capacity development.



BIG WHEELS SLUDGE SPREADER TRUCK

The major advantage of truck spreading is that it is not restricted to any field or portion of a field. This flexibility would allow a single truck to quickly serve any portion of a farmer's land or several different fields in a single day. The truck spreader would require special operating skills and therefore should be operated by MMSD personnel.

Truck spreading has several disadvantages related to its effects on soils. Special high flotation tires are required to minimize soil compaction. Even with these special tires, the truck cannot be used on wet, soft soils or on steep hillsides. The tires, being quite wide, would do much damage to crops such as corn or grain. The trucks would be most suitable for sludge application in the fall after crop harvest while the soil is dry.



TRUCK SPREADERS AND TANKER TRAILERS

A single truck which would be filled from tankers at the edge of the field could cover about 4.2 acres per 8-hour day. The estimated cost of truck spreading in this case would be about $11.90 per ton solids. The development of the costs and capacity are shown in Table B-11.

Tractor Spreading. This is a term we have applied to a new concept in liquid sludge application. It consists of a tractor which carries or pulls a liquid sludge spreader on a small trailer. This spreader device consists of an apparatus for connecting a flexible feed hose to it, a valve controlled from the tractor, and a spreader deflector plate or nozzle for spreading the sludge. The spreader would be fed by dragging a flexible hose as described for the soil injection system and shown on Figure 7-2. It spreads sludge

TRACTOR SPREADER AND NURSE TANK SUPPLY

in a 10- to 30-foot-wide path behind the tractor. This system has the advantage of being continuously fed by a flexible hose plus it applies sludge with a relatively inexpensive uncomplicated piece of equipment. A schematic diagram of the spreader device is shown on Figure 7-3. The tractor could be owned and operated by the farmer and could have low power. The only requirement would be that a cab be provided to protect the operator from the sludge spray. Many farmers already have cabs installed on their tractors. The pump, hose, and spreader device would be supplied by the District.

This system has the disadvantage of crop damage by the effect of the hose being dragged across the field, prohibiting its use on crops such as grain or corn. It would be best suited for fallow or harvested land, although it could be used on recently mowed or grazed forage crops.

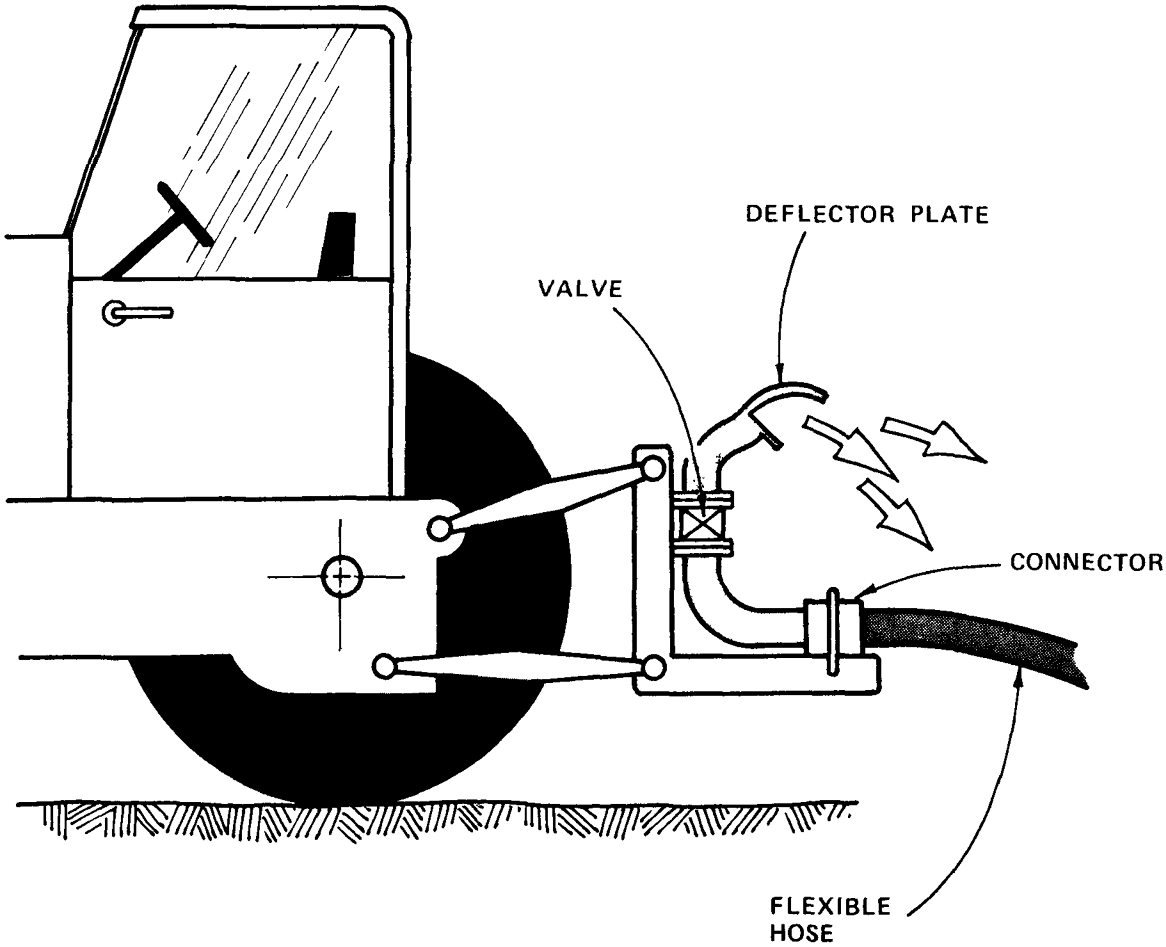


FIGURE 7-3

SCHEMATIC DIAGRAM OF
TRACTOR SPREADER DEVICE

MADISON METROPOLITAN
SEWERAGE DISTRICT
MADISON, WISCONSIN

CH2M HILL

S9166.0

Of the four sludge application methods discussed, tractor spreading has the fastest ground coverage rate, about 15 acres per day. This high efficiency and the relatively minor equipment specialization account for the low cost, estimated to be about $2.44 per ton solids. The basis for the costs and system capacity is given in Table B-12.

Other Sludge Application Methods. Many other sludge application methods are available and have been used successfully. No attempt was made to determine the cost of or investigate all variations in detail since the four described methods cover the major basic types. Some variations from the described methods could be used in order to meet the special needs of MMSD and the local farmers.

One different type of feed system which should be discussed is the use of a tank trailer pulled by a tractor which would supply sludge to either a soil injector or spreader. Many dairy farmers will already own equipment of this type for manure handling. A trailer tank would have the same disadvantage of a truck spreader: the necessity of traveling back to the source to fill. This method would be most suitable where the farmer already has the equipment, where a long time period for application to the field is available, and on small fields.

Comparison of Sludge Application Methods

The four described sludge application methods are compared in Table 7-1. The big gun sprinkler system is least suitable because of its adverse environmental problems of great visual impact and odor potential. The restrictions which would be required for separating distance between the sprinkler system and houses, roads, water courses, etc., also make this method generally unfeasible. The remaining methods are all acceptable, but each have their own major advantage. Subsoil injection's advantage is that it places the sludge out of sight of the sensitive public. Truck spreading is most mobile and flexible. Tractor spreading is the most efficient and most economical method.

TABLE 7-1

COMPARISON OF SLUDGE APPLICATION METHODS
MADISON METROPOLITAN SEWERAGE DISTRICT

FACTORS OF COMPARISON	SLUDGE APPLICATION METHOD: BIG GUN SPRINKLER	SOIL INJECTION	TRUCK SPREADING	TRACTOR SPREADING
Soil Compaction	None	None	Minor in Fall High in Spring	Minor
Suitability on Wet on Soft Soil	Suitable	Moderately Suitable	Not Suitable	Moderately Suitable
Suitability on Slopes	Suitable	Suitable	Least Suitable	Suitable
Soil Sealing Potential	Moderate	None	Moderate	Moderate
Suitability on Crops				
Corn and Grain	Suitable	Not Suitable	Not Suitable	Not Suitable
Harvested Forage	Suitable	Not Suitable	Suitable	Suitable
Field Efficiency*	Medium (56%)	High (80%)	Very Low (18%)	Medium (64%)
Tied to Source Location	Yes	Yes	No	Yes
Feed Methods	Continuous	Continuous Possible	Intermittent	Continuous Required
Visual Impact	Yes	None	Moderate	Moderate
Odor Potential	Yes	None	Moderate	Moderate
Nitrogen Loss	Highest	None	Moderate	Moderate
Labor Required	Medium (0.08 man-day/Ac)	High (0.11 man-day/Ac)	Very High (0 24 man-day/Ac)	Low (0 07 man-day/Ac)
Land Coverage Rate	Low (6 Ac/day)	Medium (9 Ac/day)	Low (4 Ac/day)	High (15 Ac/day)
Cost**	Low ($3.56/ton)	Medium ($5 93/ton)	High($11 90/ton)	Low ($2.44/ton)

*Field efficiency is the time actually spent applying sludge divided by the time in the workday.

**Cost per ton for 5% solids content liquid sludge applied at rate of 14,400 gallons/acre or 3 dry tons/acre.

The four sludge application methods were explained to the farmers at the 2 October 1975 public meeting. Results from six farmers who completed the questionnaire on which method they would prefer indicated that truck spreading was most preferred and tractor spreading was second most preferred. These results are not conclusive enough to base a recommendation on because of the few respondents and because the farmers have actually seen only truck spreading in operation. It is expected that initially truck spreading will be most acceptable to the farmers because it is flexible and does not require their labor. After the farmers have seen the advantages of soil injection and tractor spreading, though, many should accept those methods also. From the District's point of view, it may be best to first use mainly trucks, even though the cost would be higher, in order to build a market for sludge reuse. After a market is established and some permanent on-farm facilities are arranged, then the District should promote the less costly tractor spreading and more environmentally acceptable soil injection methods.

It is recommended that in the first year of operation, MMSD purchase equipment for one soil injection system and one tractor spreading system and enough truck spreaders to handle land application of most of the sludge. The soil injector and tractor spreader systems would primarily be used for demonstrations in the first year. The combined systems' capacity should be sized to handle the amount of sludge produced by the treatment plant. Net recovery of sludge from the lagoons is not expected to be possible until the market for sludge grows in the second and third years. Then, as farmers begin to accept the soil injection and tractor spreading methods, these types of equipment should be purchased to match the increasing total sludge handling requirements. The District should by then have received commitments from some farmers and have constructed some permanent on-farm facilities. The permanent on-farm facilities, such as small lagoons and pipelines across fields, are desirable for most efficient soil injection and tractor spreader operations.

7.6 COMPARISON OF SLUDGE REUSE PROGRAMS

Farmer Acceptance

The farmers at the second farm community meeting were asked by questionnaire which type of reuse program they would prefer: Program 1, sludge supplied by MMSD at the farmer's request; Program 2, lease land to MMSD for 1 year; or Program 3, combination of Programs 1 and 2. Five out of six respondents preferred Reuse Program 1. One farmer indicated he would prefer Program 3. Sludge Reuse Program 2 apparently is not acceptable to the farmers and therefore was not considered further in this study.

Reuse Program 1 has been shown by the questionnaire and by the interest in the existing sludge reuse program to be most acceptable to the farmers. Reuse Program 3 will apparently be acceptable to only a very few farmers. These few farmers would most likely consider leasing only a part of their land to the District for sludge application.

Cost Comparison

The only major cost differences between Reuse Programs 1 and 3 are the cost of leasing land for sludge application and the cost of the sludge handling system. The cost of leasing land would occur only in Program 3. To realize the cost saving feature of Program 3, that of providing a lower capacity sludge handling system, requires a large amount of land available for leasing every year. Indications are that few farmers will want to lease their land for sludge application. Therefore, the sludge handling system would have to be designed for the same capacity in Program 3 as in Program 1. Since Program 3 has the added expense of leasing land, but no offsetting cost saving, Reuse Program 1 will be more cost effective.

Recommended Sludge Reuse Program

Sludge Reuse Program 1, market all sludge to farmers, is the best apparent program based upon farmer acceptance, reliability, and costs.

Program 2, leasing land for sludge application, is not suitable because it would not be acceptable to enough farmers. Reuse Program 3, combination of Programs 1 and 2, is not cost effective compared to Program 1. However, the concept of leasing land from farmers should not be completely abandoned. Even though it would cost extra to lease land for sludge application, this may become necessary if the sludge supply greatly exceeds the demand.

8.1 REUSE PROGRAM DESCRIPTION

8.2 PROGRAM MANAGEMENT

8.3 MONITORING PROGRAM

8.4 MARKETING PROGRAM

8.5 SLUDGE HANDLING FACILITIES

8.6 REUSE PROGRAM COST

RECOMMENDED SLUDGE REUSE PROGRAM 8

Chapter 8
RECOMMENDED SLUDGE REUSE PROGRAM

The recommended sludge reuse program, its management, operation, and costs are described in this chapter.

8.1 REUSE PROGRAM DESCRIPTION

The initial reuse program should consist of marketing liquid anaerobically digested sludge to farmers near the Nine Springs Sewage Treatment Works. The District should manage the program and provide for distribution and application of the sludge to land. The sludge will be stabilized by anaerobic digestion to make it acceptable for land application. The sludge from both the existing lagoons and from the treatment plant will be disposed of by this program. The lagoons will be abandoned for sludge disposal as described in Chapter 5.

Seasonal storage of the treatment plant sludge will be provided in the west side of Lagoon 1. The sludge now in the existing large lagoons will be removed and applied to farmland. This will allow the lagoons, which have been a threat to the environment of the marsh and downstream waterways, to return to a natural and safe condition.

The sludge will be transported to farmland initially by tanker trucks and possibly later by pipeline. The sludge will be applied to farmland by three main methods: truck spreader, soil injector, and tractor spreader. The District will be responsible for managing and monitoring the sludge reuse program. The District will maintain control over sludge reuse to ensure that the requirements for site location, application rates and methods, and site management as described in this report will be followed. The District control of sludge reuse will be in the form of site inspections, site monitoring, and control of sludge handling facilities.

8.2 PROGRAM MANAGEMENT

The reuse program operation and methods of reuse must be managed by MMSD to ensure orderly, efficient operation and environmentally acceptable land application. The major components of program management will be a program manager, initial farmer interview and site inspection, rate determination, sludge application, and recordkeeping.

Program Manager

The District should appoint a person to manage the sludge reuse program. The reuse program manager will be responsible for overseeing the required sludge handling facilities, developing and maintaining a market for the sludge, scheduling sludge distribution and application, farmer contact, performing site inspection, and directing the monitoring program. This will require a full-time position for the program. The program manager must be able to relate to the farmers, be familiar with Dane County agriculture, and be enthusiastic about the program.

The manager must keep abreast of the latest technology of sludge reuse in agriculture in order to make needed changes in the reuse program. He should review the monitoring data to detect potential problems. When an apparent or potential problem develops, the program manager must be able to remedy it or know whom to ask for assistance.

Initial Interview and Site Screening

When a farmer first contacts the District and requests that sludge be applied to his land, the program manager should set up an informal interview. At this interview, the farmer will indicate his land location on a suitability map developed from the soil suitability classification for sludge reuse which is contained in Appendix C. The program manager will determine from the map how suitable the farmer's land is for sludge reuse. If the farmer's land is suitable, the next step will be to open a set of records under the farmer's name. These records must include the farmer's name, address, phone number, and field locations. The farmer's fields should be outlined on small Agricultural Stabilization and Conservation Service (ASCS) maps, and each field should be denoted by a field number. Thereafter, each field can be referred to by farmer's name and field number. The ASCS field maps should be used by the program manager when he checks the site conditions. Examples of record sheets and field map are given in Appendix D.

After the initial interview and before sludge is applied to the farmer's land, the program manager should walk over each field on which sludge will be applied to visually check the site and surrounding conditions. He should determine buffer widths and areas requiring special management for erosion control and mark these on the file copy of the ASCS map. He should also determine the location of all water supply wells on and within 500 feet of the site. These wells should also be denoted on the ASCS map and this information used for ground-water monitoring. In determining buffer widths, the program manager should also contact all residents bordering the sludge application site to explain the sludge reuse methods and to ask their permission to apply sludge within 200 feet of their home or garden. The program manager will use a checklist to be sure that the site meets all criteria for sludge application. An example checklist is contained in Appendix D.

During the initial interview and site inspection, the program manager should explain to the farmer the importance of using careful management and the reasons for the buffer areas of no sludge application. An ASCS map showing buffer areas and other areas of special concern should be given to the farmer so that he can plan his farming and fertilizing operations. If possible, the interview and site inspection should be performed a few months before sludge is needed and should cover all the farmer's land, not just the portion using sludge that year.

Sludge Application Rate Determination

Tables 6-5 and 6-6 gave suggested total and annual sludge application rates based upon certain assumptions which were explained in Section 6.3. In the sludge reuse program, the application rates should be determined according to each field condition and its management. Before sludge is applied the first time, the soil should be tested for cation exchange capacity (CEC) and background heavy metals. The CEC of the unsludged soil and the zinc equivalent method will be used to determine the total allowable sludge application rate as shown in Appendix D. As explained in Chapter 6, the total application limits determined by this method are very conservative. Before the preliminary total application rate limits are reached, in 30-60 years, more research results should be available to better determine allowable rates.

On sites which have had sludge applied in the past, the total application limits should be checked against the amount already applied. If the application rate is excessive, no additional sludge should be applied to those sites.

The annual sludge application rates should be based upon results of the University of Wisconsin Soil Testing and Fertilizer Recommendation program. This annual soil sampling program will be required as part of the soil monitoring program which will be explained later in this chapter. The fertilizer rate recommendations from the University of Wisconsin Extension program will be used in determining the sludge application rate. Example computations of annual sludge application rates are given in Appendix D.

Recordkeeping

The District should keep records of the dates, locations, and rates of sludge application on every field. The date of sludge application can be used with sludge monitoring data to determine the characteristics of the sludge applied to the land. The location should be denoted by farmer name and field number. The rate of sludge application in tons dry solids per acre should also be recorded. This must be done carefully so that the total amount of sludge applied to each field can be determined long after the data are recorded. An accumulated total of sludge applied to every field should also be kept to determine when the total limit is reached. A sludge application record sheet similar to that shown in Appendix D should be used for each field. Copies of the record sheets should be made available to the farmer.

The monitoring program records will be discussed in Section 8.3.

8.3 MONITORING PROGRAM

The sludge reuse program should be monitored to protect the environment, to provide farmer confidence in the program, and to comply with regulatory agency requirements. The program should include monitoring of the sludge, soils, crops, and ground water. The monitoring program is explained in detail in Appendix E. A summary of the monitoring program is given here.

Sludge Monitoring

The objective of sludge monitoring is to define the quality of the sludge, and from this the allowable loading rates will be determined.

A detailed characterization of the existing Nine Springs lagoon sludge has been determined as a part of this study. The results of this characterization revealed that the quality of the lagoon sludge was relatively uniform throughout the lagoons with the exception of the nitrogen and solids content. Therefore, only the total solids and ammonia and organic nitrogen need to be continually monitored in the existing lagoons to determine application rates. Normally, total Kjeldahl and ammonia nitrogen are measured and organic nitrogen is computed as the difference between the two. These should be measured daily in composite samples collected as the sludge is removed from the lagoons for application to land.

The quality of the sludge taken from the digesters, storage lagoon, and on-farm lagoons may change from time to time. Therefore, extra analyses must be performed on these sludges. Daily composite samples should be obtained at these sources whenever sludge is taken directly from them for land application. These daily composite samples should also be analyzed for solids content and ammonia and organic nitrogen. The digester sludge should be monitored on a monthly grab sample basis for solids content, ammonia and organic nitrogen, total phosphorus, potassium, cadmium, zinc, copper, and nickel. Quarterly grab samples should also be taken from the digesters and storage lagoon for a complete characterization. The complete characterization should include the following: ammonia and organic nitrogen, total phosphorus, potassium, total solids, total volatile solids, total soluble salts, pH, iron zinc, copper, titanium, lead, barium, chromium, manganese, nickel, tin, cadmium, molybdenum, cobalt, aluminum, arsenic, boron, selenium, mercury, sulfate, alkalinity, calcium, magnesium, and sodium. Techniques for sludge sampling and analysis are discussed in Appendix E.

Soil Monitoring

The soil monitoring program should consist of two parts. One will be to make use of the University of Wisconsin Agricultural Extension soil testing, fertilizer recommendations, and lime recommendations program. Another part will be to determine background levels of sludge constituents which may accumulate in the soil and to determine the factors used in computing the total allowable sludge application rate.

The extension program consists of gathering soil samples every year before the crop is fertilized and planted. The extension service or their selected laboratories then analyze the samples for available phosphorus, potassium, organic carbon, and pH. They then make a recommendation for fertilizer and lime application based upon the test results, soil type, immediate past cultural practices, and crop to be grown. As part of the MMSD sludge reuse program, the fertilizer and lime recommendations will be used to determine the sludge application rate and will be required before each sludge application. MMSD should perform the soil sampling and deliver the soil samples for testing.

The background level soil monitoring samples should be collected before sludge is applied the first time. The results of the first analysis will be recorded as background levels and kept on file. All of the soil monitoring results should be provided to the farmer as a service to aid in determining basic soil fertility. The initial soil samples should be analyzed for CEC, electrical conductivity, exchangeable calcium, magnesium and sodium, total iron, aluminum, zinc, copper, nickel, cadmium, molybdenum, mercury and manganese, and boron. Techniques for sampling and testing are discussed in Appendix E.

Crop Monitoring

The final effect of application to the land of the various constituents in the sludge is on the plants grown on the land. Plant tissue analysis will provide the most sensitive and accurate assessment of these effects. Regular monitoring by tissue analysis of the crops grown on the sludge application sites will be used, along with the soils, sludge, and ground-water monitoring, to determine the effects realized by the sludge applications. The first crop sampling should be performed during the first crop season following the first sludge application. Thereafter, crop sampling will be performed in the crop season following every third sludge application. The plant tissue samples should be analyzed for boron, cadmium, copper, manganese, mercury, nickel, zinc, arsenic, chromium, cobalt, lead, molybdenum, selenium, and vanadium. Techniques for sampling and testing are discussed in Appendix E.

Ground-Water Monitoring

The ground-water monitoring program should consist of sampling and analyzing the water from all wells or other ground-water supplies on or within 500 feet of all sludge application sites. An initial sample should be collected before the first sludge application to establish background levels of particular indicator and health problem sludge constituents. The constituents monitored in the initial samples should consist of MBAS, nitrate-nitrogen, total dissolved solids (TDS), coliform, mercury, and arsenic. The main purpose of the background testing is to protect MMSD and the farmer against claims of ground-water degradation. Nitrate nitrogen and TDS content of all wells or other ground-water sources should also be measured every third year as a general indicator of sludge constituents reaching the ground water.

Techniques for sampling and testing of ground water are discussed in Appendix E.

Records and Data Review

Collecting the data must not become the final step of the monitoring program. Rather, the data must be reviewed thoroughly each year to determine the effects of sludge reuse and to be able to detect where problems may be developing. Suggested procedures to ensure adequate review of the data are as follows:

- Tabulate or graph data when it is developed in a form such that it can be quickly scanned to determine trends.
- Obtain University of Wisconsin Agricultural Extension review of soils and crop monitoring data.
- Prepare an annual report for the District Engineer on the monitoring program which summarizes significant differences or trends in constituents measured.
- Provide copy of monitoring data report to WDNR for their review.
- Provide copies of monitoring data to each sludge user.

Monitoring Program Costs

The costs of each element of the monitoring program are shown in Table B-13 in Appendix B. The costs will be at their highest in the first few years of the reuse program when most of the background soil and ground-water samples will be analyzed. Also, after the existing lagoons are emptied, the quantity of sludge available for reuse and consequently the monitoring requirements will both decrease.

8.4 MARKETING PROGRAM

The District should work to develop a large reliable market of farmers who want sludge applied to their land. Tools which have been used successfully to market sludge are an informational brochure, meetings with farmers, demonstration plots, and the designation of a trade name.

An attractive brochure which would inform the farmers on what the product is, what its benefits to them would be, and how they can obtain it should be prepared and distributed to all farmers in the study area. An example is the BIOGRO brochure which has proven highly successful.

The District should conduct a meeting in the winter of every year to which all sludge users and prospective users are invited. The meetings can be used to obtain farmers' suggestions for better operation, to explain the program, and to present new information. Farmers who have had sludge applied to their land and are pleased with the results could be asked to help the marketing effort by written or stated endorsement of sludge use.

Interested farmer cooperations could assist in marketing sludge by informing their members of the program, sponsoring meetings, etc. Some cooperatives now have equipment suitable for sludge application. Cooperative participation in the reuse program should be allowed and encouraged to the extent that MMSD can still maintain the control necessary to ensure acceptable reuse methods.

The District should use demonstration plots to show the effect of sludge application. One demonstration site should be located near the Nine Springs Works which the program manager can readily show to prospective sludge users. Other plots should be set up in more distant areas where sludge is used. The District should attempt to set up the demonstration plots on land of sludge users. Several farmers have already offered to provide land for such plots. The demonstration plots should consist of an area with no fertilizer, an area with sludge applied, and an area with commercial fertilizer applied. The plots should be visible from frequently traveled roads, and signs could be used to bring attention to the plots. The plots need not necessarily be set up in a scientific manner to prove effects with extensive data, but rather just to demonstrate the general effect of sludge use. The University of Wisconsin Extension should be asked to cooperate in this program because county agents are quite experienced in setting up demonstration plots.

The general public's image of the sludge reuse facilities and operation should be enhanced and maintained. The sludge should be given a trade name and logo such as HYDIG or BIOGRO. It would be used on sludge handling equipment and all promotional literature. This name would avoid the need to call it sewage sludge, which admittedly is a negative term.

The public image of the program will also be influenced by the program staff. The sludge handling field men and their equipment will be in closest, most frequent contact with the farmers and rural public. They must therefore be courteous and helpful and keep the trucks and other sludge handling equipment clean.

Many of the foregoing elements of a successful marketing program have already been initiated as a part of this study. This work should be expanded and continued. In summary, the essential elements are:

- Public informational meetings.
- Use of a trade name.
- Use of an informational brochure for distribution.
- Maintenance of public image.
- Annual progress meetings with the farmers.

8.5 SLUDGE HANDLING FACILITIES

Sludge handling will include storage, transportation, distribution, and land application. The number and types of facilities required are difficult to estimate because of the possible differences in size and location of the sludge market. This discussion of facilities requirements is based upon our best estimate of the development of an orderly sludge reuse program. Plot plans of the major facilities are shown on Figures 8-1 and 8-2.

The major sludge storage will be provided in the west half of Lagoon 1 as described in Chapter 5.

The sludge distribution and land application facilities must have capacity for the peak handling requirement. This peak is expected to be about 35 percent of the amount of sludge handled in a year and is expected to occur in April, before corn planting. The amount and kind of sludge handling equipment will increase and change as the market for sludge grows. The amount of land to which sludge will be applied each year is estimated as follows: first year, 2,000 acres; second through tenth years, 5,000-6,000 acres; and after the lagoons are emptied, 2,500-3,000 acres.

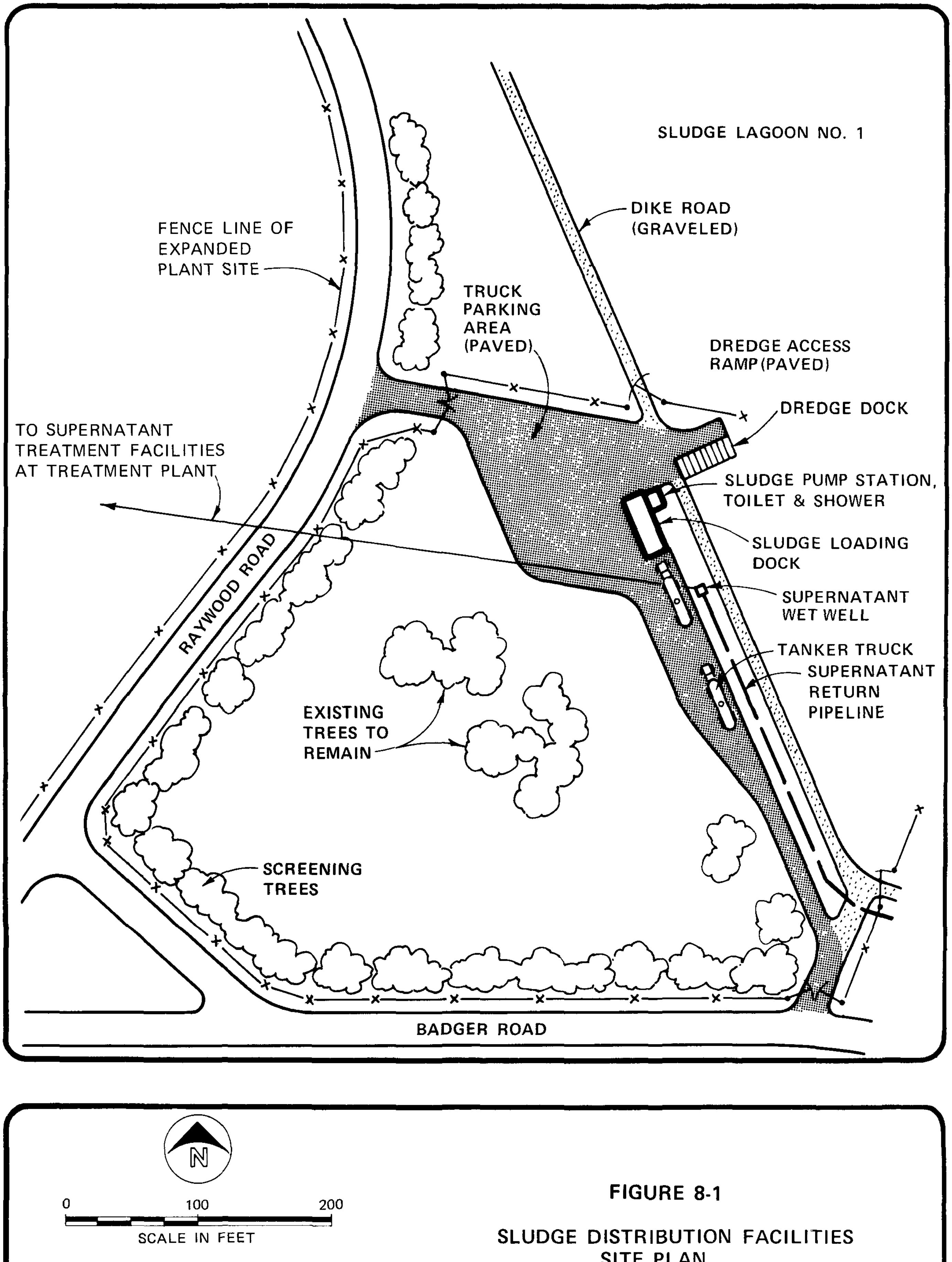


FIGURE 8-1

SLUDGE DISTRIBUTION FACILITIES SITE PLAN

MADISON METROPOLITAN
SEWERAGE DISTRICT
MADISON, WISCONSIN

CH2M HILL

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Sludge Application Equipment

Truck spreaders should be used as the main method of sludge application in the first few years because the farmers will more readily accept them and because they allow the most flexible operation. Four truck spreaders can handle most of the first year's peak month sludge application requirement. One soil injector and one tractor spreader should also be available in the first year to help meet the peak sludge handling requirements and to demonstrate the economy of these sludge application methods. Soil injection should be used on fields where runoff could be a problem and near incompatible land use areas such as subdivisions, schools, parks, etc.

As the sludge use increases in the second and third years, soil injection and tractor spreader systems should be added to match the increases. A total of two soil injectors, two tractor spreaders, and four truck spreaders will be required for sludge application between the third and tenth years of the program.

After the lagoons are emptied, the sludge application system could be reduced to one tractor spreader, one soil injector, and one truck spreader. The tractor spreader could handle about half of the acreage by itself. The soil injection system could handle about one-third of the acreage and would be used primarily near developments where the sludge reuse management requires subsoil application of the sludge. The truck spreader could handle the remainder of the sludge application requirement.

Sludge Transportation Facilities

Transportation of the sludge to farmland during the first 2 or 3 years will be totally by tank truck. Six tanker trucks will be required during the peak sludge application period in the first year. The number of trucks could remain at six in the second and third years of the reuse program if several on-farm lagoons are constructed to help level off the peak period sludge transportation requirement. It is estimated that by the fifth year of the reuse program, about 20 small on-farm lagoons would be accepted by farmers. A pipeline should not be installed until a strong market can be identified in a particular area. By the fifth year of the reuse program, a large market area should be developed to make pipeline transport feasible. Several farmers in the Cottage Grove area have already shown strong interest and have suggested a distribution site in their area. This area would be especially well suited as a central sludge distribution point if a strong market exists because it is somewhat remote from the Nine Springs Treatment Works. With pipeline transporation, it is assumed that the number of tanker trucks could be reduced to four.

8.6 REUSE PROGRAM COST

Construction Cost

Reuse Program. The initial construction cost requirements for the sludge reuse program are presented in Table 8-1. Additional capital expenditures will be required as the program grows to install additional facilities such as the dike across Lagoon 1, on-farm storage lagoons, sludge transmission pipeline, and additional application equipment. A year-by-year listing of the anticipated capital costs is presented in Table B-14. The basis of the cost estimates are presented in Appendix B.

TABLE 8-1

ESTIMATED INITIAL CONSTRUCTION COST
SLUDGE REUSE PROGRAM
MADISON METROPOLITAN SEWERAGE DISTRICT

ITEM	ESTIMATED* COST
REUSE PROGRAM	
Lagoon Sludge Removal Equipment	$ 130,000
Sludge Distribution Equipment (6 tanker trucks 1 sludge loading dock 2 nurse tanks, 1 slurry pump)	457,000
Sludge Application Equipment (4 truck spreaders, 1 soil injector, 1 tractor spreader)	312,000
SUBTOTAL REUSE PROGRAM	$ 899,000
UPGRADING AND EXPANSION OF EXISTING SOLIDS HANDLING SYSTEM	
Upgrading	
Gravity Thickener Upgrading	$ 5,000
Digester Upgrading	425,000
Supernatant Pretreatment System	2,370,000
Expansion	
Gravity Thickeners	110,000
Flotation Thickeners	650 000
Sludge Blenders	55 000
Digester and Control Building	1,740,000
Utility Tunnel	220,000
SUBTOTAL SOLIDS HANDLING SYSTEM	$5,575,000
TOTAL INITIAL CONSTRUCTION COST	
Estimated Total Initial Construction Cost	$6 474 000
Less Federal Grant (75%)	4 855 000
Less State Grant (5%)	324 000
NET COST TO MMSD	$ 1 295 000

*Engineering, Administration Legal and Fiscal, and Contingencies included

Upgrading and Expansion of Existing Solids Handling System. Chapter 4 of the Wastewater Treatment Plan discussed the need to upgrade the solids handling system of the existing treatment plant. In Chapters 8 and 9, we discussed the need to expand the solids handling system to handle the increase in solids production resulting from various levels of advanced treatment. Since the solids handling system is an integral part of the reuse program, we also discussed the desirability of implementing the upgrading and expansion of the system at the same time the reuse program is implemented. With this plan, the sludge handling and disposal problems of the existing plant can be resolved on a shorter schedule than if they were implemented separately.

The initial construction cost requirements for the upgrading and expansion of the system are presented in Table 8-1. The costs for expansion are based on the assumption that Effluent II will be required to meet the future discharge strategy and that a biological nitrification process will be used to produce an Effluent II. As the load to the treatment plant increases in later years, additional construction will be necessary. These costs are summarized in Appendix F of the Wastewater Treatment Plan.

Program Operation Requirements

Personnel Requirements. Due to the scope of the proposed reuse program, there will be a need for substantial staff increases to manage, operate, and monitor the program. One full-time position will be required to perform the duties described for the program manager. A full-time position of clerical help will also be required to support the manager.

The lagoon cleanout program will normally require two men during the 6-9 months' period of lagoon sludge removal. These two men should both be trained to operate the dredge. During some peak sludge reuse periods, two 8-hour shifts may be required each day. The two experienced dredge operators could then work the different shifts with the help of a less experienced man to handle the floating pipeline and guide cables.

Ten to 14 men will be required for 6-9 months each year to operate the sludge distribution and land application equipment. The number will depend upon the amount of sludge reused and the kinds of facilities used each year. There should be one man for each tanker truck and sludge spreader truck. The truck loading facilities should be designed so that the truck drivers can load the trucks and thereby eliminate the need of an extra man at the loading facility. All the sludge application equipment except for the truck spreader can be operated by the farmer or his hired help. The District, however, should have up to four men available to operate any of the sludge application equipment for farmers who do not supply the labor.

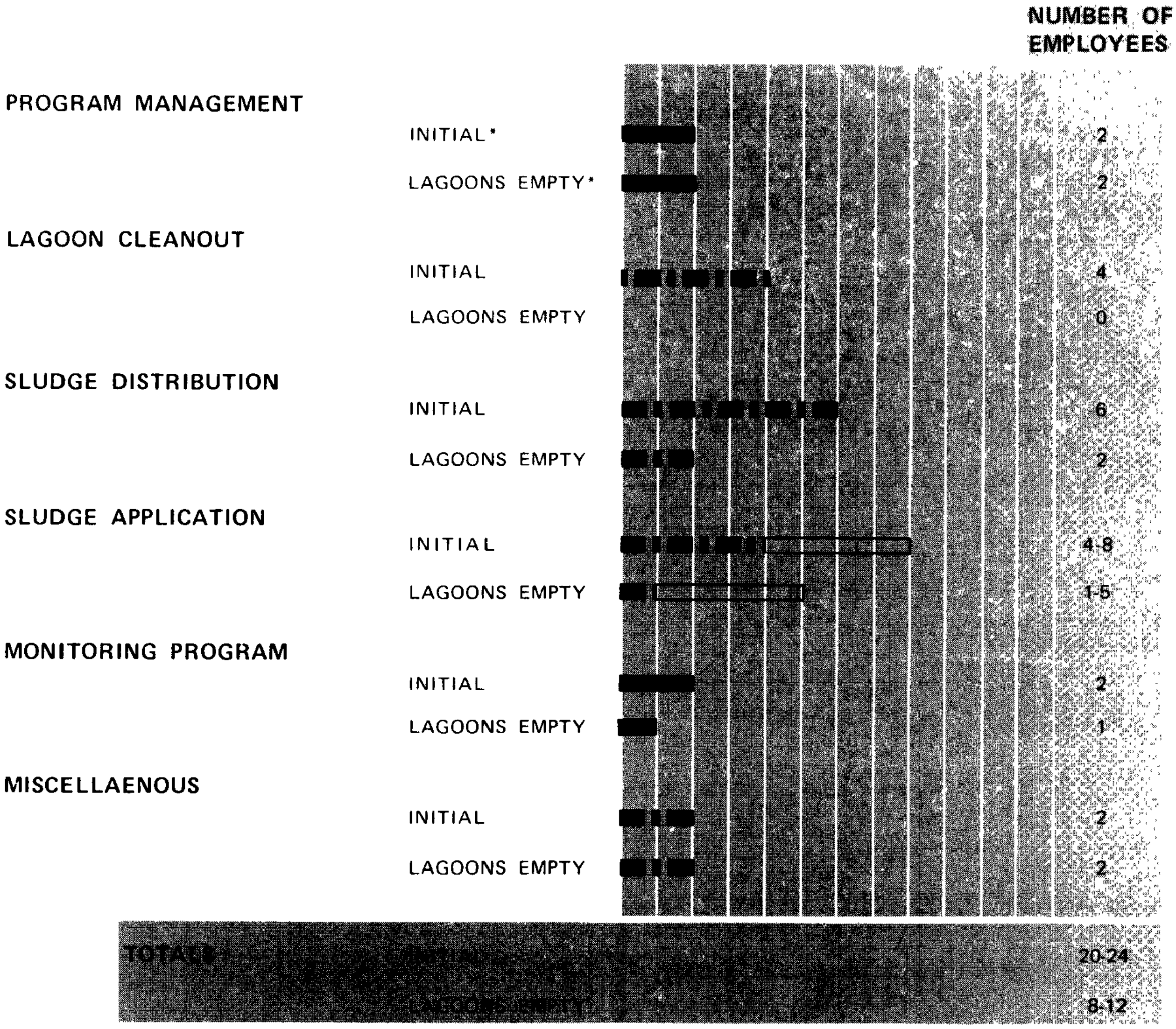
One or two men, depending upon the rate of sludge handling, will be required to perform miscellaneous chores such as transporting sludge application equipment to farms, operating the on-farm lagoon sludge slurrying pumps, and performing general maintenance of equipment. This will also be seasonal work lasting 6-9 months a year.

The monitoring program will require one to two people to collect samples, perform the laboratory analysis, and assemble and record the data. A detailed breakdown of the total staff requirements is given on Figure 8-3.

It is apparent from the foregoing that much of the sludge reuse program staff requirements will be seasonal. The number will vary from a minimum of three or four full-time positions (program manager, clerical assistant, and laboratory technician[s]) to a possible maximum of about 24 positions during the peak sludge reuse season (four full-time positions, four lagoon cleanout equipment operators, six tanker truck operators, four tractor spreader and soil injector operators, four truck spreader operators, and two miscellaneous helpers). Off-season equipment maintenance and filling on-farm lagoons should be used to keep part of the seasonal labor force employed year round. The job descriptions should be carefully written so that off-season maintenance and related work can be done by part of the summer sludge handling work force. The District should also draw on available summer labor whenever possible as many students would be available for seasonal employment.

A summary of the initial operation and maintenance costs is presented in Table 8-2. The average cost of labor, $15,300 per year, is based on current union scale with allowances for inflation and includes a 25-percent allowance for payroll overhead and insurance. The program manager labor cost is assumed to be about $17,000 per year.

The staff required to operate the expanded solids handling facilities will also need to be increased. The current staff assigned to these facilities consists of five men. After the facilities are completed, it is estimated that the staff requirements will increase to six men. A summary of these requirements is also presented in Table 8-2.



LEGEND

FULLTIME

SEASONAL

SEASONAL AND VARIABLE

* "INITIAL" REFERS TO FIRST 8-10 YEARS WHEN LAGOON SLUDGE IS BEING APPLIED TO LAND

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FIGURE 8-3

REUSE PROGRAM STAFF REQUIREMENTS

MADISON METROPOLITAN SEWERAGE DISTRICT
MADISON, WISCONSIN

CH2M HILL

TABLE 8-2

ESTIMATED INITIAL ANNUAL OPERATION AND MAINTENANCE COSTS
MADISON METROPOLITAN SEWERAGE DISTRICT

ITEM	ESTIMATED* COST
REUSE PROGRAM	
Labor (4 full time, 16 part time)	$178,000
Fuel	20,000
Equipment Maintenance	20,000
Monitoring Program (labor included above)	27,000
SUBTOTAL REUSE PROGRAM	$245,000
EXPANDED SOLIDS HANDLING SYSTEM	
Labor (6 full time)	$115,000
Power	54,000
Chemicals	74,000
Chemical Recovery	-55,000
Equipment Maintenance	88,000
Lime Sludge Landfill	25,000
SUBTOTAL SOLIDS HANDLING PROGRAM	$301,000
ESTIMATED ANNUAL OPERATION AND MAINTENANCE COSTS	$546,000

*Contingencies included.

Operation and Maintenance Costs. A summary of operation and maintenance costs for the reuse program and the solids handling facility is presented in Table 8-2. A detailed breakdown of operation and maintenance costs for the various elements of the reuse program and the basis for those costs are presented in Appendix B of this report. The costs presented for the solids handling system were developed from costs presented in Appendix F of the Wastewater Treatment Plan.

Sludge User Fee

The question of whether or not to charge for the sludge and the amount of a fee is difficult to answer. If the sludge is given away, this may imply that the material is bad. Conversely, too high a charge may discourage use of the sludge. Based upon the present high interest in the reuse of sludge shown by the area farmers, we feel that a charge will be acceptable and recommend that a fee be assessed the sludge users. The primary objectives of charging a fee are to control the supply and demand for the sludge and control the type and location of sludge users. To determine the charges for sludge users, several criteria must be considered.

- The cost of sludge must be appreciably less than the cost of commercial fertilizers to create a demand for the sludge.

- Since transport cost is a function of distance, the cost should be higher for those farther from the sludge source.
- The cost schedules must be flexible in order to provide control of sludge supply and demand.
- Special considerations should be available to farmers who make a commitment to MMSD to accept sludge for long periods or agree to permanent on-farm facilities.

To meet all of the above criteria, we recommend that the following initial sludge user fees be established:

- Assess a one-time flat fee to cover the cost of the site inspection and recordkeeping.
- Assess a fee for the cost of the annual soil sampling and analysis.
- Establish a maximum distance from the plant or distribution center beyond which an extra fee will be assessed on a ton-mile basis for sludge transportation. No transportation fee would be assessed to farmers within the maximum distance limit. The distance can be varied to control sludge supply and demand.

Special considerations for farmers who make a commitment to MMSD for sludge reuse could consist of a priority rating for sludge and application equipment or free delivery in an area outside of the free delivery radius.

The suggested one-time flat fee for site inspection is $200 for parcels up to 200 acres. Two hundred dollars is the estimated cost for the initial interview, site inspection, and opening a set of records. If the parcel is larger than 200 acres, the fee should be increased by $0.25 per acre. No charge should be made if the site is found to be unsuitable for sludge reuse.

The annual cost to the District of soil sampling and analysis will be about $100 for a 200-acre field. We recommend that this cost be passed on to the farmer at a fixed rate of $0.50 per acre each year.

The recommended charge for supplying sludge beyond a specified free delivery radius from the sludge supply is $1.50 per ton-mile. This rate is approximately equal to the pipeline transport cost estimate.

Table 8-3 shows the sludge user fees for different circumstances. The initial flat fee and soil monitoring cost is very minor compared to the fertilizer value of the sludge. The delivery fee will add considerably to the cost of sludge use, but will still be much less than the value of the sludge. As with any marketed product, the sludge users should be told what to expect in return for the fee paid. In this case, it will be the complete program services of site inspection, soil testing, product delivery, etc.

TABLE 8-3

EXAMPLE SLUDGE USE FEES
MADISON METROPOLITAN SEWERAGE DISTRICT

	SIZE OF LAND PARCEL				
FEE ITEMS	40 ACRES	80 ACRES	160 ACRES	500 ACRES	1,000 ACRES
One-time Flat Fee	$ 200	$ 200	$ 200	$ 275	$ 400
Annual Soil Monitoring	$ 20	$ 40	$ 80	$ 250	$ 500
WITHIN FREE DELIVERY RADIUS					
Total Cost First Year	$ 220	$ 240	$ 280	$ 525	$ 900
Cost Each Succeeding Year	$ 20	$ 40	$ 80	$ 250	$ 500
5 MILES OUTSIDE OF FREE DELIVERY RADIUS					
Transport Fee(1)	$ 900	$1,800	$3,600	$11,250	$22,500
Total Cost First Year	$1,120	$2,040	$3,880	$11,775	$23,400
Cost Each Succeeding Year	$ 920	$1,840	$3,680	$11,500	$23,000
VALUE OF SLUDGE(2)	$1,800	$3,600	$7,200	$22,500	$45,000

(1) Based upon application rate of 3 tons/acre.

(2) Value of sludge as fertilizer is about $15.00/ton or $45.00/acre.

We recommend that the free delivery radius be set at 12 miles the first year. This will include several large farmers in the Cottage Grove area who have shown a strong interest in sludge use at the meetings. The sludge user fees should be reevaluated every few years to ensure that the objectives of charging fees are met or to change the objectives. It should be possible to shorten the free delivery distance to 10 miles or maybe even 7 miles within a few years. Reducing the free delivery radius will likely upset users accustomed to free delivery. Therefore, the users should be informed from the outset that the distance may be reduced. Also, a full year advance notice should be given to affected users. The reuse program costs are based upon reducing the free delivery distance to 5 miles from the Nine Springs Works or distribution points by the sixth year of the reuse program.

Program Cost Summary

The estimated initial costs for the expanded solids handling system and sludge reuse program are summarized in Table 8-4. Also summarized are the cost effects of receiving Federal grants and the effect of the annual revenue from sludge user fees.

TABLE 8-4

PROGRAM COST SUMMARY
MADISON METROPOLITAN SEWERAGE DISTRICT

ITEM	EXPANDED SOLIDS HANDLING SYSTEM	REUSE PROGRAM	TOTAL SYSTEM
TOTAL CONSTRUCTION COST	$5,575,000	$899,000	$6,474,000
Annual Debt Service, 7% for 20 years	526,000	85,000	611,000
NET CONSTRUCTION COST, with grants	$1,115,000	$180,000	$1,295,000
Annual Debt Service, 7% for 20 years	105,000	17,000	122,000
ANNUAL OPERATION AND MAINTENANCE COST	$ 301,000	$245,000	$ 546,000
LESS ANNUAL REVENUE	–	$5,000	$5,000
TOTAL ANNUAL COST, without grants	$ 827,000	$325,000	$1,152,000
Cost per Dry Ton Leaving System*	50.10	19 70	69 80
TOTAL ANNUAL COST TO DISTRICT, with grants	$ 406,000	$257,000	$ 663,000
Cost per Dry Ton Leaving System*	24 60	15 60	40.20

*16,500 tons solids per year

Based on this summary, the initial annual net cost to the District for the proposed reuse program is $266,000 per year. The expansion of the solids handling system will add another $433,000 per year, bringing the total annual cost of the entire solids handling and disposal system to $699,000 per year. It has been estimated that the District is currently spending $272,000 per year for solids handling and disposal. Of this, about $180,000 per year is spent on the current sludge reuse program.

Program costs are also often summarized in terms of cost per dry ton of sludge leaving the treatment plant. This allows one to compare proposed costs to other projects with a similar system and also allows comparison with other methods of solids handling and disposal. The District's program will initially handle and dispose of all the treatment plant sludge production and also dispose of accumulated lagoon sludge. Over the next 8-10 years, it is expected that an average of 16,500 dry tons of digested sludge will be applied to farmland each year. Based on this quantity, the estimated total unit cost for solids handling and disposal will be $69.80 per dry ton. Of this, about $19.70 per dry ton is attributable to the reuse program alone. This reuse program unit cost is based upon the initial construction and equipment purchase costs and average operation and maintenance costs during the period of lagoon sludge removal. As shown in Table B-14, the average cost of sludge reuse through the year 2000 will be about $31.70 per ton solids. This is higher due to the several construction and equipment purchase costs which will occur after the first year of the program. Also, the quantity of sludge recycled each year will decrease after the lagoons are emptied.

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS 9

Chapter 9
SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

A summary of the findings and conclusions of this report on sludge reuse is presented here, chapter by chapter.

9.1 INTRODUCTION

The Madison Metropolitan Sewerage District (MMSD), in compliance with Wisconsin Pollutant Discharge Elimination System Permit No. WI-0024597, must prepare a facilities plan for advanced waste treatment, sludge disposal, and effluent disposal. This report is an investigation of sludge disposal. The objective is to develop a plan for abandoning sludge disposal in the existing lagoons and implementing agricultural reuse of sludge produced in the future. MMSD has been disposing of sludge by discharge to lagoons in the Nine Springs Marsh during the past 33 years. In 1970 a lagoon dike failure prompted the District to seek a more reliable sludge disposal method.

9.2 REVIEW OF SLUDGE DISPOSAL ALTERNATIVES CONSIDERED

Major studies of sludge disposal were performed for MMSD by Greeley and Hansen Engineers and by Roy F. Weston, Inc., Environmental Scientists and Engineers. Alternatives investigated by Greeley and Hansen Engineers included the following: A. Spread dried digested sludge on land, B. Incinerate digested sludge, C. Incinerate raw sludge, D. Heat treat and landfill digested sludge, and E. Apply liquid digested sludge to land. They determined that Alternative E would be the most cost effective.

The 1974 Weston study investigated several methods of sludge treatment and disposal. Their evaluations and testing indicated that dewatering the sludge for incineration would be costly to accomplish. Sanitary landfill, land application of liquid sludge, and land application of compost were found to be suitable methods and were analyzed on the basis of costs. Of these, a system for land application of liquid sludge was determined to be most cost effective.

The MMSD staff prepared an addendum to the Weston report which included additional sludge disposal alternatives. Of seven alternatives investigated, anaerobic digestion of thickened raw sludge followed by pipeline transportation to a lagoon and land irrigation was found to be most economical. In June 1974, based upon the aforementioned studies, the MMSD Commission resolved that liquid digested sludge from the Nine Springs Treatment Works would be handled through the process of application on land.

9.3 LAND APPLICATION OF SLUDGE STATE OF THE ART

In reviewing various sludge reuse projects in this country and in Great Britain, several basic practices were determined. Sludge has been applied at what can be described as fertilization, high-rate fertilization, and disposal rates. The fertilization application rate allows the most beneficial use of sludge nutrients. It is also evident that the cooperation of the local farming community is essential for a successful sludge recycle system. Experience of the Herts Authority in Great Britain emphasizes the importance of a well-managed distribution operation and a strong marketing program.

9.4 TREATMENT PLANT SLUDGE CHARACTERIZATION

The quality and quantity of sludge produced at the Nine Springs Works were determined as a basis of the facilities planning study. The sludge presently produced in the digesters was analyzed to characterize its condition. Estimates of the future sludge quality and quantity were also made based upon the sludge handling methods being investigated in the Advanced Waste Treatment (AWT) facilities plan study.

The quantity of sludge expected from the treatment plant is as follows: The sludge production in 1976 will be approximately 5,800 dry tons. In 1977 when the Fifth Addition to the treatment plant goes on line, the sludge production is expected to increase to about 6,000 dry tons per year. The sludge quantity is then expected to increase in proportion to the influent flow volume until 1981 when the AWT facilities are expected to go on line. With the addition of AWT, the sludge quantity will again increase to about 6,700 dry tons and will continue to increase gradually to about 8,500 tons dry per year in 2000. Level II treatment, an effluent with 10 mg/l of biochemical oxygen demand and 10 mg/l suspended solids, was used as the basis of this planning study. The character and quantity of sludge produced in other levels of treatment were discussed in Section 4.2.

The sludge quality is summarized in Table 4-3. The solids content, which is now 2.3 percent, is expected to be increased to about 5 percent; and the nitrogen content, now 10.5 percent, is expected to be reduced to about 5 percent with the addition of AWT facilities or by lagoon aging. The cadmium content of the treatment plant sludge is currently high compared to the zinc content. A program to find and reduce the major cadmium point sources has been started and should be continued.

9.5 SLUDGE LAGOON STUDY

The quantity and quality of the sludge in the Nine Springs Lagoons were determined by extensive field sampling and laboratory analyses. The depth of sludge in the 135 acres of lagoons varies from 2 feet to 7.1 feet in Lagoon 1 and 3.9 feet to 6.2 feet in Lagoon 2. The percent dry solids content averages 12.9 and 8.2 in Lagoons 1 and 2, respectively. The total sludge quantity in the lagoons is approximately 89,700 dry tons.

The quality of the lagoon sludge, as shown in Table 5-1, indicates its suitability for agricultural reuse. The sludge sampling investigation included gathering samples of the underlying peat and marl to determine leaching of sludge constitutents and indicated that there is little or no leaching past the first foot of the peat-soil layer. A hydrogeologic investigation of the lagoon area and monitoring of water quality in Nine Springs Creek indicate only minor leaching occurs through the dikes.

The condition of the lagoon embankments was studied in detail, and a special report was presented to MMSD which concluded that failures and possible sludge spills are imminent and recommended that certain portions of the dikes be stabilized. The District has proceeded with the recommended dike stabilization program.

A program for abandonment of the present method of sludge disposal in the Nine Springs Lagoons was prepared as required by the Wisconsin Department of Natural Resources. The recommended program consists of removing all sludge from Lagoon 2 and from approximately the east half of Lagoon 1. The west half of Lagoon 1 will continue to be used for seasonal storage of the treatment plant sludge.

9.6 CONSIDERATIONS FOR AGRICULTURAL REUSE OF SLUDGE

A study area consisting of the land within a 10-mile radius of the Nine Springs Sewage Treatment Works was delineated as a basis for discussion of agricultural reuse of sludge. The study area contains about 91,000 acres of very productive farmland. Its soils, land use, and ground-water conditions were investigated for their suitability for sludge reuse. Based upon the site investigations, it was determined that about 40,000 acres is suitable for sludge application. Farmers representing more than 5,000 acres of farmland have already shown a strong interest in having sludge applied to their land. The amount of farmland available for sludge reuse is expected to increase rapidly after the reuse program is started.

The amount of land required for reuse of all the Nine Springs Sewage Treatment Works sludge will be between 5,200 and 5,700 acres until the lagoons are emptied. Thereafter, about 2,400 to 3,000 acres will be needed each year. The land area required is based upon recommended annual and total sludge application rates which are shown in Tables 6-5 and 6-6. The sludge application rates were established to prevent potentially harmful overapplication of crop nutrients and heavy metals.

Chapter 6 also included criteria for determining the suitability of particular sites for sludge application and the site management necessary to protect the surrounding environment.

9.7 SLUDGE REUSE PROGRAMS CONSIDERED

Several alternatives were developed and then compared to select a cost-effective, reliable, and farm-community-supported sludge reuse program. The programs eliminated from detailed consideration included the following:

- MMSD ownership and operation of a site for recycle of all the treatment plant and lagoon sludge.
- High-rate fertilizer and disposal methods of sludge application to the land.

District ownership and operation of a site for recycle of all the treatment plant and lagoon sludge was eliminated because it was concluded, based on previous experience with the approach, that it would not be acceptable to the farm community. This program would require the purchase of several thousand acres of Dane County farmland and relocation of many farming and rural families, which would be very expensive and politically difficult, if not impossible to implement. The high-rate fertilization and disposal application rates were eliminated from consideration because they would result in environmental degradation and wasting of valuable nutrients.

Three alternative reuse programs were selected for further study. They are:

- Program 1--Market all sludge to farmers.
- Program 2--Lease land for short periods for sludge application.
- Program 3--Combination of marketing and land leasing.

In Reuse Program 1, the District would make sludge available to area farmers as they request it for fertilizer rate application to their farmland. A public relations program would be developed to aid in marketing the sludge. The farmer would have complete control over his land. He would contact MMSD when he wanted sludge, then he and a District representative would determine the suitable time, location, and application rates for sludge application. MMSD would be responsible for monitoring and managing the program.

In Reuse Program 2, the District would lease or rent land from farmers for sludge application. Since sludge would be applied during the growing season, no crops would be grown that year. The lease cost, therefore, would have to offset the net returns the farmer would have otherwise received from a crop plus the fixed costs of equipment and land ownership. Two purposes for obtaining leases for the land are: (1) assuring the District of land for sludge application for some period in advance, and (2) scheduling of sludge application evenly throughout the summer, thereby reducing peak handling requirements. The farmer would benefit from knowing he would not be hurt by crop failure, fertilizer would be applied onto his land, and he would not need to farm the land for one season.

Sludge Reuse Program 3 would be set up to market sludge to farmers for use on their land as in Reuse Program 1, plus it would include provisions for MMSD leasing land as in Program 2. MMSD-leased land would be used to apply sludge during the low-use months of July and August. This would spread the application period out more evenly over the year and thus reduce peak sludge handling requirements.

Sludge Reuse Program 1, market all sludge to farmers, was determined to be the best apparent program based upon farmer acceptance, reliability, and costs. Program 2, leasing land for sludge application, is not suitable because it would not be acceptable to enough farmers. Reuse Program 3, a combination of Programs 1 and 2, is not cost effective when compared to Program 1 but could be employed in some special cases.

In the event the sludge reuse market is lost, a contingency plan must be available for sludge handling. Alternative plans considered included:

- Acquisition of several thousand acres of District-owned or option-to-control land available for sludge application.

- Have facilities for incineration or dewatering and landfill available for sludge disposal.

- Retain capacity to store sludge until a permanent solution can be found.

The first and second alternatives are not feasible because of the high cost and impracticability. The third alternative is recommended: store the sludge until a permanent solution can be found. The west half of the Lagoon 1 storage area will have capacity to store 75 percent of 1 year's sludge production at 2.3 percent solids. With concentration to 10 percent solids, as is currently achieved after a freeze-thaw cycle, this storage area could hold 3 years' treatment plant sludge production. Also, the dikes surrounding the east half of Lagoon 1 should be left intact, except as required to allow drainage, after the sludge is removed. This area would then, with minor rehabilitation, be suitable for storage of an additional 3 years' sludge production in an emergency.

If loss of a sludge reuse market is to occur, it will most likely happen in the first years of the program before sludge reuse becomes a common, well-accepted practice. After many years of sludge reuse, the chance of losing the sludge market would be very remote. Sludge marketing is a vital element of the sludge reuse program and all should be done, especially by way of public education, to assure the program's success.

Sludge distribution and application methods were also investigated. Tanker truck and pipeline were determined to be the most feasible transportation methods. A pipeline would be constructed after a market for sludge develops in an area large enough to make the investment in a pipeline cost effective compared to truck transportation. Other facilities which would be included in the distribution system would be small on-farm storage lagoons and nurse tanks.

Methods considered for sludge application included sprinkler application, soil injection, truck spreading, and tractor spreading. The big gun sprinkler system is least suitable because of its adverse environmental impact caused by visibility and odor potential. The remaining methods are all acceptable, but each have their own major advantage. Subsoil injection's advantage is that it places the sludge out of sight of the public. Truck spreading is most mobile and flexible. Tractor spreading is the quickest and most economical method.

9.8 RECOMMENDED SLUDGE REUSE PROGRAM

The major components of the recommended sludge reuse program are program mangement, monitoring, marketing, and sludge handling. The reuse program operation and methods of reuse must be managed by MMSD to ensure orderly, efficient operation and environmentally acceptable land application. The major components of program management are a program manager, initial interview with the farmer and site screening, rate determination, sludge application, and recordkeeping. The District must appoint a person to manage the sludge reuse program.

The sludge reuse program must be monitored to protect the environment and to provide farmer confidence in the program. The program includes monitoring of the sludge, soils, crops, and ground water. The monitoring program is explained in detail in Appendix E.

The District must work to develop a large reliable market of farmers who want sludge applied to their land. Tools which have been used successfully to market sludge are an informational brochure, meetings with farmers, demonstration plots, and the designation of a trade name.

In addition, it is necessary to upgrade the solids handling system of the existing treatment plant. In Chapters 8 and 9 of the Wastewater Treatment Plant report, we discussed the need to expand the solids handling system to handle the increase in solids production resulting from various levels of advanced treatment. Since the solids handling system is an integral part of the reuse program, we also discussed the desirability of implementing the upgrading and expansion of the system at the same time the reuse program is implemented. With this plan, the sludge handling and disposal problems of the existing plant can be resolved on a shorter schedule than if they were implemented separately.

It is expected that the District can obtain regulatory agency acceptance and begin the recommended sludge reuse program in early 1977. As soon as the program is accepted, the District should begin to set up the required facilities. For the first year, 1978, four truck spreaders, one soil injection system, one tractor spreader system, six tanker trucks, one loading dock, and two nurse tanks are recommended. It is estimated that about five on-farm lagoons can be arranged and built each year during the second through fifth years of the program. Another set of soil injector and tractor spreader systems will probably be required in about the third year of the program. After the existing lagoons are emptied, in about 1987, the District will probably need only one truck spreader, one soil injector, and one tractor spreader. These items will probably need to be replaced in 1987 and 1997. We estimate that it will be feasible to build a pipeline and remote loading dock in about 1982. Also, the existing lagoons should be emptied enough by about 1984 to allow construction of a dike across Lagoon 1 for the seasonal storage lagoon.

We recommend that sludge users be assessed a fee to provide control of the supply and demand of the sludge. The fee structure should include a one-time flat fee to cover the cost of the site inspection and recordkeeping, a fee for the cost of the annual soil sampling and analysis, and a transportation fee based on haul distance from a distribution center. Also, the fee should be considerably less than the cost of commercial fertilizer to encourage the use of sludge.

The total average annual costs for the lagoon abandonment and sludge reuse program is estimated to be $350,000 per year for the next 20 years. It is expected that the District will receive up to 75 percent Federal grants to assist in the construction of the required facilities. If this occurs, the total average annual cost will drop to an estimated $212,000 per year. For the average residential customer, this will amount to an annual charge of about $1.85 per year or about 15 cents per month. This, of course, is the cost of only the sludge reuse program. This does not

5. Implementation of an industrial waste survey to locate sources of heavy metals, particularly cadmium.

6. Revision of the sewer service ordinance to require users to pretreat their wastes for the removal of heavy metals.

- Separate the construction of the proposed new solids handling facilities from the proposed advanced waste treatment addition and combine them with the implementation of the sludge reuse program.

- Adopt the implementation schedule shown on Figure 9-1. A condensation of the required action items is as follows:

1.	Adopt and submit plan and EAS to WDNR and DCRPC	June 1976
2.	Authorize appropriate engineering to assist District in implementing selected elements of sludge reuse program	June 1976
3.	Authorize final design engineering of program facilities subject to DNR and EPA approval	March 1977
4.	Advertise for Bids	November 1977
5.	Award Contracts	January 1978
6.	Start up Sludge Reuse Program	August 1978
7.	Start up New Solids Handling Program	November 1979

include the cost of sludge handling prior to digestion, sludge digestion, and the treatment of wastewater itself.

In 1975 the District spent a total of $172,000 for sludge application to farmland. For the average residential customer, this amounted to about $1.15 per year, or about 10 cents per month of their current bill for sewer service. The proposed program will, therefore, require an increase of about $0.70 per year or 6 cents per month. Based on this minimal increase, we believe the proposed project is feasible and well within the financial capabilities of the community.

9.9 RECOMMENDATIONS AND IMPLEMENTATION SCHEDULE

Based upon the findings and conclusions of this report, we recommend that the Commissioners of the Madison Metropolitan Sewerage District:

- Adopt the findings of this report.
- Submit the report to the appropriate agencies as part of the Facility Plan for the Madison Metropolitan Sewerage District.
- Proceed with the existing sludge disposal program until final acceptance of the proposed program.
- Authorize appropriate engineering to assist the District in proceeding with selected elements of the proposed sludge reuse program prior to final regulatory agency acceptance of this report. The elements selected will serve to upgrade the existing program without any significant capital investment. The elements include:

    1. Appointment of a full-time sludge reuse manager.
    2. Implementation of the program management tools outlined in Appendix D as present equipment will allow.
    3. Implementation of a sludge, soil, groundwater, and crop monitoring program, as outlined in Appendix E.
    4. Development of appropriate marketing tools necessary to launch a strong marketing program.

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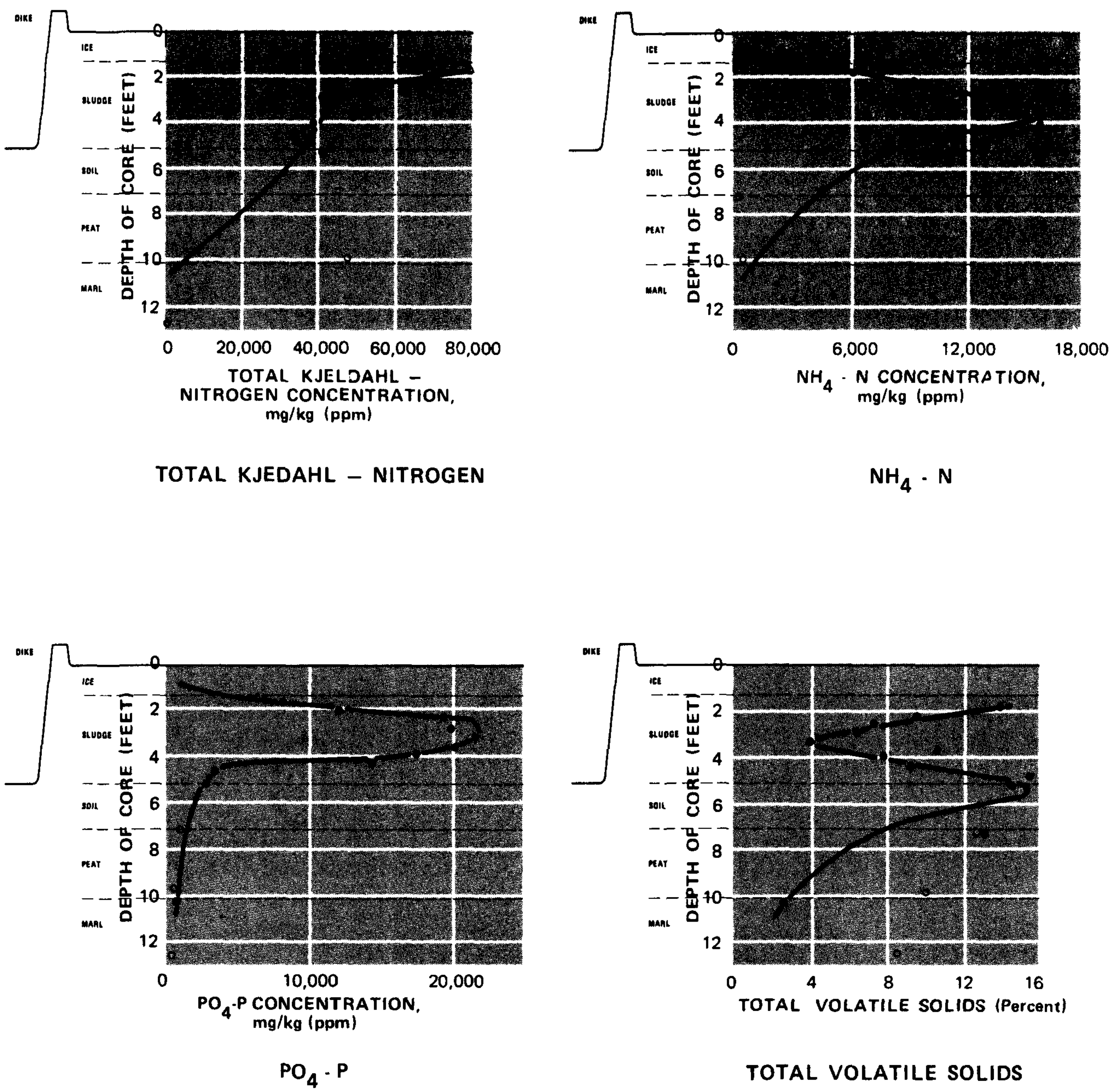
SLUDGE LAGOON
CHEMICAL DEPTH PROFILES **A**



LEGEND

- • CORE SAMPLE NUMBER 2 FROM LAGOON 1
- ∘ CONTROL SAMPLE N-2 TAKEN OUTSIDE LAGOON

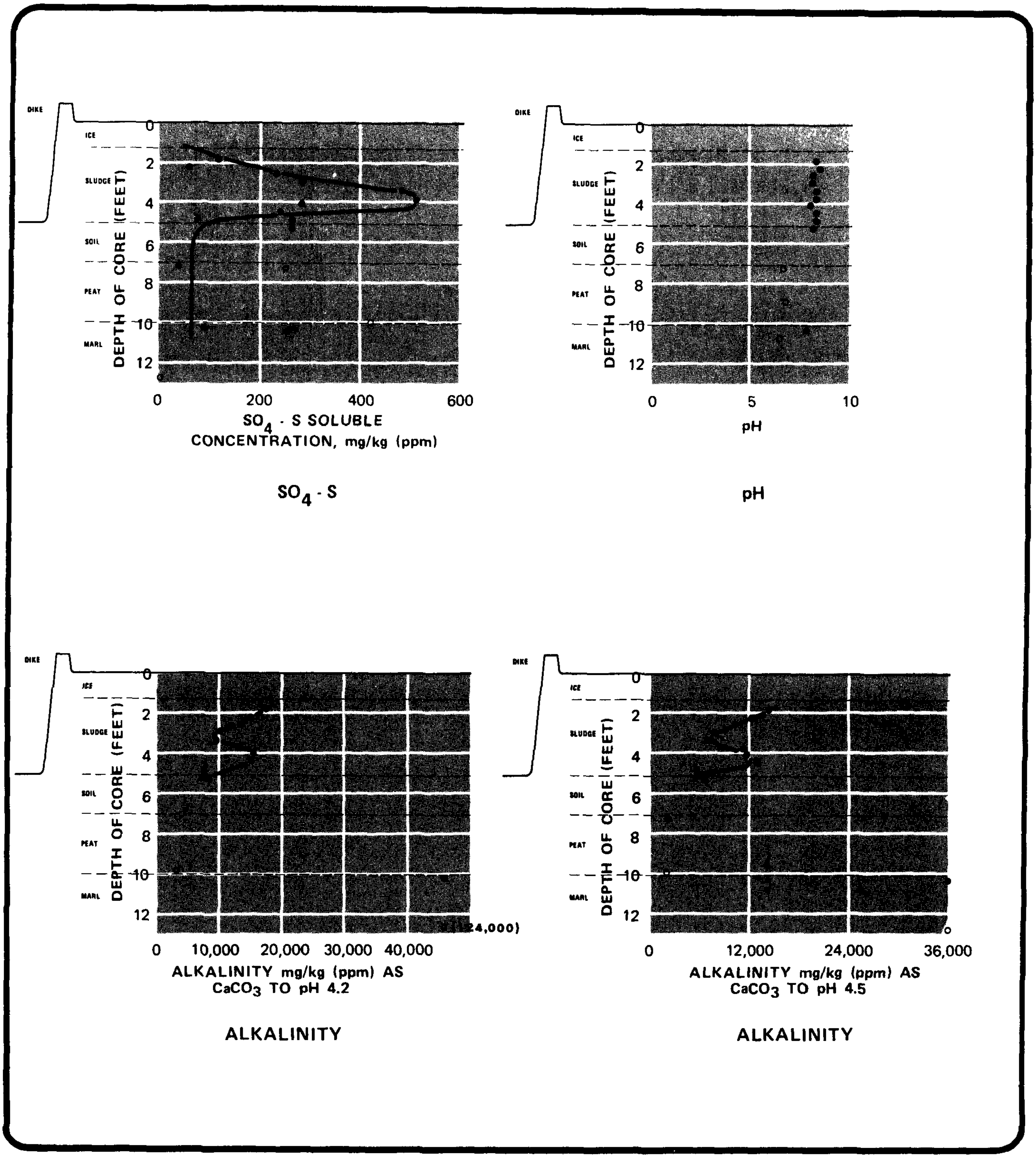
FIGURE A-1

LAGOON 1
CHEMICAL DEPTH PROFILE

MADISON METROPOLITAN
SEWERAGE DISTRICT
MADISON, WISCONSIN

CH2M HILL

S9166.0



LEGEND

- • CORE SAMPLE NUMBER 2 FROM LAGOON 1
- ∘ CONTROL SAMPLE N-2 TAKEN OUTSIDE LAGOON

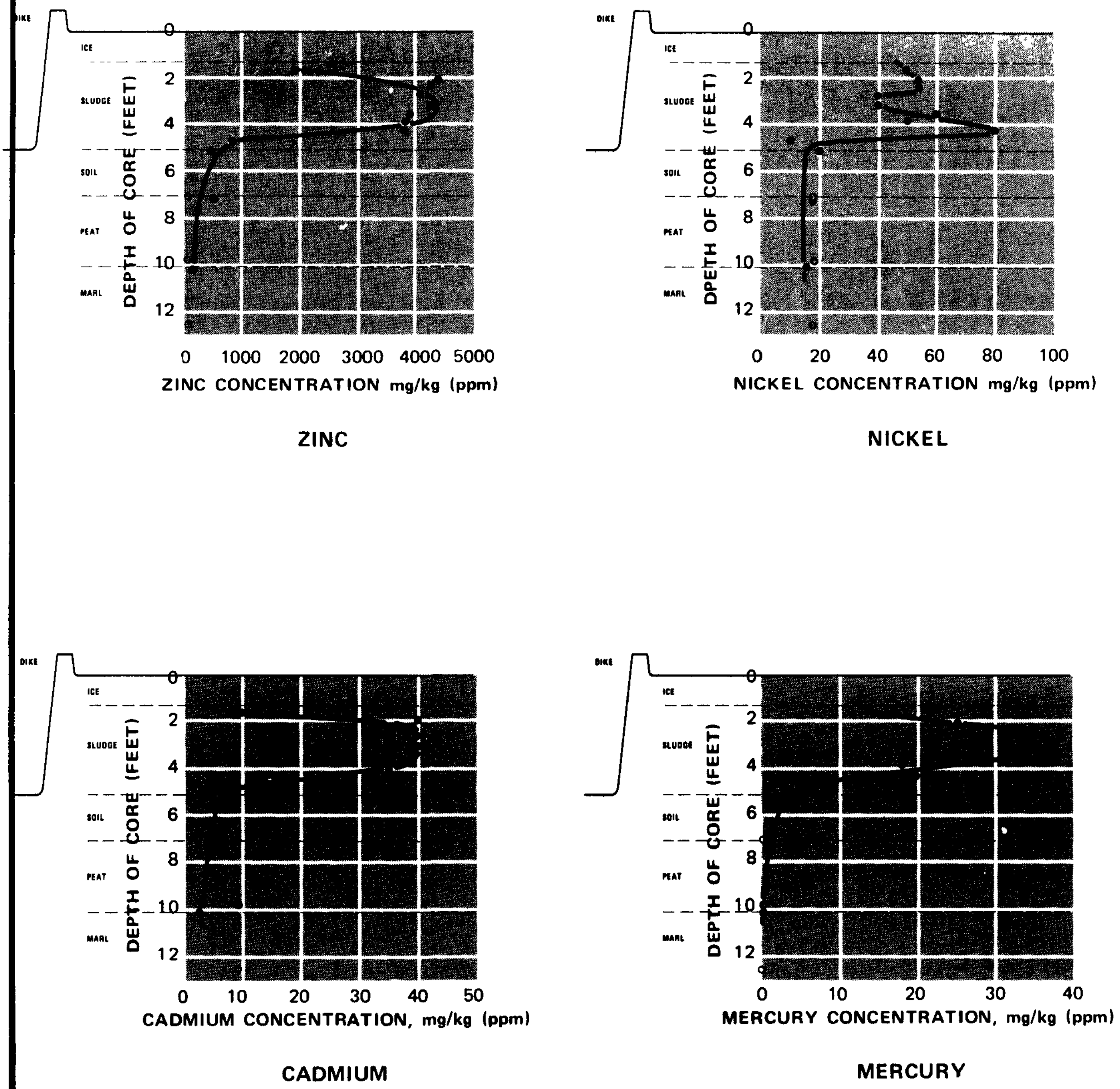
FIGURE A-2

LAGOON 1
CHEMICAL DEPTH PROFILE

MADISON METROPOLITAN
SEWERAGE DISTRICT
MADISON, WISCONSIN

CH2M HILL

S9166.0



LEGEND

- • CORE SAMPLE NUMBER 2 FROM LAGOON 1
- o CONTROL SAMPLE N-2 TAKEN OUTSIDE LAGOON

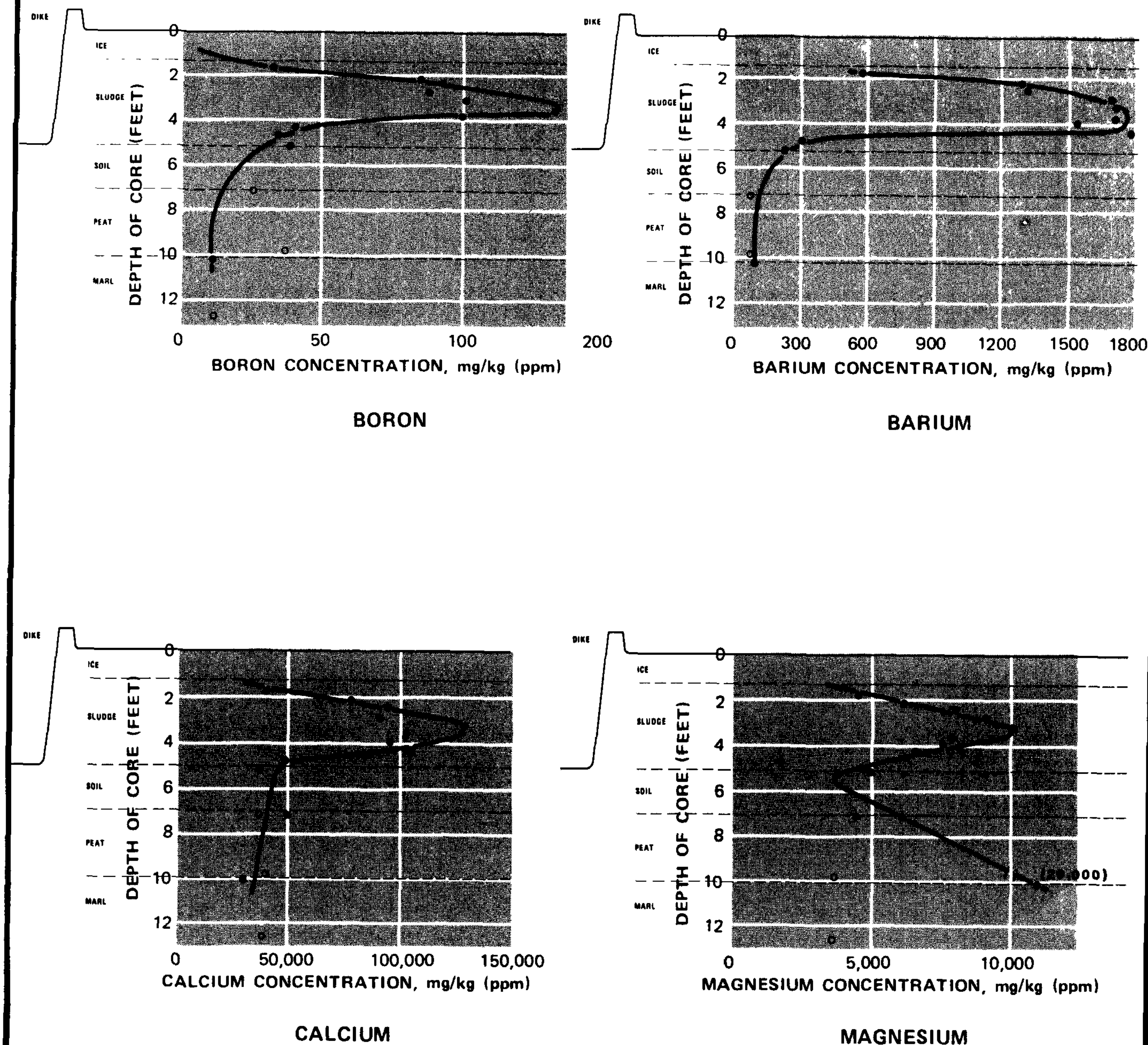
FIGURE A-3

LAGOON 1
CHEMICAL DEPTH PROFILE

MADISON METROPOLITAN
SEWERAGE DISTRICT
MADISON, WISCONSIN

CH2M HILL

S9166.0



LEGEND

- • CORE SAMPLE NUMBER 2 FROM LAGOON 1
- ○ CONTROL SAMPLE N-2 TAKEN OUTSIDE LAGOON

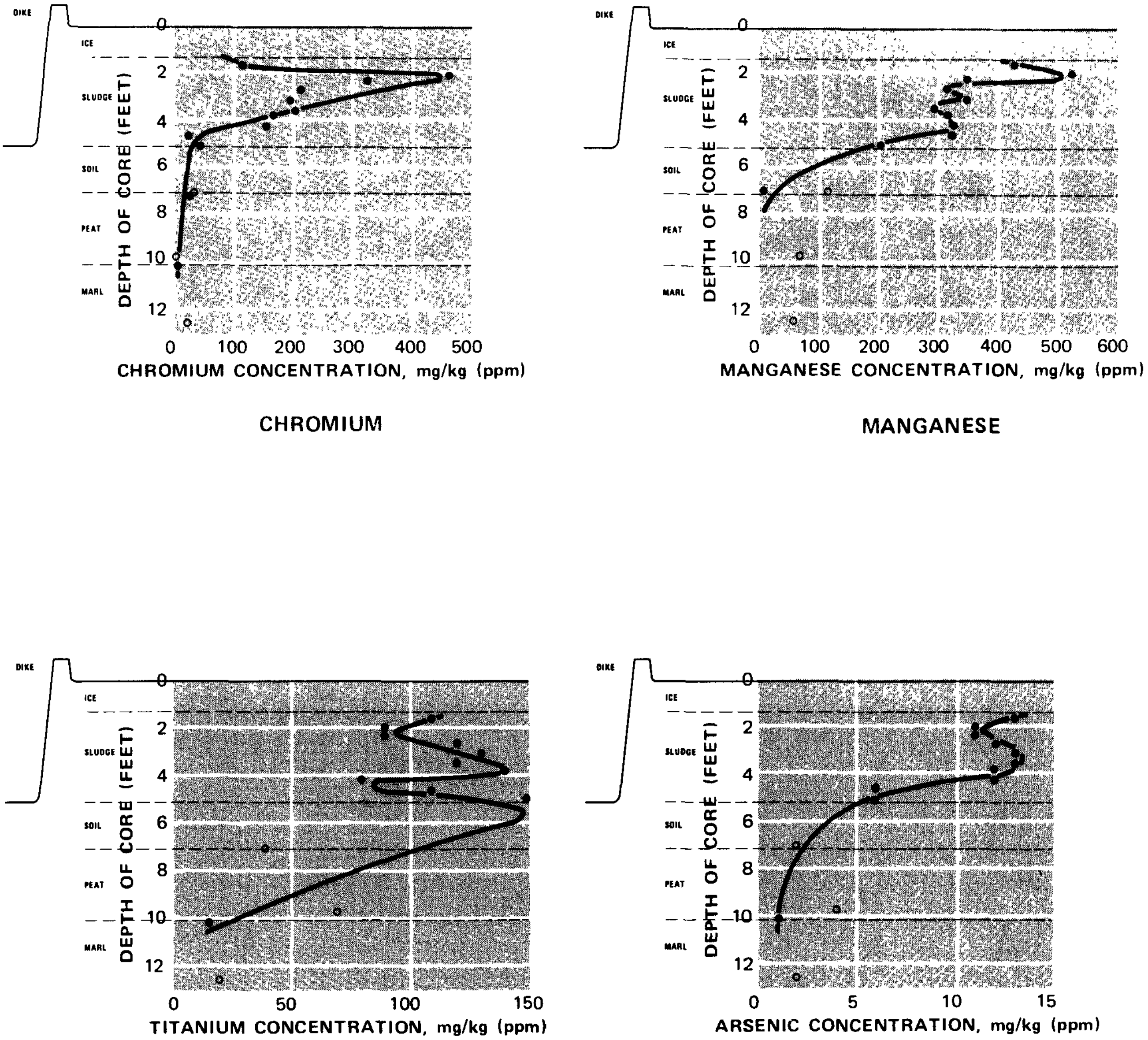
FIGURE A-4

LAGOON 1
CHEMICAL DEPTH PROFILE

MADISON METROPOLITAN
SEWERAGE DISTRICT
MADISON, WISCONSIN

CH2M HILL

S9166.0



LEGEND

- • CORE SAMPLE NUMBER 2 FROM LAGOON 1
- ∘ CONTROL SAMPLE N-2 TAKEN OUTSIDE LAGOON

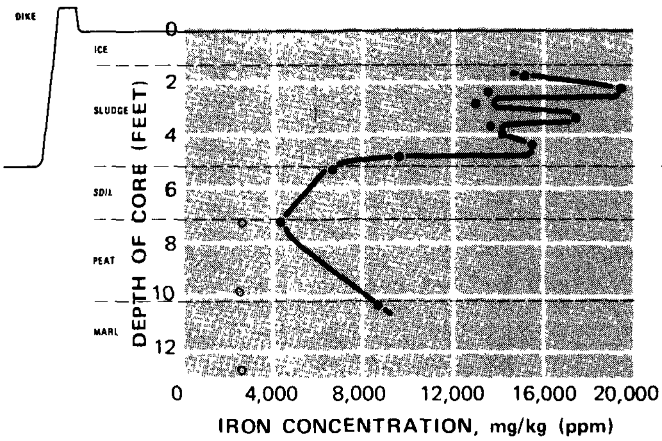
FIGURE A-5

LAGOON 1
CHEMICAL DEPTH PROFILE

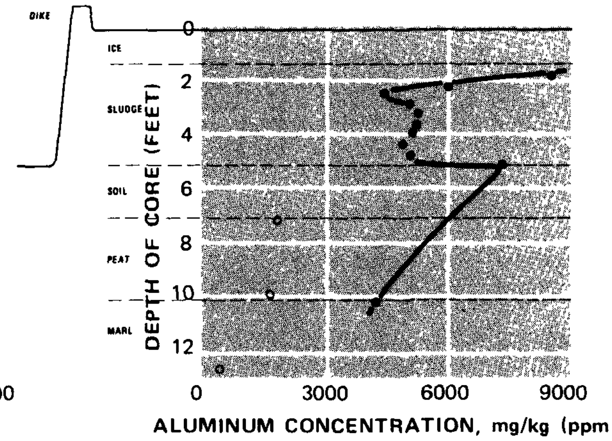
MADISON METROPOLITAN
SEWERAGE DISTRICT
MADISON, WISCONSIN

CH2M HILL

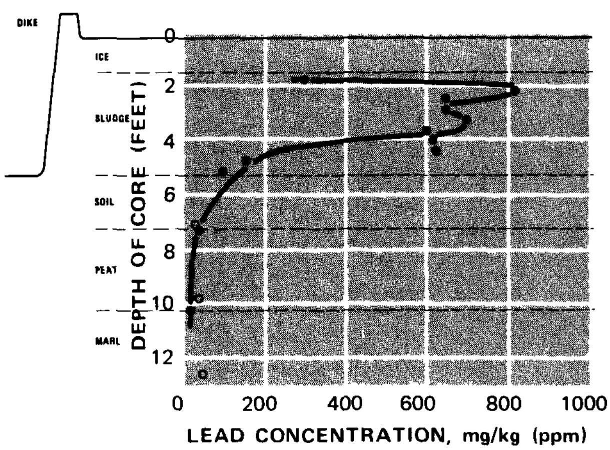
S9166.0



IRON



ALUMINUM



LEAD

LEGEND

- • CORE SAMPLE NUMBER 2 FROM LAGOON 1
- ○ CONTROL SAMPLE N-2 TAKEN OUTSIDE LAGOON

FIGURE A-6

LAGOON 1
CHEMICAL DEPTH PROFILE

MADISON METROPOLITAN
SEWERAGE DISTRICT
MADISON, WISCONSIN

CH2M HILL

S9166.0

COST ESTIMATING AND CALCULATION PROCEDURES FOR SLUDGE REUSE PROGRAM PLANNING B

Appendix B
COST ESTIMATING AND CALCULATION PROCEDURES FOR SLUDGE REUSE PROGRAM PLANNING

B.1 BASIC ASSUMPTIONS

Following are the basic assumptions used in preparing cost estimates for the MMSD Sludge Reuse Plan. These assumptions represent a consensus of opinions of MMSD, Dane County Regional Planning Commission, O'Brien and Gere, and CH2M HILL.

Planning Period

The planning period is for 1976 through 2000. All costs were referenced to January 1, 1976.

Interest Rate

The interest rate (discount rate) was 7.0 percent. This rate was established through consultation with representatives of Region V EPA and the WDNR.

Method of Analysis

The present worth (present value) analysis was used for the purpose of comparing (ranking) alternatives. In this analysis, all the project costs for each alternative were scheduled as they might occur in the future. Each cost was then discounted to a common point in time: January 1, 1976. The sum of these discounted costs, or their present value, was used to determine the relative order of the alternatives. This procedure conforms with the EPA's guidelines for cost-effective analysis which are stipulated for all wastewater management projects qualifying for Federal grant funding.

Inflation

The rate of inflation for energy costs is expected to exceed that of the general price level, during the planning period, by 2 percent. For that reason, costs for electrical power were escalated 2 percent per year. Inflation was not included in other costs because they are expected to parallel the general price level.

B.2 COST ESTIMATES

Construction cost data were obtained from our files and from equipment suppliers. The operation and maintenance costs were estimated from unit prices. These unit prices are shown with the cost development of each item. Phased construction was used wherever practicable. For this sludge reuse program, the time for additions is dependent upon the demand for sludge, so this had to be estimated based upon an assumed market growth. The salvage value of equipment and structures at the end of the planning period were computed using straight-line depreciation over their remaining service lives. The totals were then converted from current dollars to present-worth values. The useful lives of equipment and structures were based upon manufacturers' claims, American Society of Agricultural Engineers Machinery Management Data, and California planning guidelines.

The following overhead allowances were applied to all estimated costs:

CAPITAL COSTS	
Engineering	12%
Administration	0.5%
Legal and Fiscal	2.5%
Contingencies	15%
OPERATION AND MAINTENANCE COSTS	
Contingencies	15%

B.3 TOTAL PRESENT WORTH CALCULATION

The procedure for calculating the total present worth of the alternatives conformed basically with guidelines established by the Wisconsin Department of Natural Resources (WDNR) on August 19, 1974. The procedure consists of the following steps:

1. Estimate the cost of initial capital expenditures for construction, including overhead costs, in terms of current prices (January 1976 dollars).

2. Estimate the cost and timing of future capital expenditures, in terms of current prices.

3. Estimate the annual O&M costs for the first year of operation, in current prices.

4. Compute the present worth of the estimated capital expenditures, using the single-payment present-worth factor (SPPWF) for the appropriate time period. For all capital expenditures, assign the cost anticipated to be spent during a particular year to the beginning of the year.

For Costs on January 1	Elapsed Years	SPPWF @ 7.0%
1976	0	1.0000
1980	4	0.7629
1985	9	0.5439
1990	14	0.3878
1995	19	0.2765
2000	24	0.1971

5. Compute the present worth of the estimated O&M costs by multiplying each year's O&M cost by its respective single payment present worth factor or by computing the present worth factor for a uniform series or a gradient series as the particular case requires.

6. Calculate the salvage values of the capital costs, and convert the sum of the salvage values to a present-worth value.

7. Calculate the total present worth of the alternatives. This was done by subtracting the present-worth salvage value from the present-worth sum of capital and O&M costs.

TABLE B-1

NEW LAGOON COST DETERMINATION
MADISON METROPOLITAN SEWERAGE DISTRICT

LAGOON DESCRIPTION:

Capacity	150 acre-feet
Depth	7 feet
Surface Area	about 23 acres
Dike Section	10 feet top width
	2.1 side slopes
	10 feet total height
	3 feet freeboard
Earth Fill Required	45,000 cu.yds.
Land Area Required	26 acres

BASIS OF CONSTRUCTION COST

EQUIPMENT	COST
1 Large Dozer	$ 500/day
Tractor and Compactor	750/day
Blade and Loader	500/day
5 Trucks	1,250/day (5 mile haul, 400 cu.yd./day)
Total	$3,000/day

Construction would require an estimated 112 working days.

COST ESTIMATE

Construction	$336,000
Materials	113,000
Land 26 ac at $700/ac	18,000
Subtotal	$467,000
Overhead and Contingency Allowances (30%)	140,000
Total Cost	$607,000

TABLE B-2

LAGOON SLUDGE REMOVAL COST DETERMINATION
MADISON METROPOLITAN SEWERAGE DISTRICT

BASIS:

Use Small Floating Dredge (such as Mud Cat)
Pumping Rate 700 gpm in 10% solids
Operating Efficiency 70%
Sludge Removal Capacity 100 tons/8 hr day
Days per Year 100 days
Amount of Sludge to Remove 89,700 tons
Rate of Removal 10,000 tons/Year (9 Years)
Time Spent in Weed Removal and Slurrying Sludge - 1 Year
Life of Machine - 10 Years
Sludge Pumped to Wet Well, Capacity - 17,000 gallons

INITIAL COSTS:

Small Floating Dredge with Accessories and Pipeline	$ 85,000
Wet Well	14,000
Herbicide Application	1,000
Total	$100,000
Overhead and Contingency Allowances (30%)	30,000
Total Initial Costs	$130,000

OPERATING AND MAINTENANCE COSTS:

Fuel	$ 3.90/hr
Grease, Filters, Lubrication, Hydraulic Oil	.45
Insurance	1.56
Labor – 2 men at $7 33/hr	14.66
Miscellaneous	1.43
Total	$ 22.00/hr
Overhead and Contingency Allowances (15%)	3.30
Total O&M	$ 25.30/hr
or	$ 20,000/yr

PRESENT WORTH

O&M = (20,000) (7 024)	$140,000
Initial Costs	130,000
Total Present Worth	$270,000

ANNUAL COST

Capital $130,000 x (crf = 14238)	$ 19,000
O&M	20,000
Total Annual Cost	$ 39,000

COST PER DRY TON

$39,000 ÷ 10,000 tons = $3.90/dry ton

TABLE B-3

REHABILITATE WEST HALF OF LAGOON 1 COST DETERMINATION
MADISON METROPOLITAN SEWERAGE DISTRICT

BASIS:

Construct 1,100 feet long dike across Lagoon 1 to form a 150 acre feet capacity storage area using corduroy and berm technique.

Dike Height - 10 feet
Top Width - 10 feet
Side Slopes - 3 1
Fill Volume - 12,000 cu.yds.

BASIS OF CONSTRUCTION COST

EQUIPMENT	COST
Crane	$ 500/day
4 Trucks	1,000
Loader	500
Miscellaneous	400
	$ 2,400/day

Construction would require an estimated 50 working days

COST ESTIMATE

Construction	$120,000
Material	35,000
Miscellaneous Costs	25,000
Subtotal	$180,000
Overhead and Contingency Allowances (30%)	54,000
Total Cost in 1984	$234,000

PRESENT WORTH

P W = 234,000 (pwf = .5820)	$136,000

TABLE B-4

LAGOON SUPERNATANT TREATMENT ALTERNATIVES
MADISON METROPOLITAN SEWERAGE DISTRICT

DESCRIPTION	ALTERNATIVES A NO SLUDGE REMOVAL ARRP TREATMENT FOR OVER 100 YEARS	B REMOVE SLUDGE ARRP TREATMENT FOR 10 YEARS	C* REMOVE SLUDGE TREATMENT AT SEWAGE TREATMENT PLANT FOR 10 YEARS
INITIAL CONSTRUCTION COSTS (1980)			
ARRP Modules	$1,875,000	$ 500,000	–
Clarifiers	90,000	35,000	–
Lime System	50,000	25,000	–
Subtotal	$2,015,000	$ 560,000	–
Overhead and Contingency Allowances (30%)	605,000	168,000	–
Total Initial Costs	$2,620,000	$ 728,000	None
OPERATION AND MAINTENANCE COSTS (first year)			
Labor	$ 13,000/yr	$ 13,000/yr	$ 1,500/yr
Power	15,000	4,000	23,500
Parts	56,000	15,000	1,000
Lime	60,000	60,000	–
Acid	26,000	26,000	–
Sludge Disposal	66,000	66,000	–
Byproduct Recovery	-49,000	-49,000	–
Net O&M Costs	$ 187,000/yr	$ 135,000/yr	$26,000/yr
Overhead and Contingency Allowances (15%)	28,000	20,000	7,800
Total O&M	$ 215,000/yr	$ 155,000/yr	$33,800/yr
PRESENT WORTH			
Capital Costs (pwf = 0.713)	$1,868,000	$ 519,000	–
O&M	3,150,000	1,090,000	250,000
Total Present Worth	$5,018,000	$1,609,000	$250,000
ANNUAL COST			
Capital (crf = 0.08719)	$ 163,000	$ 45,000	–
O&M	215,000	155,000	$33,800
Total Annual Cost	$ 378,000	$ 200,000	$33,800

*If no sludge is removed the supernatant would have to be treated for over 100 years at a present worth of $600,000.

TABLE B-5

LAND LEASE COST DETERMINATION
(Grain Corn)
MADISON METROPOLITAN SEWERAGE DISTRICT

VARIABLE COSTS

MATERIALS:		
Fertilizer		
125 lbs N @ 21¢	$26.25/Ac	
80 lbs P_2O_5 @ 21¢	16.80	
50 lbs K_2O @ 8¢	4.00	
Corrective	5.00	
Seed – 1/3 bu/A¢	13.00	
Chemicals	17.50	
EQUIPMENT:		
Machine Operation	10.15	
Drying – 100 bu @ 15¢	15.00	
LABOR:		
4.5 Hrs. @ 3.50	15.75	
OVERHEAD:		
Intent on Operating Capital – 9% for 6 mo.	5.55	
Miscellaneous	2.00	
TOTAL VARIABLE COSTS		$131.00/Ac

FIXED COSTS

INVESTMENT	PER ACRE	DEPR.	INTEREST	TAXES	
Land	$700		$56.00	$14.00	
Machinery & Equip.	135	$13.50	5.40	1.35	
Storage	60	3.00	2.40	.60	
TOTAL	$895	$16.50	$63.80	$15.95	
TOTAL FIXED COSTS (depr., interest and taxes)					$ 96.25/Ac

NET RETURN

Total Returns – 100 bu @ $2.50	$250.00/Ac
Total Cost = $131.00 + $96.25	- 227.25/Ac
NET RETURN	$ 22.75/Ac

LEASE COST

Fertilizer value derived from 6.8 tons of applied sludge (extra sludge is applied to make up for nitrogen losses)	$ 86.10/Ac
Cost to farmer to disk field twice in lease year	$ 5.72/Ac

LEASE COST = Fixed Costs + Net Return - Fertilizer Value + 2 Diskings
= $38.62/Ac
= $ 5.68/dry ton of applied sludge

TABLE B-6

TRUCK TRANSPORTATION COST DETERMINATION
MADISON METROPOLITAN SEWERAGE DISTRICT

BASIS:

- 5,000 gallon Capacity
- 5 mile Haul Distance
- 35 mph Average Haul Speed
- 15 minutes Fill Time
- 15 minutes Unload Time
- 48 minutes per Load, 10 Loads per day
- 200 days per Year Operation
- 10 year Truck Life
- 2,083 dry tons or 10,000,000 gallons/Year Capacity

INITIAL COSTS	
Truck with 5,000 gallon trailer	$48,000
Overhead and Contingency Allowances (30%)	14,400
Total Initial Cost	$62,000
ANNUAL O&M	
Maintenance	$ 2,500
Fuel	2,100
Operator – 200, 8 hr days @ 7.33/hr.	11,700
Total	16,300
Overhead and Contingency Allowances (15%)	2,400
Total Annual O&M	$19,000
PRESENT WORTH FOR 10 YEARS	
Initial Costs	$62,000
Annual Costs 19,000 (pwf = 7.024 for 10 yrs)	133,000
Total Present Worth	$195,000
ANNUAL COST	
Initial Cost 62,000 (crf = .14238 for 10 yrs)	$ 8,800
O&M	19,000
Total Annual Cost	$ 28,000

COST PER TON-MILE

$28,000 ÷ 2,083 dry tons, 5 miles = $2.69/dry ton-mile

TABLE B-7

PIPELINE TRANSPORTATION COST DETERMINATION
MADISON METROPOLITAN SEWERAGE DISTRICT

BASIS

- 5 mile Transport Distance
- 500 gallons/minute Capacity
- 100 feet Static Head
- 8" diameter Pipeline – 50 Year Life
- 90 horsepower Pump Station – 20 Year Life
- Operate 120 days or 960 hours per Year to Transport 28,800,000 gallons/Year or 6,000 dry tons)
- Energy Required 64,450 kW - hr/year
- Power Demand 67 kW
- Constructed in 1980

INITIAL COSTS	
26,400 feet of 8" pipe @ $10.00/lin ft installed	$264,000
Values and Miscellaneous Appurtences	15,000
Right-of-Way Acquisition – 42 Acres @ $700/Ac	29,000
2 Major Highway or Creek Crossings	20,000
Pump Station	15,000
Total	$343,000
Overhead and Contingency Allowances (30%)	103,000
Total Initial Costs (in 1980)	$446,000
ANNUAL O&M COSTS	
Energy @ 2.9¢/kW-hr	1,900
Maintenance @ 0.5% of Initial Cost	1,900
Total	$ 3,800
Overhead and Contingency Allowances (15%)	600
Total O&M Costs (1976 price level)	$ 4,400
Total O&M in 1981 (with 2%/year energy cost escalation)	$ 4,600
PRESENT WORTH	
Initial Costs	$300,000
O&M	40,000
Total Present Worth in 1976	340,000
ANNUAL COST IN 1981	
Initial Costs	$ 42,000
O&M	4,600
Total Annual Cost in 1981	$ 47,000

COST PER TON-MILE

$43,000 - 6,000 dry tons, 5 miles = $1.57/dry ton-mile

TABLE B-8

SMALL ON-FARM LAGOON COST DETERMINATION
MADISON METROPOLITAN SEWERAGE DISTRICT

BASIS:

- 4.5 Acre-feet volume or 300 tons Solids Capacity
- Located on Farmer Owned Land
- Dikes with 10 feet Top Width, 3:1 Side Slopes
- 3,000 yds Balanced Cut and Fill Earthwork
- 10 feet wide Concrete Ramp to Extend to Bottom of Lagoon
- Pad Provided for Portable Pump (does not include pump)
- Weed Control and Other Maintenance Performed by Farmer
- Fenced

CONSTRUCTION COST	
Embankments @ $2.00/cu.yd.	$6,000
Concrete	500
Total	$6,500
Overhead and Contingency Allowances (30%)	2,000
Total with Contingencies	$8,500

TABLE B-9

SPRINKLER APPLICATION COST DETERMINATION
MADISON METROPOLITAN SEWERAGE DISTRICT

BASIS:

- Effective Land Coverage per Set – 1 Acre
- 450 gallons/minute Pump Rate
- 80 pounds/square inch Pressure at Nozzle
- 4.5 hours/day Operating, the Remainder used in Moving Pipe and Sprinkler
- 1 Man could keep Two Sprinklers going – Farm Labor Rate
- 6 Acres/day Land Coverage
- Appurtenances included are Portable Pump, 1,320 feet of Hand Moveable Pipe
- 45 Horsepower Pump Required
- 10 year Equipment Life
- Will Operate 100 days/year or 800 hrs/year

INITIAL COSTS	
Big Gun Sprinkler and Stand	$ 1,000
Portable Pump and Engine	5,800
Pipeline	3,000
Total	$ 9,800
Overhead and Contingency Allowances (30%)	2,900
Total Initial Costs	$12,700
O&M COSTS	
Farm Labor $3.50/hr x ½ Man/Sprinkler	$1.75/hr
Pump Fuel, Lube, and Maintenance	3.25
Total	$5.00/hr
Overhead and Contingency @ (15%)	0.75
Total O&M	$5.75/hr
or	$4,600/yr
PRESENT WORTH	
Initial	$12,700
O&M 4,600 (pwf = 7.024)	32,300
Total Present Worth	$ 45,000
ANNUAL COST	
Initial 12,700 (crf = 14238)	$ 1,800
O&M	4,600
Total Annual Cost	$ 6,400

COST PER DRY TON

$6,400/1,800 tons = $3.56/dry ton

TABLE B-10

SOIL INJECTION COST DETERMINATION
MADISON METROPOLITAN SEWERAGE DISTRICT

BASIS:

Equipment – Tractor, Injector, 660 feet of Flexible Hose, Hand Move Pipeline, and Portable Pump
40 Horsepower Crawler Tractor
10 feet wide, 7 Sweep Injector
Field Speed 1.25 mph
Can Cover 9 Acres/day
Tractor Life 15 Years
Injector Life 5 Years
Flexible Hose Life 3 Years
Pump and Pipeline Life 10 Years
100 days or 800 hrs/Year Operation
2,700 dry tons/Year Applied

INITIAL COSTS	
Tractor	$25,000
Injector	6,000
Flexible Hose	4,500
Pipeline	1,700
Portable Pump	3,800
Total	$41,000
Overhead and Contingency Allowances (30%)	12,000
Total Initial Costs	$53,000
O&M COSTS	
Farm Labor	$3.50/hr
Tractor Fuel, Lube, and Maintenance	2.50
Pump Fuel, Lube and Maintenance	2 00
Total	$8.00/hr
Overhead and Contingency Allowances (15%)	1.20
Total O&M	$9.20/hr or $7,400/yr
PRESENT WORTH	
Initial Costs (for a 10 yr period)	$ 63,000
O&M 7,400 (pwf = 7 024)	52,000
Total Present Worth	$115,000
ANNUAL COST	
Initial Costs 63,000 (crf = 14238)	$ 9,000
O&M	7,400
Total Annual Cost	$ 16,000

COST/TON

$16,000 – 2,700 dry tons = $5.93/dry ton

TABLE B-11

TRUCK SLUDGE SPREADER COST DETERMINATION
MADISON METROPOLITAN SEWERAGE DISTRICT

BASIS:

Equipment – Liquid Sludge Spreader Truck with 1,600 gallon Tank and High Flotation Tires
2 Passes to Apply Sludge
700 gpm Discharge Rate
12 minutes Required per Load to Travel across Field, Load Truck, and Unload Truck
Sludge Supply to Spreader Truck at Field
Truck Life 10 Years
4.2 Acre/day Ground Coverage Rate
100 days/Year Operation
1,260 dry tons/Year Applied

INITIAL COSTS	
Sludge Spreader Truck and Accessories	$42,000
Overhead and Contingency Allowances (30%)	12,600
Total Initial Costs	$55,000
O&M COSTS	
MMSD Labor	$7.33/hr
Fuel, Maintenance, Insurance	0.45/hr
Total	$7.78/hr
Overhead and Contingency Allowances (15%)	1.17
Total O&M	$8.95/hr or $7,200/yr
PRESENT WORTH	
Initial Costs	$55,000
O&M = 7,200 (pwf = 7 024)	51,000
Total Present Worth	$106,000
ANNUAL COST	
Initial Cost = 55,000 (crf = .14238)	$ 7,800
O&M	7,200
Total Annual Cost	$15,000

COST/TON

$15,000/1,260 dry tons = $11.90/dry ton

TABLE B-12

TRACTOR SLUDGE SPREADING COST DETERMINATION
MADISON METROPOLITAN SEWERAGE DISTRICT

BASIS:

Equipment – Spreader Device, 660 feet of Flexible Hose, Portable Pump and Engine, Hand Moveable Pipeline, Tractor assumed to be owned by Farmer and Charged as an Operating Cost
700 gpm Flow Rate
15 Acres per Hose Attachment
Farmer will Operate Tractor
Continuous Sludge Supply Assumed
30 Horsepower Pump Required
10 Year Spreader Device Life
10 Year Pump and Pipeline Life
3 Year Flexible Hose Life
Ground Coverage Rate 15 Acres/day
4,500 dry tons Applied/Year, 100 days/Year Operation

INITIAL COSTS		
Spreader Device*		$ 2,500
Flexible Hose		4,500
Pump and Pipeline		5,500
Total		$12,500
Overhead and Contingency Allowances (30%)		3,800
Total Initial Costs		$16,000
O&M COSTS		
Small Tractor Own and Operating Expenses		$2.50/hr
Labor, Farmer		3.50
Pump Fuel, Maintenance, etc.		2.00
Total		$8.00
Overhead and Contingency Allowances (15%)		1.20
Total O&M Costs		$9.20/hr
	or	$7,400/yr
PRESENT WORTH		
Initial Costs (for 10 yr. period)		$26,000*
O&M $7,400 (pwf = 7.024)		52,000
Total Present Worth		$78,000
ANNUAL COSTS		
Initial Costs 26,000 (crf = .14238)		$ 3,700
O&M		7,400
Total Annual Cost		$11,000

COST/TON

$11,000/4,500 dry tons = $2 44/dry ton

*Does not include cost of spreader device development, estimated to be $3,000, which would be applied to the first device built.

TABLE B-13

MONITORING PROGRAM COST DETERMINATION
MADISON METROPOLITAN SEWERAGE DISTRICT

SLUDGE ANALYSIS				
Daily Composits		300 Samples	@ $ 20 00	$ 6,000
Monthly Digesters		12 Samples	@ $120 00	$ 1,440
Quarterly – Digesters		4 Samples	@ $260 00	$ 1,040
– Storage Lagoon		4 Samples	@ $380.00	$ 1,520
Total				$10,000/yr
SOIL ANALYSIS				
Background (average 1 sample/5.5 acres)				
Years 1-4		360 Samples	@ $ 78 00	$28,000
Years 5+		36 Samples	@ $ 78 00	$ 3,000
Annual (cost for analysis by Extension Service)				
Average every Year		700 Samples	@ $ 1 50	$ 1,000
Totals Years 1-4				$29,000/yr
Years 5+				$ 4,000/yr
CROP ANALYSIS *(assume 1 sample/35 ac., 1/3 of fields each year)*				
Years 1-10	6,000 ac,	57 Samples	@ $152 00	$ 8,700/yr
Years 10+	2,000 ac,	19 Samples	@ $152 00	$ 2,900/yr
GROUND WATER ANALYSIS				
Background				
Years 1-4		25 Wells	@ $ 64 00	$ 1,600
Years 5+		2 Wells	@ $ 64 00	$ 100
Subsequent Monitoring (every third year)				
Years 5+		35 Wells	@ $ 11 50	$ 400
Totals Years 1-4				$ 1,600/yr
Years 5+				$ 500/yr

TOTAL MONITORING PROGRAM COST

	YEARS 1-4	YEARS 5-10	YEARS 11+
Sludge	$10,000	$10,000	$10,000
Soil	29,000	4,000	4,000
Crops	8,700	8,700	2,900
Ground Water	1,600	500	500
Sample Collection*	1,000	1,000	1,000
Subtotals	$ 50,000	$24,000	$18,000
Contingency (15%)	8,000	4,000	3,000
Totals	$ 58,000/yr	$28,000/yr	$21,000/yr

*Cost of average 20 man-days/year to collect samples

TABLE B-14

SLUDGE REUSE PROGRAM YEAR-BY-YEAR COST ESTIMATE
MADISON METROPOLITAN SEWERAGE DISTRICT

YEAR	LAGOON	PROGRAM	SLUDGE DISTRIBUTION	SYSTEM	LAND APPLICATION SYSTEM		PROGRAM MANAGEMENT	MONITORING PROGRAM	TOTAL CAPITAL COSTS	DEBT[1] SERVICE	TOTAL O&M COSTS	PROGRAM INCOME	TOTAL[2] ANNUAL COST	ESTIMATED[3] SLUDGE RECYCLED	COST PER TON
	CAPITAL	O&M	CAPITAL	O&M	CAPITAL	O&M	O&M	O&M						(TONS)	($/TON)
1978	$130,000	$20,000	$ 457,000	$ 52,000	$312,000	$29,000	$ 32,000	$ 58,000	$ 899,000	$ 85,000	$191,000	$ 3,000	$273,000	5,800 tons	$47 07/dry ton
1979	–	20,000	103,000	140,000	–	53,000	32,000	58,000	103,000	95,000	303,000	5,000	393,000	16,000	24 56
1980	–	20,000	103,000	141,000	89,000	47,000	32,000	58,000	192,000	113,000	298,000	7,000	404,000	16,100	25 09
1981	–	20,000	103,000	143,000	–	48,000	32,000	58,000	103,000	122,000	301,000	7,000	416,000	16,300	25 52
1982	–	20,000	599,000	145,000	–	48,000	32,000	28,000	599,000	179,000	273,000	7,000	445,000	16,500	26.97
1983	–	20,000	–	97,000	–	49,000	32,000	28,000	–	179,000	226,000	7,000	398,000	16,700	23.83
1984	234,000	20,000	–	98,000	–	49,000	32,000	28,000	234,000	201,000	227,000	7,000	421,000	16,800	25.06
1985	–	20,000	–	99,000	–	50,000	32,000	28,000	–	201,000	229,000	7,000	423,000	16,900	25.03
1986	–	20,000	–	100,000	–	50,000	32,000	28,000	–	201,000	230,000	7,000	424,000	17,000	24.94
1987	–	20,000	–	101,000	–	50,000	32,000	28,000	–	201,000	231,000	7,000	425,000	17,100	24 85
1988	–	–	124,000	30,000	144,000	19,000	32,000	21,000	268,000	226,000	102,000	5,000	323,000	7,100	45 49
1989	–	–	–	32,000	–	19,000	32,000	21,000	–	226,000	104,000	5,000	325,000	7,300	44 52
1990	–	–	–	33,000	–	19,000	32,000	21,000	–	226,000	105,000	5,000	326,000	7,400	44.05
1991	–	–	–	33,000	–	19,000	32,000	21,000	–	226,000	105,000	5,000	326,000	7,400	44 05
1992	–	–	–	34,000	–	20,000	32,000	21,000	–	226,000	107,000	5,000	328,000	7,500	43.73
1993	–	–	–	35,000	–	20,000	32,000	21,000	–	226,000	108,000	5,000	329,000	7,600	43.29
1994	–	–	–	35,000	–	20,000	32,000	21,000	–	226,000	108,000	5,000	329,000	7,700	42.73
1995	–	–	–	36,000	–	20,000	32,000	21,000	–	226,000	109,000	5,000	330,000	7,800	42.31
1996	–	–	–	37,000	–	21,000	32,000	21,000	–	226,000	111,000	5,000	332,000	7,900	42 03
1997	–	–	–	38,000	–	21,000	32,000	21,000	–	226,000	112,000	5,000	333,000	8,000	41.63
1998	–	–	124,000	39,000	144,000	21,000	32,000	21,000	268,000	167,000	113,000	5,000	275,000	8,100	33.95
1999	–	–	–	40,000	–	21,000	32,000	21,000	–	157,000	114,000	5,000	266,000	8,200	32 44
2000	–	–	–	41,000	–	22,000	32,000	21,000	–	139,000	116,000	5,000	250,000	8,300	30.12
TOTALS	$364,000	$200,000	$1,613,000	$1,579,000	$689,000	$735,000	$736,000	$673,000	$2,666,000	$4,300,000	$3,923,000	$129,000	$8,094,000	255,500 tons	$31.68/dry ton

(1) To pay off capital cost in 20 years @ 7% interest

(2) Total Annual Cost = Debt Service + Total O&M Costs–Program Income

(3) Digested sludge quantity in terms of tons of solids

SOIL PROPERTIES AND SUITABILITY FOR SLUDGE APPLICATION C

TABLE C-1

SOIL PROPERTIES AND SUITABILITY FOR SLUDGE APPLICATION

MADISON METROPOLITAN SEWERAGE DISTRICT

SOIL NAME	MAPPING NUMBER	SLOPE PHASE (%)	ERODIBILITY CLASS.	ERODIBILITY POINTS	DEPTH TO SEASONAL HIGH WATER TABLE (feet)	DEPTH TO SEASONAL HIGH WATER TABLE POINTS	FLOOD HAZARD OCCUR.	FLOOD HAZARD POINTS	DEPTH TO BEDROCK (feet)	DEPTH TO BEDROCK POINTS	CATION EXCHANGE CAPACITY (Meq./ 100 gm)	CATION EXCHANGE CAPACITY POINTS	TEXTURE CLASS.	TEXTURE POINTS	PERMEABILITY CLASS.	PERMEABILITY POINTS	POINT RATING (0-100)	CLASS FOR SLUDGE APPLIC	COMMENTS
Houghton	01,04	–	–	–	Surface	0	Freq.	0	>6	1 00	–	–	Variable	–	Mod. Rapid	95	0	4	
Palms	015,017,047	–	–	–	Surface	0	Freq.	0	>6	1 00	–	–	Muck	–	Mod. Rapid	95	0	4	
Adrian	016,046	–	–	–	Surface	0	Freq.	0	>6	1.00	–	–	Muck/Sand	–	Mod Rapid	95	0	4	
Huntsville	05	0-3	None	1.00	3-5	70	Occas.	40	>6	1.00	20-25	1 00	Fine Silty	1 00	Moderate	1 00	28	3	
Marsh	4	–	–	–	Surface	0	Freq.	0	>5	1.00	–	–	Variable	–	–	–	0	4	a
Otter	5W,749,788	–	–	–	0-1	0	Freq.	0	>6	1.00	–	–	Fine Silty	–	Moderate	1 00	0	4	
Marshan	8,176,719	–	–	–	0-1	0	Freq.	0	>6	1.00	–	–	Fine Loamy/Sandy	–	Moderate	1 00	0	4	
Arenzville	10	0-3	None	1 00	3-5	70	Freq.	0	>5	1.00	10	70	Coarse Silty	90	Moderate	1.00	0	4	
Alluvial	11				<2	0	Occas.	40	>5	100	–	–	Variable				0	4	a
Billett	16	0-2	None	1.00	>5	1.00	None	1.00	>5	1.00	6	60	Coarse Loamy	75	Mod. Rapid	95	.43	2	
		2-6	Slight	90	>5	1.00	None	1.00	>5	1.00	6	60	Coarse Loamy	75	Mod. Rapid	95	38	2	
		6-12	Severe	60	>5	1.00	None	1 00	>5	1.00	6	60	Coarse Loamy	75	Mod. Rapid	95	.26	3	
		12-20																4	b
Fayette, Valley Phase	22	6-12	Mod.-Severe	70	>5	1.00	None	1.00	>5	1.00	18	1.00	Fine Silty	90	Mod. Rapid	95	60	2	
		12-30															0	4	b
Worthen	23	0-2	None	1.00	3-5	70	Freq.	0	>5	1 00	20-25	1.00	Fine Silty	90	Moderate	1 00	0	4	
		2-6	Slight	90	3-5	70	Freq.	0	>5	1.00	20-25	1.00	Fine Silty	90	Moderate	1 00	0	4	
		6-12	Moderate	80	3-5	70	Freq.	0	>5	1.00	20-25	1.00	Fine Silty	90	Moderate	1 00	0	4	
Lindstrom	24	2-6	Slight	90	>5	1.00	None	1.00	>5	1.00	20-25	1.00	Fine Silty	1 00	Moderate	1.00	90	1	
		6-12	Moderate	80	>5	1.00	None	1.00	>5	1.00	20-25	1.00	Fine Silty	1.00	Moderate	1 00	80	1	
		12-20															0	4	b
Fayette	25	0-2	None	1 00	>5	1 00	None	1.00	>5	1.00	18	1 00	Fine Silty	1 00	Moderate	1 00	1.00	1	
		2-6	Slight	90	>5	1.00	None	1.00	>5	1.00	18	1.00	Fine Silty	1 00	Moderate	1 00	90	1	
		6-12	Severe	60	>5	1.00	None	1.00	>5	1.00	18	1.00	Fine Silty	1.00	Moderate	1 00	60	2	
		12-30															0	4	b
Decorra	26,759	0-2	None	1 00	3-6	70	None	1.00	>6	1.00	15-18	95	Fine Silty	.95	Moderate	1 00	63	2	
		2-6	Slight	90	3-6	70	None	1 00	>6	1.00	15-18	95	Fine Silty	95	Moderate	1 00	.57	2	
		6-12	Moderate	80	3-6	70	None	1 00	>6	1 00	15-18	95	Fine Silty	95	Moderate	1 00	51	2	
Tama	28,29	0-2	None	1.00	>5	1.00	None	1.00	>5	1 00	19	1.00	Fine Silty	1 00	Moderate	1 00	1 00	1	
		2-6	Slight	90	>5	1 00	None	1 00	>5	1.00	19	1 00	Fine Silty	1.00	Moderate	1 00	.90	1	
		6 12	Moderate	80	>5	1 00	None	1.00	>5	1.00	19	1.00	Fine Silty	1.00	Moderate	1 00	80	1	
		12 20															0	4	b
Newglarus	30,31	0-2	None-Slight	95	>5	1.00	None	1 00	2-3 5	0	15-18	.95	Fine Silty/Clayey	90	Moderate	1 00	0	4	
		2-6	Slight	90	>5	1 00	None	1.00	2-3.5	0	15-18	95	Fine Silty/Clayey	90	Moderate	1 00	0	4	
		6-12	Severe	60	>5	1 00	None	1 00	2-3 5	0	15-18	.95	Fine Silty/Clayey	90	Moderate	1 00	0	4	
		12 30															0	4	b
Dunbarton	31s	–	–	–	>5	1.00	None	1 00	<1.5	0	–	–	Fine	–	Mod Slow	95	0	4	
Ashdale	33	2 6	Slight	90	>5	100	None	1 00	3 5-5	45	15-18	95	Fine Silty	90	Mod Slow	95	33	3	
		6-12	Moderate	80	>5	100	None	1 00	3 5-5	45	15-18	95	Fine Silty	90	Mod. Slow	95	29	3	

CONTINUED

a Landform – not a soil series
b Soil Phases with slopes greater than 12 percent.
c. Non-cultivated

TABLE C-1

SOIL PROPERTIES AND SUITABILITY FOR SLUDGE APPLICATION
MADISON METROPOLITAN SEWERAGE DISTRICT

SOIL NAME	MAPPING NUMBER	SLOPE PHASE (%)	ERODIBILITY CLASS.	ERODIBILITY POINTS	DEPTH TO SEASONAL HIGH WATER TABLE (feet)	DEPTH TO SEASONAL HIGH WATER TABLE POINTS	FLOOD HAZARD OCCUR.	FLOOD HAZARD POINTS	DEPTH TO BEDROCK (feet)	DEPTH TO BEDROCK POINTS	CATION EXCHANGE CAPACITY (Meq./100 gm)	CATION EXCHANGE CAPACITY POINTS	TEXTURE CLASS.	TEXTURE POINTS	PERMEABILITY CLASS.	PERMEABILITY POINTS	POINT RATING (0-100)	CLASS FOR SLUDGE APPLIC.	COMMENTS
Gale	34	2-6	Slight	90	> 5	1.00	None	1.00	1.5-3.5	0	12-15	85	Fine Silty/Sandy	80	Mod Slow	.95	0	4	
		6-12	Severe	60	> 5	1.00	None	1.00	1.5-3.5	0	12-15	85	Fine Silty/Sandy	80	Mod Slow	.95	0	4	
		12-45															0	4	b
Boone	37	2-6	None	1.00	> 5	1.00	None	1.00	< 3.5	0	3	20	Sandy	70	Rapid	85	0	4	
		6-12	None-Mod	90	> 5	1.00	None	1.00	< 3.5	0	3	.20	Sandy	70	Rapid	.85	0	4	
		12-20															0	4	b
Hersch	40,41,704	2-6	Slight	90	> 5	1.00	None	1.00	3.5	45	8-10	.70	Coarse Loamy	75	Moderate	1.00	.21	3	
		6-12	Slight	90	> 5*	1.00	None	1.00	3.5	45	8-10	.70	Coarse Loamy	.75	Moderate	1.00	.21	3	
		12-20															0	4	b
Rocky & Stony Land	42	–	–	–	> 6	1.00	None	1.00	0-2	0	–	–	Variable	–	–	–	0	4	a
Elkmound	45,635,636	–	–	–	> 5	1.00	None	1.00	< 1.5	0	–	–	Loamy	–	Mod. Rapid	.95	0	4	
Hixton	47	2-6	Slight	90	> 5	1.00	None	1.00	1.5-3.5	0	10-12	80	Fine Silty/Sandy	.75	Moderate	1.00	0	4	
		6-12	Severe	.60	> 5	1.00	None	1.00	1.5-3.5	0	10-12	.80	Fine Silty/Sandy	.75	Moderate	1.00	0	4	
		12-20															0	4	b
Eleva	48	2-6	Slight-Mod	.85	> 5	1.00	None	1.00	1.5-3.5	0	5-7	60	Coarse Loamy	.75	Moderate	1.00	0	4	
		6-12	Moderate	.80	> 5	1.00	None	1.00	1.5-3.5	0	5-7	.60	Coarse Loamy	75	Moderate	1.00	0	4	
		12-30															0	4	b
Ossian	51,215	–	–	–	0-1	0	Freq.	0	> 6	1.00	–	–	Fine Silty	–	Moderate	1.00	0	4	
St. Charles	61d	0-2	None-Slight	95	> 5	1.00	None	1.00	> 5	1.00	15-18	.95	Fine Silty	.90	Moderate	1.00	.81	1	
		2-6	Slight	.90	> 5	1.00	None	1.00	> 5	1.00	15-18	.95	Fine Silty	.90	Moderate	1.00	.77	1	
		6-12	Severe	.60	> 5	1.00	None	1.00	> 5	1.00	15-18	.95	Fine Silty	.90	Moderate	1.00	.51	2	
		12-30															0	4	b
Colwood	63,290	–	–	–	0-1	0	Freq	0	> 6	1.00	–	–	Fine Loamy	–	Moderate	1.00	0	4	
Granby	66,771	–	–	–	0-1	0	Occas	.40	> 6	1.00	–	–	Sandy	–	Moderate	1.00	0	4	
Fox	72,73	0-2	None-Slight	.95	> 5	1.00	None	1.00	> 6	1.00	10-18	.80	Fine Loamy/Sandy	.80	Moderate	1.00	.61	2	
		2-6	Slight	.90	> 5	1.00	None	1.00	> 6	1.00	10-18	.80	Fine Loamy/Sandy	.80	Moderate	1.00	.58	2	
		6-12	Severe	.60	> 5	1.00	None	1.00	> 6	1.00	10-18	.80	Fine Loamy/Sandy	.80	Moderate	1.00	.38	2	
		12-20															0	4	b
Rodman	75	2-30	Severe	.60	> 5	1.00	None	1.00	> 6	1.00	5	.55	Sandy Skeletal	.60	Rapid	.85	.17	3	c
Meridian	80	0-2	None	1.00	> 5	1.00	None	1.00	> 5	1.00	6	60	Fine Loamy/Sandy	75	Moderate	1.00	.45	2	
		2-6	Slight	90	> 5	1.00	None	1.00	> 5	1.00	6	.60	Fine Loamy/Sandy	.75	Moderate	1.00	.41	2	
		6-12	Severe	.60	> 5	1.00	None	1.00	> 5	1.00	6	.60	Fine Loamy/Sandy	.75	Moderate	1.00	.27	3	
		12-20															0	4	b
Chaseburg	82	0-2	None	1.00	3-5	.70	Freq	0	> 5	1.00	10-12	.80	Coarse Silty	1.00	Moderate	1.00	0	4	
		2-6	Slight	.90	3-5	.70	Freq	0	> 5	1.00	10-12	80	Coarse Silty	1.00	Moderate	1.00	0	4	
		6-12	Moderate	.80	3-5	.70	Freq	0	> 5	1.00	10-12	.80	Coarse Silty	1.00	Moderate	1.00	0	4	
Sumner	90	0-2	None	1.00	> 5	1.00	None	1.00	> 5	1.00	10-12	.80	Coarse Loamy	.80	Mod Rapid	.95	.61	2	
		2-6	Slight-Mod	.85	> 5	1.00	None	1.00	> 5	1.00	10-12	.80	Coarse Loamy	.80	Mod. Rapid	.95	.52	2	
Plano	91d	0-2	None	1.00	> 5	1.00	None	1.00	> 6	1.00	17	1.00	Fine Silty	90	Moderate	1.00	90	1	
		2-6	Slight	90	> 5	1.00	None	1.00	> 6	1.00	17	1.00	Fine Silty	90	Moderate	1.00	.81	1	
		6-12	Slight Mod	.85	> 5	1.00	None	1.00	> 6	1.00	17	1.00	Fine Silty	90	Moderate	1.00	.77	1	
Gotham	107G	0-2	None	1.00	> 5	1.00	None	1.00	> 5	1.00	5-6	55	Sandy	85	Rapid	.85	.40	2	
		2-6	None	1.00	> 5	1.00	None	1.00	> 5	1.00	5-6	55	Sandy	85	Rapid	.85	40	2	
		6-12	None Mod	90	> 5	1.00	None	1.00	> 5	1.00	5-6	55	Sandy	85	Rapid	.85	36	2	

a. Landform – not a soil series
b. Soil Phases with slopes greater than 12 percent
c. Non-cultivated

CONTINUED

TABLE C-1

SOIL PROPERTIES AND SUITABILITY FOR SLUDGE APPLICATION
MADISON METROPOLITAN SEWERAGE DISTRICT

SOIL NAME	MAPPING NUMBER	SLOPE PHASE (%)	ERODIBILITY CLASS.	ERODIBILITY POINTS	DEPTH TO SEASONAL HIGH WATER TABLE (feet)	DEPTH TO SEASONAL HIGH WATER TABLE POINTS	FLOOD HAZARD OCCUR.	FLOOD HAZARD POINTS	DEPTH TO BEDROCK (feet)	DEPTH TO BEDROCK POINTS	CATION EXCHANGE CAPACITY (Meq./100 gm)	CATION EXCHANGE CAPACITY POINTS	TEXTURE CLASS.	TEXTURE POINTS	PERMEABILITY CLASS.	PERMEABILITY POINTS	POINT RATING (0-100)	CLASS FOR SLUDGE APPLIC.	COMMENTS
Alluvial Land, Wet	111	–	–	–	0-1	0	Freq	0	>6	1.00	–	–	Variable	–	–	–	0	4	a
Warsaw	119	2-6	Slight	90	>5	1.00	None	1.00	>5	1.00	19	1.00	Fine Loamy/Sandy	80	Moderate	1 00	72	1	
		6-12	Severe	60	>5	1.00	None	1.00	>5	1.00	19	1.00	Fine Loamy/Sandy	80	Moderate	1 00	48	2	
Sogn	125	–	–	–	>5	1.00	None	1.00	<2	0	–	–	Loamy	–	Moderate	1 00	0	4	
Kickapoo	137	0-3	None	1.00	3-5	70	Occas	40	>5	1.00	10	70	Coarse Silty	85	Moderate	1 00	17	3	
Elburn-Gravelly Substratum	142G	–	–	–	1-3	0	Occas.	40	>5	1.00	–	–	Fine Loamy	90	Mod. Slow	95	0	4	
Rockton	149	2-6	Slight	90	>5	1.00	None	1.00	1.5-3 5	0	15	90	Fine Loamy	90	Moderate	1.00	0	4	
		6-12	Severe	60	>5	1.00	None	1.00	1.5-3 5	0	15	90	Fine Loamy	90	Moderate	1 00	0	4	
		12-20															0	4	b
Virgil	178d	–	–	–	1-3	0	Rare	80	>5	1.00	–	–	Fine Silty	–	Moderate	1.00	0	4	
Spinks	181b,784	0-2	None	1.00	>5	1.00	None	1.00	>5	1.00	5-6	55	Sandy	80	Mod. Rapid	95	42	2	
		2-6	None	1.00	>5	1.00	None	1.00	>5	1.00	5-6	55	Sandy	80	Mod. Rapid	95	42	2	
		6-12	None-Mod	90	>5	1.00	None	1.00	>5	1.00	5-6	55	Sandy	80	Mod Rapid	.95	38	2	
		12 45															0	4	b
Orion	197	–	–	–	1-3	0	Freq.	0	>5	1.00	–	–	Coarse Silty	–	Moderate	1.00	0	4	
Whalan	204,208	0-2	None-Slight	95	>5	1.00	None	1.00	1.5-3.5	0	12-15	85	Fine Loamy	1.00	Mod Slow	.95	0	4	
		2-6	Slight	90	>5	1.00	None	1.00	1.5-3.5	0	12-15	85	Fine Loamy	1.00	Mod Slow	95	0	4	
		6-12	Severe	60	>5	1.00	None	1.00	1.5-3.5	0	12-15	85	Fine Loamy	1.00	Mod. Slow	95	0	4	
		12-20															0	4	b
Elvers	210	–	–	–	0-1	0	Freq.	0	>5	1.00	–	–	Coarse Silty	–	Moderate	1 00	0	4	
Pectonica	223	2-6	Slight	90	>5	1.00	None	1.00	>5	1.00	15-18	.95	Fine Loamy	90	Moderate	1.00	77	1	
		6-12	Severe	60	>5	1.00	None	1.00	>5	1.00	15-18	.95	Fine Loamy	90	Moderate	1.00	51	2	
		12-20															0	4	b
Elburn	226	–	–	–	1-3	0	Occas.	40	>6	1.00	–	–	Fine Silty	–	Moderate	1 00	0	4	
Hayfield	233	0-2	None-Slight	95	3-5	70	None	1.00	>5	1.00	8-10	70	Fine Loamy/Sandy	.70	Moderate	1.00	33	3	
		2-6	Slight	90	3-5	70	None	1.00	>5	1.00	8-10	70	Fine Loamy/Sandy	.70	Moderate	1.00	31	3	
		6-12	Severe	60	3-5	70	None	1.00	>5	1.00	8-10	.70	Fine Loamy/Sandy	70	Moderate	1.00	21	3	
Westville	255,258	2-6	Slight	90	>5	1.00	None	1.00	>5	1.00	15-18	95	Fine Loamy	1.00	Moderate	1 00	86	1	
		6-12	Severe	60	>5	1.00	None	1.00	>5	1.00	15-18	95	Fine Loamy	1.00	Moderate	1 00	57	2	
		12-30															0	4	b
Virgil Silt Loam Gravelly Substratum	271,842	–	–	–	1-3	0	Rare	80	>5	1.00	–	–	Fine Silty	–	Mod. Slow	95	0	4	
Marcellon	276,458, 748	–	–	–	1-3	0	None	1.00	>5	1.00	–	–	Fine Loamy	–	Moderate	1 00	0	4	
Washtenaw	328	–	–	–	<1	0	Freq.	0	>5	1.00	–	–	Fine Loamy	–	Moderate	1 00	0	4	
Dodgeville	331	2 6	Slight	90	>5	1.00	None	1.00	3 5	45	12 15	85	Fine Silty/Clayey	90	Moderate	1 00	31	3	
		6-12	Severe	60	>5	1.00	None	1 00	3.5	45	12 15	85	Fine Silty/Clayey	90	Moderate	1 00	21	3	
		12 20															0	4	b

a Landform – not a soil series
b Soil Phases with slopes greater than 12 percent
c Non-cultivated

CONTINUED

TABLE C-1

SOIL PROPERTIES AND SUITABILITY FOR SLUDGE APPLICATION
MADISON METROPOLITAN SEWERAGE DISTRICT

SOIL NAME	MAPPING NUMBER	SLOPE PHASE (%)	ERODIBILITY CLASS.	ERODIBILITY POINTS	DEPTH TO SEASONAL HIGH WATER TABLE (feet)	DEPTH TO SEASONAL HIGH WATER TABLE POINTS	FLOOD HAZARD OCCUR.	FLOOD HAZARD POINTS	DEPTH TO BEDROCK (feet)	DEPTH TO BEDROCK POINTS	CATION EXCHANGE CAPACITY (Meq./ 100 gm)	CATION EXCHANGE CAPACITY POINTS	TEXTURE CLASS.	TEXTURE POINTS	PERMEABILITY CLASS.	PERMEABILITY POINTS	POINT RATING (0-100)	CLASS FOR SLUDGE APPLIC.	COMMENTS
Edmund	331s	–	–	–	>5	1.00	None	1.00	<1.5	0	–	–	Fine	–	Moderate	100	0	4	
Nippersink	354	0-2	None	1.00	>6	1.00	None	1.00	>6	1.00	15	.90	Fine Loamy	1.00	Moderate	1.00	.90	1	
		2-6	Slight	90	>6	1.00	None	1.00	>6	1.00	15	90	Fine Loamy	1.00	Moderate	1.00	81	1	
		6-12	Moderate	80	>6	1.00	None	1.00	>6	1.00	15	90	Fine Loamy	1.00	Moderate	1.00	72	1	
McHenry	355	0-2	None Slight	95	>5	1.00	None	1.00	>5	1.00	18	1.00	Fine Loamy	1.00	Moderate	1.00	95	1	
		2-6	Slight	90	>5	1.00	None	1.00	>5	1.00	18	1.00	Fine Loamy	1.00	Moderate	1.00	90	1	
		6-12	Mod Severe	70	>5	1.00	None	1.00	>5	1.00	18	1.00	Fine Loamy	1.00	Moderate	1.00	70	1	
		12-20															0	4	b
Kidder	356,358	2-6	Slight	90	>5	1.00	None	1.00	>5	1.00	15	90	Fine Loamy	1.00	Moderate	1.00	.81	1	
		6-12	Severe	60	>5	1.00	None	1.00	>5	1.00	15	90	Fine Loamy	1.00	Moderate	1.00	54	2	
		12-30															0	4	b
Wascousta	362	–	–	–	0-1	0	Freq.	0	>5	1.00	–	–	Fine Silty	–	Moderate	1.00	0	4	
Griswold	591,592	0-2	None-Slight	95	>6	1.00	None	1.00	>6	1.00	15	90	Fine Loamy	1.00	Moderate	1.00	.86	1	
		2-6	Slight	90	>6	1.00	None	1.00	>6	1.00	15	90	Fine Loamy	1.00	Moderate	1.00	.81	1	
		6-12	Severe	60	>6	1.00	None	1.00	>6	1.00	15	90	Fine Loamy	1.00	Moderate	1.00	.54	2	
		12-20															0	4	b
Hennepin	600	2-6	Moderate	80	>6	1.00	None	1.00	>6	1.00	15-20	95	Fine Loamy	95	Moderate	1.00	.72	1	
		6-12	Severe	60	>6	1.00	None	1.00	>6	1.00	15-20	95	Fine Loamy	95	Moderate	1.00	54	2	
		12-45															0	4	b
Ringwood	620	0-2	None-Slight	95	>5	1.00	None	1.00	>5	1.00	15	90	Fine Loamy	1.00	Moderate	1.00	.86	1	
		2-6	Slight	90	>5	1.00	None	1.00	>5	1.00	15	90	Fine Loamy	1.00	Moderate	1.00	.81	1	
		6-12	Severe	60	>5	1.00	None	1.00	>5	1.00	15	.90	Fine Loamy	1.00	Moderate	1.00	.54	2	
Radford	698	–	–	–	1-3	0	Freq	0	>6	1.00	–	–	Fine Silty	–	Moderate	1.00	0	4	
Oshtemo	708	0-2	None	1.00	>6	1.00	None	1.00	>6	1.00	8-10	70	Coarse Loamy	85	Mod. Rapid	.95	.57	2	
		2-6	Slight	90	>6	1.00	None	1.00	>6	1.00	8-10	70	Coarse Loamy	85	Mod. Rapid	95	.51	2	
		6-12	Severe	60	>6	1.00	None	1.00	>6	1.00	8-10	70	Coarse Loamy	85	Mod. Rapid	.95	.34	3	
		12-30															0	4	b
Mifflin	722	2-6	Slight	90	>5	1.00	None	1.00	3.5-4.5	.45	12-15	85	Fine Loamy	1.00	Moderate	1.00	.34	3	
		6-12	Severe	60	>5	1.00	None	1.00	3.5-4.5	.45	12-15	85	Fine Loamy	1.00	Moderate	1.00	.23	3	
		12-30															0	4	b
Watseka	724	–	–	–	1-3	0	Rare	80	>5	1.00	–	–	Sandy	.80	Rapid	.85	0	4	
Oakville	725	0-2	None	1.00	3-5	70	None	1.00	>6	1.00	5	55	Sandy	.80	Rapid	85	.26	3	
		2-6	None	1.00	3-5	70	None	1.00	>6	1.00	5	55	Sandy	.80	Rapid	85	.26	3	
		6-12	None-Mod	90	3-5	70	None	1.00	>6	1.00	5	55	Sandy	80	Rapid	85	24	3	
Troxel	752	0-2	None	1.00	3-5	70	Freq	0	>5	1.00	10	70	Fine Silty	1.00	Moderate	1.00	0	4	
		2-6	Slight	90	3-5	70	Freq	0	>5	1.00	10	70	Fine Silty	1.00	Moderate	1.00	0	4	
		6-12	Moderate	80	3-5	70	Freq	0	>5	1.00	10	70	Fine Silty	1.00	Moderate	1.00	0	4	
Plano, Gravelly Substratum	753	0-2	None Mod	90	3-5	70	None	1.00	>10	1.00	17	1.00	Fine Silty	85	Moderate	1.00	54	2	
		2-6	Mod Severe	70	3-5	70	None	1.00	>10	1.00	17	1.00	Fine Silty	85	Moderate	1.00	.42	2	
		6-12	Severe	60	3-5	70	None	1.00	>10	1.00	17	1.00	Fine Silty	.85	Moderate	1.00	.36	2	
Waukechon	755	–	–	–	0-1	0	Occas	40	>10	1.00	–	–	Coarse Loamy	–	Mod Rapid	95	0	4	
Arland	758	2-6	Slight	90	>6	1.00	None	1.00	>6	1.00	10	80	Fine Loamy/Sandy	85	Moderate	1.00	.61	2	
		6-12	Severe	60	>6	1.00	None	1.00	>6	1.00	10	80	Fine Loamy/Sandy	85	Moderate	1.00	.41	2	
		12-20											Fine Loamy/Sandy				0	4	b

a Landform – not a soil series
b Soil Phases with slopes greater than 12 percent
c. Non-cultivated

CONTINUED

TABLE C-1

SOIL PROPERTIES AND SUITABILITY FOR SLUDGE APPLICATION
MADISON METROPOLITAN SEWERAGE DISTRICT

SOIL NAME	MAPPING NUMBER	SLOPE PHASE (%)	ERODIBILITY CLASS.	ERODIBILITY POINTS	DEPTH TO SEASONAL HIGH WATER TABLE (feet)	DEPTH TO SEASONAL HIGH WATER TABLE POINTS	FLOOD HAZARD OCCUR.	FLOOD HAZARD POINTS	DEPTH TO BEDROCK (feet)	DEPTH TO BEDROCK POINTS	CATION EXCHANGE CAPACITY (Meq./100 gm)	CATION EXCHANGE CAPACITY POINTS	TEXTURE CLASS	TEXTURE POINTS	PERMEABILITY CLASS.	PERMEABILITY POINTS	POINT RATING (0-100)	CLASS FOR SLUDGE APPLIC	COMMENTS
Stoughton	761	0-2	None-Slight	95	>5	1.00	None	1.00	>5	1.00	10	.80	Fine Silty/Sandy	80	Moderate	1.00	61	2	
		2-6	Slight	90	>5	1.00	None	1.00	>5	1.00	10	80	Fine Silty/Sandy	80	Moderate	1.00	58	2	
		6-12	Severe	60	>5	1.00	None	1.00	>5	1.00	10	.80	Fine Silty/Sandy	80	Moderate	1.00	38	2	
		12-20															0	4	b
Basco	763,764	2-6	Mod.-Severe	70	>5	1.00	None	1.00	1.5-3.5	0	15	.90	Fine	85	Mod. Slow	95	0	4	
		6-12	Severe	.60	>6	1.00	None	1.00	1.5-3.5	0	15	90	Fine	.85	Mod. Slow	.95	0	4	
		12-30															0	4	b
Kegonsa	765	0-2	None-Slight	95	>5	1.00	None	1.00	>5	1.00	6	.60	Fine Silty/Sandy	.80	Moderate	1.00	.46	2	
		2-6	Slight	.90	>5	1.00	None	1.00	>5	1.00	6	.60	Fine Silty/Sandy	.80	Moderate	1.00	.43	2	
		6-12	Severe	.60	>5	1.00	None	1.00	>5	1.00	6	.60	Fine Silty/Sandy	.80	Moderate	1.00	.29	3	
		12-30															0	4	b
Batavia, Gravelly Substratum	766	0-2	None-Slight	.95	3-5	.70	None	1.00	>10	1.00	8	.65	Fine Silty	.90	Moderate	1.00	.39	2	
		2-6	Slight	.90	3-5	70	None	1.00	>10	1.00	8	.65	Fine Silty	90	Moderate	1.00	.37	2	
		6-12	Severe	.60	3-5	.70	None	1.00	>10	1.00	8	.65	Fine Silty	.90	Moderate	1.00	.25	3	
Grays	767	0-2	None-Slight	.95	3-5	.70	None	1.00	>6	1.00	15-18	.95	Fine Silty	1.00	Moderate	1.00	.63	2	
		2-6	Mod.-Severe	.70	3-5	.70	None	1.00	>6	1.00	15-18	.95	Fine Silty	1.00	Moderate	1.00	.47	2	
		6-12	Severe	.60	3-5	.70	None	1.00	>6	1.00	15-18	.95	Fine Silty	1.00	Moderate	1.00	.40	2	
		12-20															0	4	b
Derinda	768	0-2	None-Slight	.95	3-5	.70	None	1.00	2.0-3.5	0	15-18	.95	Fine	.95	Slow	.80	0	4	
		2-6	Slight	.90	3-5	.70	None	1.00	2.0-3.5	0	15-18	.95	Fine	.95	Slow	.80	0	4	
		6-12	Severe	.60	3-5	.70	None	1.00	2.0-3.5	0	15-18	.95	Fine	.95	Slow	.80	0	4	
Salter, Dark Surface Variant	772	0-2	None-Slight	.95	3-5	.70	None	1.00	>5	1.00	15-20	.95	Coarse Loamy	.80	Moderate	1.00	.51	2	
		2-6	Slight-Mod.	.85	3-5	.70	None	1.00	>5	1.00	15-20	.95	Coarse Loamy	.80	Moderate	1.00	.45	2	
Hebron	773	0-2	None-Slight	.95	3-6	.70	Rare	.80	>6	1.00	15-18	.95	Fine Loamy	1.00	Moderate	1.00	.50	2	
		2-6	Slight	.90	3-6	.70	Rare	.80	>6	1.00	15-18	.95	Fine Loamy	1.00	Moderate	1.00	.48	2	
		6-12	Severe	.60	3-6	.70	Rare	.80	>6	1.00	15-18	.95	Fine Loamy	1.00	Moderate	1.00	.32	3	
Sisson Acid Variant	774	0-2	None-Slight	.95	>5	1.00	None	1.00	>5	1.00	15-18	.95	Fine Loamy	1.00	Moderate	1.00	.90	1	
		2-6	Slight	90	>5	1.00	None	1.00	>5	1.00	15-18	.95	Fine Loamy	1.00	Moderate	1.00	.86	1	
		6-12	Mod.-Severe	.70	>5	1.00	None	1.00	>5	1.00	15-18	.95	Fine Loamy	1.00	Moderate	1.00	.68	1	
Kibbe Acid Variant	776	–	–	–	1-3	0	Rare	.80	>5	1.00	–	–	Fine Loamy	–	Moderate	1.00	0	4	
Terrace Escarpment	777	20-60	–	–	>5	1.00	None	1.00	>5	1.00	–	–	Sandy Skeletal	–	Mod. Rapid	95	0	4	a
Hillside Seep	778	–	–	–	0-3	0	Rare	.80	>5	1.00	–	–	Variable	–	–	–	0	4	a
Calamine	779	–	–	–	0-1	0	Occas.	.40	2.5-4.0	.60	–	–	Fine	–	Mod. Slow	95	0	4	
Colwood, Clayey Subsoil Variant	780	–	–	–	0-1	0	Freq.	0	>5	1.00	–	–	Fine	–	Mod. Slow	95	0	4	
Manawa	781,782	–	–	–	1-3	0	Occas.	40	>6	1.00	–	–	Fine	–	Mod. Slow	.95	0	4	
Nekoosa	783	0-3	None	100	3-5	.70	Rare	80	>5	1.00	5-6	.55	Sandy	–	Rapid	.85	.22	3	
Lamont	785	0-2	None	100	>5	1.00	None	1.00	>5	1.00	5	.55	Coarse Loamy	.85	Mod. Rapid	.95	.44	2	
		2-6	Slight	.90	>5	1.00	None	1.00	>5	1.00	5	.55	Coarse Loamy	.85	Mod. Rapid	.95	.40	2	
		6-12	Severe	.60	>5	1.00	None	1.00	>5	1.00	5	.55	Coarse Loamy	85	Mod. Rapid	.95	.27	3	
		12-45															0	4	b
Mazo	786	2-6	None	100	>5	1.00	None	1.00	>5	1.00	5-6	55	Sandy	80	Mod. Rapid	.95	.42	2	
		6-12	None-Mod.	.90	>5	1.00	None	1.00	>5	1.00	5-6	.55	Sandy	.80	Mod. Rapid	.95	.38	2	
Dells	787	–	–	–	1-3	0	Rare	.80	>5	1.00	–		Fine Silty/Sandy	–	Moderate	1.00	0	4	
Joy	789	–		–	1-3	0	Freq.	0	>6	1.00	–		Fine Silty/Sandy	–	Moderate	1.00	0	4	

a Landform – not a soil series
b Soil Phases with slopes greater than 12 percent
c Non cultivated

SLUDGE REUSE
PROGRAM MANAGEMENT TOOLS **D**

Appendix D
SLUDGE REUSE PROGRAM MANAGEMENT TOOLS

This appendix contains examples of tools which should be used to manage the sludge reuse program. These tools consist of a permanent record, an annual record, and procedures for determining sludge application rates.

D.1 THE PERMANENT RECORD

The permanent record will contain basic identification, a report on detailed site investigation, and a record of sludge applications and monitoring data.

Basic Identification

This record will be opened during the initial interview. It will contain the sludge user's identification, name, address and phone number, and field identification. An example form is shown as Table D-1. The field identification will include a reference number, acreage, and legal description of location (i.e., NE1/4 of NW1/4 of Section 21 of Town of Dunn). Agricultural Stabilization and Conservation Service (ASCS) section maps should also be included which outline the boundaries and include the reference numbers for all fields. These same maps will also be marked up with the site investigator's comments and buffer area notes. A marked up example ASCS map is included as Figure D-1.

Detailed Site Investigation

Another permanent record will be required which reports the findings of the site investigation. This form will be used by the program manager as he walks over each site and will contain a checklist of factors he should investigate. This form will also include the field identification, site investigator's name, date of investigation, and restrictions for sludge application. An example Site Investigation Checklist is shown as Table D-2.

Record of Data

All of the monitoring data and records of sludge applications must be kept in the sludge user's permanent file. Example data forms are shown as Tables D-3 through D-5 for the soils, crop, and ground-water monitoring records. An example form for recording sludge applications is shown as Table D-6. The zinc equivalent metal loading, as computed in Section D.3, should also be recorded on this form for use in determining the total allowable sludge application to the site. Copies of the Sludge User and Field Identification Form and marked up ASCS maps should be given to the sludge users for use in planning their farming operations.

D.2 THE ANNUAL RECORD

A record of the activities on every field receiving sludge will be prepared and a copy given to the sludge user each year for his records. The information needed for MMSD's permanent records will be taken from the annual records. The annual record will contain the following: the crop grown; the sludge application rate; the sludge quality data as applied; and the soil, crop, and ground-water monitoring data for the year. A form for the Annual Record is shown as Table D-7.

D.3 TOTAL SLUDGE APPLICATION RATE DETERMINATION

Explanation

As shown in Section 6.3, there are several bases on which to limit total application. For this sludge reuse program, we recommend, as an interim guide, the zinc equivalent equation to calculate maximum sludge loading in relation to metal toxicity to plants because it is most conservative.

Maximum Sludge Application (tons dry solids/acre) =

$$\frac{32{,}500 \times \text{CEC}}{(\text{ppm Zn})+2(\text{ppm Cu})+4(\text{ppm Ni})}$$

where CEC represents cation exchange capacity of nonsludged soil in meq/100g and the sludge metals are expressed in ppm or mg/kg solids. The 32,500 represents a conversion factor. The equation is based on the hypotheses that (a) CEC is related to soil factors controlling metal availability in soils, and (b) that Cu is 2 times and Ni 4 times as toxic to plants as Zn. It limits metal additions to 10 percent of soil CEC. There is to date no experimental evidence to support or refute this equation, and it must be regarded as empirical and subject to revision.

The equation is difficult to use because of the inherent variability of sludges with source and time. The equation,

TABLE D-1

SLUDGE USER AND FIELD IDENTIFICATION

MADISON METROPOLITAN SEWERAGE DISTRICT

SLUDGE USER IDENTIFICATION

NAME JOHN DOE PHONE 241-6917

ADDRESS BOX 21
ROUTE 3
MADISON, WISCONSIN

FIELD INFORMATION AND IDENTIFICATION

REFERENCE NUMBER	ACREAGE	FIELD LOCATION
1	45	E 1/2, NE 1/4, NW 1/4, SEC. 21 DUNN
2	15	E 1/2, NE 1/4, NW 1/4, SEC. 21 DUNN
3	50	E 1/2, NE 1/4, NW 1/4, SEC. 21 DUNN
4	42	W 1/2, NE 1/4, NW 1/4, SEC. 21 DUNN
5	40	W 1/2, NE 1/4, NW 1/4, SEC. 21 DUNN

OTHER COMMENTS: HAS ANOTHER 125 ACRES IN TOWN OF FITCHBURG.

AGREEMENTS FOR PERMANENT FACILITIES: WOULD LIKE ON-FARM STORAGE LAGOON, CONTACT AGAIN IN SPRING TO DISCUSS FURTHER.

NOTE:

COMMENTS ON MAP TO BE BASED ON A FIELD INSPECTION OF SITE.

FIGURE D-1

MAP OF SLUDGE USER'S LAND

MADISON METROPOLITAN
SEWERAGE DISTRICT
MADISON, WISCONSIN

CH2M HILL

S9166.0

TABLE D-2

SITE INVESTIGATION CHECKLIST
MADISON METROPOLITAN SEWERAGE DISTRICT

SLUDGE USER NAME JOHN DOE
FIELD REFERENCE NUMBER 5
FIELD CONDITION WHEN INSPECTED PLOWED

INSPECTION PERFORMED BY GJH
DATE OF INSPECTION 8-3-76

Place a check mark (√) beside all factors investigated and describe location of particular factors and problems as applicable. Determine and describe here and on ASCS map location the size of buffer strips and allowable methods of sludge application. Describe or show on ASCS map the location of different soil classes.

FACTORS — **DISCUSSION OF EACH FACTOR**

(✓) EROSION NO EVIDENCE OF EROSION, GENTLE SLOPES
(✓) FLOOD HAZARD NONE
(✓) WET SPOTS NONE
(✓) CITY BOUNDARY NONE
(✓) GARDEN AREAS NEAR HOUSE
(✓) STREAMS ALONG EAST SIDE
(✓) NEIGHBORS

NAME	LOCATION	CONTACTED	COMMENTS
JOE SMITH	ACROSS ROAD	✓	NO OBJECTIONS
	ON S.		
RIM ROCK HOUSING	ON SE		USE SOIL INJECTION
DEVELOP	CORNER		

(✓) WELLS OR SPRINGS WELL "A" NEAR HOUSE DOMESTIC USE
(✓) BUFFERS

LOCATION	WIDTH	COMMENTS
DITCH EAST	50'	
SIDE		
AROUND HOUSE		PROVIDED BY FENCE

(✓) SUITABLE APPLICATION METHODS SOIL INJECTION ONLY
(✓) SOIL CLASSES

	LOCATION	COMMENTS
1. VERY SUITABLE	ALL EXCEPT AS NOTED	GENTLE SLOPE
2. SUITABLE	≈ 5 AC. SE. CORNER	GOOD DRAINAGE
3. SUITABLE W/ LIMITATIONS	NONE	
4. NOT SUITABLE	NONE	

(✓) BACKGROUND CHEMICAL ANALYSIS:

The following background data has been collected and is on file.
SOIL CHEMICAL ANALYSIS DATE 9-9-76
GROUND WATER CHEMICAL ANALYSIS DATE 9-9-76

TABLE D-3

SOIL MONITORING DATA
MADISON METROPOLITAN SEWERAGE DISTRICT

SLUDGE USER NAME JOHN DOE FIELD REFERENCE NO. 5

SOIL BACKGROUND CONDITION

Sample No.	5-1	5-2	5-3			AVERAGE
Location	SEE MAP	SEE MAP	SEE MAP			
Date	9-9-76	9-9-76	9-9-76			9-9-76
Cation Exchange Capacity meq/100 g	9	12	9			10
Electrical Conductivity, µmho/cm	136	109	124			123
Calcium, mg/kg	1600	1500	1900			1700
Magnesium, mg/kg	800	900	1100			930
Sodium, mg/kg	100	120	90			130
Iron, mg/kg	1.2	1.5	1.6			1.4
Aluminum, mg/kg	190	181	192			188
Zinc, mg/kg	0.11	0.19	0.02			0.11
Copper, mg/kg	0.05	0.09	0.03			0.06
Nickel, mg/kg	0.02	0.01	0.02			0.02
Cadmium, mg/kg	<.01	<.01	<.01			<.01
Molybdenum, mg/kg	0.01	0.03	0.05			0.03
Mercury, mg/kg	0.01	0.01	0.03			0.02
Manganese, mg/kg	0.02	0.009	0.01			0.01
Boron, mg/kg	1.0	1.2	1.2			1.1

ANNUAL SOIL SAMPLING

DATE	SAMPLE NUMBER	LOCATION	AVAILABLE PHOSPHORUS (mg/kg)	POTASSIUM (mg/kg)	ORGANIC CARBON (%)	pH
9-9-76	5-A	COMPOSITE, FIELD 5	34	16	2.1	6.7
9-15-77	5-B	COMPOSITE, FIELD 5	51	19	2.4	6.6
8-3-78	5-C	COMPOSITE, FIELD 5	42	28	2.9	6.8

TABLE D-4

CROP MONITORING DATA

MADISON METROPOLITAN SEWERAGE DISTRICT

SLUDGE USER NAME JOHN DOE

FIELD REFERENCE NO. 5

DATE	CROP	SAMPLE NO.	B	Cd	Cu	Mn	Hg	Ni	Zn	As	Cr	Co	Pb	Mo	Se	V	COMMENTS
9-77	CORN	5-1	10	.06	21	23	.009	.02	23	.01	.1	.02	0.9	.3	.07	.2	
9-78	CORN	5-2	15	.05	29	21	.002	.02	21	.01	.1	.01	1.2	.3	.07	.2	10% BETTER YIELD VS. '77
8-79	CORN	5-3	11	.09	30	27	.003	.03	42	.01	.1	.02	0.3	.2	.08	.2	

DATA IS IN TERMS OF µg/g DRY WEIGHT.

TABLE D-5

GROUND WATER MONITORING DATA
MADISON METROPOLITAN SEWERAGE DISTRICT

SLUDGE USER NAME JOHN DOE

FIELD REFERENCE NO. 5

SAMPLE NUMBER	SAMPLE DATE	LOCATION	TYPE OF SOURCE (WELL OR SPRING)	USE OF GROUND WATER	NO_3 (mg/l)	TDS (mg/l)	INITIAL SAMPLES ONLY MBAS (mg/l)	Coliform (MPN/100 ml)	Hg (mg/l)	As (mg/l)
A-1	9-9-76	WELL A	WELL	DOMESTIC	2.0	90	<.1	.01	.00005	<.001
A-2	9-9-76	WELL B	WELL	IRRIGATION	6.0	64	<.1	.04	.0001	.002
B-1	5-4-79	WELL A	WELL	DOMESTIC	3.0	78				
B-2	5-4-79	WELL B	WELL	IRRIGATION	5.0	70				

COMMENTS:

TABLE D-6

SLUDGE APPLICATION RECORDS

MADISON METROPOLITAN SEWERAGE DISTRICT

SLUDGE USER NAME JOHN DOE　　　FIELD REFERENCE NO. 5

DATE APPLIED	SLUDGE APPLICATION RATE (ton/acre)	METAL EQUIVALENTS CONTENT (lbs/acre)	ACCUMULATED METAL CONTENT (lbs/acre)	CROP GROWN	NOTES
4-2-77	3.1	23	23	CORN	
4-9-78	2.9	22	45	CORN	10% BETTER YIELD
5-2-79	1.8	14	59	OATS	WET SPRING
4-8-80	3.0	23	82	CORN	
4-10-81	2.8	21	103	CORN	
10-3-81	1.4	11	114	WHEAT	WINTER COVER CROP

TOTAL ALLOWABLE SLUDGE APPLICATION FOR THIS FIELD 87 tons/acre.
TOTAL ALLOWABLE METAL EQUIVALENTS LOADING FOR THIS FIELD 650 lbs/acre.

TABLE D-7

ANNUAL RECORD

MADISON METROPOLITAN SEWERAGE DISTRICT

SLUDGE USER NAME JOHN DOE

FIELD REFERENCE NO. 5

CROP YEAR 1977

PARAMETER	SLUDGE	SOIL	CROP	GROUND WATER WELL A
Total Kjeldahl Nitrogen	58,000 mg/kg			
Ammonia Nitrogen	51,000 mg/kg			
Phosphorus	13,000 mg/kg	51 mg/kg		
Potassium	1,500 mg/kg	19 mg/kg		
Total Solids	2.3 %			
Total Volatile Solids (organic carbon)	1.5 %	2.4 %		
Total Dissolved Solids	9,000 mg/l			
pH	8.2	6.6		
Iron	8,850 mg/kg	1.4 mg/kg		
Zinc	2,370 mg/kg	0.11 mg/kg	23 μg/g	
Copper	525 mg/kg	0.06 mg/kg	21 μg/g	
Titanium	< 90 mg/kg			
Lead	286 mg/kg		0.9 μg/g	
Barium	1,140 mg/kg			
Chromium	234 mg/kg		.1 μg/g	
Manganese	189 mg/kg	0.01 mg/kg	2.3 μg/g	
Nickel	81 mg/kg	0.02 mg/kg	.02 μg/g	
Tin	< 10 mg/kg			
Cadmium	73 mg/kg	< .01 mg/kg	.06 μg/g	
Molybdenum	< 10 mg/kg	0.03 mg/kg	.3 μg/g	
Arsenic	14 mg/kg		.01 μg/g	< .001 mg/l
Boron	300 mg/kg	1.1 mg/kg	10 μg/g	
Selenium	< 4 mg/kg		.07 μg/g	
Mercury	11.6 mg/kg	0.02 mg/kg	.009 μg/g	.00005 mg/l
Sulfate	335 mg/kg			
Alkalinity @ pH 4.5	5,950 mg/kg			
Alkalinity @ pH 4.2	6,450 mg/kg			
Calcium	51,200 mg/kg	1700 mg/kg		
Magnesium	8,970 mg/kg	930 mg/kg		
Sodium	10,100 mg/kg	103 mg/kg		
Cation Exchange Capacity		10 meq/100g		
Electrical Conductivity		123 umhos/cm		70 umhos/cm
Vanadium			.2 μg/g	
Cobalt			.02 μg/g	
MBAS				< .1 mg/l
Nitrate-Nitrogen				2.0 mg/l
Coliform				.01 MPN/100ml

CROP GROWN CORN

AVAILABLE NITROGEN APPLICATION 125 lbs/acre.

PHOSPHORUS APPLICATION 134 lbs/acre.

POTASSIUM APPLICATION 62 lbs/acre.

SLUDGE APPLICATION 3-1 tons/acre.

as written, allows accounting for annual sludge application. Since the metal content of sludge can vary, this cannot be easily accounted for with the equation as written. However, the equation can readily be modified to permit calculation of total allowable metal loadings on a lbs per acre basis as:

Total Allowable Metal Application, lbs/acre = 65 x (CEC)

where metal equivalents of sludge applied (lb/ton of sludge) are:

Metal Equivalent Content, lbs/ton of sludge =

$$\frac{(\text{ppm Zn})+2(\text{ppm Cu})+4(\text{ppm Ni})}{500}$$

The value 500 converts parts per million to pounds per ton. The total sludge application is thus a matter of an accounting of yearly metal equivalent loadings until the maximum permitted loading is reached.

In addition to the metal equivalents' limitations, Cd additions must be limited to a maximum of 2 lbs per acre per year with a total lifetime maximum of 20 lbs per acre.

These limitations on heavy metal loading based on plant toxicity effects also will protect the ground water from metal contamination due to overloading of sludge on sites which meet the criteria outlined in Chapter 6. An example calculation for sludge application rate based on the Zn, Cu, Ni, and Cd content is presented below:

Sample Calculation:

Sludge metals (ppm); Zinc (Zn) = 2,370; Copper (Cu) = 525; Nickel (Ni) = 81; Cadmium (Cd) = 73. Application site soil CEC = 10 meq/100g soil.

1. Total allowable metal equivalent loading =

   65 x CEC = 650 lbs/acre.

2. Sludge metal equivalent per ton =

   $$\frac{2,370+2(525)+4(81)}{500} = \frac{3,744}{500} =$$

   7.5 lbs metal equivalents per ton of sludge.

3. Total loading permitted = $\frac{650}{7.5}$ = 87 tons/acre.

4. Check cadmium limitation.

   4a. Yearly loading limit due to Cd =

   $$\frac{2 \times 500}{\text{ppm Cd}} = \frac{2 \times 500}{73} =$$

   13.7 tons sludge/acre for 2 lbs of Cd.

   Where 500 is a conversion factor.

   4b. Total Cd loading permitted = 137 tons sludge/acre for 20 lbs of Cd.

Based on these calculations, the total sludge application for a soil with a CEC of 10 meq/100g is limited by the zinc equivalent which allows a total application of 87 tons to the soil.

The procedures just described for determining the total sludge application rate are as suggested in the WDNR guidelines. For this reuse program the total sludge application rate should be reduced by one-fourth for land which will grow vegetables for direct human consumption. The total loading should also be reduced by one-half for land growing leafy vegetables. A total sludge application worksheet is shown as Table D-8.

D.4 ANNUAL SLUDGE APPLICATION RATE DETERMINATION EXPLANATION

The annual sludge application rate is based upon the crop nitrogen requirement and the amount of available nitrogen contained in the sludge. As discussed in Section 6.3, the basis of the criteria is to assure that no excess nitrates will leach into the ground water due to an excess application of sludge nitrogen that cannot be used by the crop.

The crop nitrogen requirement will be estimated from the results of the soil monitoring described in Appendix E. Lacking a soil test, the crop nitrogen requirements can be estimated from the data given in Table 6-3.

The available nitrogen content of the sludge will be based on a laboratory analysis of sludge and estimated values for volatilization of ammonia and mineralization rates of organic nitrogen. Residual nitrogen availability from previous

TABLE D-8

TOTAL SLUDGE APPLICATION RATE WORKSHEET

MADISON METROPOLITAN SEWERAGE DISTRICT

SLUDGE USER NAME: JOHN DOE

FIELD REFERENCE NO.: 5

SLUDGE CHARACTER

ZINC CONTENT (Zn) = 2370 mg/kg
COPPER CONTENT (Cu) = 525 mg/kg
NICKEL CONTENT (Ni) = 81 mg/kg
CADMIUM CONTENT (Cd) = 73 mg/kg

CROPS WHICH MAY BE GROWN ON SITE

( ) VEGETABLES FOR DIRECT HUMAN CONSUMPTION
( ) LEAFY VEGETABLES
(✓) OTHER CROP TYPES ONLY

AVERAGE SOIL CATION EXCHANGE CAPACITY

CEC = 10 meq/100 g.

COMPUTATION BY ZINC EQUIVALENT METHOD

ALLOWABLE TOTAL METAL EQUIVALENT APPLICATION

(A) = 65 x CEC = 65 x 10 = 650 lbs/acre.

SLUDGE METAL EQUIVALENT

$$(E) = \frac{(Zn) + 2\ (Cu) + 4\ (Ni)}{500} = \frac{(2370) + 2\ (525) + 4\ (81)}{500} = 7.5 \text{ lbs/dry ton sludge.}$$

ZINC EQUIVALENT SLUDGE APPLICATION LIMIT

$$(M) = \frac{A}{E} = \frac{650}{7.5} = 87 \text{ dry tons sludge/acre.}$$

COMPUTATION BY CADMIUM METHOD

CADMIUM APPLICATION LIMIT

$$(C) = \frac{20 \times 500}{(Cd)} = \frac{20 \times 500}{(73)} = 137 \text{ dry tons sludge/acre.}$$

TOTAL ALLOWABLE SLUDGE LOADING FOR GENERAL CROPS

IS THE LESSER OF M AND C. FOR THIS SITE IT IS (T) = 87 dry tons sludge/acre.

SPECIAL CROP LIMITATIONS

LOADING ON VEGETABLES FOR DIRECT HUMAN CONSUMPTION =
.75 x (T) = .75 x ______ = __________ dry tons sludge/acre.

LOADING ON LEAFY VEGETABLES =
.50 x (T) = .50 x ______ = __________ dry tons sludge/acre.

TOTAL ALLOWABLE SLUDGE APPLICATION FOR THIS SITE IS 87 dry tons sludge/acre.

years of sludge application is not computed because (1) it is negligible compared to the annual requirement, and (2) it will be partially accounted for in the recommended soil testing program.

Following are two example calculations of the annual application rate. One is for use of the treatment plant sludge, and the other for lagoon sludge.

Sample Calculation 1 - Treatment Plant Sludge.

Assume: Nitrogen content: 5.5% ammonia N, 5.0% organic N
Crop: Grain corn
Sludge application method: Surface applied, no soil incorporation
Soil Class: 3

Annual Application Rate, (dry tons/acre/year) = $\frac{W}{N}$.

Where:

1. W = Total crop nitrogen requirement in lbs N/acre. Since we have no soil test, use 125 lbs N/acre for a grain corn crop as shown in Table 6-3.

   W = 125 lbs N/acre

2. N = Total available nitrogen content of sludge in lbs N/dry ton = Namm + Norg.

Where:

2a. Namm = available ammonia N or

Namm = % ammonia in sludge x availability coeff. x 20. The value 20 is a conversion factor.

- If sludge is soil incorporated, use an availability coeff. of 1.0.
- If sludge is surface applied, use an availability coeff. of 0.5.

Therefore, for this example:

Namm = 5.5 x 0.5 x 20 = 55 lbs/ton

Namm = 55 lbs N/ton.

2b. Norg = available organic N or

Norg = % organic x availability coeff. x 20.

- Use an availability coeff. of 0.20 which is based on an estimated mineralization rate for the first year of 20%.

Therefore, for this example:

Norg = 5.0 x 0.2 x 20 = 20 lbs/ton

<u>Norg = 20 lbs N/ton</u>.

2c. N = Namm + Norg = 55 + 20 = 75

<u>N = 75 lbs N/ton</u>.

3. Annual Application Rate = $\frac{W}{N}$

$$= \frac{125 \text{ lbs N/acre}}{75 \text{ lbs N/dry ton sludge}}$$

= 1.7 dry tons/acre/year.

4. Check the cadmium limitation, the computation of which is shown in Section D.3. Use whichever is smaller, the annual application rate computed in Step 3 or the cadmium limitation. For this example, it is assumed that cadmium is not limiting since it appears that 13.7 tons per acre per year are required to reach 2 pounds of cadmium per acre.

5. Check Soil Class 3 limitation. Reduce the annual sludge application rate by one-third if the site is on Class 3 soils. The equation is:

   Soil Class 3 Annual Application Rate = 0.67 x annual application rate determined in Step 4.

   Therefore, for this example and Class 3 soils:

   <u>Annual Application Rate</u> = 0.67 x 1.7 = <u>1.1 dry tons/acre/year</u>.

Based on the foregoing, the application rate would be 1.1 dry tons per acre per year because of the Class 3 soil limitation.

Sample Calculation 2 - Lagoon Sludge.

Assume: Nitrogen content: 1.2% ammonia, 4.6% organic
Crop: Grain corn
Sludge application method: soil injection
Soil Class: 1

1. W = total crop nitrogen requirement = 125 lbs N/acre, from Table 6-3.

2. N = Total available N content sludge = Namm + Norg.

   2a. Namm = % ammonia x available coeff. x 20 = 1.2 x 1.0 x 20 = 24 lbs/ton.

   2b. Norg = % org. x available coeff. x 20 = 4.6 x 0.20 x 20 = 18.4.

   2c. N = Namm + Norg = 20 + 18.4 = 38.4 lbs/ton.

3. Annual Application Rate = $\frac{W}{N} = \frac{125}{38.4}$.

   Annual Application Rate = 3.25 dry tons/acre/year.

4. Check cadmium limitation. Again, as in Example 1, cadmium is not limiting.

5. Check for Class 3 soils limitations. None.

Based on the foregoing, the application rate would be 3.25 tons per acre per year.

The foregoing calculations are easily adapted to a worksheet format, an example of which is shown in Table D-9.

TABLE D-9

ANNUAL SLUDGE APPLICATION RATE WORKSHEET

MADISON METROPOLITAN SEWERAGE DISTRICT

SLUDGE USER NAME: JOHN DOE

FIELD REFERENCE NO.: 3

NITROGEN CONTENT OF SLUDGE IS 5.5 % AMMONIA, 5.0 % ORGANIC

CROP TO BE GROWN IS CORN (GRAIN)

SLUDGE APPLICATION METHOD TRUCK SPREADER

THE MAJOR SOIL CLASS IS 1 2 (3) CIRCLE ONE

CADMIUM CONTENT OF SLUDGE IS 73 mg/kg.

TOTAL CROP NITROGEN REQUIREMENT, W (lbs/acre) IS 125 (FROM SOIL TEST OR TABLE 6-3).

AVAILABLE AMMONIA NITROGEN = % AMMONIA x AVAILABLE COEFFICIENT x 20

Namm = 5.5 x .5 x 20 = 55 lbs. N/ton.

FOR SURFACE APPLICATION USE AVAILABLE COEFFICIENT = 0.5.
FOR SUBSURFACE APPLICATION USE AVAILABLE COEFFICIENT = 1.0.

AVAILABLE ORGANIC NITROGEN = % ORGANIC x AVAILABLE COEFFICIENT x 20

Norg = 5.0 x .20 x 20 = 20 lbs. N/ton.

UNTIL FURTHER NOTICE, USE AVAILABLE COEFFICIENT = 0.20.

TOTAL AVAILABLE NITROGEN, N = Namm + Norg = 55 + 20 = 75 lbs. N/ton.

1. ANNUAL APPLICATION RATE = $\frac{W}{N}$ = (A) = $\frac{125}{75}$ = 1.7 dry tons/acre/year.

2. CHECK CADMIUM LIMITATION: $\frac{2 \times 500}{(\text{mg/kg cadmium})} = \frac{2 \times 500}{(73)}$ = 13.7 dry tons/acre/year.

3. CHECK SOIL CLASS. IF SOIL CLASS 3, USE:
   APPLICATION RATE = 0.67 x (A)=0.67 x 1.7 = 1.1 dry tons/acre/year.

4. USE THE LESSER OF COMPUTATION 1 OR 2, UNLESS CLASS 3 SOIL; THEN USE THE LESSER OF COMPUTATION 2 OR 3.

   RECOMMENDED ANNUAL SLUDGE APPLICATION IS 1.1 dry tons/acre/year.

Appendix E
MONITORING PROGRAM

The sludge reuse program should be monitored to protect the environment, provide farmer confidence in the program, and comply with requirements by regulatory agencies. The monitoring program will include sampling and analysis of the sludge, soils, crops, and ground water. The objectives and procedures for each part of the monitoring program are discussed in detail in this appendix. The estimated costs of the monitoring program are presented in Table B-13.

E.1 SLUDGE MONITORING

Objective

The sludge will be monitored for two purposes: characterization and documentation. The sludge will be characterized periodically to establish the quality. To document the actual quantity and quality of sludge applied, samples will be taken as sludge is applied to land.

Description

The sludge in the existing lagoons has already been characterized as a part of this planning study (see Chapter 5). Therefore, only the digester and storage lagoon sludges need to be periodically characterized. This will be done by monthly sampling and analysis of digester sludge for solids content, total Kjeldahl and ammonia nitrogen, phosphorus, potassium, cadmium, zinc, copper, and nickel. Sludge characterization monitoring will also include quarterly sampling of the digesters and storage lagoon for complete characterization. Complete characterization will consist of determining the following: total Kjeldahl and ammonia nitrogen, total phosphorus, potassium, total solids, total volatile solids, total soluble salts, pH, iron, zinc, copper, titanium, lead, barium, chromium, manganese, nickel, tin, cadmium, molybdenum, arsenic, boron, selenium, mercury, sulfate, alkalinity as $CaCO_3$ at pH 4.5 and pH 4.2, calcium, magnesium, and sodium.

The documentation sampling and analysis will consist of collecting a composite sample from each sludge source, digesters, storage lagoon, existing lagoon, or small on-farm lagoon that is used each day. These composite samples will be analyzed for total solids and total Kjeldahl and ammonia nitrogen.

Sampling Procedures

The periodic samples for characterization will be collected as grab samples. The sludge samples will be collected from a point within the distribution system to ensure that the samples are representative of the sludge that is eventually applied onto fields. Preservatives must be added to the sludge samples unless the analyses are performed on the day collected. Two samples at each sampling point must be taken; one preserved by mercuric chloride for nitrogen and total solids analyses, and one preserved by nitric acid for heavy metal analyses. The preservatives can be added in the laboratory to avoid handling them in the field. Methods of preservation are explained in *Standard Methods for the Examination of Water and Wastewater.*

The daily samples for documentation will consist of several subsamples collected throughout the day and composited into a single sample for analysis. If sludge is being taken from more than one of the sludge sources (the digesters, storage lagoon, existing lagoons, or small on-farm lagoons), a composite sample must be collected from each source. If the sludge is hauled by tanker truck, a subsample should be taken from each truckload. If the sludge is transported by pipeline for direct application to land, hourly subsamples should be collected directly from the pipeline. Each composite sludge sample should be preserved by mercuric chloride for the total solids and nitrogen analyses.

The sampling devices and sample containers must be cleaned of all growths of sewage organisms before every use.

Analysis Procedures

Table E-1 lists the references on methods for laboratory analysis of each sludge constituent.

E.2 SOIL MONITORING

Objective

The objectives of soil monitoring are to determine the condition of the soil before the initial sludge application and to determine the nutrient and pH status of the soil while sludge is being used. These parameters must be determined to set the total and annual sludge application rates and the lime requirement.

TABLE E-1

SLUDGE ANALYSIS PROCEDURES REFERENCES
MADISON METROPOLITAN SEWERAGE DISTRICT

PARAMETER	SAMPLE PREPARATION	QUANTITATIVE DETERMINATION
Total Kjeldahl Nitrogen	EPA, 1974, p. 175	EPA, 1974, p 165
Ammonia Nitrogen	EPA, 1974, p. 165	EPA, 1374, p. 165
Total Phosphorus	EPA, 1969, p. 18	EPA, 1974, p. 249
Potassium	EPA, 1969, p. 18	EPA, 1974, p. 143
Total Solids	EPA, 1974, p. 270	EPA, 1974, p. 270
Total Volatile Solids	EPA, 1974, p. 272	EPA, 1974, p. 272
Total Soluble Salts	Chapman and Pratt, 1961, p. 234	Chapman and Pratt, 1961, p. 234
pH	EPA, 1974, p. 239	EPA, 1974, p. 239
Boron (hot water soluble)	Chapman and Pratt, 1961, p. 246	EPA, 1974, p. 13
Mercury	EPA, 1974, p. 137	EPA, 1974, p. 137
Iron	Epstein, et al, 1975, p. 22	Follow methods manual supplied with AA unit
Zinc	Epstein, et al, 1975, p. 22	Follow methods manual supplied with AA unit
Copper	Epstein, et al, 1975, p. 22	Follow methods manual supplied with AA unit
Titanium	Epstein, et al, 1975, p, 22	Follow methods manual supplied with AA unit
Lead	Epstein, et al, 1975, p. 22	Follow methods manual supplied with AA unit
Barium	Epstein, et al, 1975, p, 22	Follow methods manual supplied with AA unit
Chromium	Epstein, et al, 1975, p. 22	Follow methods manual supplied with AA unit
Manganese	Epstein, et al, 1975, p. 22	Follow methods manual supplied with AA unit
Nickel	Epstein, et al, 1975, p. 22	Follow methods manual supplied with AA unit
Tin	Epstein, et al, 1975, p. 22	Follow methods manual supplied with AA unit
Cadmium	Epstein, et al, 1975, p. 22	Follow methods manual supplied with AA unit
Molybdenum	Epstein, et al, 1975, p. 22	Follow methods manual supplied with AA unit
Arsenic	Caldwell, et al, 1973, p. 734	Caldwell, et al, 1973, p. 734
Selenium	Caldwell, et al, 1973, p. 734	Caldwell, et al, 1973, p. 734
Calcium	EPA, 1969, p. 18	EPA, 1974, p. 19
Magnesium	EPA, 1969, p. 18	EPA, 1974, p. 114
Sodium	EPA, 1969, p. 18	EPA, 1974, p. 147
Sulfate	EPA, 1969, p. 18	EPA, 1974, p. 277
Alkalinity @ $CaCO_3$ @ pH 4.5	Sample prepared by mixing, dilution and settling, then supernatant is analyzed	EPA, 1974, p. 3
Alkalinity @ $CaCO_3$ @ pH 4.2		EPA, 1974, p. 3

Description

The soil monitoring program will consist of two parts. One will be to make use of the University of Wisconsin Extension soil testing and fertilizer recommendations and lime recommendations program. Another part will be to determine the background levels of sludge constituents which may accumulate in the soil. The data collected will be used in computing the total allowable sludge application rate.

The extension program consists of gathering soil samples every year before a crop is fertilized and planted. The Soil and Plant Analysis Laboratory, University of Wisconsin at Madison, then analyzes the samples for available phosphorus, potassium, organic carbon, and pH. They then make a recommendation for fertilizer and lime application based upon the test results, immediate past cultural practices, and crop to be grown. As part of the MMSD sludge reuse program, the fertilizer and lime recommendations will be used to determine the sludge application rate and the need for a lime application and will be required every year before sludge application.

Soil samples for background level determination will be collected before any sludge is applied to the field. The results of this analysis will be recorded and kept on file. The results will be used to determine the total allowable sludge application limit for each field and to quantify the soil condition as it was before any sludge was applied. The initial soil samples will be analyzed for cation exchange capacity, electrical conductivity, calcium, magnesium, sodium, iron, aluminum, zinc, copper, nickel, cadmium, molybdenum, mercury, manganese, and boron.

Sampling Procedures

The most important part of establishing useful soil analysis is obtaining representative samples. This will require careful selection of location, procedure, and time of sampling.

Location. The sampling locations will be different for the initial and annual soil sampling. When performing the initial soil samping, each major soil series on a site will be sampled at a minimum rate of one sample location per soil series per 20 acres and a maximum of one sample location per 5 acres. The extent and location of the various soil series can be found in the Dane County Interim Soil Survey. The locations for the annual sampling should be determined using standard University of Wisconsin Extension procedures which are explained in detail by Schulte and others (1968).

Procedure. The success or failure of soil analysis depends on securing a representative soil sample, plus subsequent handling operations. Several steps are needed to obtain the final sample: (1) taking and mixing a series of cores from the location to be sampled; (2) subsampling this original sample one or more times; (3) air drying, grinding, sieving, mixing, and storing. The greatest possibility for error, assuming proper subsampling, drying, grinding, and sieving techniques, lies in securing a representative sample at the beginning. Considering the time and expense required for all subsequent operations, including analysis, frequently too little time and thought are put into the original sampling plan. For these reasons, we recommend that the District staff be trained by University Extension agricultural agents or Extension soil specialists on where and how to sample the soils. The detailed procedures for soil sampling are explained by Schulte and others (1968) and by Chapman and Pratt (1961). In general, they recommend that at each sample location, a series of cores be taken according to a systematic grid layout of the area of equal diameter and comparable depth (volume). These cores should then be composited. Separate composite samples representing different segments of the soil profile or root zone should be taken. Contamination from soil surface materials (crop residues, manures, fertilizers, etc.) should be avoided, also contamination of one soil depth with that of another. The sampler should show on a map the location of the initial sampling points for later reference. The annual soil sampling locations need not be recorded.

For the initial soil monitoring, 20 soil sample cores will be taken at each location. The core samples from undeveloped, homogeneous soils will be taken to represent depths of 0-6 inches, 6 inches to 2 feet, and 3-5 feet. In developed soils, the sampling depth will be based upon the various layers. The 20 core samples for each depth will then be composited. The initial composite samples will then be split and one-half of each labeled as to depth, date, location in field and field location, and stored in a dry place for future reference. The remaining half of each initial soil sample will be analyzed. The soil cores can normally be collected by a standard closed face hand auger or a Gliddings pickup-mounted soil probe and sampler or equivalent.

The detailed procedures for annual soil sampling are explained by Schulte and others (1968).

Time of Soil Sampling. The initial soil sample must be collected prior to the first sludge application on sites which have not had sludge applied in the past. Sites which have had sludge applied in the past should be sampled prior to any additional sludge application. Also, enough time should be allowed (1 month) so that the samples can be analyzed before sludge is applied to the field.

There are also some time constraints on when samples should be collected for annual soil testing. The University Extension recommends that the samples be collected in the fall, after harvest and before snowfall, where sludge will be applied the following spring. The minimum turnaround time from delivery of the sample to the laboratory until the fertilizer and lime recommendations are developed is 2-3 weeks.

Analysis Procedures

The annual phosphorus. potassium, pH, and organic carbon soil analyses will be performed using the procedures outlined for the Extension soil test program by Schulte, Olsen, and Genson (revised 1975).

Procedures for the many analyses performed on the initial condition samples are contained in several references. These are listed in Table E-2.

TABLE E-2

SOIL ANALYSIS PROCEDURES REFERENCES
MADISON METROPOLITAN SEWERAGE DISTRICT

PARAMETER	SAMPLE PREPARATION	QUANTITATIVE DETERMINATION
Electrical Conductivity	Bower and Wilcox, 1965, p. 937	Bower and Wilcox, 1965, p. 937
Calcium	Schulte, et al, 1975, p. 17	Schulte, et al, 1975, p. 17
Magnesium	Schulte, et al, 1975, p. 17	Schulte, et al, 1975, p. 17
Sodium	Pratt, 1965, p. 1033	Pratt, 1965, p. 1033
Iron	Epstein, et al, 1975, p. 22	Follow methods manual supplied with AA unit
Aluminum	Epstein, et al, 1975, p. 22	Follow methods manual supplied with AA unit
Zinc	Epstein, et al, 1975, p. 22	Follow methods manual supplied with AA unit
Copper	Epstein, et al, 1975, p. 22	Follow methods manual supplied with AA unit
Nickel	Epstein, et al, 1975, p. 22	Follow methods manual supplied with AA unit
Cadmium	Epstein, et al, 1975, p. 22	Follow methods manual supplied with AA unit
Molybdenum	Epstein, et al, 1975, p. 22	Follow methods manual supplied with AA unit
Mercury	Ure and Shand, 1974, p. 63	Ure and Shand, 1974, p. 63
Manganese	Epstein, et al, 1975, p. 22	Follow methods manual supplied with AA unit
Boron	Schulte, et al, 1975, p. 13	Schulte, et al, 1975, p. 13
Cation Exchange Capacity	Chapman, 1965, p. 894	Chapman, 1965, p. 894

E.3 PLANT MONITORING

Objective

The principal objective of the plant monitoring program is to determine whether the application of the sludge to the land is creating an excess of noxious or toxic elements resulting in potentially harmful impacts to crop productivity or the food chain. The principal potentially harmful elements found in the sludge are the heavy metals and boron. These elements are usually "fixed" in the soil to varying degrees and therefore will require a buildup in the soil before becoming readily available to the plants.

Description

The final effect of application to the land of the various constituents in the sludge is the effect on the plants grown on the land. Plant tissue analysis will provide a sensitive and accurate assessment of these effects; therefore, the crops will be monitored on all areas receiving sludge by periodic plant tissue analysis.

TABLE E-3

SUGGESTED MAXIMUM TOLERANCE LEVELS FOR VARIOUS ELEMENTS IN SUCCULENT PLANT TISSUE
MADISON METROPOLITAN SEWERAGE DISTRICT

ELEMENT	NORMAL RANGE µg/g	SUGGESTED MAXIMUM TOLERANCE LEVEL µg/g
Boron	7-75	100
Cadmium	0.05-0.2	3
Copper	3-40	150
Manganese	15-150	300
Mercury	0.001-0.01	0.04
Nickel	0.01-1.0	3
Zinc	15-150	350
Arsenic	0.01-0.1	2
Chromium	0.1-0.5	2
Cobalt	0.01-0.3	5
Lead	0.1-5.0	10
Molybdenum	0.2-1.0	3
Selenium	0.05-2.0	3
Vanadium	0.1-1.0	2

Table E-3 lists suggested maximum tolerance levels for various elements in succulent plant tissue of crops normally grown in the project area. These suggested levels include a safety factor and are, in effect, a warning level beyond which toxicity symptoms might be expected. The monitoring program will include analysis of all of the elements listed in Table E-3. These elements have been found to be potentially hazardous to plant growth or in the food chain.

Sampling Procedures

TABLE E-4

SUGGESTED PLANT PARTS FOR SAMPLING
MADISON METROPOLITAN SEWERAGE DISTRICT

CROP	PLANT PART
Corn	Leaves at or opposite and below ear level at tassel stage
Legumes	Upper stem cuttings in early flower stage
Cereals	Whole plants at boot stage
Grasses	Whole plants at early hay stage
Soybeans	Youngest mature leaves and petioles on the plant after first pod formation.

Methods. Proper sampling of the plant tissue for the particular crop is critical to the dependability of the results. Plant sampling should initially be conducted under the direction of an experienced plant scientist or agricultural chemist. After some training, the staff can perform the sampling. Table E-4 indicates the suggested plant parts to be sampled from the crops typically grown in the project area. Guides for sampling other crops are described by Chapman (1966). It is also important to obtain representative samples; procedures for this are also explained by Chapman (1966).

Frequency of Sampling

Sampling will commence during the first crop season following the first application of sludge. This will provide background information and measure any possible effect of initial introduction of an element. Subsequent sampling will be performed in the crop season following every third annual application of sludge. This will monitor any possible effect of a potential buildup of elements resulting from repeated applications. Also, the crops should be monitored in the fifth year after a sludge application if the site is no longer used for sludge reuse.

Analysis Procedures

The procedures for analysis of plant tissue for various elements are referenced in Table E-5.

TABLE E-5

PLANT TISSUE ANALYSIS PROCEDURES REFERENCES
MADISON METROPOLITAN SEWERAGE DISTRICT

PARAMETER	SAMPLE PREPARATION	QUANTITATIVE DETERMINATION
Boron	Chapman and Pratt, 1961, p. 88	Chapman and Pratt, 1961, p. 88
Cadmium	Epstein, et al, 1975, p. 22	Follow methods manual supplied with AA unit
Copper	Epstein, et al, 1975, p. 22	Follow methods manual supplied with AA unit
Manganese	Epstein, et al, 1975, p. 22	Follow methods manual supplied with AA unit
Mercury	Bouchard, 1973, p. 115	Bouchard, 1973, p. 115
Nickel	Epstein, et al, 1975, p. 22	Follow methods manual supplied with AA unit
Zinc	Epstein, et al, 1975, p. 22	Follow methods manual supplied with AA unit
Arsenic	Caldwell, et al, 1973, p. 734	Caldwell, et al, 1973, p. 734
Chromium	Epstein, et al, 1975, p. 22	Follow methods manual supplied with AA unit
Cobalt	Epstein, et al, 1975, p. 22	Follow methods manual supplied with AA unit
Lead	Epstein, et al, 1975, p. 22	Follow methods manual supplied with AA unit
Molybdenum	Epstein, et al, 1975, p. 22	Follow methods manual supplied with AA unit
Selenium	Caldwell, et al, 1973, p. 734	Caldwell, et al, 1973, p. 734
Vanadium	Epstein, et al, 1975, p. 22	Follow methods manual supplied with AA unit

Use of Analysis Results

The results of the analyses of the samples will be compared to generally accepted "normal" ranges of the elements in the respective types of plants. The normal ranges shown in Table E-3 have been suggested by Melsted (1973). As additional research is conducted on soil-plant relations concerning the fate of sludge constituents following land applications, the normal and maximum levels of the elements in plant tissue will be refined. As new information is accumulated, it should be used in determining the effects of the sludge application to land in the project area.

In the event that suggested maximum tolerance levels of any of the elements are reached in any of the samples, it will be considered a warning of potential danger. An additional set of samples should be taken from the affected site to verify the condition. If it is verified, sludge application on that site should be discontinued until the reason is determined. Monitoring should continue with samples taken each year for a reasonable length of time. Consultation with knowledgeable plant scientists should be made and suggested remedial action taken. Such remedial action may be a crop change or an effort to change soil pH which would affect the availability of the potentially harmful element.

E.4 GROUND-WATER MONITORING

Objective

The ground-water monitoring program will consist of sampling and analyzing ground water from on or near all sludge application sites. The objective of this monitoring is to establish background levels and detect ground-water quality changes, if any, after sludge application.

Description

Ground water from all wells and other ground-water sources on and within 500 feet of all sludge application sites will be monitored. An initial sample will be collected from each ground-water source before sludge is applied to establish background levels. Thereafter, a sample will be collected every 3 years to monitor changes in ground-water quality. If a site is no longer used for sludge application, the ground water should be monitored 5 years after the last sludge application.

The initial samples used to determine background conditions will be analyzed for MBAS, arsenic, nitrate-nitrogen, total dissolved solids, mercury, and coliform. The periodic monitoring samples will be analyzed for nitrate-nitrogen and total dissolved solids.

Sampling Procedures

Wells should be pumped long enough prior to sampling to evacuate at least three times the volume of water in the casing if volume is known; otherwise, the well should be pumped for 20 minutes prior to sampling. Where domestic or municipal wells are connected to pressure tanks or storage tanks, the sample should be collected from the most readily available point before the point of chlorination. If sample collection is from a domestic faucet, enough time should be allowed for water in the pipe from the pressure tank to the faucet to be completely replaced by fresh water. From a pressure source, the water should be run into sample bottles slowly to minimize agitation and the resultant excessive aeration or loss of gas. Upon sampling, the following information should be recorded:

- Date and time of collection.
- Name of collector.
- Well location and point of sample collection.
- Well type and use.
- Duration of pumping prior to sampling.
- Appearance of water at time of sampling (clear, colored, turbid, sediments, etc).
- Description of natural or manmade factors that may assist in interpreting chemical quality.

The water sample from each well shall consist of three separate specialized samples. The laboratory samples should consist of 1 gallon as is for chemical analysis, 1 gallon preserved in nitric acid for heavy metal analysis, and 1 pint in a sterilized container for coliform analysis. Samples should be kept in the dark and at low temperatures until analyzed. Except for tests run in the field, the samples should be analyzed within 24 hours after collection. The coliform analysis sample should be analyzed within 8 hours after collection. All samples should be labeled and recorded.

Analysis Procedures

All analyses will be performed in accordance with "Standard Methods for Examination of Water and Wastewater" 1971. If in the future, after background levels have been established, new laboratory procedures are adopted, correlation to background levels will be required.

E.5 SURFACE WATER MONITORING

A broad surface water monitoring program is not recommended for the sludge reuse program. However, limited monitoring may be useful in some instances where runoff is occurring from a sludge-applied field. Samples could be taken to determine if the stream is being polluted, the magnitude of the problem, and the source of the problem. With this information, the District can more effectively correct the problem.

ENVIRONMENTAL ASSESSMENT

O'BRIEN & GERE
ENGINEERS

ENVIRONMENTAL ASSESSMENT STATEMENT

MADISON METROPOLITAN SEWERAGE DISTRICT

ORGANIC SOLIDS REUSE PROGRAM

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SECTION 1 - BACKGROUND

1.01. GENERAL

Under provisions contained in the Federal Water Pollution Control Act Amendments of 1972, the Madison Metropolitan Sewerage District (MMSD) initiated a program for the development of a 201 Facilities Planning study. The objective of the 201 Study is to determine a wastewater treatment and discharge alternative which will meet the requirements of the Federal and State legislation regarding protection of the environment. Also included in the 201 Facilities Plan is the development of an organic solids (sludge) reuse alternative.

These studies are in compliance with Wisconsin Pollutant Discharge Elimination Permit No. WI 0024597. This permit requires completion of a Facilities Plan prior to any further design or construction of advanced wastewater treatment, effluent discharge or sludge disposal facilities. This report will assess the alternatives presently available for the disposal or reuse of the sludge resulting from the treatment of wastewater at the Nine Springs Wastewater Treatment Plant.

1.02. DESCRIPTION OF PROPOSED ACTIONS

The proposed method of sludge handling and disposal encompassing both the sludge produced during future wastewater treatment and the sludge presently being stored in the lagoons adjacent to the Nine Springs Wastewater Treatment Plant is summarized below.

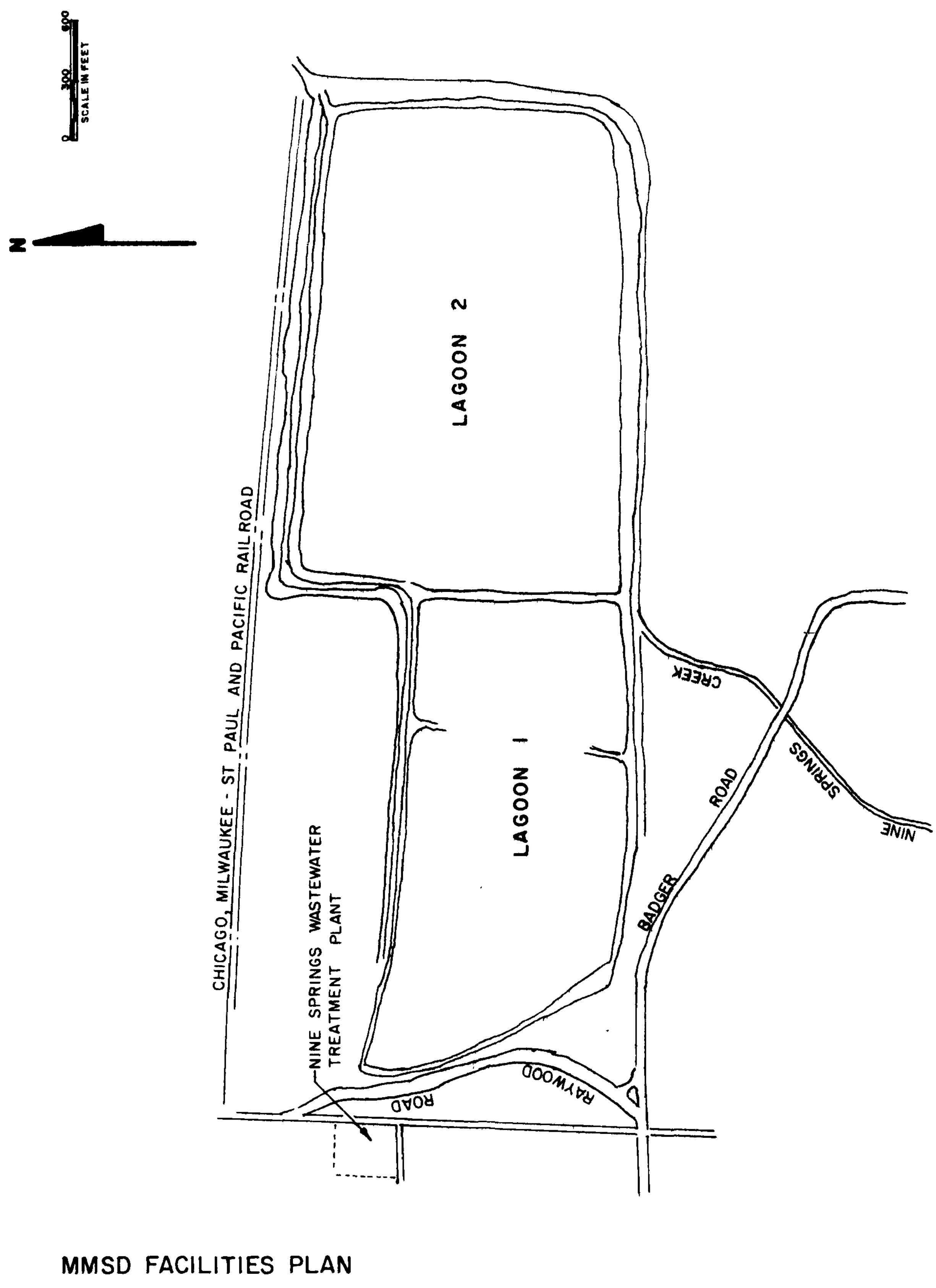
It is recommended that liquid anaerobically digested sludge be made available to the agricultural community in the vicinity of the Nine Springs treatment plant for application to agricultural lands for the utilization of its nutrient value. The sludge from the treatment plant and from the existing lagoons (Figure 1-1) will be disposed of in this manner. The major portion of the existing lagoons will be abandoned and allowed to return to the natural state of the surrounding area. A portion of the western lagoon (Lagoon 1) will be retained for the the seasonal storage of sludge.

The sludge application program would be administered by MMSD staff personnel. Transportation of sludge would be accomplished by the utilization of tanker trucks or pipeline. Field application would utilize truck spreaders initially, with additional spreading capacity furnished by subsurface injection equipment and tractor spreaders.

MMSD personnel would have overall responsibility for the management and monitoring of the proposed program. Adherance to State and Federal regulations and guidelines regarding the land application of sludge must be maintained. Site location and management, application rate development, monitoring of environmental indicators, and the necessary record keeping required to maintain proper program control will be conducted by MMSD. A marketing program to develop a strong and reliable demand for the sludge will be a part of the proposed actions.

A contingency sludge handling and disposal program is required in the event of the land application program becoming inoperative for any reason. With pumping of the sludge supernatant back to the treatment plant, as at the present, a sufficient volume for approximately three years of sludge production would be provided by the seasonal storage

FIGURE 1-1



MMSD FACILITIES PLAN

SLUDGE STORAGE LAGOONS

lagoon located in Lagoon 1. This assumes solids concentration of approximately 10% in the lagoons after supernatant return. This is the concentration currently obtained. During this period the problems which caused the halt of the land application program should be investigated and corrected. If the problem cannot be corrected or modified such that the land application program could be resumed, then the period should be utilized to develop an alternative sludge handling and disposal program. It is also proposed that the existing dikes for Lagoon 1 be left in place and that their structural integrity be maintained. Surface drainage from the unused portion of Lagoon 1 would be provided. The capacity provided by having the entire volume of Lagoon 1 in reserve would enable the MMSD to utilize Lagoon 1 in the event of some unforeseen development.

The implementation of the proposed actions would begin immediately upon approval of the regulatory agencies. It is anticipated that review of the proposed actions should be completed by early 1977. Establishing the required market for the proposed actions and the purchasing of all required equipment would mean that full implementation of the program would not begin until 1978. The marketing and monitoring programs would begin during 1976 as interested farm owners expressed a desire for the application of sludge to their lands.

Annual costs for implementation of the proposed actions have been developed in Table B-14 of Volume III - Organic Solids Reuse Plan by CH2M-Hill. Capital costs were established for the purchase of equipment required to implement the program and to construct required facilities. The costs reported reflect amortization over a period of 20 years at a 7% interest rate. As additional spreaders, nurse tankers, pipeline or other facilities are required, the costs have been adjusted accordingly. Also included is the estimated costs for operation and maintenance of the program and anticipated program revenues.

During the first ten-year period, it is proposed that sludge currently stored in the existing lagoons be removed. The operation and maintenance figures estimated reflect the increased costs during this period. After the lagoons have been emptied the operation and maintenance costs would drop significantly. Table 1-1 summarizes the total annual costs (without State or Federal grant allocations) estimated for the implementation of the proposed reuse program.

TABLE 1-1

ESTIMATED ORGANIC SOLIDS REUSE PROGRAM COSTS

	1978-1987	1988-2000
Capital Costs	$ 2,130,000	$ 536,000
Average Annual Debt Service[1]	157,700	209,500
Average Annual Operation & Maintenance	250,900	108,800
Average Annual Program Revenue	6,400	5,000
Total Annual Cost[2]	$ 402,200	$ 313,300

Source: Table B-14, Organics Solids Reuse Plan by CH2M-Hill

1. To pay off capital costs in20 years @ 7% interest.
2. Total Annual Cost = Debt Service + Operation and Maintenance - Program Revenue

In addition to the implementation of the proposed reuse program, upgrading of the existing handling system is proposed. Detailed evaluation of the alternative cost estimates required to provide improved solids handling of the expected increase in solids production resulting from various levels of advanced wastewater treatment may be found in Volume II Wastewater Treatment Plant, by CH2M-Hill.

1.03. LOCATION OF THE PROPOSED ACTIONS

The MMSD treatment facility, Nine Springs Wastewater Treatment Plant, provides treatment for the wastewater generated in the City of Madison and the surrounding area. The sludge produced as a result of the wastewater treatment and the sludge currently stored in the lagoons adjacent to the treatment plant are proposed to be applied to agricultural lands within 5 to 12 miles of the treatment plant as shown on Figure 1-2.

Required sludge handling facilities such as pumping stations, loading docks, laboratory facilities, equipment storage and maintenance areas and administrative offices will be provided at the Nine Springs Wastewater Treatment Plant and possibly at a remote site. Additional laboratory facilities providing required analyses of a special (soils and plant tissue analysis) nature may be provided by qualified agencies in the area.

Field application of the sludge will be limited to those sites possessing suitable soil, topography, bedrock geology, groundwater and other requirements as outlined in Section 3. It is planned that the market developed for the organic solids will be limited to the southcentral portion of Dane County. This would minimize the program costs for transportation of sludge. Also there is an apparent abundance of land area in this portion of the county suitable for the land application of sludge.

1.04. SLUDGE QUALITY, QUANTITY AND STORAGE LAGOON PROBLEMS

A. General

The quality of the sludge produced by the present treatment processes at the Nine Springs Wastewater Treatment Plant was analyzed during a sampling and analysis program conducted during 1975 and by reviewing sludge quality data provided by MMSD.

Grab samples of the digested treatment plant sludge were taken at the inlet pipe of the storage lagoons. Lagoon sludge samples were taken at 18 stations in Lagoon 1 and at 30 stations in Lagoon 2. These stations were located in a rectangular grid pattern which assured coverage of the entire lagoon storage area. Analyses were run according to standard procedures outlined in the following publications:

- EPA, Methods for Chemical Analysis of Water and Wastes (1974)
- APHA, AWWA, WPCF, Standard Methods for the Examination of Water and Wastewater (1971)
- Roberts, et al; Methods of Soil Analysis Used in the Soil Testing Laboratory at Oregon State University (Special Report No. 321, April 1971), Agricultural Experiment Station, Oregon State University, Corvallis, Oregon

- EPA, Great Lakes Region Committee on Analytical Methods: Chemistry Laboratory Manual - Bottom Sediments (December 1969)

B. Existing Treatment Plant Sludge Characteristics

The digested treatment plant sludge samples were analyzed for several physical and chemical constituents. The characteristics of the treatment plant sludge may be different in the future due to changes in the wastewater input or to changes in treatment processes. Table 1-2 summarizes the data on the existing treatment plant sludge.

Additional analyses were conducted to determine the amount of nitrogen occurring in the treatment plant sludge. These results are summarized in Table 1-3.

Most of the sludge constituents are within the typical digested sludge values reported in various studies (Konrad, J.G., and Klienert, S.J., 1974; Dean, R.B. and Smith, Jr., J.E., 1973). The report by Konrad and Klienert presented data collected from thirty-five sewage treatment plants in Wisconsin. The values reported for the Nine Springs Wastewater Treatment Plant were in the lower portion of those reported. The high ammonia levels are the result of ammonia accumulation in the digesters and should be corrected by future modifications to the digestion system. The higher ammonia values would be of benefit to farmers in a land application program, however, State and Federal guidelines would require that additional land area be utilized to meet application limitations. The low solids content means that excess liquid material is being handled in comparison to the typical digested sludge. This results in the need for additional storage area and larger capacity transportation or conveyance facilities.

The cadmium to zinc ration (73 to 2370 mg/kg) is approximately 3.1%. It has been suggested (Chaney, R.L., 1973, Chaney, R.L., et al, 1975) that in order to overcome cadmium toxicity problems, the cadmium to zinc ratio should be limited to 1% or less for sludges to be applied to agricultural lands. Applications rate considerations are developed in more detail in Section 3.02C of this report. Other factors affecting the annual and total application rates, as shown in that Section, appear to be more limiting than the cadmium to zinc ratio.

TABLE 1-3

NITROGEN ANALYSIS
TREATMENT PLANT DIGESTED SLUDGE[1]

Parameter	Range (%)	Average (%)	Typical Digested Sludge[2]
Total Nitrogen	8.2-14.8	10.5	5.0
NH_3-N	3.9-7.9	5.5	1.6
Organic-N	4.3-6.9	5.0	3.4

Source: Organic Solids Reuse Program Study CH2M Hill

[1] Values reported on dry weight basis.

[2] After Dean, R.B. and Smith, Jr., J.E., 1973. The Properties of Sludge In Proceeding of the Joint Conference on Recycling Municipal Sludges and Effluents on Land, Champaign, Illinois.

TABLE 1-2

TREATMENT PLANT SLUDGE CHARACTERISTICS

Parameter[1]	Range	Average	Typical Digested Sludge[2]
Total Solids (%)	1.88-2.92	2.34	4-6
Total Volatile Solids (%)	1.6	1.6	
Total Soluble Salts (uohms/cm)	6380-7840	7150	
pH	8.11-8.12	8.11	
Potassium	4820-9100	7670	12000-19000
Iron	6800-10800	8850	8000-78000
Zinc	1600-3032	2370	490-12200
Copper	500-570	525	140-10000
Titanium	<90	<90	
Lead	175-640	286	40-4600
Barium	600-1820	1140	530-1340
Chromium	100-312	234	50-32000
Manganese	170-200	189	180-1130
Nickel	45.6-270	81	15-1700
Tin	<10	<10	
Cadmium	37.7-160	73	5-400
Molybdenum	<10	<10	
Cobalt	<20-40	30	
Alumium	2640-3100	2870	3600-12000
Arsenic	14	14	
Boron (hot water soluble)	4-500	300	150-750
Selenium	< 4	< 4	
Mercury	4.8-19.3	11.6	0.6-31
SO_4-S (soluble)	200-470	335	
Alkalinity as $CaCO_3$ pH 4.5	5800-6100	5950	
Alkalinity as $CaCO_3$ pH 4.2	6300-6600	6450	
Calcium	13400-77900	51200	42000-180000
Magnesium	6600-12900	8970	8000-12000
Total Phosphorus	6000-26800	13970	27000-61000

Source: Organic Solids Reuse Plan CH_2M Hill Engineers, Inc., 1975

[1] Values reported in mg/kg except as noted.

[2] Konrad, J.G. and Klienert, S.J., 1974. Surveys of Toxic Metals in Wisconsin: Removal of Metals from Waste Water by Municipal Sewage Treatment Plants. Technical Bulletin No. 74, Wisconsin Department of Natural Resources.

C. Future Treatment Plant Characteristics

Several locations are being investigated as possible points of future effluent discharge. Dependent upon the final discharge point, the effluent quality may vary somewhat as required to protect the water quality of the streams. The degree and type of treatment required to produce a given quality effluent will determine possible changes in the quality and quantity of sludge produced in the future.

There are basically three different effluent qualities which would satisfy the requirement to protect the water quality of the potential receiving streams. These are summarized below:

- Effluent I - Less than 30 mg/l BOD and suspended solids; Less than 2.0 mg/l ammonia nitrogen

- Effluent II - Less than 10 mg/l BOD and suspended solids; Less than 0.2 mg/l ammonia nitrogen

- Effluent III (industrial reuse) - Less than 150 mg/l total hardness; Less than 1,000 mg/l total dissolved solids; Less than 0.2 mg/l ammonia nitrogen

Effluent quality levels I and II can be achieved through conventional biological treatment processes. Level III could be achieved utilizing lime softening in addition to the biological treatment required for Levels I and II. The sludge produced as a result of biological treatment is generally suitable for application to agricultural land. The problems of high ammonia nitrogen and water (liquid) content are expected to be reduced with improved wastewater treatment and sludge processing in the future. The sludge which would be produced as a result of the lime softening associated with level III might be suitable as soil pH conditioner. However, the large volumes of sludge which would be produced through lime softening, as well as the possible poor quality of such a sludge, may require that all or a portion of it be disposed of by landfill methods.

Estimates of the sludge quantities which would be produced in the future would increase as the level of treatment required and the volume of flow to the treatment plant increase. Conservative estimates of quantities of sludge produced in the future are summarized in Table 1-4.

TABLE 1-4

ESTIMTED FUTURE SLUDGE QUANTITIES
(Tons of dry solids per year)

Year	Level I	Level II	Level III
1981	5870	6730	6730 + Lime Sludge
1990	6560	7500	7500 + Lime Sludge
2000	7460	8520	8520 + Lime Sludge

The sludge which would be produced in the lime softening process would require separate handling from that produced through the biological process. The more conservative estimates for the Level II treatment will be utilized for making cost estimates, sizing of handling and transportation facilities, and estimating other required facilities. If a lesser degree of treatment is required, and consequently, a lesser volume of sludge produced, then the estimated cost and other figures would have to be adjusted accordingly.

D. Lagoon Sludge

1. Sludge Characteristics

The sludge from the storage lagoons was sampled and analyzed as described earlier. Table 1-5 summarizes the characteristics of the sludge contained in the lagoons. The higher percentage of solids noted in Lagoon 1 has resulted from the solids contained in the sludge having settled out near the point of discharge (Lagoon 1). The slightly higher ammonia nitrogen levels noted for Lagoon 1 have resulted from the high values of the treatment plant sludge. Through volatilization, the ammonia nitrogen levels of the sludge have decreased by the time it has reached Lagoon 2. The cadmium to zinc ratio of the combined lagoon sludges is approximately 1.3%. This is much lower than the current ratio found in the treatment plant sludge (3.1%). Increased industrial use and discharge of cadmium in recent years would explain the higher cadmium content of the present treatment plant sludge.

TABLE 1-5

LAGOON SLUDGE CHARACTERISTICS

Parameter	Lagoon 1 Range	Lagoon 1 Average	Lagoon 2 Range	Lagoon 2 Average
Depth of Sludge (ft)	2.0-7.1	5.74	2.7-17.2	5.30
Total Solids (%)	3.1-24.1	12.90	4.2-12.7	8.20
Volatile Solids (%)	–	9.8	–	–
Total Nitrogen (%)	2.74-9.23	5.71	4.16-8.66	5.98
Ammonia Nitrogen (%)	0.81-1.85	1.30	0.50-1.88	1.16
Total Phosphorus (%)	1.39-2.67	1.88	0.73-1.41	1.07
Total Potassium (%)	0.12-0.20	0.15	0.07-0.31	0.18
Zinc (mg/kg)	2145-3456	2934	2012-2080	2046
Copper (mg/kg)	470-490	479	259-541	420
Cadmium (mg/kg)	30.0-39.1	35.5	25.3-33.3	29.3
Nickel (mg/kg)	50.0-60.3	56.8	50.7-55.5	53.1
Mercury (mg/kg)	19.4-21.7	20.7	17.3-26.9	22.1
Total Soluble Salts (uohms/cm)	2670-4430	3703	2740-4730	3687

Source: Organic Solids Reuse Plan, CH2M-Hill Engineers, Inc., 1975

In addition to the analyses conducted on the sludge itself, several samples were taken of the peat and marl material underlying the lagoons and analyzed for a number of chemical constituents. It was recognized that the potential for groundwater contamination through leaching from the stored sludge existed. Analyses indicated that the concentrations in the peat and marl below the sludge, returned to levels consistent with those of a control sample obtained away from the immediate lagoon area within one foot below the peat/marl and sludge interface. Since Lagoon 1 has been utilized for sludge storage since 1942 and Lagoon 2 since 1967, it was concluded that there is no appreciable threat to groundwater contamination through leaching from the sludge material.

E. Storage Lagoon Problems

Investigations of the sludge storage lagoon dikes and a review of the dike failures of Lagoon 2 indicated that the dike embankments, especially of Lagoon 2, are not stable. Failures of a portion of the dikes of Lagoon 2 in 1970 and the resultant spill of sludge and supernatant to nearby surface waters dramatically pointed up the need for remedial action. An additional dike failure occurred in 1973 but spillage was negligible at that time.

In a report submitted to MMSD by CH_2M-Hill Engineers in July 1975 (Geotechnical Evaluation of Sludge Lagoon Embankments) several conclusions were drawn based on previous studies and field investigations of the existing conditions.

These are summarized as follows:

- Certain reaches of the lagoon dikes are unstable
- Dike failure(s) with possible damaging spillage is imminent, especially along the south side of Lagoon 2.
- The present method of removing sludge solids (draglining from the dikes) contributes to the dike instability by removing counterweight material.
- Regardless of future sludge handling and disposal methods, the existing instability of the dikes must be corrected.

It was recommended by the CH_2M-Hill report that a program be instituted which would stabilize the existing lagoon dikes as soon as possible.

1.05. PROGRAM OBJECTIVES

The objectives of the current Facilities Plan are to develop a sludge disposal alternative which will alleviate the threat of future dike failures and provide a means of disposing of both the sludge produced in the future and that sludge currently stored in the lagoons in a manner which will not cause harm to the environment.

The protection of present and future land use plans, the delicate and sensitive flora and fauna of the area, unique or rare topographical and geological formations, historical places and other environmentally sensitive factors have been considered. The Organic Solids Reuse Plan develops a sludge disposal alternative which will accomplish these objectives while fulfilling State and Federal requirements for sludge disposal.

1.06. PROGRAM COSTS AND FINANCING

A. Background

In accordance with Section 35.935 - 13 of CFR Title 40, MMSD is developing a system of User Charges and an Industrial Cost Recovery Program as a grant condition for the Fifth Addition to the Nine Springs Wastewater Treatment Plant. The User Charge and Industrial Cost Recovery systems developed in conjunction with the Fifth Addition construction will be expanded to cover subsequent additions relating to sludge handling and advanced wastewater treatment. This section has been developed to estimate the effects on the average residential users of the proposed Organic Solids Reuse Program.

Capital, debt service, operating, and maintenance costs associated with the Organic Solids Reuse Program will be accounted for in the User Charge System and in the Industrial Cost Recovery System. The parameters used in these systems are volume, BOD, suspended solids, and the number of equivalent 5/8-inch water meters.

B. Basis of Allocation of the Costs to the Parameters

The Organic Solids Reuse Program will be concerned only with the storage and ultimate disposal of anaerobically digested sludge. This end product is composed entirely of suspended solids; however, a portion of these solids were generated in the removal of BOD. Analysis of the primary and secondary treatment processes, the sludge thickening process, and the anaerobic digestion process at the Nine Springs treatment plant resulted in the following allocation of costs associated with the anaerobically digested sludge:

BOD -	40 percent
Suspended Solids -	60 percent

C. Present Organic Solids Reuse Program and Costs

In 1975, a total of 10,364 dry tons of sludge were removed from the lagoons and placed on farmland. The total cost of removing the sludge from the lagoons, transporting it to farmland, and applying the solids to the land was approximately $172,000 or $16.60 per dry ton of solids.

In 1975 all MMSD expenses were allocated to its customers on the basis of flow volume. The total volume received at the Nine Springs treatment plant in 1975 was 13,167 million gallons. The Organic Solids Reuse Program share of the users' cost was:

$$\frac{\$172{,}000}{13{,}167 \text{ MG}} = \$13.06/\text{MG}$$

The average residential customer in the MMSD has three people each using 62 gallons of water per day. To this figure is added the average daily volume of inflow and infiltration of 18 gallons per person resulting in an average daily flow per person of 80 gallons, or 240 gallons per residential customer. The yearly wastewater volume contributed by the average residential customer, including inflow and infiltration, is then calculated to be 87,600 gallons. Thus, the present Organic Solids Reuse Program costs the average residential customer:

$$\$13.06/\text{MG} \times 0.0876 \text{ MG/Yr} = \$1.14/\text{Yr}$$

D. Proposed Organic Solids Reuse Program Costs

Table B-14 of CH_2M-Hill's Organic Solids Reuse Program lists the year by year cost estimates for the sludge reuse program through the year 2000. The capital cost estimates and the debt service cost estimates do not reflect any government grant contribution. The total annual costs vary from $250,000 to $425,000 with an average annual cost of $352,000. The total annual cost is computed as the sum of the debt service costs and the total operation and maintenance costs minus the annual program income.

Table 1-6 shows the estimated annual cost for the average residential customer if no grants are received to reduce the annual debt service costs. The total annual costs are allocated on the basis of 40 percent to BOD and 60 percent to suspended solids. The tons of BOD and suspended solids received at the Nine Springs treatment plant in a year are based on the design values of 0.23 pounds of BOD per capita per day and 0.23 pounds of suspended solids per capita per day. These per capita figures include the commercial and industrial contributions in addition to the residential contribution. The residential contributions of BOD and suspended solids are 0.152 and 0.200 pounds per capita per day respectively. This results in an annual contribution of 166 pounds of BOD and 219 pounds of suspended solids for the average residential customer. The estimated annual cost to the average residential customer if no grants are considered varies from $1.96 to $4.23 with an average annual cost of $3.09.

Table 1-7 shows the estimated annual cost for the average residential customer if grants are received to cover 75 percent of the capital costs, thus reducing the debt service costs by 75 percent. The total annual costs of the Organic Solids Reuse Program would vary from $146,000 to $324,000 with an average annual cost of $212,000. The resulting estimate of the annual cost for the average residential customer would vary from $1.14 to $3.16 with an average annual cost of $1.85.

At this time MMSD has funds in its Construction Account. These funds have accumulated through interceptor benefit charges collected from new users and through delayed grants. These grants were received for projects financed entirely by MMSD through general obligation bonds. At the time of construction these grants were not available, and since MMSD financed the construction through its Construction Account, when the grants were received they were deposited in the Construction Account. Now, depending on the sequence of construction of the Organic Solids Reuse Project and the Advanced Wastewater Treatment Project, some or all of the capital costs of the Organic Solids Reuse Project will be paid for using the funds in the Construction Account. Thus it may not be necessary to pass future bond issues, and the debt service costs for the Organic Solids Reuse Program could be nonexistent or substantially less than those shown in Table B-14 of CH_2M-Hill's Organic Solids Reuse Program. This will further reduce the total annual cost of the project resulting in the cost to the average residential customer being as little as $1.45 per year on the average through the year 2000.

1.07. HISTORY OF THE SLUDGE DISPOSAL PROGRAM

Since the Nine Springs Wastewater Treatment Plant was placed in operation in the early 1930's the problem of disposing of the sludge produced during wastewater treatment has been present. From the 1930's until 1942, the sludge produced was dried on sand beds and

TABLE 1-6

Estimated Annual Cost for the Average
Residential Customer Without Grants

	Total Annual Cost (x $1,000)			Influent BOD			Influent Suspended Solids			Est. Annual Cost for Avg. Res. Customer
Year	Total	BOD	SS	Tons	$/Ton	$/Cust	Tons	$/Ton	$/Cust	
1978	273	109	164	9,929	10.98	0.91	9,929	16.52	1.81	2.72
1979	393	157	236	10,050	15.62	1.30	10.050	23.48	2.57	3.87
1980	404	162	242	10,171	15.93	1.32	10,171	23.79	2.60	3.92
1981	416	166	250	10,292	16.13	1.34	10,292	24.29	2.66	4.00
1982	445	178	267	10,413	17.09	1.42	10,413	25.64	2.81	4.23
1983	398	159	239	10,534	15.09	1.25	10,534	22.69	2.48	3.73
1984	421	168	253	10,655	15.77	1.31	10,655	23.74	2.60	3.91
1985	423	169	254	10,776	15.68	1.30	10,776	23.57	2.58	3.88
1986	424	170	254	10,897	15.60	1.29	10,897	23.31	2.55	3.84
1987	425	170	255	11,018	15.43	1.28	11,018	23.14	2.53	3.81
1988	323	129	194	11,140	11.58	0.96	11,140	17.41	1.91	2.87
1989	325	130	195	11,261	11.54	0.96	11,261	17.32	1.90	2.86
1990	326	130	196	11,382	11.42	0.95	11,382	17.22	1.88	2.83
1991	326	130	196	11,503	11.30	0.94	11,503	17.04	1.86	2.80
1992	328	131	197	11,624	11.27	0.94	11,624	16.95	1.86	2.80
1993	329	132	197	11,745	11.24	0.93	11,745	16.77	1.84	2.77
1994	329	132	197	11,866	11.12	0.92	11,866	16.60	1.82	2.74
1995	330	132	198	11,987	11.01	0.91	11,987	16.52	1.81	2.72
1996	332	133	199	12,108	10.98	0.91	12,108	16.44	1.80	2.71
1997	333	133	200	12,229	10.88	0.90	12,229	16.35	1.79	2.69
1998	275	110	165	12,350	8.91	0.74	12,350	13.36	1.46	2.20
1999	266	106	160	12,471	8.50	0.70	12,471	12.83	1.40	2.10
2000	250	100	150	12,592	7.94	0.66	12,592	11.91	1.30	1.96
Total	8,094	3,236	4,858	258,993			258,993			
Avg.	352	141	211	11,260	$12.49	$1.04	11,260	$18.76	$2.05	$3.09

Source: Madison Metropolitan Sewerage District

TABLE 1-7

Estimated Annual Cost for the Average Residential Customer with 75 Percent Grants

	Total Annual Cost (x $1,000)			Influent BOD			Influent Suspended Solids			Est. Annual Cost for Avg. Res. Customer
Year	Total	BOD	SS	Tons	$/Tons	$/Cust	Tons	$/Tons	$/Cust	
1978	209	84	125	9,929	8.46	0.70	9,929	12.59	1.38	2.08
1979	322	129	193	10,050	12.84	1.06	10,050	19.20	2.10	3.16
1980	319	128	191	10,171	12.58	1.04	10,171	18.78	2.06	3.10
1981	324	130	194	10,292	12.63	1.05	10,292	18.85	2.06	3.11
1982	311	124	187	10,413	11.91	0.99	10,413	17.96	1.97	2.96
1983	264	106	158	10,534	10.06	0.83	10,534	15.00	1.64	2.47
1984	270	108	162	10,655	10.14	0.84	10,655	15.20	1.66	2.50
1985	272	109	163	10,776	10.12	0.84	10,776	15.13	1.66	2.50
1986	273	109	164	10,897	10.00	0.83	10,897	15.05	1.65	2.48
1987	274	110	164	11,018	9.98	0.83	11,018	14.88	1.63	2.46
1988	154	62	92	11,140	5.56	0.46	11,140	8.26	0.90	1.36
1989	156	62	94	11,261	5.50	0.46	11,261	8.35	0.91	1.37
1990	156	62	94	11,382	5.45	0.45	11,382	8.26	0.90	1.35
1991	156	62	94	11,503	5.39	0.45	11,503	8.17	0.89	1.34
1992	158	63	95	11,624	5.42	0.45	11,624	8.17	0.89	1.34
1993	160	64	96	11,745	5.45	0.45	11,745	8.17	0.89	1.34
1994	160	64	96	11,866	5.39	0.45	11,866	8.09	0.88	1.33
1995	160	64	96	11,987	5.34	0.44	11,987	8.01	0.88	1.32
1996	162	65	97	12,108	5.37	0.44	12,108	8.01	0.88	1.32
1997	164	66	98	12,229	5.40	0.45	12,229	8.01	0.88	1.33
1998	150	60	90	12,350	4.86	0.40	12,350	7.29	0.80	1.20
1999	148	59	89	12,471	4.63	0.39	12,471	7.14	0.78	1.17
2000	146	58	88	12,592	4.61	0.38	12,592	6.99	0.76	1.14
Total	4,868	1,948	2,920	258,993			258,993			
Avg.	212	85	127	11,260	$ 7.52	$0.62	11,260	$11.27	$1.23	$1.85

Source: Madison Metropolitan Sewerage District utilized as a fertilizer for lawns, gardens, flower beds, etc. Small amounts were ground and bagged. With the outbreak of World War II the manpower required to operate and maintain this system was no longer available.

In 1942 Lagoon 1 was constructed and the sludge produced at the plant was diverted to it for storage. This lagoon has been in continuous use since that time. As the capacity of the original lagoon was reached, a second lagoon (Lagoon 2) was constructed immediately to the east of Lagoon 1 in 1968. The total area of the two lagoons is approximately 145 acres.

In April, 1970 portions of the dike of Lagoon 2 failed, allowing lagoon supernatant to flow into Nine Springs Creek and thence into the Yahara River just upstream of Lake Waubesa. An additional dike failure occurred in November, 1973 but spillage was negligible at that time. As a result of the first failure, MMSD paid $20,000 in damages and entered into an agreement with WDNR stipulating that an alternative method of sludge disposal was to be implemented by MMSD as soon as practicable.

A number of studies were then initiated which investigated the alternatives for sludge disposal and the stability of the lagoon dikes. A major finding of these reports (Warzyn Engineering and Service Co., Inc., 1970; CH_2M-Hill Engineers, Inc., 1975) concluded that the dikes of Lagoon 2 were quite unstable and were subject to probable failures in the future. Other reports (Greeley and Hansen Engineers, 1971; Roy F. Weston, Inc., 1974) evaluated and concluded that sludge reduction and disposal methods such as incineration, heat treating, mechanical dewatering and landfilling were not feasible. The staff of MMSD prepared an addendum to the Weston report evaluating other sludge handling and disposal alternatives not considered in the Weston Report. For a number of reasons, including the physical and chemical characteristics of the MMSD sludge and high energy requirements, these methods were eliminated from further consideration. Further information regarding the evaluation of these methods of sludge disposal may be found in Section 3 of this report. The recommended method of sludge disposal was land application of the sludge to utilize its nutrient value as a fertilizer substitute.

The current Facilities Plan studies are being conducted in fulfillment of a requirement of Wisconsin Pollutant Discharge Elimination System (WPDES) Permit No. WI-0024597 received by MMSD on 27 September 1974. The sludge disposal portion of the Facilities Plan has evaluated the various methods presently available to implement a land application program. Consideration was given to the factors necessary to develop site location and management, environmental factors and program costs.

SECTION 2 - THE ENVIRONMENT WITHOUT THE PROPOSED ACTIONS

2.01. GENERAL

A more detailed write-up of the environmental conditions as they exist in Dane and Rock Counties may be found in the Environmental Inventory which is included as Appendix A of the Facilities Plan. The material presented in the following sections is a brief summary of the material and data included in Appendix A.

2.02. CLIMATE

A. Temperature

South-central Wisconsin's climate is typical of the continental interior of North America. Annually, temperatures vary over a wide range. In summer months (June, July, August and September) mean temperatures reach a high of 70.1°F in July while the January mean temperature is a low 16.8°F. Extreme temperature values recorded at the National Oceanic and Atmosphere Administration weather station, located at Dane County Regional Airport in Madison, over the past 15 years (1959-1974) reached a maximum of 98°F during July, 1965 and a minimum of -30°F during January, 1963. These values have been exceeded in the area by a high reading of 107°F recorded during July, 1936, at the Madison City Office Building and by a minimum of -37°F recorded during January, 1951 at Truax Field (Dane County Regional Airport).

B. Precipitation

Precipitation is generally sufficient throughout the year to supply the needs of crops. The Madison area receives the water equivalent of, on the average, 30.47 inches per year while the Beloit area receives an average of 32.64 inches annually. The water equivalent value accounts for precipitation in all forms (rainfall, snow, sleet, hail, etc.). There are no predominantly "wet" or "dry" seasons, however, during the summer months most of the precipitation occurs during thunderstorm activity. As a result, there may be short periods when soil moisture falls below the optimum for crop growth. Many areas experience some minor effects of drought. The problem has not been of such severity to warrant general use of supplemental irrigation to supply water to agricultural areas.

C. Snowfall

The snowfall in Dane and Rock Counties averages approximately 35.5 inches per year. The maximum amount recorded in Madison since 1935 was 67.1 inches during the winter of 1970-71. Due to the normally low temperatures during the winter months, there is often a snow cover on the ground from December to mid-March.

D. Winds

The winds have an annual mean speed of 10.0 mph. Coming out of the west-northwest and northwest during the months of January through April, they carry relatively cold, dry air masses which account for the normally low temperatures and snowfall of the area. During the summer and autumn, the winds are generally southerly. Maximum wind speeds are associated with storm events. The maximum recorded value at the weather station was 77 mph, during May, 1950.

E. Severe Climatological Events

Severe climatological events include hurricanes, tornadoes and severe thunderstorms. Hurricanes have not occurred in Wisconsin, being limited to the Atlantic and Gulf of Mexico coastal states and those states immediately inland. Tornadoes pose some threat to the area. Over the past 60 years, an average of one tornado in four years has been reported in the Madison area. The northwest quadrant of Wisconsin experiences more tornadoes than any other portion of the State.

Thunderstorms occur on the average of seven (7) days per month during the period of July to September. High winds and short periods of intense precipitation often accompany thunderstorms events.

2.03. TOPOGRAPHY

A. General

The south-central portion of Wisconsin is an area of varied terrain. Glaciers, which progressed over much of the area from the northeast, resulted in the formation of two distinct geographical provinces, the Driftless Area and the Glaciated Area. A line running approximately northwest to southeast and passing through the areas of Lake Wisconsin, Middleton and Janesville marks the approximate extent of the latest glaciation.

B. Driftless Area

The Driftless Area is found in the southwestern corner of Wisconsin. The western portions of Dane County and Rock County are included in this area. During the glacial periods, this area was not covered by the glaciers as was the remainder of the area. The absence of the scouring, erosion and deposition of morainal material associated with glacial action, preserves an area of Wisconsin in its pre-glacial condition.

The topography of this Driftless Area is typified by a hilly terrain with narrow, steep sided valleys of the Western Uplands. The streams in this area have a well developed branching or dendrite pattern, typical of older topographical regions.

C. Glaciated Area

To the east of the Driftless Area lies the area covered by the Green Bay Lobe during the latest continental glaciation. Relief here is relatively gentle with broad valleys and gently sloping hillsides typical of the Eastern Ridges and Lowlands. There are numerous lakes and wetlands areas present here which are virtually absent in the Driftless Area.

Two features unique to glaciated regions are common here. These are the kettle or pothole lakes found in depressions left by ice blocks broken off from the receding glaciers and the numerous drumlins present. Drumlins are low, elongated hills of unconsolidated glacial material. They are interesting in that the long axis of the drumlins indicate the direction of the glaciers' movements.

2.04. GEOLOGY

The study area is underlain by a series of rock formations and above these a layering of unconsolidated material. Table 2-1 describes the geologic layering in Dane and Rock Counties.

The Precambrian rocks are the oldest found in the area and occur at a minimum depth of 300 feet below the surface. Granite, basalt and rhyolite are common igneous and metomorphic rock types of the Precambrian system.

Overlying the Precambrian system are the dolomites, sandstones and shales of the Cambrian system. These rocks are sedimentary formations deposited during periods when the area was covered by ancient seas. The Cambrian system rocks are utilized as the primary source of water supply by most municipalities in Wisconsin. The following rock formations make up the Cambrian system:

Mount Simon Sandstone)
)
Eau Claire Sandstone) Dresbach Group
)
Galesville Sandstone)

Franconia Sandstone

Trempealeau Formation

The Ordovician system is geologically younger than the Cambrian rocks. Having been deposited at a later time than the underlying formations, these rocks have been subjected to more of the erosional forces. As a result, the layering is not as consistent in this system, with some rock layers having been completely removed by wind and water erosion or by glacial action. The following rock formations make up the Ordovician system:

Prairie du Chien Group

St. Peter Sandstone

Platteville, Decorah and Galena Formation

Maquoketa Shale

TABLE 2-1

GEOLOGIC UNITS
DANE - ROCK COUNTIES, WISCONSIN

System	Geologic Unit	Thickness (ft.)	Primary Characteristics
Quaternary	Pleistocene and Recent Deposits	0-372	Unconsolidated deposits of silt, sand, gravel, boulders and organic materials
Ordovician	Maquoketa Shale	0-100	Dolomite shale; found only in southwestern Dane County
	Platteville, Decorah, Galena Formation	0-315	Dolomite layers with some fine to medium grained sandstone in some areas
	St. Peter Sandstone	0-185	Fine to medium grained sandstone with some areas of chert, shale and conglomerate
	Prairie du Chien Group	0-203	Dolomite layers with some areas of chert, shale and sandstone
Cambrian	Trempealeau Formation	28-125	Fine to medium grained sandstone and fine grained siltstone
	Franconia Sandstone	70-155	Fine to medium grained sandstone with some areas of fine grained siltstone
	Galesville Sandstone	25-150	Fine to medium grained sandstone
	Eau Claire Sandstone	50-348	Fine to medium grained sandstone with extensive areas of shale and siltstone
	Mt. Simon Sandstone	223-850	Medium grained sandstone with some shale layers
Pre-Cambrian		300-	Igneous or metomorphic rocks such as granite, basalt and rhyolite

The Quartenary system contains the deposits of most recent origin. Materials making up this system include loess, glacial lake deposits, morainal deposits and other unconsolidated deposits. These deposits range from sand, silt and gravel to organic matter. Erosional forces, acting on the rock formations of older geologic systems, have helped form these deposits.

2.05. SOILS

Soils are those materials making up the uppermost surface of the earth's covering except where unweathered bedrock is exposed. The soil is composed of various combinations of inorganic materials originating from the underlying bedrock and of organic materials resulting from the decomposition of plant and animal life.

The hundreds of different soil types are differentiated from one another by their texture, color, slope, stoniness, permeability and other physical and chemical properties. Soil series, groupings of soil types with similar characteristics, have been further grouped into soil associations. The soil associations are mapped for areas having distinctive patterns of soil areas.

In Dane County, the over ninety soil series which are present have been grouped into seven soil associations. The sixty soil series present in Rock County have been grouped into nine soil associations. Mapping of the soil associations can be used as a guide for general planning purposes. For detailed agricultural management or construction design work, the soil series data are required. Table 2-2 summarizes the characteristics of the soil associations in Dane and Rock Counties.

2.06. HYDROLOGY

A. General

The general area of the proposed land application project lies entirely within the Lower Rock River Basin. The following sections are a summary of the information available for the basin. A more detailed account of water uses, sources of pollution, water quality and water resources management of the basin may be found in Appendix A.

The basin drains approximately 1,900 square miles of south-central Wisconsin. Much of the basin is included in the Eastern Ridges and Lowlands geographical province, a result of past glaciation. Major tributaries of the Rock River include the Bark and Yahara Rivers, Turtle, Koshkonong, Marsh and Bass Creeks. Wetland areas and lakes are common to this region. Major lakes located in the basin are Lakes Mendota, Wingra, Monona, Waubesa and Kegonsa on the Yahara River and Lake Koshkonong on the Rock River.

The groundwater resources are abundant in the basin. Virtually all public, industrial and private water supplies are drawn from the groundwater aquifer.

TABLE 2-2

SOIL ASSOCIATIONS OF DANE AND ROCK COUNTIES

Soil Associations (% of Association)	Drainage	Terrain	Texture	Limitations for Cropping	Limitations for On-Site Sewage Disposal
Dane County					
1. St. Charles (40%) McHenry (30%) Ossian (10%) Minor Soils (20%)	good	gentle to moderate slopes	silty clay loam to sandy loam	slight to severe	slight to moderate
2. Plano (50%) Ringwood (30%) Griswold (10%) Minor Soils (10%)	good	gentle slopes	silty to sandy loam	slight to moderate	slight to moderate
3. Ossian (30%) Kegonsa (30%) Palms (10%) Minor Soils (30%)	poor to good	level to gently sloping	silt loam to sandy clay loam	moderate (when drained)	very severe
4. Dodgeville (20%) New Glarus (20%) Sogn (10%) Minor Soils (50%)	good	gently sloping to very steep	silty clay loam to clay	moderate to very severe	moderate to very severe
5. Dunbarton (30%) Basco (20%) Elkmound (20%) Minor Soils (30%)	good	gently sloping to very steep	silt loam to silty clay loam and clay	moderate to severe	severe
6. Granby (30%) Alluvial Land, Wet (20%) Adrian (20%) Minor Soils (30%)	poor	level to gently sloping	sandy soil with organic mater-ials	severe	very severe
7. Derinda (30%) Calamine (30%) New Glarus (10%) Minor Soils (30%)	poor to good	gently to steeply sloping	silty clay loam to clay	moderate	very severe

TABLE 2-2

SOIL ASSOCIATIONS OF DANE AND ROCK COUNTIES

(Continued)

Soil Associations (% of Association)	Drainage	Terrain	Texture	Limitations for Cropping	Limitations for On-Site Sewage Disposal
Rock County					
1. Kidder (26%) St. Charles (17%) Minor Soils (57%)	fair to good	level to steeply sloping	sandy clay loam to silty clay loam	moderate	slight to moderate
2. Dresden (40%) St. Charles (20%) Warsaw (10%) Minor Soils (30%)	fair to good	level to steeply sloping	sandy and silty clay loam to sand and gravel	slight to moderate	severe
3. Plano (35%) Warsaw (22%) Dresden (8%) Minor Soils (35%)	fair to good	level to gently sloping	silty and sandy clay loam to sand and gravel	slight	severe
4. Sebewa (30%) Kane (25%) Minor Soils (45%)	poor	level to gently sloping	clay loam to loam over sand and gravel	moderate to severe	moderate to severe
5. Pecatonica (15%) Ogle (14%) Durand (11%) Minor Soils (60%)	fair to good	level to gently sloping	silty and sandy clay loam over sandy loam	moderate	slight
6. Edmond (18%) Rockton (12%) Minor Soils (60%)	good	level to steeply sloping	clay to clay loam	moderate	severe
7. Mahalasville (40%) Elburn (25%) Minor Soils (35%)	poor	level to gently sloping	silty clay and silty loam over sandy loam and sand and gravel	slight to moderate	moderate to severe
8. Colwood (20%) Sebewa (17%) Minor Soils (63%)	poor	level	clay loam over silt, sand and gravel	severe	severe
9. Marshan (22%) Gotham (18%) Dickman (13%) Minor Soils (47%)	poor to excessive	level to gently sloping	clay loam and loamy sand over sand and gravel	severe	severe

B. Surface Water Resources

1. Quantity

The Yahara River basin drains all of the southern-central portion of Dane County. This basin includes the Madison Lakes as well as the Badfish Creek.

Table 2-3 shows the flow values for the Yahara River and the Badfish Creek. Over its length (60 miles) the Yahara River falls a total of 190 feet. Most of this is absorbed through the Madison Lakes and at the four dams located downstream of the lakes system. There are numerous wetland areas and small kettle lakes in the basin. These are associated with the topographical features left by glaciation.

2. Quality

Surface waters of the basin are generally rich in nutrient materials and profuse growths of aquatic vegetation and algae are common. Siltation results in increased turbidity and sediment loading to the basin. These conditions are due, in part, to the natural fertility of the lands of the basin, but are augmented by urban development and agricultural activities. Table 2-4 summarizes the water quality data for several monitoring stations in the basin.

3. Uses

The surface waters of the Yahara River Basin are utilized for recreation, fish and aquatic life propagation, power generation, industrial cooling water, irrigation, stock watering and waste assimilation. A major asset of the basin is the recreational opportunities afforded by the lakes and streams. Fishing, swimming and boating are all enthusiastically pursued by residents and visitors of the area.

The dams located on the River are not presently utilized for power generation. The dams at Dunkirk and Stebbinsville are currently undergoing repair and will be put into operation in the near future.

Irrigation and stock watering utilize relatively small amounts of the flow in the basin.

The Badfish Creek is used most extensively for waste assimilation receiving the effluent from the MMSD (approximately 36 MGD in 1975) and the Village of Oregon wastewater treatment plants. Diversion of the MMSD effluent from the Yahara River, upstream of Lake Waubesa to the Badfish Creek was initiated in December of 1958. The City of Stoughton treatment plant discharges 1.0 MGD directly to the Yahara River. The Village of Cottage Grove treatment plant discharges 0.03 MGD to Door Creek which flows into the Yahara River.

4. Sources of Pollution

Pollution of surface waters may occur as the result of point source or non-point source discharge of possible contaminants. Point source discharges (direct discharges) generally originate either from a municipal or industrial wastewater treatment plant. Non-point source discharges (indirect discharges) may result from

TABLE 2-3

FLOW DATA, YAHARA RIVER BASIN

Stream	Location	Drainage Area Sq. Miles	Low Flow ($Q_{7,10}$) cfs	Average[e] Discharge cfs	100 Yr. Flood Discharge cfs	Period of Record
Badfish Creek	near Stoughton U.S.G.S.5-4301	43.5	1.9[a]	52.4	871[d]	1956-66
Badfish Creek	Mouth	83.1	8.8[a]	–		
Yahara River	McFarland U.S.G.S.5-4295	327	4.7[b]	148	867[d]	1930-
Yahara River	at Stoughton	407	6.6[a]	–	970[c]	
Yahara River	Mouth		15.4[a]	–	–	

a - Harza Engr. Co., "Water Quality of Badfish Creek", 1971
b - Determined for post diversion flow data, O'Brien & Gere Engineers
c - U.S.G.S., Open file report
d - Maximum recorded discharge, period of record
e - U.S.G.S., "Water Resources Data for Wisconsin", 1974

TABLE 2-4

WATER QUALITY DATA

FOR SUMMER MONTHS (JUNE-SEPT.)[1]

	Yahara River[2]		Main Stem Badfish Creek		Badfish Creek Rutland Branch	
	1955-1958	1972-1975	1955-1958	1972-1975	1955-1958	1972-1975
Temperature (°C)	20.2	20.4	16.2	19.3	13.3	13.5
Dissolved Oxygen	10.8	6.8	8.6	2.5	10.2	8.8
pH	9.1	8.3	8.0	7.6	8.1	8.0
BOD5	6.8	10.8	2.6	18.1	1.7	1.6
Suspended Solids	35.1	84.0	32.9	24.4	20.0	13.8
Vol. Suspended Solids	17.6	50.3	23.3	9.0	14.0	4.1
Phosphorus	1.0	1.5	0.6	6.0	0.09	0.1
OrgN	2.6	2.4	0.7	1.8	0.4	0.5
Ammonia-N	0.07	1.3	0.3	10.5	0.05	0.15
Nitrite-N	0.02	0.22	0.09	0.35	0.02	0.04
Nitrate-N	0.17	1.2	1.8	1.3	2.8	3.7
Total Coli	2,124	55,704	14,719	86,239	6,749	17,561

Source: MMSD Water Quality Monitoring Program

1 Values reported in mg/l, except as noted

2 Data collected at three locations:
Fulton, Section 18, Town of Fulton
Stebbinsville, Section 2, Town of Porter
STH 59, Section 10, Town of Porter

overland runoff, contaminated groundwater discharge, or from precipitation which contains particulate matter. Stormwater drains are considered as point sources of pollution since stormwater drainage systems serve to concentrate these wastes.

5. Surface Water Resource Management

The Yahara River basin is managed by the WDNR as a part of the Rock River Basin. An interim basin plan was prepared in accordance with Public Law 92-500. Management includes water quality monitoring, non-point source studies, self-surveillance of point-source discharges, and administration of the construction grants for pollution abatement facilities. Future management goals include the continuation and expansion of the above programs as well as implementation of an area-wide waste management study under Section 208 of Public Law 92-500.

C. Groundwater Resources

1. Quantity

The Yahara River basin has an abundant groundwater supply. A deep aquifer consisting of sandstone and dolomitic deposits of Ordovician and Cambrian ages contains much of the groundwater utilized for deep well water supply in the basin. Shallow wells draw groundwater from the glacial till, ground moraine and outwash deposits of the Quaternary age. The surface deposits are in general sufficiently permeable to permit moderately rapid recharge of the groundwater.

Surface water flow in the basin is normally augmented by groundwater discharge. In Dane County it has been estimated (Cline, D.R., 1965) that approximately 60 to 95 per cent of the annual average stream flow is contributed by groundwater discharge. In areas of heavy groundwater pumpage, such as in the immediate vicinity of the City of Madison wells, drawdown of the groundwater may result in recharge by the nearby surface waters.

2. Quality

Groundwater quality is good in the Yahara River basin. The quality of the groundwater is reflected by the values shown in Table 2-5. The high concentrations indicated for dissolved solids and total hardness result from the percolation of the groundwater through the sandstone and dolomite which make up the area's aquifer. Due to the high hardness, many homeowners in the area have had water softeners installed. In a few isolated wells, iron concentrations have been sufficiently high to cause staining problems. The background concentrations of nitrate nitrogen are less than 5 mg/l. A few isolated wells have had concentrations reported in excess of the accepted drinking water standard of 45 mg/l (U.S. Public Health Service).

TABLE 2-5

GROUNDWATER QUALITY DATA

	Range	Average
Dissolved Solids	175 - 500	270
Total Hardness as $CaCO_3$	170 - 470	260
Total Alkalinity as $CaCO_3$	100 - 390	300
Sodium & Potassium as Sodium	0 - 45	8
Chlorides	0 - 100	10
Sulfate	0 - 140	25
Nitrate	1 - 18	3.8

Source: Cotter, R.D., et al, 1969
Values reported in mg/l

3. Uses

As discussed above, the groundwater aquifer furnishes virtually all the water utilized in the basin for public, industrial and private water supplies. The City of Madison, the major water user in the basin, currently withdraws approximately 30 MGD. Other users include Oscar Mayer, Inc. and other municipalities.

4. Sources of Pollution

Potential contaminants of the groundwater may reach the aquifer from a number of sources, including poorly located or designed sanitary landfills, industrial or municipal wastewater seepage lagoons, private wastewater septic tank drainage fields, animal feedlots, and improperly conducted fertilization programs. Materials applied to the soil surface at rates faster than they can be removed by surface runoff or utilized by the flora and fauna, pose a threat to the groundwater and potentially contribute to its pollution.

5. Groundwater Resource Management

The WDNR and the USGS have established a groundwater monitoring network on a statewide basis. This program enables these agencies to monitor the groundwater quality and to locate quality problem areas.

Regulations and guidelines have been established to control activities which may lead to groundwater contamination. Siting and design criteria for septic tank systems and sanitary landfills and fertilizer application rates help to minimize the hazards of groundwater pollution from these sources.

2.07. BIOLOGY

A. General

The study area biology includes all the animal and plant life of both terrestrial and aquatic habitats. The native and introduced species of mammals, birds, reptiles, fish, amphibians, insects, trees, shrubs and grasses are all a part of the area's environment.

B. Mammals

Mammal species of Wisconsin have been reported to have numbered 78 species in all (Wildlife, People and the Lane, 1970). Some species such as the bison, cougar and wolverine have disappeared from the state. Other species remaining in the area include squirrels, foxes, weasels, white-tailed deer, mice, muskrat, rabbits, bats and badgers. While some species are found exclusively in fields, others in woodlands and others in marshy habitats, many species are found in overlapping habitat areas. The south-central portion of Wisconsin, including Dane and Rock Counties, is extensively cultivated. As a result, species found primarily in field and light woods are common. This would include the rabbits, mice, skunks, foxes and some weasels. Species found in woods and deep woods are not common or not found at all in the area. This would include the white-tailed deer and the black bear.

C. Reptiles

Reptiles common to the area include many snakes and turtles and a few lizard species. These are important in the control of the insect and small rodent populations. Two species of poisonous snakes are found in Wisconsin, the Massasaqua and the timber rattlesnake. However, neither of these are found in the Dane and Rock County area.

D. Amphibians

The amphibians, frogs, toads and salamanders, find ample habitat areas in the eastern portions of Dane and Rock Counties in the numerous wetlands and along streams and rivers. They are not as abundant in the western areas of the counties due to the scarcity of wetlands. The amphibians also play an important role in the control of the insect population.

E. Birds

The bird species of Wisconsin include upland game species, waterfowl, shore birds, birds of prey and song birds. Depending upon the species, bird habitats can range from the wild lake and woods areas favored by the bald eagle to the typical backyard inhabited by the sparrows, robins and other song birds. Some species are year-round inhabitants while others are migratory or only occasional visitors to the area. The upland game birds and the waterfowl species offer abundant opportunities for hunting in the area.

A record number, 91 bird species, were recorded in the Madison vicinity during the 1974 annual Christmas Bird Count sponsored by the Audubon Society. Similar counts in Evansville, Cooksville and Beloit recorded 37, 28 and 49 species, respectively.

F. Invertebrates

Invertebrates include all of the various species of spiders, ticks, grasshoppers, crickets, beetles, dragonflies and the many other related groups found in Wisconsin. A complete listing of the invertebrates is impossible since not all species have been enumerated or classified as yet. An investigation of the aquatic insects of the Badfish Creek and at two locations on the Yahara River was conducted during the summer months of 1975. The results of that program are found in Appendix E.

G. Fish

Fish species of Wisconsin range from the intolerant game species such as the rainbow trout to the very tolerant rough fishes such as the carp and bowfin. Many fish species are quite sensitive to water quality and habitat changes while others are not and may be found in a variety of habitats. An analysis of a water body's fish population may be useful in indicating the general water quality of a lake or stream. During 1975 a fish sampling program was conducted on the Badfish Creek and at two locations on the Yahara River. Results of that program are found in Appendix D. Table 2-6 is a summary of the types of fish which may be found in the Dane and Rock Counties' waters.

H. Endangered Species

The United States Department of the Interior (USDI) has published an extensive listing of the species which are threatened with extinction throughout the world. This list has been utilized by the Wisconsin Department of Natural Resources (WDNR) as an aid in developing a similar list for the state. This listing (Table 2-7) is much more restricted than that of the USDI. The only species included on the WDNR list which may now be found in the study area is the ornate box turtle. Members of this species occur along streams in wooded areas and may possibly occur in the western regions of Dane County. Also, at one time an active fishery for cisco was reported to be in the Madison Lakes. However, this species is no longer found due to a combination of intensive fishing pressure and changes in the water quality and habitat of the Lakes.

The Rare and Endangered Animal Species list provided by the U.S. Environmental Protection Agency, Region V, is shown as Table 2-8. The blue pike (Stizostedium vitreum glaucum) included on this list is a subspecies of the commonly found walleyed pike (Stizostedium vitreum). The blue pike was found in Lakes Erie and Ontario but reports of the species have been so sporadic that it is now thought that the species has totally disappeared from the lakes (Scott and Crossman, 1973). The Kirtland's warbler (Dendroica kirtlandii) and the Indiana bat (Myotis sodalis) are not found in Wisconsin.

I. Vegetation

Native terrestrial vegtation species of the study area included the grasses, shrubs, wildflowers and marsh plants common to the once extensive prairie lands and wetlands. Through the increased activities of man, these areas have been drastically

TABLE 2-6

SURFACE WATER FISHERIES

	Typical Gamefish Species						Typical Panfish Species					Forage Fish	Rough Fish
	Trout	Large Mouth Bass	Small Mouth Bass	Walleye Pike	Northern Pike	Channel Catfish	Yellow Perch	Bluegill	Crappie	Bullhead	White Bass		
Badfish Creek					X					X		X	X
Black Earth Creek	X	X	X	X			X	X	X	X	X	X	X
Koshkonong Creek					X	X				X		X	X
Lake Kegonsa		X	X	X	X		X	X	X	X	X	X	X
Lake Koshkonong												X	X
Lake Mendota		X	X	X	X		X	X	X	X	X	X	X
Lake Monona		X	X	X	X		X	X	X	X	X	X	X
Rock River		X	X	X	X	X		X	X	X		X	X
Lake Waubesa		X	X	X	X		X	X	X	X	X	X	X
Wisconsin River		X	X	X	X	X	X	X	X	X		X	X
Yahara River		X	X	X	X		X			X		X	X
Sugar River			X		X	X			X	X	X	X	X

TABLE 2-7

WISCONSIN ENDANGERED SPECIES LIST

MAMMALS

Canada lynx - Lynx canadensis
Marten - Martes Americana
Timber wolf - Canis lupus lycaon

BIRDS

Bald eagle - Haliaetus leucocephalus
Osprey - Pandion haliaetus
Double crested cormorant - Phalacrocorax
Peregrine falcon - Falco peregrinus

REPTILES

Ornate box turtle - Terrapene ornata
Queen snake - Natrix septemvitatta
Massasauga - Sistrurus catenatus
Wood turtle - Clemmys insculpta

FISHES

Greater redhorse - Maxostoma valenciennesi
Ozark minnow - Dionda nubila
Pugnose shiner - Notropis anaogenus
Longjaw cisco - Coregonus alpenae
Kiyi - Coregonus kiyi
Shortjaw cisco - Coregonus zenithieus
Shortnose cisco - Coregonus reighardi

Source: Wisconsin Department of Natural Resources

TABLE 2-8

RARE & ENDANGERED ANIMAL SPECIES
(USEPA REGION V)

FISH	
Salmoniformes	
Longjaw Cisco	Coregonus alpenae
Perciformes	
Blue Pike	Stizostedion vitreum glaucum
BIRDS	
Falconiformes	
Arctic Peregrine Falcon	Falco peregrinus tundrius
Passeriformes	
Kirtland's Warbler	Dendroica kirtlandii
MAMMALS	
Chiroptera	
Indiana Bat	Myotis sodalis
Carnivora	
Eastern Timber Wolf	Canis lupus lycaon

Source: U.S. List of Endangered Fauna, U.S. Department of the Interior, Fish and Wildlife Service, May 1974 reduced, so that at present, only scattered and isolated areas of prairie land remain and the acreage of wetlands remaining is becoming less each year. In the western portion of the study area, hardwood trees of the northern deciduous forest are common. These include maples, oaks, hickory and birch trees.

Some species of wildflowers are protected under Wisconsin statutes. Trailing arbutus, lady slippers, American bittersweet, pitcher plants and various wild lily species are protected from cutting, injury, destruction or removal from any public lands or from private lands without the owner's permission.

Aquatic vegetation includes the large rooted plants and the free floating and attached algae. The species found in any given water body are dependent upon the water quality and physical characteristics of the lake or stream. Many algal species have been grouped into the broad categories of clean or polluted water algae. Various investigators (Birge and Juday, 1922; Lawton, 1950; Fitzgerald, 1955) have found the dominant species of algae in the Madison Lakes have been from the polluted water species. These species include the Melosira, Anabaena and Anacystis. A sampling program to identify the algae species present in the Badfish Creek was conducted during 1975. Results of this program are found in Appendix D.

2.08. AIR QUALITY

The Federal government has established the National Ambient Air Quality Standards (NAAQS) which would, if universally met, provide for the protection of the public health with an adequate margin of safety. Among the various air pollutants for which maximum recommended standards have been set are the following:

- Sulfur oxides
- Particulate matter
- Carbon monoxide
- Photo chemical oxidants
- Hydrocarbons
- Nitrogen oxides

Air quality monitoring stations have been established in Dane and Rock Counties at several locations in Madison and Beloit, respectively. Data for 1974 collected at these stations are summarized in Table 2-9. During 1974 the stations in Madison and Beloit have met the standards set by the NAAQS. Measurements taken over the past five to ten years have indicated a reduction in the amount of particulate matter in the Madison area. The annual geometric mean for particulate matter in 1961 was 76 ug/m^3. A steady decline has resulted until, as shown in Table 2-9, the 1974 value is 42.32 ug/m^3. Other data show that the dustfall in Madison has decreased from 24.1 tons/sq mi/month in 1966 to 13.1 tons/sq mi/month in 1972.

TABLE 2-9

1974 AIR QUALITY DATA

Pollutant	Madison, Dane Co. (avg. for all sta.)	Beloit, Rock Co. (avg. for all sta.)	Time of Avgs.	Primary Ambient Air Qual. Stan.[1]
sulfur oxides	16.37 ug/m^3	14.38 ug/m^3	Ann. Arith. Mean	80 ug/m^3
particulate matter	42.32 ug/m^3	52.98 ug/m^3	Ann. Geo. Mean	75 ug/m^3
carbon monoxide	7.38 ppm	–	Max. - 8 hours	10 ug/m^3 (9 ppm)
total oxidants	105.0 ug/m^3	–	Max. - 1 hour	160 ug/m^3 2.
nitrogen dioxide	-	51.71 ug/m^3	Ann. Arith. Mean	100 ug/m^3

1. National Ambiant Air Quality Standards
2. Value for photo chemical oxidants

2.09. LAND USE

Land use inventories for Dane and Rock Counties have been prepared by the Dane County Regional Planning Commission and the Rock County Planning Department. Aerial photographs and field investigations have been utilized in developing a thorough compilation of the land uses. Tables 2-10 and 2-11 summarize the data collected for the two counties.

There has been increased development in each county as increasing populations have required additional acreage for housing, services, transportation and recreational opportunities. Vacant, agricultural and natural land use categories have shown the greatest declines as it is generally from these categories that the needs of the increasing population for developed land are satisfied. Other losses, especially in Dane County, have resulted from the annexation of acreage formerly under the jurisdiction of rural townships to existing urbanized areas. This again is the result of the demands of the increasing population.

As the population continues to increase, if past trends are followed, additional land areas will be developed to accommodate the greater number of people. The projected year 2000 Dane County population of 400,000 would be an increase of approximately 38% over the 1970 population of 290,272. The MMSD planning area had a population in 1970 of 240,406. DCRPC projects this to increase by 44% to 345,715 by the year 2000. Based on this projected increase in population, the DCRPC has estimated that there would be a demand for an additional 2040 acres of developed land (commercial, residential and manufacturing) in the MMSD planning area by the year 2000. As population projections are revised and changes in land use patterns take place this estimate might also be revised to reflect these changes.

2.10. SIGNIFICANT ENVIRONMENTALLY SENSITIVE AREAS

A. General

Areas with significant environmental sensitivity include areas of unique or scarce wildlife habitat or of scientific interest. Wetlands, wood lots, geological formations and prairie land are typical of environmentally sensitive areas. Special care must be taken to protect these areas from change or destruction.

B. Wetlands

The wetlands provide many valuable services including the following:

1. Watershed protection
2. Recreation
3. Education
4. Scenic value

TABLE 2-10

DANE COUNTY - LAND USE

	1970		1964	
	Land Use in acres	Percent of total	Land Use in acres	Percent of total
RESIDENTIAL	29,969.6	3.8	24,291.9	3.1
Single Family	15,595.1		N.C.	
Two Family	747.5		N.C.	
Multiple Family	913.7		N.C.	
Farm Dwellings	11,756.2		N.C.	
Group Quarters	56.8		N.C.	
Mobile Homes	528.0		N.C.	
Hotel and Motel	123.0		N.C.	
Seasonal Dwellings	249.3		N.C.	
MANUFACTURING	991.2	.1	N.C.	N.C.
TRANSPORTATION AND UTILITIES	34,392.0	4.4	N.C.	N.C.
Street and Road R.O.W.	29,144.0		25,992.7	
Other	5,248.0		N.C.	
COMMERCIAL	1,941.8	.2	N.C.	N.C.
Wholesale	515.8		N.C.	
Retail	1,426.0		N.C.	
SERVICES	6,382.0	.8	N.C.	N.C.
General	1,049.1		N.C.	
Government and Education	5,332.9		N.C.	
RECREATION	11,632.2	1.5	11,459.6	1.5
AGRICULTURAL AND VACANT	678,716.1	86.3	686,555.8	88.2
WATER	22,651.4	2.9	16,270.3	2.1
TOTALS	786,676.3	100.0	778,232.9	N.C.
DEVELOPED ACREAGE	85,308.8	10.8	75,406.8	9.7

N.C. - Not Comparable, similar data was not collected in 1964

Source: Dane County Regional Planning Commission

TABLE 2-11

ROCK COUNTY - LAND USE

TOWNSHIP TOTAL

	1973		1968	
	Land Use in acres	Percent of total	Land Use in acres	Percent of total
Residential	9,565.50	2.18	8,400.00	1.91
Trailer Park	236.25	.05	26.00	.01
General Industrial	33.00	.01	18.50	–
General Extractive	519.50	.12	401.25	.09
Transportation, Communication and Utilities	901.75	.21	782.25	.18
Street and Roadway R.O.W.	12,216.75	2.78	11,932.00	2.71
Railroad R.O.W.	1,684.00	.38	1,755.00	.40
General Commercial	260.50	.06	145.50	.03
Motels and Hotels	23.25	.01	12.00	–
Personal and Business Services	236.25	.05	136.00	.03
Government Services	51.00	.01	17.00	–
Educational Institutions	146.50	.03	61.00	.01
Cemeteries	158.75	.04	159.50	.04
Cultural, Entertainment and Recreational	956.00	.22	233.75	.05
Public Parks and Waysides	954.75	.22	663.00	.15
Agricultural	375,573.25	85.58	380,336.00	86.28
Vacant Land	2,572.25	.59	2,571.25	.59
Vacant Buildings	38.75	.01	31.50	.01
Woodland	28,591.25	6.51	29,190.25	6.62
Water	4,135.50	.94	3,920,75	.89
TOTAL	438,854.70	100.00	440,792.50	100.00
Developed Acreage	27,982.50	6.38	24,774.25	5.62

Source: Rock County Environmental Inventory-Rock Valley Metropolitan Council, 1975

However, it is not often that the value of such areas is readily apparent in monetary terms. Consequently, there is pressure from private owners and developers to initiate drainage or other measures which would enhance the immediate monetary value of a wetland area.

Wetlands of Dane County have been studied (Bedford, et al., 1974) and a priority rating system has been set up. This has been an attempt to rate the quality and importance of each wetland area in the county. Priority groups range from I to V, with I being the highest rating. The ratings now can be used as an aid in planning future development within the county.

Rock County has not had an intensive study of its wetlands. Most of the wetlands in Rock County are located in the Yahara and Rock River valleys. In 1968 a survey indicated that there were approximately 4,200 acres of wetlands within the towns of Union, Porter, Fulton, Milton and Janesville.

C. Scientific and Natural Areas

In order to aid in the protection of other environmentally sensitive areas, the Wisconsin Department of Natural Resources has established the Scientific Areas Preservation Council. This Council has indentified and listed many sites within the state which have significant value for their educational, research, scarce or unique characteristics. Examples of native prairie land, wood lots, wetlands and geological formations are among those areas listed. Most of the sites inventoried and listed by the Scientific Areas Preservation Council are privately-owned and are not open to the public for their use nor is there any direct control over the use or management of such sites. A relatively few (approximately 124 in the state) are under public ownership or management. Two public sites are located in Dane County and three in Rock County. These are listed in Table 2-12 below.

TABLE 2-12

PUBLIC SCIENTIFIC AREAS

Site	Location	Acres
New Observatory Woods	Dane County	13
Waubesa Wetlands	Dane County	129
Avon Bottoms	Rock County	40
Swenson Prairie and Oak Opening	Rock County	40
Newark Road Prairie	Rock County	22.5

Additions to the listing of scientific areas are continually being made as more are identified and inventoried. At present there are about 70 privately owned sites in Dane County and 95 similar sites in Rock County in the Council's data file.

2.11. POPULATION

Population data is collected and tabulated by the United States Bureau of the Census. Wisconsin's total population has increased from the 30,945 reported by the Bureau of Census in 1840 to 4,417,731 for 1970.

Dane and Rock County's population in 1970 had increased significantly in the decade since 1960. Table 2-13 summarizes the population changes between 1960 to 1970.

TABLE 2-13

POPULATION DATA

	1960	1970	% Change
Wisconsin	3,951,777	4,417,731	+11.8
Dane County	222,095	290,272	+30.7
Rock County	113,913	131,970	+15.9
City of Madison	126,706	173,258	+36.7

As evidenced by the above data, the urban areas have experienced the greatest population increases.

2.12. OTHER WATER QUALITY MANAGEMENT PROGRAMS IN THE AREA

A. General

The present 201 Facilities Plan Study for the Madison Metropolitan Sewerage District is being conducted under the scope of Section 201 of Public Law 92-500. It is the goal of the 201 Study to identify an environmentally sound and economically feasible wastewater treatment and discharge strategy and a sludge disposal program which will be consistent with other region-wide plans.

Other programs concerned directly with water quality management or wastewater treatment and discharge in the area include the following:

1. 208 Planning Program for Dane County

2. 201 Facilities Plan Studies - several communities are in various stages of completion.

3. National Wild and Scenic Rivers System Study for the lower portion of the Wisconsin River.

B. Dane County 208 Planning Program

The Dane County Regional Planning Commission has been designated as the 208 Planning Agency for Dane County. This planning effort will investigate various operational and administrative alternatives and determine the most practicable program which will insure the protection of the surface and groundwater quality. The work plan for the program has identified the following work elements.

- Non-point Sources
- Municipal Wastewater Treatment Plants
- Water Quality Standards
- Waste Load Allocations
- Land Use - Water Quality Linkages
- Institutional Considerations
- Wisconsin Pollutant Discharge Elimination System
- Protection and Preservation of Streams
- Protection and Preservation of Marshes and Wetlands

Each of these work elements will be investigated and recommendations or aid will be given in appropriate areas which will help to implement the goal of the program.

C. 201 Facilities Planning Studies

In addition to the 201 Facilities Plan being conducted for the Madison Metropolitan Sewerage District, the communities of Deerfield, Edgerton, Mt. Horeb, Sun Prairie, Marshall, Brooklyn and Verona area also conducting similar studies in the general study area. An investigation of alternative discharge sites and treatment processes is an integral part of a 201 study. The recommendations of a 201 study should be compatible with other study plans in the area.

D. Wisconsin River - National Wild and Scenic Rivers System Study

It is the objective of the Wild and Scenic Rivers Act passed by the U.S. Congress in 1968 to preserve and protect "for the benefit and enjoyment of present and future generations" the rivers or sections of the rivers which possess "outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural or other similar values". The Wisconsin River, in that section reaching from its mouth at Prairie du Chien, upstream to Prairie du Sac, has been included as being worthy of further study under this act. Dependent upon the results and recommendations of the initial study various land use and water management alternatives may be implemented.

2.13. AESTHETICS AND RECREATION

A. Aesthetics

Aesthetic qualities are difficult to evaluate. Enjoyment of natural areas, scenic overlooks, pleasing architectural styles or even the knowledge that the opportunities exist to enjoy these areas are a part of the aesthetic quality of an area. Dane and Rock Counties offer ample opportunities to observe native wildlife in their natural habitats. The University of Wisconsin Arboretum in Madison in an excellent area in which to view not only many mammals, birds and other animal species but also a variety of the scarce habitat regions (wetlands, prairie and oak openings) that were once common in Wisconsin. Numerous other sites in Dane and Rock Counties are available for those interested in the enjoyment of nature.

B. Recreation

Recreation facilities are readily available in Dane and Rock Counties. County parks offer a variety of outdoor sports opportunities including skiing, golf, picnicking, camping, swimming and fishing. Privately-owned and village-operated areas are also available for use. The many lakes and streams in the area have generally easy public access and are widely utilized for water orientated activities. Fishing and boating are popular with both area residents and visitors. Hunting for the upland game birds and waterfowl species are also important recreational outlets available in the area. During 1974 a total of 54,599 regular fishing licenses and over 55,000 hunting licenses were sold in the area. In addition, approximately 25,000 "Voluntary Sportsmen's" licenses were sold in Dane and Rock Counties. These licenses entitle the holder to all fishing and hunting privileges (except deer and bear hunting) while providing a means to contribute funds directly to fish and game management programs.

2.14. ENERGY

A. General

Electrical power in the Dane and Rock County area is supplied primarily by the Wisconsin Power and Light Company (WP&L) and by the Madison Gas and Electric Company (MG&E). MG&E supplies the power needs for the City of Madison and other areas in the immediate vicinity. MMSD obtains most of their power from MG&E. WP&L furnishes power for one pumping station.

B. MMSD Usage

Electrical energy is utilized by the Madison Metropolitan Sewerage District to operate the multitude of motors, pumps and miscellaneous equipment required to collect, convey, treat and discharge the wastewater from the District. The total electrical energy requirements of MMSD have increased annually as the wastewater flow has increased and the degree of treatment has been upgraded to provide improved treatment. In 1937, the first year after the activated sludge treatment process was added, the electrical requirements of MMSD were 2,415,590 KWH. At that time, it is estimated, only 20% of MMSD's power requirements were used for the treatment and discharge of the wastewater.

By 1974 total electrical requirements had reached 19,262,456 KWH. Discharge pumping alone is estimated to demand 60% of the total.

Gasoline and diesel fuel are used to run the trucks, cars, earth moving equipment and gasoline powered pumps. The 1974 consumption of gasoline and diesel fuel for the operation and maintenance of the Nine Springs Wastewater Treatment Plant was: gasoline, approximately 4,158 gallons and diesel fuel, approximately 19,601 gallons. All of the diesel fuel and an estimated 75% of the gasoline was utilized for the processing and storage of organic solids (sludge).

2.15. PUBLIC HEALTH

A. General

The State and local public health agencies have the responsibility of maintaining a surveillance of the areas which would effect the public health. Food inspection, well water analysis, swimming area water analysis and mosquito control are only some of the areas in which the public health agencies are involved.

B. Waterborne Diseases

Typhoid, cholera and dysentery are caused by bacteria associated with improper wastewater collection, treatment and disposal. Periodic epidemic outbreaks of these and related diseases were not uncommon in the United States even into the early 1900's. There have been no major occurrances of waterborne diseases in either Dane or Rock County in recent years. Only isolated individual cases resulting from well water contamination by improper septic tank placement or maintenance have been reported.

Occasional outbreaks of schistosome dermatitis, or "swimmers itch", have occurred at various beaches on the Madison Lakes. This is a relatively minor skin irritation caused by a parasitic blood fluke. The species found in Wisconsin appears to be incapable of surviving in a human host and therefore the irritation is limited to the skin or region of initial contact.

C. Mosquito Control

There are no area-wide mosquito control programs in effect in either Dane or Rock County. Limited spraying or fogging operations are conducted primarily in recreational facility areas such as picnic or camp grounds as much for nuisance control as for prevention of disease.

Mosquitoes can transmit such diseases as yellow fever and encephalitis. During 1975 a number of cases of the St. Louis strain of encephalitis were reported in Missouri and Illinois. Locally, two or three suspected cases were reported, but it could not be confirmed that the individuals had contacted the disease locally as all had travelled outside of the state.

2.16. HISTORICAL AND ARCHEOLOGICAL SITES

A. Historical Sites

There are many sites of local, state and national historical significance in Dane and Rock Counties. A total of 26 sites in Dane County have been listed in the National Register of Historic Places. Twenty-one of these sites are located within the City of Madison. There are six sites in Rock County which have been listed. The hamlet of Cooksville, located in the Town of Porter, has been included as an historic district due to several examples of early architecture found there. In addition to the National Register of Historic Places listing, which is limited to sites of more than local significance, there are numerous sites connected with local history.

B. Archeological Sites

The State Historical Society of Wisconsin maintains a data file on known archeological sites. It has been reported by the Historical Society that there are many known archeological sites located in Dane and Rock Counties. These sites include indian effigy and burial mounds, campsites and village sites.

SECTION 3

SLUDGE DISPOSAL ALTERNATIVES

3.01. PREVIOUS STUDIES

A. General

The Madison Metropolitan Sewerage District has had a number of studies done to determine a more reliable and feasible method of sludge disposal. After the 1970 failure of the dike on the eastern sludge lagoon, a study by Warzyn Engineering and Service Company, Inc. indicated that the lagoon dikes were built on a base of peat and silt. There was very little bearing strength and a good possibility existed of further dike failures. Extensive dike maintenance and repair work were required to prevent further failures from occurring.

B. Waste Treatment Report, Greeley and Hansen Engineers, 1971

The firm of Greeley and Hansen Engineers submitted its "Report on Sewage Treatment Additions to the Nine Springs Sewage Treatment Works" in March of 1971. In addition to evaluating improvements of the waste water treatment processes, the report evaluated five sludge handling and disposal alternatives. These alternatives were as follows:

- Spread dried, digested sludge on land
- Incinerate digested sludge
- Incinerate raw sludge
- Heat treat and landfill digested sludge
- Apply liquid, digested sludge to land

An economic analysis of these alternatives indicated that the application of liquid digested sludge alternative, with a 25 mile pipeline transport system, was the least costly. It was estimated that the cost of this alternative was $23.00 per ton of dry solids. The other alternatives ranged in cost from $66 to $91 per ton of dry solids.

C. Sludge Disposal Study, Roy F. Weston Engineers, 1974

The firm of Roy F. Weston Engineers submitted a report, "Nine Springs Sewage Treatment Works Sludge Disposal Study" in 1974. This study dealt entirely with sludge treatment and disposal alternatives.

Seven methods of sludge disposal were evaluated during the course of this study as follows:

- Sanitary landfill
- Subsurface placement
- Lagoon storage

- Land application of liquid sludge
- Land application of dried sludge
- Land application of compost
- Dispersion to the atmosphere (Incineration)

The alternatives were ranked by their ability to fulfill a series of six primary objectives, each broken down into several categories. The primary objectives were as follows:

- Public acceptability
- Environmental preservation
- Resource recovery potential
- Adaptability to disposal site constraints
- Operational flexibility
- Product marketability

Four methods of disposal were eliminated from detailed evaluation after a preliminary screening.

Lagoon disposal of sludge had ranked high in a number of categories, most notably in the operational flexibility and in the minimization of the accumulation of heavy metals in the food chain and in the minimization of air pollution parameters other than odor.

The possibility of continued lagoon disposal of the digested sludge was eliminated despite the high ranking noted above because of the dike instability and the probable lack of support from public officials. In addition, the WDNR had included as a requirement of pollution abatement order number 4B-71-1L-22, issued in 1971, that the present method of sludge disposal to the existing lagoons be abandoned and that an alternative method of sludge dispoal be implemented as soon as practicable. As clarification of this point, the WDNR indicated in 1972 that the following methods of sludge disposal would be acceptabile: spreading of liquid digested sludge on farmland; composting; vacuum filtration of digested sludge and disposal of the cake on land; and vacuum filtration of undigested sludge followed by incineration.

Land application of dried sludge also ranked high in a number of categories. It was judged to rank high in public acceptability, in several categories under environmental preservation, in providing nutrients to the soil under resource recovery potential, in adaptability to disposal site constraints and in several categories under product marketability.

Testing of the sludge produced at the Nine Springs treatment plant during the course of the study indicated that the dewatering characteristics of the sludge were quite poor. This, coupled with the variable quality of the sludge in regard to meeting the "guaranteed nutrient level" of other dried sludge products (i.e. "Milorganite" which has been marketed by the Milwaukee Sewerage Commission for a number of years), would make the production of a marketable product difficult.

While the land application of dried sludge had ranked high in most categories, under the product marketability objective it had ranked low in one important category, that of market assessability. The Milwaukee Sewerage Commission had marketed its dried sludge under the name of "Milorganite" as mentioned. Despite the early success of this program, the market had dwindled to a specialized group of customers. Since relations with these customers, mainly golf courses, had been established over a number of years, it was judged that MMSD would find the market assessability very tight. Land application of dried sludge was, therefore, eliminated from further consideration.

Incineration of the sludge was also eliminated. Various alternatives for dewatering the sludge, including vacuum filtration and centrifugation, were considered necessary prior to incineration. Due to the high moisture content of the sludge cakes subsequent to dewatering tests, the use of supplemental fuel was considered necessary to maintain combustion in an incinerator. The heat value of the sludge cakes was not high enough to support combustion. Sandbed drying and lagooning for dewatering the sludge was not considered as an efficient method of drying sludge as it would not meet the requirement of continuous feed to incinerator. It was judged that incineration was not practicable without the use of supplemental fuel for sludge drying and the maintenance of combustion.

The only categories in which incineration received high rankings were the minimization of groundwater pollution, insect breeding and odor emissions. In all other categories, incineration received low rankings. Due to the limited supply of commonly available fuels, incineration of sludge was eliminated.

Subsurface placement, or trenching, of sludge had been eliminated due to the strong possibility that such a disposal alternative would not gain WDNR approval. The Weston report states that "The ranking of options (alternatives) with respect to this objective (favorable enforcement agency attitude) was based principally upon the consultant's interpretation of conversations with Wisconsin Department of Natural Resources personnel concerning disposal options for municipal wastewater treatment sludge. DNR specifically stated that they would not approve of the Subsurface Placement disposal option under any circumstances".

Three other alternatives evaluated in this report were the land application of liquid sludge, land application of compost and sanitary landfill. These alternatives were all found to be suitable and were further evaluated.

In the judgement of Roy F. Weston, Inc. sufficient disadvantages existed for the probable successful implementation and operation of the sanitary landfill and the land application of compost alternatives, such that land application of liquid sludge was the recommended method of sludge disposal. The land application of liquid sludge was calculated to be the least costly with an estimated disposal cost of $63 per dry ton of solids.

D. Addendum to Roy F. Weston Sludge Disposal Study, 1974

The staff of MMSD prepared an addendum to the Weston Report evaluating the costs associated with sludge conditioning (chemical addition, mechanical dewatering, centrifugation), and transportation for seven additional alternatives. The least costly alternative of the MMSD investigation was anaerobic digestion of thickened raw sludge, followed by pipeline transport to a lagoon and land irrigation at a cost of $41 per dry ton of solids.

E. Summary

The studies which were conducted regarding the final disposal of sludge produced at the Nine Springs Wastewater Treatment Plant determined land application of liquid digested sludge to be the most practicable method of sludge disposal. The MMSD Commission resolved in June, 1974, that sludge disposal would be handled through the land application of liquid digested sludge. As a part of the 201 Facilities Planning Study being conducted jointly by the firms of O'Brien & Gere Engineers, Inc. and CH2M-Hill Engineers, the investigation for the most environmentally sound and socially acceptable methods of implementing land application was conducted by the firm of CH2M-Hill.

3.02. LAND APPLICATION

A. General

Land application of sludge to agricultural land as a substitute for manufactured fertilizers or as a soil conditioner has gained in acceptance in recent years. Three basic levels of reuse are in general operation based on the application rate of sludge to the land. These are fertilization, high-rate fertilization and disposal. The rate of sludge application is dependent upon the sludge characteristics, soil conditions and the crop grown along with other considerations such as climate and farm community acceptance.

1. Fertilization

The reuse of sludge for its fertilizer value relies primarily upon the nutrient content of the sludge and the nutrient requirements of the crop being grown. Application rates typically range from 1 to 20 tons dried sludge per acre per year. While a beneficial reuse of the sludge solids is realized in this type of operation through the utilization of its nutrient value, maximization of crop production is the objective rather than the complete disposal of all sludge solids. Application of sludge is therefore limited to times when nutrient supply is critical to the crop growth and when application will not physically damage the crop. The toxic accumulation of heavy metals in the plant materials may also be limiting. If there is sufficient amount of agricultural acreage devoted to such a reuse program, then it may be possible to fully dispose of all sludge solids by this method. Storage facilities are required for those periods when it is not possible to apply the sludge to the crops.

2. High-rate Fertilization

High-rate fertilization differs from the fertilization method discussed above in that it is the objective of this method to completely dispose of all sludge produced dependent upon the soil's capacity to accept the sludge. Application rates typically range from 5 to 75 tons dried sludge per acre per year. Limitations are based on the protection of ground and surface water quality and climatic conditions as well as the soil characteristics. Maximization of crop production is secondary to sludge disposal. Storage facilities are again required to store the sludge produced during the winter months when it is impossible to apply sludge to the land.

3. Disposal

The maximum utilization of limited acreage for sludge disposal is possible with this method. Usage of the nutrient value of the sludge for crop growth is of minimal importance. Application rates are dependent almost entirely upon the protection of the ground and surface water quality. Climatic conditions are not of as great a limitation as with the other methods of sludge utilization.

B. Land Application Regulations

1. General

Regulations and guidelines pertaining to the land application of sludge have been developed by the WDNR and the USEPA. Local governmental agencies have indicated that no regulations have been developed at that level. Township, village, city and county agencies rely upon the state and federal requirements for regulation of sludge application to the land.

2. State Guidelines

The WDNR has prepared and issued, in 1975, Technical Bulletin 88, "Guidelines for the Application of Wastewater Sludge to Agriculatural Land in Wisconsin." This report provides the information required to develop a land application program. The considerations of soil suitability, public attitudes, system economics, public health aspects, system monitoring, crop requirements, sludge characteristics and site selection and management are discussed.

The WDNR guidelines should be utilized by planning and design agencies in the developement of any land application system. WDNR personnel will use these guidelines as an aid in determining if a particular land application program will be granted operation permits. The recommendations are summarized as follows:

- Raw sludge should not be applied to agricultural land.
- Sludges should be applied to soils consistent with the nitrogen needs of the crops being grown.
- At least 2 feet and preferably greater than 4 feet of soil should exist between the sludge application zone and bedrock, any impermeable layer, or the water table.
- Sludge should not be applied to soil in the year the area is used for any root crops or other vegetables which are consumed uncooked.

- If sludge is surface applied to sloping land, runoff should be minimized by use of contour strips, terraces and border areas. Also, runoff can be reduced by injection or immediate incorporation of the sludge.

- Pasture land (or corps which are harvested green) should not be used for milk cow feeding for 2 months following sludge application. Other animals should not graze pasture land or be fed greenchop material for at least 2 weeks after sludge application.

- Metal loadings must be kept within acceptable limits to minimize the potential of crop damage or food chain accumulation. The soil pH must be maintained at 6.5 or greater.

- Application systems must be such that they minimize the runoff potential and odor problems while remaining cost-effective.

- Sludge application sites should be at least 500 feet from the nearest residence. If the sludge is injected or incorporated into the soil, a reduction in this distance may be possible.

- Site management must be such that nutrient deficiency and soil acidity problems do not occur, public access is limited, and crop yields are maximized.

- Site monitoring should be the responsibility of the municipality. If sludge additions consistent with nitrogen requirements are used, monitoring needs include only sludge and plant analyses as well as routine soil testing. If higher rates, on dedicated land, are used, comprehensive groundwater monitoring must be included.

- To insure adequate protection of water supplies, the sludge application site should be a minimum of 1,000 feet from the nearest public water supply well and 500 feet from the nearest private water supply well.

The requirements that a 500 foot radius buffer zone around all private water supply wells would eliminate 15% of the available land area from further evaluation for the land application of sludge. Section NR 112.07(k) of the Wisconsin Administrative Code on Well Construction and Pump Installation Standards and Related Information requires that a 200 foot distance be maintained between any sludge disposal area and any well used to supply water for human consumption or for food preparation. Agricultural lands falling within a 500 foot radius of a private well would require the utilization of artificial fertilizers to provide the nutrients needed for maximum crop production if sludge application is prohibited.

3. Federal Guidelines

Federal guidelines regarding land application of sludge are contained in a supplement to the "Federal Guidelines: Design, Operation, and Maintenance of Wastewater Treatment Facilities" entitled "Municipal Sludge Management: Environmental Factors." The USEPA guidelines, which must be used by federal grant applicants, are summarized as follows:

- The sludge nutrient value, heavy metals and other constituents which may be economically recycled or cause environmental damage should be determined.

- The site soils should be tested for cation exchange capacity (C.E.C.), pH, and background heavy metals.

- The soils and groundwater conditions should be investigated at each site.

- Sludge must be stabilized before land application.

- Pathogen reduction may be required in some projects.

- The suitability of the crop for sludge amended soils must be determined.

- The project should be designed so that groundwater will be protected from pollution.

- Surface water runoff must be controlled.

- The annual application rate must be such that the amount of plant available nitrogen added is not greater than twice the nitrogen requirement of the crop.

- The grant applicant must show the capability to manage and operate the system.

- The grant applicant must develop and implement a monitoring program. The monitoring data must be periodically reviewed.

- The sludge heavy metal additions calculated as zinc equivalent must not exceed 10 percent of the C.E.C. of the unsludged soil.

- The soil pH must be maintained at 6.5 or greater for a period of at least 2 years after sludge application.

- Sludge having a cadmium content greater than 1 percent of its zinc content should not be applied to cropland except under certain specified conditions.

- Special precautions should be taken when sludge is applied to pasture.

- The facility plans should be reviewed by the U.S. Department of Agriculture (USDA) and Food and Drug Administration (FDA).

- Products in the human food chain grown on sludge amended land should be monitored for heavy metals, persistent organics, and pathogens.

Many of the federal and state regulations are similar in the concern for protection of ground and surface water quality, heavy metal buildup, establishment of a monitoring program and investigation of the capacity of the soils and potential crop to accept the sludge loading. Notable differences are apparent in the WDNR's in calling for application of sludge a rate "consistent with the nitrogen needs of the crop being grown." The USEPA's guidelines would allow application of sludge at a rate not to exceed twice the nitrogen requirements of the crop being grown.

C. Sludge Application Rate Considerations

1. Soil Suitability

Seven soil characteristics were evaluated for each soil series found in the study area to determine its suitability for sludge application. The soil characteristics were as follows:

- erosion hazard
- depth to groundwater
- depth to bedrock
- flood hazard
- soil texture
- soil permeability
- cation exchange capacity

Each soil characteristic was given a point rating ranging from 0 to 1.0, based upon pertinent data for that characteristic. The highest ratings were given to those soils most suitable for sludge application. A rating number for each soil series was obtained by multiplying the rating numbers of each individual soil characteristic together. The soils were then grouped into four classifications based on the final numerical rating as follows:

Class 1 - .66 - 1.00	- Most suitable
Class 2 - .35 - .65	- Suitable with minor limitations
Class 3 - .01 - .34	- To be used only if Class 1 & 2 soils are not available
Class 4 - 0	- Not suitable

Of the over 200 soil series and phases evaluated, only 83 obtained a classification of 1 or 2. These soils correspond to the WDNR guidelines' classification of soils with slight limitations for sludge application. Class 3 soils correspond to those with moderate limitations and Class 4 soils correspond to those with severe limitations.

2. Crop Suitability

Sludge application to crops for the utilization of its fertilizer value is based upon the fertilizer requirements of the crop and the fertilizer value content of the sludge. Crops grown in the study area require approximately 35 to 200 pounds/acre/year of nitrogen. (leguminous crops such as alfalfa are able to obtain nitrogen directly from the air but will utilize soil nitrogen if it is readily available.) Phosphorus requirements range from 15 to 85 pounds/acre/year and potassium requirements range from 40 to 400 pounds/acre/year. The annual sludge applications should not be greater than that which will meet the crop requirements for nitrogen. The nitrogen contents of the treatment plant and lagoon sludges differ due to the amounts of nitrogen available in each as shown in Section 1.04 of this report. In general, more lagoon sludge must be applied in order to reach the same level of nitrogen availability as with treatment plant sludge. Dependent upon the crop being grown, soil characteristics, past fertilization and crop management practices, annual sludge application rates, based on the nitrogen requirements, may range from .05 to over 6.0 tons/acre/year. Other possibly limiting factors such as the suggested limit of 2 pounds/acre/year (WDNR, 1975) of cadmium are not as restrictive as the nitrogen due to the characteristics of the MMSD sludge.

Based on the limit of 2 lbs/acre/year application of cadmium, the annual application rate for the existing treatment plant sludge would be 14 tons/acre/year and 31 tons/acre/year for the lagoon sludge. These are well above the maximum annual application rate of approximately 6 tons/acre determined by the nitrogen requirements.

Even though the cadmium to zinc ratio exceeds the suggested 1% limit (Chaney, P.L., 1973; Chaney, R.L., et al, 1975) as stated in Section 1.04, the potential toxicity problems associated with high cadmium loadings will not be significant due to the more restrictive nitrogen loading limits as they apply to the MMSD treatment plant and lagoon sludges.

Total application of sludge (over a period of years) is limited by the heavy metals loading. The USEPA and the WDNR have recommended the use of the "zinc equivalent" method of determining the permissible total heavy metals loading. Based on this method, total application would be limited to approximately 140 tons/acre of sludge for Class 1 soils, 90 tons/acre for Class 2 soils and 60 tons/acre for Class 3 soils.

Suggested total cadmium loadings are limited to 20 lbs/acre (WDNR, 1975). For the treatment plant sludge this would limit the total sludge loading to approximately 137 tons/acre and for the lagoon sludge to approximately 308 tons/acre. These are both well above the total loading limits established through the use of the "zinc equivalent" method as shown above.

Recommendations regarding the application of irrigation water developed at the University of California would limit the total application of lagoon sludge to 120 tons/acre based on its iron content. The effects of dissolved salts, mercury and phosphorus were also evaluated. Due to the characteristics of the treatment plant and lagoon sludges, the allowable loadings based on these parameters are not as restrictive as those established above.

The total sludge application should be reduced by approximately 25% for those areas where vegetables are grown for direct human consumption. Reduction of the total application by 50% in fields where leaf vegtables such as lettuce may be grown, since cadmium has a tendency to accumulate in the leaves should also be made.

Annual and total sludge application loadings must be determined on an individual basis. Soils analysis to determine the characteristics of the soils found on any given parcel of land must be carried out by qualified soils testing personnel. The planned crop for a given parcel of land must also be determined and the crop management practices must be adhered to. This will insure that the proper application rates are calculated and maintained. The sludge character must also be monitored so that changes in its character may also be accounted for in maintaining the proper application rate.

3. Other Considerations for Agricultural Reuse

a. Fertilizer Market

The fertilizer industry has experienced a shortage of natural resources and of the energy resources required to produce the quantity of fertilizers needed to meet the agricultural demand in recent times. As a result, the cost of manufactured fertilizers has risen sharply and the farm community has expressed a greater interest in obtaining alternate sources of fertilizer. The sludges produced at wastewater treatment plants, having a nutrient content capable of supplying at least a portion of the fertilizer demand, are being used to some extent to fill this need.

Due to projected costs for manufactured fertilizers remaining high, the demand for alternate sources is expected to also remain high. It is estimated that the Nine Springs Wastewater Treatment Plant could supply only 3% of the area's nitrogen requirements. This relatively limited supply should assure that the high demand for the available treatment and lagoon sludge continues.

b. Farm Community Acceptance

Two public mettings were held with members of the farm community of the area during the course of the study to determine the local attitudes toward the reuse of available sludge material. Questionnaires filled out at those meetings, as well as in response to a mailing to area farmers, resulted in approximately 26 farmers expressing a strong interest in using sludge on their agricultural land. These farmers, together, represent a potential sludge reuse area of over 5,000 acres. Estimates regarding the land area required for the land application of MMSD's treatment plant and lagoon sludges range from 5,200 to 5,700 acres. For the treatment plant sludge only, approximately 2,400 to 3,000 acres would be required.

The interest already expressed along with an anticipated public relations program appear to assure that sufficient land area would be made available through the farm community for land application.

c. Land Ownership

Evaluation of the alternative between private versus public (MMSD) ownership indicated that the cost of public ownership would be considerably greater than private ownership. For a more easily managed program under public ownership, a single large parcel of land would be beneficial. Condemnation proceedings would most probably be required in order for MMSD to purchase the large parcel of land area required. This would be both expensive and time consuming. Having a large parcel of land devoted to the land application of sludge under public ownership would place the public agency in competition with the private farmers for the sale of crops grown.

Maintaining the present privately owned land arrangements would appear to avoid the problems described above. No purchase of large land areas would be required as the sludge would be supplied only to those farmers who are voluntary participants in the program. The present competition for crop sales would also be maintained. The sludge application sites would of necessity be relatively small and scattered compared to a large publically owned site. This would require implementation of a well planned and managed program to insure the program's success.

4. Sludge Application Periods

Several factors will have a bearing on periods when sludge may be applied to the land. Cultural practices, stage of crop growth, weather, application equipment, and public health considerations affect the periods when sludge is applied. Weather conditions alone prohibit land application from December through March when there is a high probability that the ground may be frozen. Recommendations of the USEPA and WDNR also limit the periods when sludge may be applied to growing crops or to fields to be grazed or harvested for human or animal food.

Field conditions, whether they are wet and muddy or not, may determine the type of application equipment which must be utilized to enter the field. In general, tractor-drawn equipment would probably be able to operate in less favorable field conditions than even specially designed truck-drawn equipment.

The recommendations of the USEPA and the WDNR outlined previously, are meant to provide a reasonable degree of safety in regards to the public health. For those crops which are to be eaten by humans (sweet corn, green peas, etc.) and the crops which are to be fed to livestock (silage corn, forage grasses, etc.) minimum periods have been established which must elaspe between the sludge application and the harvesting. As discussed in Section 3.02 B, sludge should not be applied to sites in the year when any root crops or other vegetables which are cooked prior to consumption are grown. In addition, for vegetables which are commonly eaten uncooked, there should be no sludge application within three years of the time when the crops are grown. Dairy cows should not be allowed to graze in pastures or be fed greenchop (forage crops which are harvested green) for a period of two months following sludge application. Other livestock should not be allowed to graze in pastures or be fed greenchop for a period of two weeks following sluge application.

D. Methods of Sludge Transportation, Storage and Application

1. Transportation Methods

Of the three most feasible methods of sludge transport; rail haul, pipeline transport and truck transport, only pipeline and truck transport were considered applicable for the study area. Rail haul is feasible when suitable land areas are not available in the immediate vicinity of the wastewater treatment plant and the sludge would consequently have to be transported a considerable distance. Such is not the case in the study area where sufficient land area with suitable soil types for sludge application are available within 10 to 15 miles of the wastewater treatment plant.

Truck transportation of sludge utilizes closed tank trucks to convey sludge from the treatment plant to the various application sites. Tank capacities of up to 6,000 gallons are commonly available. In general, the larger the tank capacity, the less costly the transportation costs since fewer trips would be required to transport a given quantity of sludge. It is estimated that transportation costs would be approximately $2.69/dry ton mile utilizing a 5,000 gallon capacity truck.

Most trucks would be loaded at a central loading dock or wet well at the treatment plant and would discharge their loads to a temporary storage facility or directly to the field application equipment at the site. Some trucks have been specifically designed or modified to enable them to be utilized for both over-the-road haul and in-field application.

One of the primary advantages of a truck transport system is the flexibility of operations afforded by the mobility of a truck fleet. A disadvantage of such a system is the additional traffic load which would be required by the transportation of the sludge.

Class B town roads in the Dane County area are subject to seasonal load limits to protect the road surface from heavy traffic. Generally these restricted load limits extend from March to May each year to coincide with softened road conditions resulting from the spring thaw. Since the early spring is one of the periods of potentially heavy sludge transportation and application activity, scheduling of the sludge transportation may require adjustment. It may mean that the majority of the sludge transportation requiring travel on Class B roads would be conducted during the fall months and the sludge could be either applied at that time or stored in on-farm lagoons for later application. Class A roads are not subject to the same restrictive limitations as Class B roads. If transportation could be limited to Class A roads, then scheduling would not cause any major problems.

Pipeline transport is utilized to convey sludge via an underground system. The sludge would be pumped from the treatment plant to a number of discharge points. Dependent upon the market demand for the sludge, these points could serve as loading areas for a limited scope truck transport system, or the route of the pipeline could be laid out so as to enable discharge points to be set up at individual farms.

Advantages of a pipeline transport system are the lack of any visual impact of the conveyance of the sludge once the pipeline is installed and it is more cost effective than truck transport. It is estimated that the cost for this system would be $1.57/ton-mile. A major disadvantage of pipeline transport of sludge is the inflexibility of the system. If for some reason an established market demand for the sludge in the discharge point area declines, it would not be feasible to relocate the pipeline system.

2. Intermediate Storage Facilities

Intermediate storage facilities are utilized to increase the efficiency of the sludge transportation and application systems. By being able to store a quantity of sludge at the application site, transportation facilities could be utilized at a more uniform rate and not be required to deliver large volumes of sludge during peak application periods. Storage facilities may take the form of a small lagoon on the individual farms using the sludge. It is estimated that a lagoon with approximately 3 to 5 acre feet (980,000 to 1,630,000 gallons) of storage capacity would hold sufficient sludge required for a 100 acre application and would cost approximately $8,500 to install. Proper precautions would be required to protect ground and surface water quality and to limit unnecessary access.

Large nurse tanks (15,000 gallons and over) could be utilized as mobile storage facilities. These could be moved to a point of easy access for either truck transport or pipeline discharge and then moved to a point close to the actual field application. An advantage of this type of intermediate storage is that there is no need for any land area on individual farms to be permanently devoted to a storage facility. The estimated cost of a nurse tank would be about $15,000.

3. Application Methods

There are three basic methods of sludge application. These are:

- sprinkler gun
- subsurface injection
- truck or tractor drawn spreader

A variety of models, manufacturers and combinations of these basic systems are available.

Sprinkler guns have the advantage of allowing application to be done during periods when the soil is too soft to allow other types of application equipment to operate. Also, they would allow application to small grain crops at periods during their growth when other equipment would cause injury to the crop. Disadvantages lie in the adverse visual impact of the spraying operation and the potential sealing effect a thin layer of sludge has unless broken up after application. The cost of this system is estimated at $3.56/dry-ton of solids.

Subsurface injection is done in the field using specially designed equipment to incorporate sludge directly into the soil. A feeder hose is commonly used to supply sludge, under pressure, from an intermediate storage facility or nurse tank to the tractor drawn injection machine. This method of application minimizes the adverse visual impact of the application operation since it would closely resemble normal farming practices. By placing the sludge directly into the soil, possible loss of the nutrient value through subsequent runoff is also minimized. Application would be possible only during periods when there are no corps growing in the fields. The injector blades and feeder hose would cut the plant roots and tear the plants out of the ground. The cost of this system is estimated at $5.93/ton of solids.

Truck spreaders would be able to drive directly from the wastewater treatment plant or intermediate storage facility to any field, allowing great flexibility in the application program. The relatively small capacity (1500 to 2500 gallons) of the truck tanks would require frequent return to the plant or storage facility for refilling resulting in a decrease in efficiency. The truck spreaders would be restricted to periods when the soils are relatively dry to limit soil compaction. Large flotation tires can be utilized to reduce this problem. However, these large tires would damage crops such as corn and small grains. The estimated cost of this system is approximately $11.90/ton of solids.

Tractor spreaders could utilize the feeder hose system described above or pull a small tank. The feeder hose would allow a more continuous type of operation since the need to return to an intermediate storage facility or nurse tank would be eliminated. However, the limitations regarding damage to crops by the hose would be restrictive to the types of crops or periods when this system could be used. The tank system would require the frequent refilling as required with the truck spreader system. The cost of a feeder is estimated at $2.44/ton of solids.

3.03. NO ACTION

No action in regard to sludge disposal would mean the continued discharge of sludge to the existing lagoons adjacent to the Nine Springs Wastewater Treatment Plant. Pumping of supernatant to the treatment plant and continued maintenance of the lagoon dikes would be required to prevent over-topping or failure of the dikes in the future.

The pollution abatement order issued in 1971 by the Wisconsin Department of Natural Resources discussed earlier required that the method of sludge disposal to the existing lagoons be abandoned and an alternative method of sludge disposal be instituted.

The potential damages which might result from further release of sludge through a dike failure or accidental discharge to nearby surface waters as well as the requirements of the WDNR pollution abatement order necessitate the abandonment of the present disposal system.

SECTION 4 - DESCRIPTION OF THE PROPOSED ACTIONS

4.01. GENERAL

Land application of the anaerobically digested wastewater treatment plant sludge and the sludge currently stored in the lagoons is recommended as the proposed method of sludge disposal for the Madison Metropolitan Sewerage District. The following sections outline the program management, monitoring, marketing and sludge handling programs as well as the manpower requirements, implementation schedule and program costs.

4.02. PROGRAM DESCRIPTION

Liquid anaerobically digested sludge would be made available to the local farm community for application to agricultural lands. Sludge application rates would be developed through procedures which would determine the capacity of the soils found on an individual farm and the planned crop to utilize the nutrient content of the sludge. Other factors, such as erosion potential, depth to groundwater, depth to bedrock, soil permeability, flood hazard and soil texture are also important factors which would be considered in determining the proper application rate for a given site.

The land application program would be administered by MMSD, which would conduct or supervise the soils sampling and analysis, schedule application operations, monitor the sludge, soil, plant material and groundwater for various chemical constituents and maintain the records necessary for the efficient administration of the program.

During the first few years of this program, sludge currently stored in the sludge lagoons would be removed and applied to the land along with sludge produced at the treatment plant. Once sufficient storage volume is available, and from then on, the treatment plant sludge would be temporarily stored in a portion of Lagoon 1 during the periods when field application is not possible.

Removal of the lagoon sludge would be continued until all material currently stored in the lagoons would be removed and the area, except for the portion of Lagoon 1 to be used for seasonal storage, would be allowed to return to its natural state. The dikes of Lagoon 1 would be structurally maintained as an emergency backup to the contingency plan. The contingency plan is the utilization of the seasonal storage lagoon to store sludge for a period of up to three years. It would be implemented in the event of the proposed reuse program becoming inoperative. Sufficient volume would be obtained in the seasonal storage lagoon for the three-year period by re-instituting the return pumpage of lagoon supernatant to the treatment plant as is the current practice.

Transportation of sludge to the application sites would be accomplished by tanker trucks. If a great enough demand is developed and the marketing area warrants it, then pipeline distribution of sludge may become feasible in the future. Application would be by truck spreader, tractor spreader and subsurface injection. The type of application equipment utilized would depend partially upon the physical characteristics of a particular site, equipment availability and the type of crop planned for the site.

4.03. PROGRAM MANAGEMENT

A. Program Administration

Day-to-day and long term program management would be the responsibility of MMSD. A program manager would be assigned who would be responsible for the operation and maintenance of the sludge storage, handling, transportation and application facilities. He would also conduct interviews with prospective sludge users, conduct site screening surveys and interpret the results of the soil and water tests. Determination of annual application rates and record keeping would be required to maintain a successful program.

Development and maintenance of a sludge market would be of prime importance for the program manager to insure that the farm community is well informed of the potential benefits that may be gained through the use of sludge as well as of the precautions necessary to protect the environment. The program manager should also be aware of the advances made in land application of sludge and be prepared to modify operating procedures so as to take advantage of improvements made in storage, handling, transportation and application technology.

B. Monitoring Program

The land application of sludge may affect the environment of the area surrounding each application site. Therefore, a monitoring program would be beneficial to document any changes in the surrounding area. The data which would be collected would be used to protect the public health, to provide a basis of confidence in the reuse program for user farmers, and to build up a continuing documentation of the effect of the proposed sludge reuse on the agricultural community. Four areas of sampling and analysis would be implemented in the recommended monitoring program. These are the sludge characterization, soils, crops and groundwater effects.

All sampling would be conducted by MMSD staff personnel. In instances where specialized sampling procedures are required, training would be provided by qualified people to insure that representative samples are obtained. Analyses would be conducted in accordance with standard procedures appropriate for the material (sludge, soil, plant tissue or water) and parameter being analysed. The analyses would be performed either in the MMSD laboratory or in a laboratory especially equipped to perform certain analyses.

Monitoring of the sludge quality would be required to detect any changes in the sludge quality resulting from variations of the wastewater influent characteristics or operational changes which may occur. If the sludge quality warrants it, application rates would be adjusted to compensate for such changes. Parameters monitored would include the following:

Ammonia Nitrogen	Nickel
Total Kjeldahl Nitrogen	Tin
Total Phosphorus	Cadmium
Potassium	Molybdenum
Total Solids	Cobalt
Total Volatile Solids	Aluminum
Total Soluble Salts	Arsenic
pH	Boron
Iron	Selenium
Zinc	Mercury
Copper	Sulfate
Titanium	Alkalinity
Lead	Calcium
Barium	Magnesium
Chromium	Sodium
Manganese	Nitrate

A limited sludge characterization sampling and analysis would be conducted on a monthly basis for a selected set of parameters. The monthly characterization would include analysis for the following parameters: solids content, total Kjeldahl nitrogen, ammonia nitrogen, phosphorus, potassium, cadmium, zinc, copper and nickel. A complete characterization would be conducted on a quarterly basis which would include, in addition to the above set of parameters, the following: total volatile solids, total soluble salts, pH, iron, titanium, lead, barium, chromium, manganese, tin, molybdenum, arsenic, boron, selenium, mercury, sulfate, cobalt, aluminum, alkalinity, calcium, magnesium and sodium. A daily sampling of each sludge source (treatment process), digester or lagoon, would be analyzed for total solids, total Kjeldahl and ammonia nitrogen in order to maintain control of the sludge application procedures.

The solids monitoring program would consist of two parts. The first portion would be the continued utilization of the University of Wisconsin Extension soils testing program which has been set up as an aid to the farm community in determining fertilizer applications rates for optimum crop growth. This service would be utilized for the same purposes, to determine the proper annual sludge application rates.

The other portion of the soil sampling program would be the determination of the background levels of the constituents which would determine the total allowable sludge loading. Samples would be collected prior to any sludge application. The parameters to be monitored include the following: cation exchange capacity (CEC), electrical conductivity (EC), sodium, iron, aluminum, zinc, copper, nickel, cadmium, molybdenum, mercury, manganese and boron. This sampling and analysis would establish the suitability of a given site for inclusion in the sludge application program and, if suitable for inclusion in the program, determine the proper application rates, as mentioned above.

The crop monitoring program would be conducted to determine if potentially harmful concentrations of the heavy metals are being approached in the plant tissues which may enter the food chain. The heavy metals normally are not readily available to the plants and must accumulate in the soil before they become a major concern. Sampling of the plant tissues of crops commonly grown in the study area would be taken prior to the first sludge application and at three year intervals thereafter. Analyses would determine the concentrations of the following elements: boron, cadmium, copper, manganese, mercury, nickel, zinc, arsenic, chromium, cobalt, lead, molybdenum, selenium and vanadium. If the suggested maximum levels are reached for any of the elements, application of sludge would be discontined at once and investigation into the causes of the buildup and possible remedial actions would be undertaken.

Groundwater monitoring would be done in order to establish the background levels and to detect any changes in the water quality which may occur as the result of sludge application. Regulations limit the proximity of land application of sludge to any wells utilized for water supply. Any groundwater source within 500 feet of a sludge application would initially be sampled prior to the sludge application and at three year intervals thereafter. The initial sampling and analyses would determine the levels of the following parameters: MBAS, arsenic, nitrate nitrogen, total dissolved solids, mercury and coliforms. The periodic samples thereafter would be analyzed for nitrate nitrogen and total dissolved solids only. The periodic nitrate and TDS monitoring would provide a general indication of sludge constituents reaching the groundwater.

While the recommended groundwater program represents a significant effort to establish background levels and to detect any groundwater quality changes, it is suggested that MMSD consider the expansion of the monitoring program to include all existing wells within one-half mile of each application site on a yearly basis. It is felt that the additional number of analyses which would be required by the extention of the monitoring program would provide a much wider data base with which to document the groundwater quality. It is suggested that sampling of the wells be conducted during the summer months or in the periods subsequent to major application of sludge to nearby sites.

The recommended monitoring program does not include any provision for surface water monitoring. Proper program implementation and management controls would prevent sludge application to sites where or during periods when runoff to surface water would be anticipated. Due to these controls, as outlined in Volume III, Organic Solids Reuse Plan chances of surface water contamination are felt to be minimal. The MMSD should continue the program of sampling and analysis of the surface waters of Badfish Creek and the Rutland Branch (Anthony Branch). The Rutland Branch is identified as a Class II trout stream. If a sludge application site were to be located within the Rutland Branch drainage basin, it is suggested that the monitoring of that stream be expanded to include sampling at a number of locations, both upstream and downstream of the sludge application site, after major rainfall events. Sampling should also be conducted during snowmelt periods when soil materials may be washed into the stream. Such a surface water monitoring program would enable MMSD to document what affects on the surface water quality, if any, may be attributable to the land application of sludge.

C. Marketing Program

An active marketing program will be initiated which will be used to develop and maintain a reliable demand for the sludge. Components of a successful marketing program should include an easy access by the public to information regarding the land application operations. Data concerned with the volume of sludge applied, and results of the analyses performed under the monitoring program should be made available. In addition, information on new technology in the area of land application equipment and research should be made available through the use of brochures and public meetings. Public meetings could also be utilized as a forum for obtaining the views, and suggestions of user farmers regarding the operating practices of the program.

An initial objective of the marketing program should be the establishment of a trade name and logo to be utilized thereafter in place of the term sludge or sewage sludge. Such a trade name would provide a means to disseminate information to the public without having to constantly use the word sludge, which has negative connotations for many people. The trade name and logo could be utilized as a identification on the trucks and other equipment required for the proposed land application program.

Another component of the marketing program should be the establishment of demonstration plots both near the treatment plant site and at other distant locations where sludge is used. These plots could be utilized for demonstration and promotional activities to show the effects of land application of sludge.

Day to day personal contact with the user farmers as well as the general public will be made by the drivers of the trucks used to transport the sludge from the treatment plant to the land application sites. A special effort should be made to obtain people who will maintain a courteous and helpful attitude towards the members of the farm community and the general public with which they come in contact. Cleanliness of the drivers' uniforms and of the trucks would aid greatly in maintaining a good public image of the program.

D. Sludge Handling Facilities

Estimates of the storage, transportation, distribution and land application facilities required will depend upon the size and location of the sludge market which is developed. Seasonal storage of the treatment plant sludge will require that approximately half (23 acres) of the existing Lagoon 1 be retained for this purpose.

The transportation and distribution equipment required will be at a maximum during the first ten years of the program while, in addition to the land application of the treatment plant sludge, the sludge from the storage lagoons will be removed. It is estimated the lagoon sludge will be completely removed after ten years and then the transportation and distribution equipment requirements will be significantly reduced.

A total of six tanker trucks (5,000 gallon capacity) should be sufficient to meet the peak demand periods of application. It is hoped that while the market for sludge can be expanded over the first few years, an accompanying development of on-farm storage lagoons will enable the initial number of tanker trucks to keep pace with the demand.

After a reliable sludge market is developed, the feasibility of a pipeline distribution system could be evaluated. Such a system would become viable if a strong and reliable market is developed for a particular area.

Field application equipment will be comprised initially of four truck spreaders. These vehicles have received favorable comments from the farm community and would also provide for maximum flexibility during the first stages of the proposed land application program. A tractor spreader and a subsurface injector should also be provided to meet the peak application demands and as demonstrators of these application methods. As the sludge market is expanded an additional tractor spreader and an additional subsurface injector should be added. After ten years (or when the storage lagoons have been emptied) the field application equipment inventory could be reduced to one each of the truck spreaders, tractor spreaders and subsurface injectors.

The land requirements during the first year of the proposed program is estimated at 2,000 acres. After the first year the market will have hopefully been expanded sufficiently to provide 5,000 to 6,000 acres for land application. This level of land usage is expected to continue until the existing sludge storage lagoons have been emptied. After the lagoons have been emptied, land usage is expected to drop to approximately 2,500 to 3,000 acres. This level would continue indefinitely.

In order to alleviate a portion of the peak demand for the transportation of sludge during the early spring months, a number of on-farm storage lagoons should be installed. A lagoon capable of storing approximately 4.5 acre-feet (1,470,000 gallons) of sludge would provide sufficient storage for the needs of a 100 acre farm. A total of 20 such lagoons would supply the storage capacity needed to keep the tanker truck requirements to a minimum.

E. Manpower Requirements

The implementation of the proposed land application program will necessitate the commitment of a number of MMSD staff personnel. A program manager will be required on a full time basis to schedule the sludge handling, distribution and application operations, maintain the sampling and analysis records and to keep abreast of the technological advances and research relevant to the land application of sludge.

Other staff personnel will be required to maintain and operate the sludge removal equipment, tanker trucks, field application equipment, miscellaneous pumps and other equipment. The monitoring program will also require the commitment of additional laboratory technicians to perform the analyses as outlined earlier. Clerical help will be required for filing, correspondence and related office work.

Field operations will, of necessity, be limited to a 6 to 9 month period dependent upon climatic conditions. However, equipment maintenance and other tasks necessary to the program would be required such that the staff personnel would be fully employed on a year around basis. During the first few years, there would be a higher demand for laboratory work as new sites are added to the program and the initial sampling to establish background levels present is at a maximum.

F. Program Implementation Schedule

The evaluation of various sludge handling and disposal alternatives for the MMSD has been a continuing effort. The current study has been actively looking at the existing sludge storage and the limited land application programs utilized by MMSD and alternative programs since the early part of 1975. It is expected that approval of the proposed land application program will be obtained from the appropriate regulatory agencies by early 1977.

The proposed land application and monitoring programs should be begun as soon as practicable after regulatory agency approval is received. Required equipment to implement the program should be ordered as soon as approval of the program is received. Prior to receipt of the specially ordered tanker trucks, spreaders and other related equipment, the present limited land application program would be continued. By the operating season of 1978, it is expected that all equipment would be on hand and full scale operation of the proposed program could begin.

The marketing program would begin in earnest during 1976. The development of a reliable market would be of prime concern to insure the success of the proposed program. Preliminary informational public meetings have been held during the planning stages of the current study. A portion of these meetings were devoted to an explanation of the advantages and disadvantages associated with a land application of sludge program. Various methods of field application were presented for the review and comment of those in attendance.

If the proposed program were to be fully implemented by 1978, it is estimated that the removal of the majority of the sludge currently stored in the lagoons would be completed by approximately 1986. Continued removal operations may extend to 1990.

Equipment replacement (field application equipment, tanker trucks, etc.) should be phased so as to avoid the need to replace several pieces of equipment at one time.

During the second through fifth years of the program on-farm storage lagoon construction should begin. The goal of the program is to construct five such lagoons each year with a total of twenty on-farm lagoons available after the fifth year. As discussed earlier the utilization of these lagoons would alleviate some of the peak transportation demand scheduling.

G. Program Cost

Yearly capital, operation and maintenance and debt service costs have been estimated for the proposed program as shown in Section 1.06 of this report and in the Organic Solids Reuse Plan by CH_2M-Hill.

Capital costs include the purchase of required equipment and the construction of facilities necessary to implement the proposed program. These costs would be amortized over a period of 20 years at a 7% interest rate and are reported as the debt service.

The cost of providing gasoline, lubricants, informational materials, office supplies and any other services necessary to maintain the equipment in proper running condition and to administer the program are reported as operation and maintenance (O & M) costs. Salaries for the drivers, vehicle maintenance personnel, laboratory technicians, clerical help and program manager are also included in the O & M costs.

A portion of the program income would result from the charging of a sludge user fee. Since the sludge which would be applied to a farmer's field would substitute for a portion of the artificial fertilizer normally applied for optimum crop growth, its use would contribute a service of value for the farmer. A user fee would help offset the costs required for the monitoring program and for the transportation and application operations. It would not be the purpose of the user fee to recover the entire costs, or even a significant portion of the program. Its primary functions would provide a control over supply and demand of the sludge and dispel the impressions which might arise from supplying the sludge at no cost. That is that the sludge would have no value.

The sludge user fee could be set up in a number of ways. The proposed fee schedule would include a standard fee for the initial site inspection, sampling and analysis. The suggested fee for this initial work is $200. For parcels larger than 200 acres the fee should be increased at a rate of $2.25/acre. An annual fee for monitoring should be set at $.50/acre.

In order to control the distance which the sludge would be transported to as little as practicable, an initial maximum distance beyond which a transportation fee would be charged, should be established. Initially it is suggested that this distance be set at twelve miles from the treatment plant facility. Farmers beyond this distance would be assessed a fee of $1.50/ton-mile for the sludge. As the program becomes more firmly established, the twelve mile distance could be drawn in closer to the sludge source to consolidate the marketing area.

Total annual costs have been estimated to average $402,200 during the first ten years (1978-1987) of the program. During this period sludge would be removed from the existing storage lagoons. Based on an average yearly volume of 15,500 tons of sludge solids recycled during this period, the cost would be approximately $27.97 per ton.

For the remainder of the program study period (1988-2000) the total annual costs have been estimated to be $313,300. This reflects a significant decrease in the yearly operation and maintenance costs due to the anticipated completion of removal of sludge from the existing lagoons. Debt service costs also decrease as payments for equipment purchased at the beginning of the program are completed. The cost per ton of sludge solids during this period have been estimated at $40.80 per year based on an average yearly amount of 7700 tons recycled.

H. Sludge Handling Contingency Plan

The prevention of possible loss of the sludge reuse market through a lack of interest on the part of the agricultural community and the prevention of community members from becoming frightened by unfounded claims regarding the value of sludge for its fertilizer value are the prime objectives of the marketing program. Confidence of the agricultural community should be developed through the open dissemination of information and the extensive monitoring program.

If, through an unforeseen change in sludge quality, the land application of sludge becomes impossible, an alternative sludge handling plan is required. Alternative plans could include the following:

- Have several thousand acres of MMSD owned or option-to-control lands available for sludge application.

- Have facilities for incinceration or dewatering and landfill available for sludge disposal.

- Have lagoon storage capacity to hold sludge for a minimum of three years available.

The high cost and impracticability of the first two alternatives eliminates them from further consideration. The third alternative could be implemented by the re-institution of the present practice of pumping lagoon supernatant back to the treatment plant. This would provide sufficient capacity in the seasonal storage lagoon to hold approximately three years production of sludge.

The three year storage period should be utilized to find and correct the condition causing the sludge to be unacceptable for land application. If the cause cannot be found or corrected, then studies to identify a permanent sludge disposal alternative should be initiated.

The existing dikes for Lagoon 1 would be structurally maintained. The remaining area of Lagoon 1, not utilized by the seasonal storage lagoon, could be held in reserve as an additional backup to the contingency plan in the event of some unforseen happening.

SECTION 5 - ENVIRONMENTAL IMPACTS OF THE PROPOSED ACTIONS

5.01. GENERAL

The proposed actions for the handling and disposal of sludge produced at the Madison Metropolitan Sewerage District's wastewater treatment facility, as described in Section 4.0, encompass the application of liquid anaerobically digested sludge to agricultural lands. Sludge material currently stored in the sludge lagoons adjacent to the Nine Springs Wastewater Treatment Plant would be removed and also applied to agricultural lands. Most of the present lagoon area would be allowed to return to its natural state once the sludge had been removed. A portion of Lagoon 1 would be retained for seasonal storage of sludge during periods when land application is not possible. The following sections provide information regarding the impacts which the proposed actions are expected to have on the environment.

5.02. ENVIRONMENTAL IMPACTS

A. Climate

The application of wastewater treatment plant and lagoon sludge would have virtually no effect upon the general climatic conditions of the south-central Wisconsin area. The application of sludge to agricultural lands would be similar in nature to common farm practices and hence be affected by or dependent upon climatic conditions. Sludge application could not be done during rain storms, for instance, or during periods of high winds. Neither could plowing, seed planting nor other farm related tasks be done during such periods.

B. Topography

Application of sludge material to agricultural lands for the beneficial utilization of its nutrient content would have negligible impact on the topography of the area. State and Federal guidelines and regulations limit the maximum degree of slope for sites which are to be utilized for sludge application. Sites with slopes of 0-6%, 6-12% and more than 12% have in general slight, moderate and severe limitations respectively for sludge application in regards to potential for runoff (WDNR, 1975).

The degree of slope may also pose limitations to the type of equipment most suitable for field application (WDNR, 1975). Truck or tractor drawn spreaders operate most efficiently on level to slightly sloping land and are not suitable for steep or rough slopes. Subsurface injection equipment is subject to the same slope limitations as the truck or tractor drawn spreaders. The steeper slopes would require more power and better traction for the application equipment with possible rutting of the soil.

C. Soils

1. General

Soils found on an individual farm will be tested for their suitability for sludge application as described in Section 3.02. Included in the soils analysis are the following characteristics: erosion hazard, depth to groundwater, depth to bedrock, flood hazard, soil texture, soil permeability and cation exchange capacity. If the soil of a particular site is judged suitable for sludge application, the rate of annual application and the total permissible loading will be regulated by such factors as the type of crop to be grown, the physical, chemical and biological characteristics of the sludge and the past fertilizer or sludge application practices. The following sections will discuss the impact of sludge application on soils.

2. Nutrient considerations

Soils naturally contain up to 6,000 lbs/acre of organic nitrogen. However, much of this nitrogen is not available to plants for their use. Many of the soils of Wisconsin have less than 100 lbs/acre of nitrogen available. Farm crops grown in southern Wisconsin, such as corn, tobacco, sorghum and other vegetable varieties, require up to 200 pounds of additional nitrogen per acre per year for optimum growth. By establishing the proper annual application rates, no excess of nitrogen will be applied to the land. If an excess of nitrogen were to be applied, then that portion not utilized by crop would be subject to leaching. Nitrogen leached from the soil, either by groundwater movement or surface runoff, may contaminate surface water streams and lead to a number of problems (see Section 5.02 D). Annual application rates may be limited by other nutrients (phosphorus and potassium), however, initial calculations indicate that these parameters are not as limiting as nitrogen.

3. Heavy Metal Considerations

The metals of greatest concern in the land application of sludge are the following: cadmium, chromium, copper, lead, mercury, nickel and zinc. If large concentrations of metals are applied to the soil they may reach levels toxic to plants and animals. If the metals remain in the soil and are not taken up by the plants, then there is little problem. If, however, they are taken up by the plants, then levels of toxicity may be approached. The mechanisms by which the heavy metals are retained in the soil are numerous and complex. Allowable loadings based on the metals content of the treatment plant and lagoon sludges have been calculated utilizing the "zinc equivalent" method recommended by the USEPA and the WDNR. This method of loading calculation results in the total amount of metals which may be applied to the land before possibly toxic levels are reached. For the study area soils and the crops grown in the area total allowable loadings of sludge are calculated to range from 30 tons/acre to 150 tons/acre. This would permit use of even the most restrictive of the suitable soil areas and crops for a period of 15 years before reaching potentially dangerous metals concentrations.

D. Water Quality

The proposed actions of land application of sludge possess the potential for contributing to the pollution of the surface and groundwater resources of the area if proper precautions are not followed. Restrictions on site location, soil, geological, and topographical considerations, annual application rates, and total allowable loadings have been developed so that the chances of creating a potentially hazardous pollution problem are minimized.

As an integral part of the proposed program, day to day control of the field application operations will allow supervisory personnel to make decisions based on possible variations in the sludge characteristics, weather conditions and crop requirements which will prevent excessive sludge from being applied to the fields. Excessive or improperly applied sludge is susceptible to physical overland runoff to nearby surface waters in the event of a heavy rainfall. The nutrient content of the sludge may lead to unwanted weed and algae growth in the streams and lakes. Management of the sludge application methods and of the field and cropping practices will minimize the possibility of freshly applied sludge reaching nearby surface waters.

Excessive nitrogen loading may result in contamination of the groundwater. As stated elsewhere (Section 2.07 C) the groundwater generally discharges to the surface waters supplying up to 95% of the average annual stream flow in Dane County. If groundwater containing high nitrogen concentrations discharge to the surface waters, then nuisance weed and algae growth may occur as above.

The annual sludge application rates are to be developed based on the nitrogen content of the sludge and on the crop requirements and other site criteria as discussed in Section 3.02 C. Proper annual loadings will eliminate the hazards of excessive nutrients.

Heavy metals applied to the land with the sludge tend to remain in the plow layer (upper 12 to 18 inches) of the soil (Kirkham, M.B., 1974). These elements form inert and insoluble compounds with various components of the soil and as such are less available to plants than the total loading would indicate. The soils capacity to retain the heavy metals is not unlimited. Since these elements accumulate in the soil and are not removed through crop utilization, the total allowable loading of sludge is based on the metals content. Proper management will allow control of the heavy metals and prevent the threat to the water quality (Kirkham, M.B., 1974).

Possible increases of pathogenic organisms in surface waters from sludge applied to the land would be possible only if overland runoff with severe accompanying soil erosion were to occur. The pathogenic content of an anaerobically digested and stabilized sludge is greatly reduced from that of the comparable raw sludge and continues to decrease with exposure to the soil environments. The MMSD sludge processing would include anaerobic digestion as well as other precautions to insure that the sludge will be well stabilized and, consequently, that there will be little chance of pathogenic contamination.

The threat to the water quality of Nine Springs Creek, the Yahara River and to Lake Waubesa will be substantially reduced by the proposed actions. With the removal of the stored sludge from Lagoon 2, the potentially hazardous materials threatening the water quality of these bodies of water would no longer be present.

E. Water Quantity

The proposed actions are to provide the sludge for its fertilizer value. As such it would be applied to agricultural lands in a manner which would not interfere with farming practices. The sludge would be in liquid form (approximately 5% solids). An application of three tons/solids/acre is equivalent to approximately a 0.5 inch depth of water. This is not a significant amount of water when it is considered that many rainfall events exceed this amount. However, if liquid sludge is allowed to remain on the soil surface, a crust may form which will delay drying. With incorporation of sludge into the soil, drying time is reduced.

When soil wetness may create problems for conducting necessary agricultural tasks, then sub-surface injection or incorporation into the soil by disk harrowing should be done.

There should be no appreciable increase in either the surface or groundwater volume at any site as the result of the proposed actions. The sludge will dry after application primarily by the loss of moisture through evaporation into the atmosphere and adsorbtion to the soil.

F. Water Uses

Improper application rates or poor site management could result in contamination of the surface or groundwater resources as discussed above. In the event of the surface water resources becoming contaminated, reduction of their usefulness for recreational pursuits might be realized. Excessive nutrient loadings contribute to the problems associated with enrichment of the water body (Hynes, H.B.N., 1967) such as nuisance weed and algae growth. Groundwater resources contaminated by excessive nutrients or possible increased levels of other pollutants may become unsuitable as sources of public or private water supplies.

As discussed in Section 3.02 C, development of annual application rates and total allowable loadings are meant to protect the environment, including the water resources. Implementation of the proposed actions with the required site investigations and the monitoring programs would provide the means to insure that procedures are followed which would protect delicate environment conditions.

As a part of the proposed actions the removal of sludge from Lagoon 2 and its eventual abandonment will substantially reduce the threat of contamination of nearby surface waters by supernatant spillage resulting from further dike failures. The groundwater resource in the area of the existing lagoons have not shown any evidence of contamination from leaching of stored sludge (Section 1.04). The peat/marl soils underlying the lagoons appear to effectively protect the groundwater resources.

G. Water Quality Management

Implementation of the proposed actions will fulfill the stipulations of the agreement between MMSD and WDNR which require that the present method of lagoon storage of sludge be terminated and an alternative sludge disposal method be instituted. It was the intent of this agreement that the threat of future dike failures be alleviated.

An important water quality management program of concern in the Dane County area is the 208 areawide study currently beginning under direction of the Dane County Regional Planning Commission. The program tasks of this study, discussed in Section 2.12, include the investigation of various operational and administrative alternatives which are available and to determine the most practicable program which will insure protection of the surface and groundwater resources. The proposed actions will serve to accomplish a step towards this objective.

Continued monitoring of the area's water resources by the WDNR and the USGS along with the monitoring program of the proposed actions will allow close surveillance of water quality. Changes in the water quality will provide the information needed to document future impacts on the water resources.

H. Air Quality

The primary air quality parameter of concern relative to land application of sludge is the potential for the production of odors. Liquid digested sludge, if the process is operated properly, does not have an objectionable odor. It typically has a faint, earthy odor which dissipates rapidly. The common farming practice of applying manure to fields releases a sometimes strong odor, very noticable to those on adjacent roads or living in nearby residences. The present sludge storage practice at the Nine Springs Wastewater Treatment Plant has not resulted in any complaints to the WDNR Southern District, Air Quality Section (personal communication, Richard Wales, Air Pollution Engineer, WDNR).

As a part of the application operations, subsurface injection of the sludge material will be utilized whenever necessary to prevent odor complaints. This method of application or the immediate incorporation into the soil of surface applied sludge should be utilized to keep possible odor problems at a minimum.

At transfer locations or distribution centers where there is the possibility of odor production care should be taken to prevent spillage of sludge. In the event of a spill, clean up procedures should begin at once.

The proposed transportation of sludge in closed tank trucks should preclude the possibility of odors eminating from the trucks during haul to the application sites. A program of maintaining the trucks and any other equipment which is to travel over public roads in as clean a condition as practicable should be instituted to minimize possible complaints.

I. Land Use

The proposed land application of sludge would utilize existing agriculture lands as the areas to receive sludge. It is not planned that additional land areas not already devoted to the raising of crops or in pastures would be developed for the express purpose of sludge application. This does not limit area farmers from having sludge applied to fields or other areas of their farms which are not currently active for the purposes stated above but which are part of their farm lands.

It is proposed that the construction of small on-farm storage lagoons capable of temporarily storing the sludge to be used on an individual farm be instituted at the outset of the program. This would alleviate some of the transportation scheduling problems which may arise during seasons (early spring and late fall) of peak sludge application or when highway use is restricted due to seasonal load limits. It is estimated that a lagoon with a storage capacity of approximately 4.5 acre-feet (1,470,000 gallons) of 5% solids sludge would be sufficient to store the sludge required for 100 acres of farm land. The construction of on-farm lagoons would only be done after detailed field inspection of a prospective lagoon site is conducted by qualified MMSD personnel. There would also be a long term (several years) commitment from the farmer to the District for the acceptance of sludge before any permanent installation is constructed.

The proposed removal of the sludge currently stored in the lagoons adjacent to the Nine Springs Wastewater Treatment Plant will eventually result in approximately 105 acres returning to the natural grass-sedge marsh condition which existed prior to implementation of the current sludge storage system. It is proposed that the western half of Lagoon 1 be retained as the primary storage facility for the sludge produced during treatment of the wastewater. The dikes built for Lagoon 1 have proven to be stable as no problems have arisen since its construction in 1942. It is not expected that the continued utilization of the western portion of Lagoon 1 will result in any dike instability problems in the future.

If the existing lagoons were to be totally abandoned, a new storage lagoon would have to be established. The expense, both in time and money, would require significant delay and added cost to the implementation of the program.

An investigation of the soils and land use mapping for the study area has shown that, based on the soils limitations discussed in Section 3.03.C and the regulations regarding proximity of sludge application to residences and water supply wells as outlined in Section 3.02.B, approximately 40,000 acres of land are suitable for land application of sludge. Estimates for the land required for land application range from a maximum of 6,000 acres per year until the lagoons are emptied to 2,500 acres per year thereafter. It is apparent that sufficient suitable land area is available for land application of sludge.

J. Biology

Possible impacts on the plants and animal life of the study area would result from the build-up of materials contained in the sludge to levels which may be toxic to normal life functions.

The development of the annual application rates and the total allowable loadings are done to provide for the protection of plant and animal life of the area while enabling the maximum beneficial value of the sludge to be utilized. In virtually all cases, the concentration of pollutants found in the sludge to be applied to the land would become phytotoxic (harmful to plant life) before they reach a level which would be harmful to animal life. This natural mechanism acts to protect the higher animal life forms which feed on plant life. Development of the annual application rate and the limitation on the total allowable loading for any given site are based, in part, upon the ability of the crops to be grown on the site to utilize the fertilizer value of the sludge for growth. Nutrient levels, primarily the nitrogen level, are generally the limiting factors for the annual application rate. As discussed in Section 3.02.C, typically grown field crops in Wisconsin require from 35 to 200 pounds/acre/year of nitrogen for optimum growth. Phosphorus requirements range from 15 to 60 pounds/acre/year and potassium requirements range from 40 to 400 pounds/acre/year. Excessive concentrations of these nutrients applied to the land, greater than that capable of being utilized by the crop, may run off during periods of rain and lead to an overly abundant growth of weeds and algae in streams and lakes. This condition subsequently contributes to the deterioration of the water quality and promotion of less desirable forms of animal life. Based on the nitrogen content of the existing treatment plant and lagoon sludges, and the crop requirements, annual application rates may range from .05 to 6.0 tons/acre/year.

Total allowable loadings are limited by the materials which are not utilized on an annual basis but which may be retained in the soil. The heavy metals (boron, cadmium, chromium, cobalt, copper, lead, mercury, nickel and zinc) are those of concern regarding the total allowable loading. In general, the concentrations of metals which have proven to be phytotoxic are not reached when the annual loading rate is limited by the nitrogen content of the sludge.

Since the mechanisms which relate to the metals' interaction with the soil and plants are numerous and complex, there is no one totally acceptable method of determining the safe loading rate. The "zinc equivalent" method is recommended by both the USEPA and WDNR. This method limits the total metals loading, calculated as zinc equivalent, to 10 per cent of the soils' cation exchange capacity (CEC). The resultant total loading factor is used to determine the total allowable application of sludge. Based on these calculations total application of sludge would be limited to amounts of 30 to 150 tons/acre.

Even for the most restrictive of the suitable soils and crops, the nitrogen-limiting annual application rates would allow ten years of sludge application before reaching the total allowable loading. Other soils and crops would permit application for well over one hundred years.

K. Environmentally Sensitive Areas

Areas with significant environmental sensitivity include the wetlands, prairie lands and unique geological formations. Many of these areas have been inventoried and listed by the Scientific Areas Preservation Council of the WDNR. It is proposed that the land application of sludge be limited to agricultural areas which have been utilized in the past for cropping or for grazing purposes. As such, the proposed actions should not constitute any threat to the types of areas outlined above. The proposed abandonment of a significant portion of the existing sludge storage lagoons would eventually result in the return of over 100 acres of the Nine Springs wetlands to its original condition, a complete reversal of the trend of drainage and consequent loss of wetland areas in the past.

L. Aesthetics and Recreation

The aesthetic qualities and recreational opportunities outlined in Section 2.13 are important to quality of life enjoyed by the residents and visitors of the study area. The proposed actions will limit sludge application to existing agricultural lands. The actual field application operations will not be greatly different from present farm practices. This will not affect the use of recreational areas or the enjoyment of other aesthetically pleasing areas to any great extent. It would be the responsibility of the farmer to limit access to fields where sludge have been recently applied, as an added measure of safety for health reasons. This precaution may result in limitation of hunting activities for short periods of time.

The removal of sludge from the existing storage lagoons will eliminate a potential hazard to the water quality, hence, the utilization of the water areas (Nine Springs Creek, Lake Waubesa, Yahara River, etc.) immediately downstream from the lagoons.

Care should be taken to maintain the trucks and other equipment which will be used to transport the sludge from the treatment plant to the application sites in as clean and in good operating condition as possible. This would minimize the visual and other effects that might result from spillage of sludge, either at the treatment plant or along the transport routes.

M. Energy

The proposed land application of sludge will require a significant increase in the energy consumption over the present levels utilized for sludge storage. It should be realized that the present method of sludge storage represents a minimum in regards to fuel usage. During 1974, a fairly "typical" year for the present sludge storage and disposal operation, approximately 23,800 gallons of diesel fuel and gasoline were consumed by the trucks, cranes, earth moving vehicles, and pumps required to operate and maintain the system.

With the implementation of the proposed actions fuel consumption is estimated to increase approximately 180 percent to about 40,000 gallons per year. After the existing storage lagoons have been emptied and a number of on-farm lagoons have been installed, the fuel consumption would be reduced considerably as the need for several of the tanker trucks and field application vehicles would be eliminated.

The increase in fuel consumption is required in order to meet the requirements of the pollution abatement orders issued by the WDNR in 1971. Other methods of sludge disposal, such as incineration, composting and heat treating of raw or digested sludge had been eliminated from further investigation for a number of reasons, included among which was the requirement for additional natural gas supplies. Of the available sludge disposal alternatives which would satisfy the pollution abatement orders, the land application of liquid digested sludge represents a minimal increase of fuel consumption.

N. Public Health

There is no question that digested sludge contains bacteria, viruses, intestinal worms and other protozoa which are potentially pathogenic. While the current anaerobic digestion and storage of sludge has been shown to be an effective method of pathogen reduction, complete elimination of potential public health problems is not achieved. However, there have been no reported cases of disease related to the public health traced to digested sludge. Under normal land application procedures, following the appropriate state and federal regulations, pathogens will not move more than a foot or two through the soil due to the physical filtration and the sorption-inactivation properties of the soil and the natural die-off.

State and federal regulations and guidelines regarding land application are directed towards the protection of the public health and environment. As a result, the land application of sludge is subject to a number of restrictions. The following guidelines concerning land application of sludge are obtained from those published by the WDNR and draft guidelines compiled by USEPA:

- Sludge should not be applied to soil in the year the area is used for any root crops or other vegetables which are cooked or processed. Sludge treated land should not be used for human food crops to be eaten raw until 3 years after sludge application.

- Pastureland and harvested forage should not be used for milk cow feeding for two months following sludge application. Other animals should not graze pastureland or be fed greenchop material for at least two weeks after sludge application.

- Public access must be limited in areas of sludge application.

Studies (Bertucci, et al, 1974, Bertucci, et al, 1973) have shown that viruses inoculated into anaerobic digesters have been subject to die-offs of greater than 99 per cent within 48 hours. Continuing research into the pathogen content and its control in sludge material will provide additional information regarding the levels required to constitute a health hazard. If further studies indicate that additional procedures are required to protect the public health, processes such as pasteurization, lime disinfection or heat treating can be ultilized. These processes are expensive and would require the use of additional energy resources.

O <u>Historical and Archeological Sites</u>

There are 26 sites currently included on the National Register of Historic Places in Dane County. The majority of these (21) are located within the City of Madison, with the others located at various places around the County. There are none located close to the proposed area to be utilized for land application and there will be no impact on these by the proposed actions. In Rock County six sites have been designated for the National Register of Historic Places. One of these, the hamlet of Cooksville, contains several excellent examples of the homes built during the early settlement of the area. This entire hamlet has been designated as an historic district. The proposed land application area lies to the northwest of Cooksville approximately five miles. There will be no impact felt in the hamlet assuming proper procedures are followed regarding land application.

The director of the State Historical Society of Wisconsin was contacted regarding the location of sites of known arecheological importance. A data card file is maintained at the Historical Society offices with information on the location, contents and condition of the sites. The status of the sites, as to whether they have been inventoried by knowledgeable researchers, is also maintained. The land application of sludge to existing agricultural areas will have no impact on any known archeological site. If such sites had existed in these areas, the active farming practices would have already destroyed any artifacts present.

5.03. ADVERSE IMPACTS WHICH CANNOT BE AVOIDED SHOULD THE PROPOSED ACTION BE IMPLEMENTED

There are a number of adverse impacts which cannot be avoided should the proposed actions be implemented. These impacts, however, can be minimized by careful planning, site investigation and program management.

A. Increased Traffic

The transportation of the sludge from the Nine Springs Wastewater Treatment Plant to the field application sites would cause an increase in the truck traffic. It is estimated that tanker trucks utilized to transport the sludge would travel a total of 120,000 miles annually. The presence of these trucks on the haul routes to the application sites may cause some concern regarding traffic volume. The major impact of this increased traffic would be in the immediate area of the treatment plant. As discussed in Section 3.02D of this report, seasonal load limits placed on many roads in the area may require scheduling of the transportation of sludge during periods not affected by the restricted load limits.

Associated with the transportation and application of sludge is the required consumption of fuel for vehicle operation. It is estimated that fuel consumption would be approximately 40,000 gallons per year.

B. Increase of Metals Concentrations

The land application of sludge would cause the build-up of the metals concentrations in the soil. Total allowable loadings are based on the latest available research regarding the affects which a metals build-up might have on the public health and the growth of crops. Proper program mangement would insure that the total allowable loadings would not be exceeded. As research is continued the land application loadings would be modified based on developing knowledge.

C. Construction Activities

The proposed actions include the construction of truck loading platforms and other related facilities as they become justified by the implementation of the program. Associated with any construction project are the increases in noise levels and temporary deterioration of local air quality caused by construction activities. These impacts will be of relatively short duration, being limited to actual time of construction. The area of the treatment plant is not heavily populated and consequently homeowners would not be affected by the impacts.

5.04. RELATIONSHIP BETWEEN LOCAL SHORT-TERM USAGE OF THE ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

A. Water Quality

The water quality of the surface waters of Nine Springs Creek, the Yahara River below the confluence with Nine Springs Creek, and in Mud Lake have been adversely affected in the past by the release of approximately 85,000,000 gallons of lagoon supernatant. This resulted from the failure of a portion of the Lagoon 2 dike in 1970. The spill was cited as the cause of a fish kill which occurred downstream of the spill. An additional dike failure occurred in 1973 but little supernatant was spilled, prior to the sealing of the failure zone, by a mud wave which developed in the lagoon. The proposed actions would alleviate the threat of future spillage to nearby surface waters by removing the material now stored in the lagoons.

Groundwater quality has not been affected by the storage of sludge in the lagoons as discussed in Section 1.04 of this report and in Volume III - Organic Solids Reuse Plant.

Development of annual application rates, proper site management, and close monitoring of environmental factors at the application sites would minimize possible adverse impacts on the surface and groundwater quality from developing over a period of time.

B. Recreation

Accidental spillage of supernatant from the storage lagoons in the past has contributed to the temporary degradation of the water quality in areas downstream from the lagoons. The fish Kill may have decreased the fish populations in these areas and hence the recreational opportunity afforded to fishermen by their presence. Aesthetic enjoyment of these areas may have been temporarily decreased by the presence of dead fish in the water. Increased weed and algae growth may also have been accelerated by the discharge of nutrients with the spills.

The unstable condition of the dikes of Lagoon 2 appear to be susceptible to structural failures in the future if corrective measures are not taken. The proposed actions would remove the threat of future spills. In addition to the removal of the threat to the water quality, the proposed actions would allow the land area currently devoted to Lagoon 2 (approximately 85 acres) to eventually return to its natural sedge-meadow condition. This would be a distinct departure from the general practice of draining wetland areas to provide additional acreage for farming or other development.

5.05. IRREVERSIBLE OR IRRETRIEVABLE COMMITMENT OF RESOURCES WHICH WOULD BE INVOLVED IF THE PROPOSED ACTIONS SHOULD BE IMPLEMENTED

By the implementation of the proposed actions the only irreversible or irretrievable commitment of resources would be for the manpower and the fuel which would be required. It should be noted that the present method of sludge handling disposal represents a minimum commitment of these resources. The implementation of any improved sludge handling and disposal alternative would require a substantial increase in the use of manpower and fuel.

Land areas committed to on-farm storage lagoons would not be irreversible commitments. While in use these areas could only be utilized for sludge storage, but if the farmer wished to locate a lagoon at a different site or to drop out of the program, then after the removal of sludge from the lagoon it could be restored to its original use.

SECTION 6 - PUBLIC PARTICIPATION

6.01. FACILITIES PLANNING ADVISORY COMMITTEE

The Facilities Planning Advisory Committee (FPAC) was established in the fall of 1974 by the MMSD to act as an advisory group for the engineering firms engaged to complete the Facilities Plan. Members of the FPAC included representatives from the MMSD, Dane County Regional Planning Commission, Rock County Board, Rock Valley Metropolitan Council and an independent private citizen. Also attending committee meetings were representatives of the WDNR and the USEPA.

The committee met regularly during the course of the study to monitor the progress of the study work and to offer advise to the engineers regarding areas of concern. The FPAC meetings served as a time: for presentation of work progress; to interchange views on areas of concern; and to identify additional study tasks. All committee meetings were open to the public and news media.

6.02. PUBLIC INFORMATION MEETINGS

A public information meeting was held Norvember 6, 1973, in Madison to present to the public an account of the progress of the sludge disposal study being conducted at that time by the engineering firm of Roy F. Weston, Inc.

On May 15, 1974, a second public meeting was held in Madison to present the recommendations of the Weston report and of the addendum which had been prepared by the staff of the MMSD. It was the recommendation of this report that the alternative of the land application of liquid anaerobically digested sludge be developed. Public comments on this recommendation were favorable.

The Capitol Community Citizens (CCC), a concerned group of area citizens, submitted a position statement to MMSD on May 30, 1974, stating that they approved of the land application of sludge only on a temporary basis. They suggested that a long-term sludge disposal program should include the composting of the sewage sludge along with the solid wastes generated in the area.

The commissioners of MMSD, after consideration of the Weston report recommendations, and public input, resolved on June 7, 1974, that the disposal of sludge should be handled through a land application program. On July 15, 1974, the MMSD commissioners resolved that the land application program should be implemented immediately.

A letter describing the land application alternative and a questionnaire requesting their comments was sent to area farmers in August of 1974. The comments received from the farmers were quite favorable and a high degree of interest in the alternative was shown.

During September of 1974, Wisconsin Pollutant Discharge Elimination System (WPEDS) Permit No. WI-0024597 was received. It was stated in the permit that funding for the construction of any additional wastewater treatment and disposal facilities, including sludge treatment and disposal facilities, would not be forthcoming until a Facilities Plan was completed.

Contracts were awarded for the preparation of a Facilities Plan late in 1974. Public input to the study was continued through the FPAC as described in Section 6.01 and through a series of public meetings held during the course of the study. Public meetings were held on June 26, 1975, at the Town of Dunn, Town Hall, and again on October 2, 1975, at the Town of Fitchburg, Town Hall. At each of these meetings progress of the sludge study was reported. Various methods of field application were discussed as were the potential advantages and disadvantages of land application program. Interest expressed in the program by members of the farm community in attendance was high at each meeting.

A demonstration of liquid and dry sludge spreader trucks manufactured by Big Wheels, Inc. was conducted for members of the FPAC and other interested persons on May 30, 1975, at the Nine Springs Wastewater Treatment Plant. On September 4, 1975, a demonstration of a dredge manufactured by Mud Cat was conducted at the existing sludge lagoons.

A high degree of interest has been expressed by members of the public in a program of land application of sludge. It is not expected that the implementation of such a program would generate any appreciable adverse reactions.

6.03. PUBLIC HEARING

On April 28, 1976, the firmal public hearing was held at the Town of Fitchburg Town Hall. The purpose of this hearing was to present to the public the recommended organic solids reuse plan and the assessment of that plan on the environment. Public comments and questions on the program were also accepted for the record. Notice of the hearing was published in area newspapers thirty days prior to the hearing. A copy of the notice is included at the end of this Section. Copies of the Environmental Assessment Statement were available for public review for a period of thirty days at various locations as indicated in the notice.

Approximately 80 to 100 people attended the hearing including members of the local farm community; City of Madison, Dane County, State of Wisconsin and Madison Metropolitan Sewerage District personnel; and other interested members of the public. A member of the engineering firm of CH2M-Hill presented a summary of the work which was done in the evaluation of the various alternatives available for the reuse program and a review of MMSD's sludge handling and storage programs. Members of the engineering firm of O'Brien & Gere presented a summary of the work which was done in evaluating the potential impacts which the proposed reuse program may have on the environment.

Comments and questions from the members of the public present were taken. None of the comments expressed or questions raised at the hearing were negative to the proposed reuse of sludge on agricultural lands. Several members of the farm community spoke in endorsement of the proposed program and, in general, seemed to be anxious to become a part of the program. Another endoresement was given by Professor Arthur Peterson, Soil Science professor at the University of Wisconsin. A representative of the City of Madison, Engineering Department read into the record a resolution, dated April 28, 1976, which had been passed by the City of Madison Common Council and signed by Mayor Paul Soglin, also endorsing the proposed program.

Some concerns were expressed regarding certain aspects of the proposed program, such as the suitability of lands receiving sludge application for development in the future. A review of material presented in both the Organic Solids Reuse Program and the Environmental Assessment Statement indicated that such concerns had been considered and accounted for in the development of the program.

Written comments were accepted at the MMSD offices for a period of 15 days following the public hearing. Any written comments which have been received as well as an official transcript of the public hearing are contained in Volume VIII-Public Participation of the Facilities Plan. The official transcript also contains a copy of the notice, a list of the newspapers which published the notice as well as other materials.

environmental assessment hearing for the Madison Metropolitan Sewerage District organic solids recycle system

A final public hearing on the environmental assessment of the organic solids recycle system of the Madision Metropolitan Sewerage District will be held on Wednesday April 28, 1976 in the Fitchburg Town Hall at 8:15 p.m.

Fitchburg Town Hall – 4 miles south of Beltline on Fish Hatchery Road

The organic solids recycle system involves returning waste organic solids (liquid digested sewage sludge) to agricultural land as a natural organic fertilizer and soil conditioner. Detailed information will be presented about this water pollution control project and its possible environmental effects on the area.

public testimony invited

Interested persons, groups and agencies are invited to hear this discussion and to give public testimony on the environmental and technical aspects of the project. Also, written testimony will be accepted for 15 days following the public hearing and should be addressed to:

Mr. James Nemke
Madison Metropolitan Sewerage District
104 N. First Street
Madison, WI 53704

A record of all public testimony will be submitted as part of the environmental assessment statement to the United States Environmental Protection Agency. Copies of the environmental assessment statement can be reviewed at the following locations:

PUBLIC LIBRARIES		TOWN HALLS
BELOIT COLLEGE	MILTON	DUNN
BELVIDERE	MADISON	FITCHBURG
EDGERTON	UNIVERSITY OF	FULTON
EVANSVILLE	WISCONSIN	RUTLAND
JANESVILLE	(MEMORIAL UNION)	STOUGHTON

AND AT THE OFFICES OF THE FOLLOWING·

DIRECTOR OF PUBLIC WORKS, MADISON, CITY COUNTY BUILDING
CITY ENGINEER, MADISON, CITY COUNTY BUILDING
CITY CLERK, MADISON, CITY COUNTY BUILDING
DANE COUNTY CLERK, MADISON, CITY COUNTY BUILDING
ROCK COUNTY CLERK, JANESVILLE, COUNTY COURT HOUSE
DEPARTMENT OF NATURAL RESOURCES, SOUTHERN DISTRICT
ROCK VALLEY METROPOLITAN COUNCIL, 401 W. STATE ST., ROCKFORD
DANE COUNTY REGIONAL PLANNING COMMISSION, 14 SO. CARROLL, MADISON
MADISON METROPOLITAN SEWERAGE DISTRICT, 104 N. FIRST ST., MADISON
O'BRIEN AND GERE ENGINEERS, 910 W. WINGRA DR. MADISON
CH2M HILL ENGINEERS, 2929 N. MAYFAIR RD., MILWAUKEE

This is an opportunity for the public to learn the details of this important pollution control project, and to present their views regarding its environmental and technical aspects.

MADISON METROPOLITAN SEWERAGE DISTRICT

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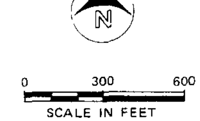

FIGURE 5-1

SLUDGE LAGOON
FAILURE ZONES AND
SAMPLING STATIONS

MADISON METROPOLITAN
SEWERAGE DISTRICT
MADISON, WISCONSIN

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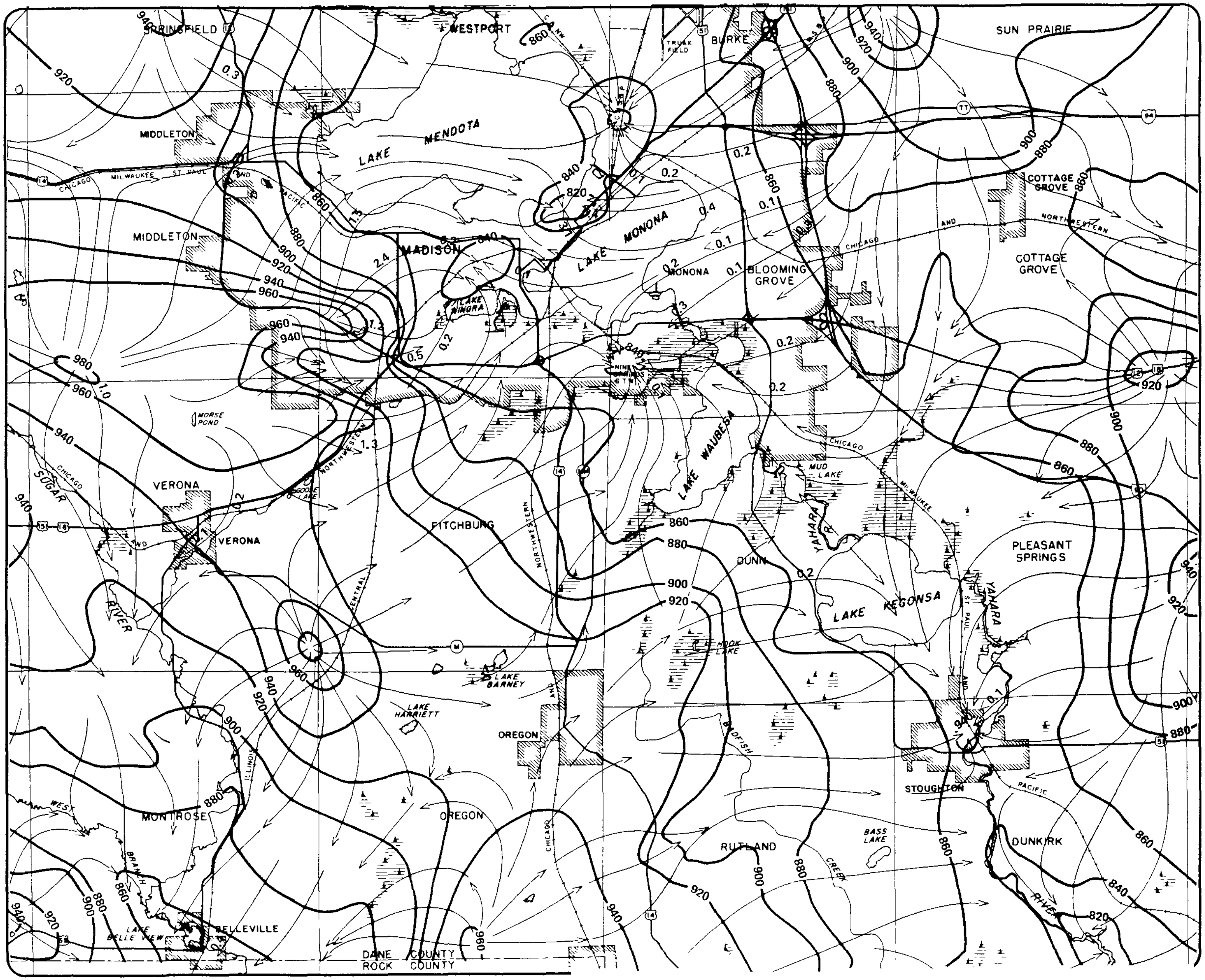


0 2 4
SCALE IN MILES

LEGEND

840 — PIEZOMETRIC SURFACE CONTOUR LINE AND ELEVATION (FEET) APRIL – MAY 1960

1.3 — GROUND WATER FLOW LINE AND VELOCITY (FEET/DAY)

FIGURE 6-1

GROUND WATER PIEZOMETRIC SURFACE AND FLOW DIRECTIONS

MADISON METROPOLITAN SEWERAGE DISTRICT
MADISON, WISCONSIN

CH2M HILL

S9166 0

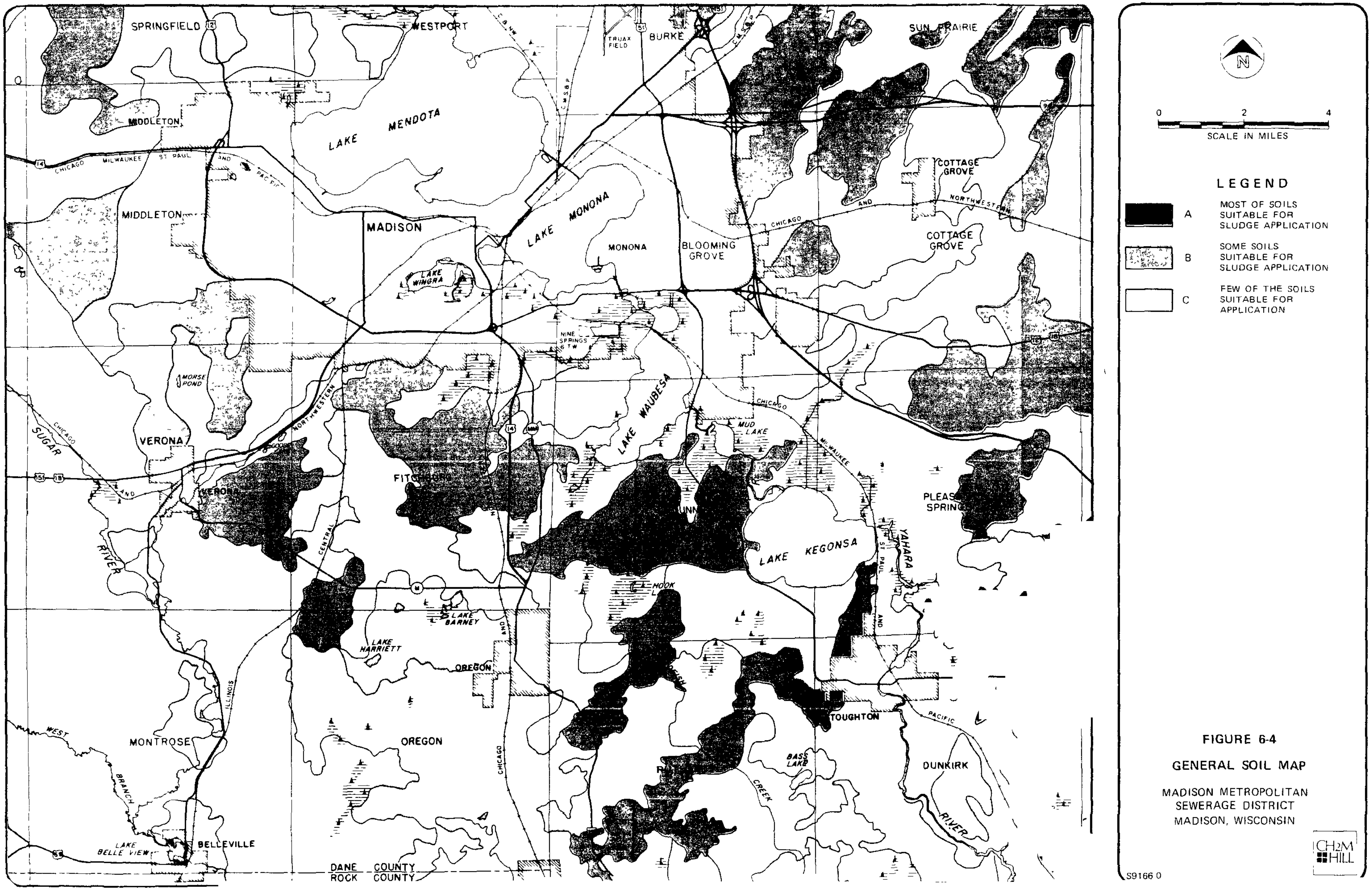


FIGURE 6-4
GENERAL SOIL MAP
MADISON METROPOLITAN SEWERAGE DISTRICT
MADISON, WISCONSIN

CH2M HILL

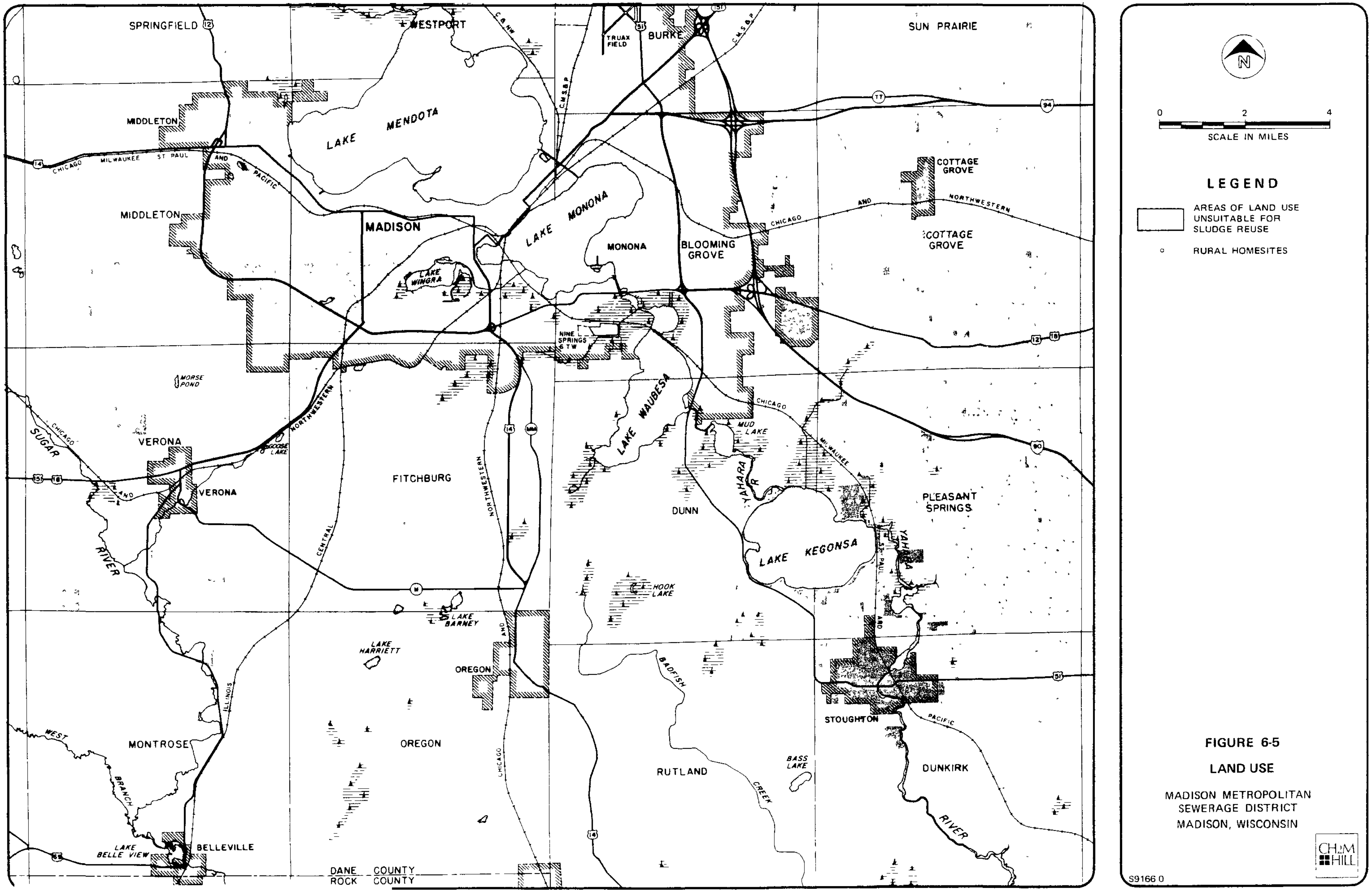


FIGURE 6-5

LAND USE

MADISON METROPOLITAN SEWERAGE DISTRICT
MADISON, WISCONSIN

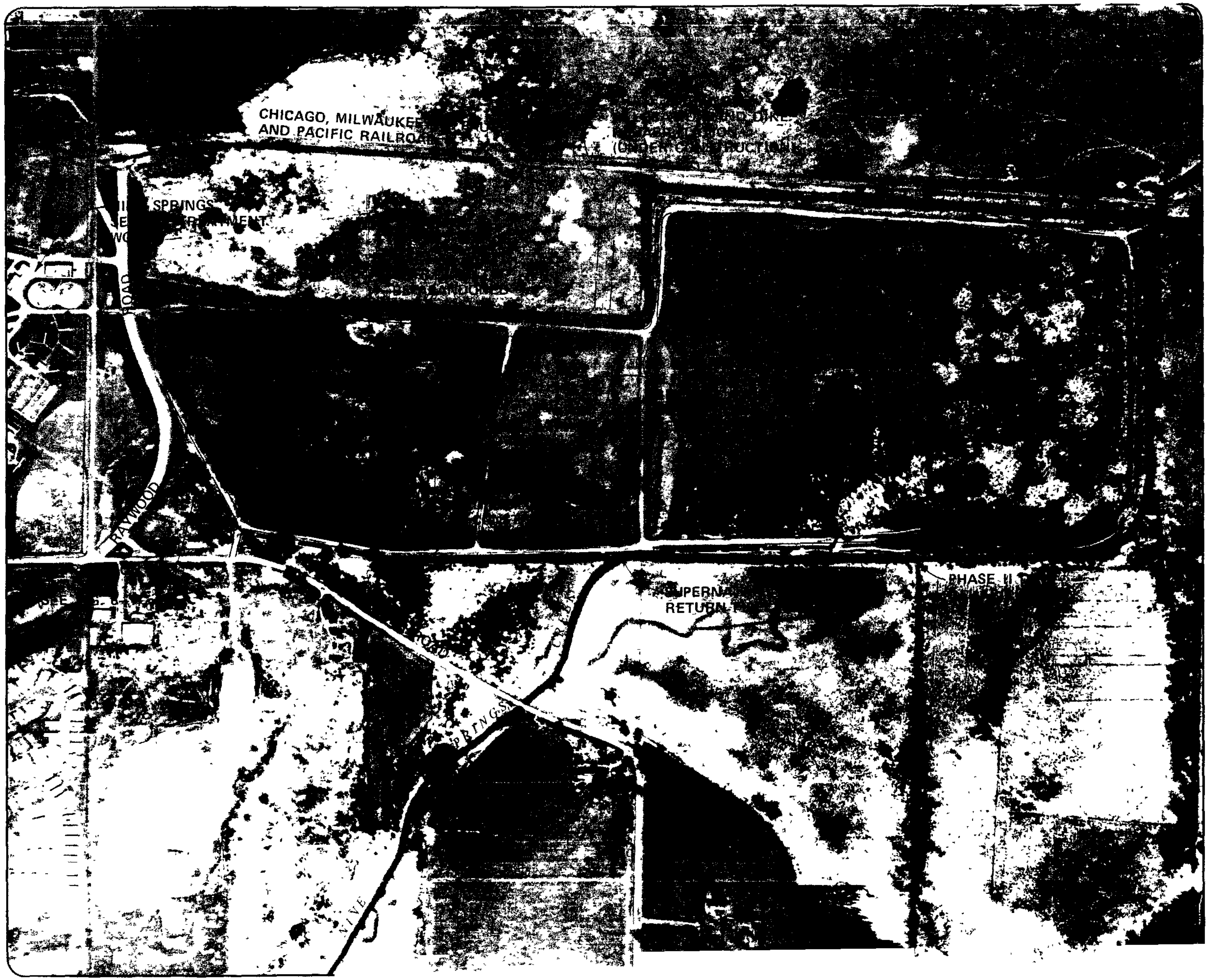


FIGURE 8-2

REUSE PROGRAM
SITE PLAN

MADISON METROPOLITAN
SEWERAGE DISTRICT
MADISON, WISCONSIN

CH2M HILL

S9166 0

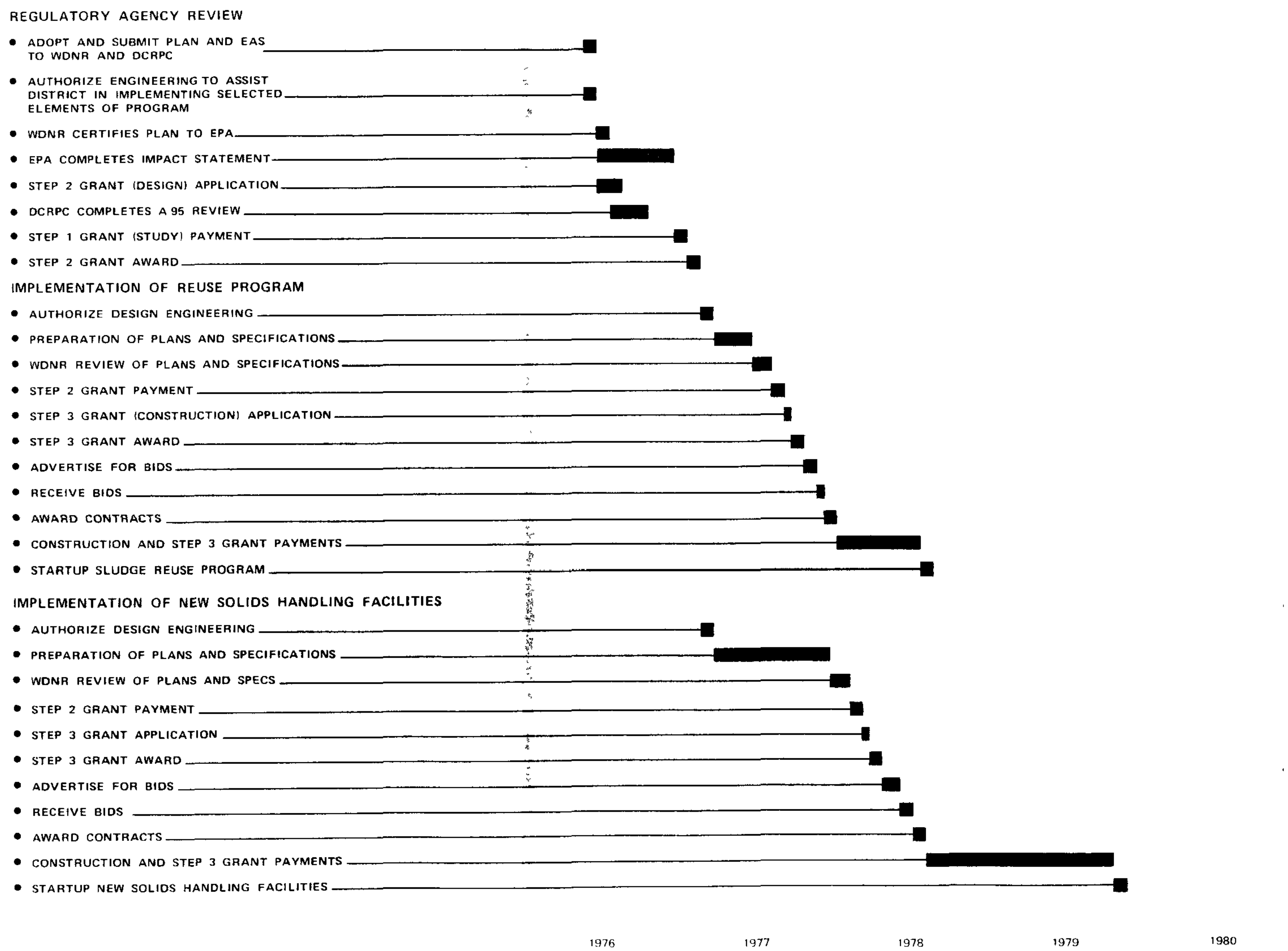


FIGURE 9-1

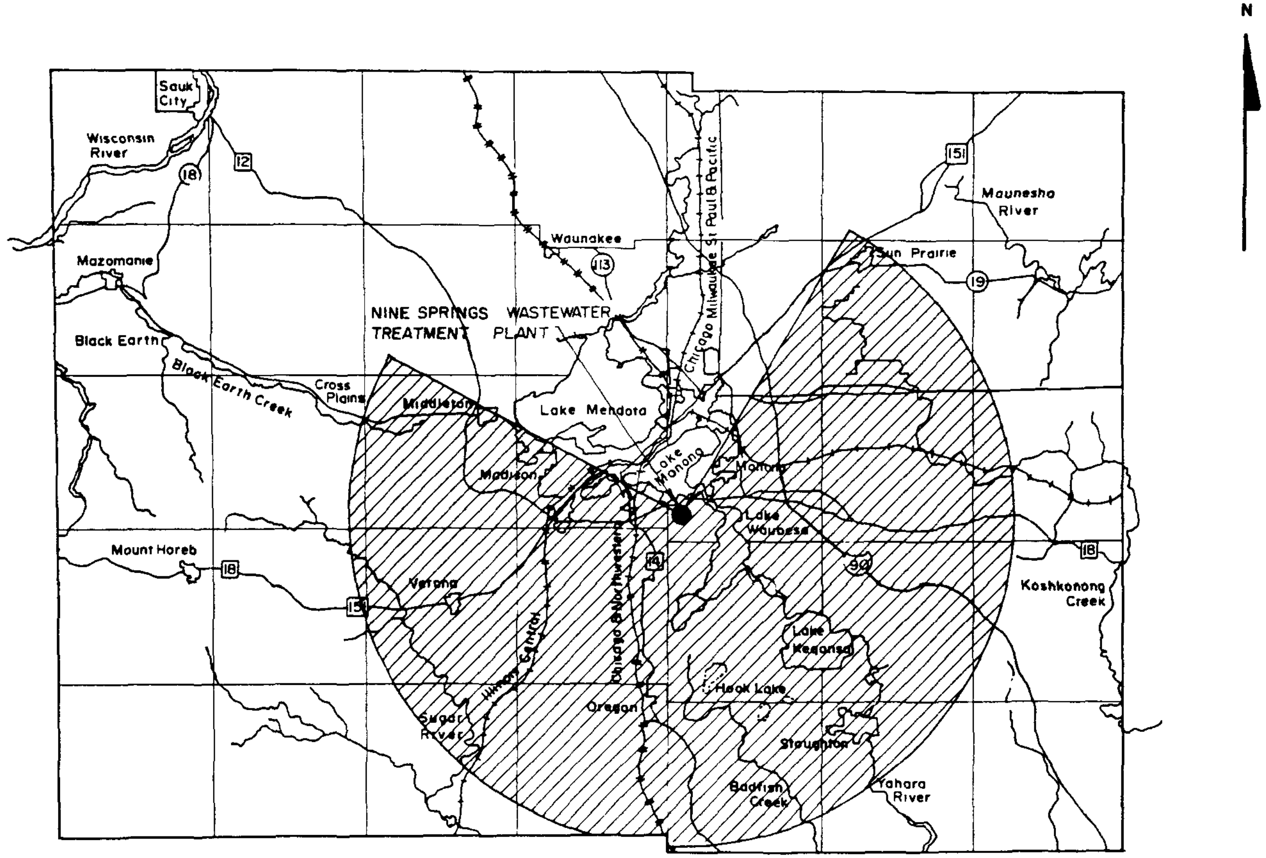
SLUDGE REUSE PROGRAM
IMPLEMENTATION SCHEDULE

MADISON METROPOLITAN
SEWERAGE DISTRICT
MADISON, WISCONSIN

CH2M HILL

S9166 0

FIGURE I-2



LEGEND:

GENERAL AREA CONSIDERED FOR LAND APPLICATION OF SLUDGE

MMSD FACILITIES PLAN

LOCATION OF THE PROPOSED ACTIONS

O'BRIEN & GERE ENGINEERS, INC

N

0 300 600
SCALE IN FEET

NOTES.
1. SLUDGE DEPTHS AT LAGOON PERIMETER ARE ESTIMATES.
2. DEPTHS ARE IN TERMS OF FEET

FIGURE 5-3

SLUDGE DEPTHS

MADISON METROPOLITAN
SEWERAGE DISTRICT
MADISON, WISCONSIN

CH2M HILL

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