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By

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ABSTRACT

AN ANALYSIS OF THE UTILIZATION OF
MUNICIPAL SEWAGE SLUDGE ON
MICHIGAN PRIVATE FARMLANDS

By

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Federal water pollution control laws have required municipalities to upgrade sewage treatment facilities. As a result, increasing quantities of sludge are being produced and communities must implement sludge management plans. The utilization of stabilized sewage sludge on private farmlands is analyzed as one alternative. Economic, institutional and technical aspects of sludge utilization are examined using a multidisciplinary approach. An analysis is presented on surveys conducted with farmers and sewage treatment plant operators who participated in utilization agreements. Representative case studies using synthetic data are used to estimate utilization costs under different contractual arrangements.

The results of this research indicated that utilization is a desirable alternative for rural municipalities with neighboring farmlands. The nutrient content of sludges was found to provide incentives for farmers to enter utilization agreements. The primary implication of this study

is that the success of utilization programs is highly dependent on the implementation of certain technical and institutional arrangements.

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CHAPTER I

INTRODUCTION

The environmental quality issue began as a popular topic for public debate in the late 1960's, and has become a focus for public policy in the 1970's. In the United States, the "awakening of the ecological conscience" has created an impetus for pollution abatement and resource conservation. In response to the demands for reform, the political process has enacted voluminous legislation and established new enforcement agencies. These governmental laws and organizations, combined with citizen action groups, have changed the rules for dealing with environmental protection. The birth of these institutions,[1] or set of rules, has had a distinct impact on the behavior in the economy. The private and public sectors of the economy have been given incentives to control pollution. Various measures such as taxes, fines, grants and outright regulation have been used to encourage waste management. But pollution abatement has also been recognized as a costly business. The benefits of eliminating all wastes would be far below the associated economic and social costs. The current approach to the problem has been to achieve a desired quality of life at a cost which is acceptable to society.

The institutions chosen to deal with pollution externalities[2] have not always performed as intended. In fact, the efforts to abate one form of pollution have caused problems in other areas of waste management. One of these undesired consequences has been the intensification of the sewage sludge disposal problem as a result of the federal water pollution control program.

The sludge management issue has been receiving increasing attention at national and local levels. This greater recognition stems from the generation of much larger volumes of sludge by municipal wastewater treatment plants throughout the country. The growing sludge disposal problem is a direct consequence of water pollution control laws for municipalities who must upgrade their sewage systems. Many communities are trying to identify disposal alternatives which are both economically feasible and socially acceptable. These municipalities are in need of additional knowledge on the available options for handling sludge. In relation to these informational needs, the aim of this thesis is to describe and analyze the farmland sludge utilization alternative.

Origins of the Wastewater Sludge Problem

Enactment of Public Law 92-500--The Water Pollution Control Act Admendments of 1972

The ninety-second Congress of the United States set a national goal of eliminating pollutant discharges to navigable waters by 1985 when it passed Public Law 92-500. One portion of these Amendments, which are abbreviated as the WPCA of 1972, specifically directs municipalities to upgrade their sewage treatment facilities.[3] The 1972 Law requires the use of advanced waste removal techniques to reduce the biochemical oxygen demand, or BOD,[4] of municipal wastewaters discharged into local rivers and streams. The organic matter (BOD) and nutrients removed by treatment processes are concentrated into a semi-liquid slurry known generically as sludge. The more advanced techniques have raised BOD reduction rates, and have therefore generated larger volumes of sludge. As a result, the abatement of pollution from wastewater outflows has been gained at the expense of increasing the difficulties of sludge disposal.

Since waterways are no longer acceptable as sludge dumping sites, municipalities are trying to develop other options for sludge management. Some of the alternatives which are presently being employed for sludge handling include:[5]

1. The transport of sludges to sanitary landfills.
2. The lagooning of sludges on public lands.
3. The incineration of sludges with the resultant ashes to be lagooned or landfilled.
4. The landspreading of sludges on publicly-owned farms and/or forests.
5. The land application of sludges for the reclamation of strip-mine and other organically deficient soils.

6. The ocean dumping of sludges.
7. The landspreading of sludges on private farmland and/or forestland by agreement of landowner and municipality.

The private farmland application strategy is the focus of this thesis. All of the above-mentioned alternatives, except ocean dumping, are legally accepted means of sludge disposal. Ocean dumping has been an interim practice of large coastal metropolitan areas, but this type of sludge disposal will be in violation of federal statute in 1981.[6] A prime example of a municipality that has been using the ocean dumping option is Philadelphia, Pennsylvania. Under political pressure to meet the federal deadline, Philadelphia, officials have announced that a recycling center will be built to begin composting sludge for use as a fertilizer.[7]

Farmland Utilization of Municipal Sewage Sludge

Sources of Controversy over Farmland Application

The potential of sludge to act as a fertilizer and soil admendment has been recognized by agronomists for some time. However, the agricultural utilization alternative has not been readily adopted. In the past, a number of objections have been raised with respect to the risks associated with sludge use. Some of these problems can be listed as follows:[8]

1. The costs of sludge utilization can be very high if the municipality must acquire land by condemnation, in addition to the transport and handling costs.

2. Excessive application rates can cause contamination of groundwaters with toxic levels of nitrates. Other problems include runoff from sludge-amended soils and the direct ingestion of sludge by domestic farm animals

3. The hygienic hazards of the human pathogens which can exist in sludge.

4. The claims that sludges are capable of improving crop yields at a lower cost have been exaggerated.

5. The odor which emanates from incompletely digested sludges is less socially acceptable than manure odor.

6. The research that has been conducted so far is thought by some to be not objective in orientation; studies have tried to justify the land utilization option.

7. Continual application of sludges on a yearly (or annual) basis could result in the buildup of heavy metals and other trace elements. Toxic levels of these sludge components can inhibit plant growth or move further up the food chain.

8. The benefits of sludge use are not readily separated from the associated hazards.

The above criticisms deserve attention, and current studies are being geared towards answering the tough questions and finding ways to improve sludge utilization programs. The technical and social problems must be overcome if land application is to be a successful endeavor.

An improperly managed sludge disposal plan can produce adverse environmental effects. Untreated sludge has an obnoxious odor and may contain dangerous pathogens. To safely implement a farmland sludge utilization plan, appropriate technical practices must be employed. Processes such as sludge stabilization, soil incorporation and groundwater monitoring are some of the techniques which should be instituted in a sludge program. In addition to preventing the occurrence of mishaps, proper landspreading methods promote the dual utilization goals: the disposal of sludge in an acceptable manner and the enhancement of crop production potentials.

Currently, all waste disposal practices are receiving more public scrutiny. In the aftermath of Michigan's PBB incident, citizens throughout the state have been sensitized to issues such as public health and environmental hazards. When this atmosphere of social awareness develops into one of public distrust, risk-related activity may encounter opposition.

A strong social reaction can markedly influence a public program. The disposal of sewage sludges is an issue capable of eliciting a vigorous response from a local community. Potential impacts such as odors, runoff and health threats quickly gain the attention of citizen action groups. Interested parties may exercise their rights under nuisance laws to block the implementation of a sludge plan or set restrictions on application practices. Such opposition becomes highly probable when local people are not consulted before a plan is implemented. Citizen participation may be a vital step in getting any program approved. The people in the community should be informed of the nature of the sludge disposal problem, what alternatives are available, and what decisions need to be made.

The choice of a specific option and its accompanying economic and technical impacts, such as private farmland utilization, should receive local consent before action is taken. But even with early citizen participation, there is no assurance of public acceptance of the program.

One of the purposes of this study is to examine the technical and social problems presented by sludge disposal. In particular, there are a number of difficulties specific to the choice of private farmland application as a disposal alternative. Also, a number of distinct advantages exist for utilizing agricultural lands. This investigation is being conducted because the private farmland option has a potential for dealing with sludge disposal in an acceptable manner.

Farmland Utilization as an Increasingly Desirable Sludge - Handling Technique

In an effort to promote the landspreading of sludges and wastewaters, the WPCA of 1972 set goals for "the encouragement of recycling of sewage pollutants through the production of agriculture, silviculture and aquaculture products."[9] The admendments also contained a statement such that "the ultimate disposal of sludges should be carried out in a manner that will not result in environmental hazards."[10]

In addition to sludge utilization becoming a federally endorsed concept, land application has recently been perceived as a more economically attractive mode of sludge management. Rural communities with populations of 10,000 or less seem to have the best opportunities for setting up sludge utilization programs. In these smaller municipalities, the wastewater treatment plants are located closer to available farmlands. Transportation is a major activity in a utilization plan, and shorter distances mean lower travel costs and easier access. Also, rural areas with less dense populations have fewer public exposures to odors and other disposal problems. Another consideration is that sludges which are generated by down-sized sewage plants do not usually contain high concentrations of heavy metals. The problem of metals or trace elements arises when the treatment plant has industrial waste inflows.

One of the provisos of any utilization program is that the sludge must be properly stabilized. The agricultural use of raw, untreated sludge is simply prohibited in most municipalities of the U.S. Most treatment plants now employ some stabilization process, regardless of whether the sludge is to be placed on farmlands. Sludge treatment is required largely for reasons of hygienic and odor nuisance control. Therefore the costs of stabilization are not solely due to landspreading programs.

Purpose of this Study

The aim of this thesis is to analyze the social, economic and technical aspects of farmland utilization as a sludge management alternative. To develop a systematic view of the disposal problem, this study has the following objectives:

1. Analyze the contractual arrangements, economic aspects and social problems of sludge utilization programs in Michigan.

2. Outline and explain the significance of the federal, state and local regulations as a legal framework within which local decisions on wastewater and sludge treatment are made.

3. Explain some of the technical aspects of utilizing sludge by examining:
   a) The physical-chemical-biological characteristics of municipal sludges
   b) the methods of stabilization and transport
   c) the potential agronomic effects of sludge utilization
   d) the environmental hazards associated with improper sludge management.

4. Describe and interpret the results of surveys conducted with farmers and wastewater treatment plant operators who have jointly participated in sludge programs. The implications of the surveys for implementing utilization programs are presented.

5. Perform some representative case studies which approximate the costs of utilization.

6. Summarize the private farmland alternative as a potential solution to the sludge disposal problem in rural Michigan.

The necessity for conducting this study stems from the rising interest of rural Michigan communities for sludge utilization. These small municipalities are demanding evidence on how well different disposal practices are able to fulfill social, economic and technical standards of performance. Until this study, the state of Michigan has had no complete documentation of the performance of sludge utilization as a disposal alternative. Research papers already completed in states such as Ohio, Illinois, Oregon and Massachusetts have demonstrated the beneficial potential of sludge utilization. This study employs a multi-disciplinary approach to gain a broader perspective on utilization in Michigan. Previous research conducted at Michigan State University has investigated the more varied aspects of the land disposal of municipal wastewater.[11]

The results of this study of sewage sludge utilization are important to municipalities and farmers who are considering farmland application as an alternative. This research proposes that municipalities can increase their ability to solve the sludge problem by developing a more organized approach. Consideration of the legal, technical, economic and social aspects of a utilization program is necessary if a municipality is to decide whether land application is a feasible and desirable option.

Thesis Plan

The desired accomplishment of this study is to analyze the feasibility of private farmland sludge utilization as a management alternative. The content is arranged into seven chapters. This first section is an introduction to sludge disposal and the farmland application option. Chapter One has also stated the purposes and justification for the study. Chapter Two sets up an outline for examining the sludge problem in an analytical manner. Chapter Two is primarily designed to give a systematic view of sludge utilization. Chapter Three examines the legal structure and institutional arrangements which have shaped the structure of sludge utilization programs. The issues of sludge management are examined at federal, state and local levels of government. The actual implementation of utilization plans is viewed from the perspective of the contractual agreements which occur between the municipality and the farmer for the landspreading of sludges. Chapter Four is an overview of the technical aspects of sludge utilization. This fourth chapter includes a brief description of stabilization and drying techniques, transportation and application equipment and the evidence on sludge's ability to yield agronomic benefits. Chapter Four also discusses the problems of pathogens, heavy metals and nitrogen overloads which are associated with sludge use and misuse. In Chapter Five, the results and implications of surveys conducted with both farmers and sewage treatment plant operators are described. This fifth section uses tables to illustrate important relationships which characterize utilization programs. Chapter Six sets up a number of case studies on the costs of farmland application of sludges. Partial budgets are used to estimate costs under various assumptions about utilization arrangements. The concluding Chapter Seven summarizes the findings of the study on the farmland application alternative in Michigan. This final chapter emphasizes the need for more informational and communicational efforts to improve existing programs. It also reviews the various aspects of beginning a sludge utilization program in a municipality. Finally, the areas in need of further research are outlined and the future aspects for land application as a disposal option are evaluated.

ENDNOTES

[1]An institution is "a set of ordered relationships among people which determine their rights, exposure to the rights of others, and their responsibilities," as defined by A. Allan Schmid, Property, Power and the Public Choice: An Inquiry into Law and Economics (New York: Praeger Publishers, 1978), p. 5.

[2]An externality is "an unintended consequence of an economic action for which no compensation is required," as defined by Brian Harvey and John D. Hallett, Environment and Society: An Introductory Analysis (Cambridge: The MIT Press, 1977), p. 97.

[3]Title II, Secion 202b of Public Law 92-500, The Federal Water Pollution Control Act Admendments of 1972, 33 U.S.C. 1251.

[4]Biochemical oxygen demand (BOD) is defined as "the quantity of oxygen used by micro-organisms in the decomposition of organic matter in wastewater," in Mark J. Hammer, Water and Waste-Water Technology (New York: John Wiley and Sons, Inc., 1975), p. 80.

[5]Hammer, pp. 433-35.

[6]Title I, Section 101 (a) of Public Law 95-153, Amendment to the Marine Protection Research and Sanctuaries Act of 1972, 33 U.S.C. 1420.

[7]Bob Frump, "City to Build Plant for Sludge" The Philadelphia Inquirer, 30 August 1978, p. 1B.

[8]D.R. Egeland, "Land Disposal: A Giant Step Backward," Journal of the Water Pollution Control Federation, 45 (July 1973), 1465-75.

[9]Title II, Section 201 (d) (1) of Public Law 92-500.

[10]Title II, Section 201 (d) (4) of Public Law 92-500.

[11]Jeffery Williams, Case Histories and Comparative Cost Analysis of Land Treatment of Wastewater by Small Municipalities in Michigan, Master's Thesis, Michigan State University, 1977.

CHAPTER II

A FRAMEWORK FOR EXAMINING FARMLAND SLUDGE APPLICATION PROGRAMS

An Outline of the Important Aspects of Sludge Utilization[1]

In order to state the sludge problem in a concise and comprehensive manner, it is useful to develop an approach for analyzing the various aspects of a landspreading program. This chapter begins by specifying the primary goals of farmland sludge application. Then the analysis proceeds to view some of the institutional and economic characteristics of sludge utilization. Next, an examination of the interested parties is conducted to highlight the potential impact of these people on the planning and operation of a sludge program. The "state of the art" technology for the treatment, transport and beneficial use of sludges is then briefly reviewed. Finally, the important dependent and independent variables of sludge management systems are broken down into identifiable categories.

Goals of Sludge Application Programs

A systematic approach to the analysis of sludge utilization begins with a description of program goals. Sludge landspreading on private farmlands are designed primarily to meet two objectives:

1. The ultimate disposal of sludges in an environmentally-safe and an economically-efficient manner.
2. The application of sludges to enhance the agricultural production goals of the participating farmer.

The municipal sludge disposal aim, the first one listed above, derives from the public policy for stricter environmental standards and the desire to find the cost-effective solution which complies with these standards. The second goal of the sludge program is just as important if utilization is to become a cooperative success. The farmer's crop production goals should be aided by the benefits of sludge as a soil admendment. Recently, an additional incentive for obtaining alternative nutrient sources such as sludge has been the rapidly rising price of petroleum-based fertilizers.

The agricultural production goal and the municipal disposal goal are potentially conflicting. To resolve the differences which may exist between the farmer and the treatment plant operator, a contract of mutual agreement is necessary for starting a sludge program.

Institutional Arrangements and Economic Aspects

Contractual Agreements for Sludge Utilization

In general, sludge utilization plans for private farmlands in Michigan involve contractual (oral or written) agreements between a municipality and a landowner.[2] In such contracts, joint arrangements are made for the transportation and application of treated sewage sludge onto the farmer's land. The farmer usually agrees to take sludges onto specified sections of his property for a certain period of time. In exchange for the use of the farmer's land, the municipality assumes responsibility for the transport, handling and monitoring costs to ensure safe disposal of all the sludge. In fulfilling the standards for proper sludge management, for example, the municipality is generally expected to perform sludge and soil sample analyses, and slope and runoff evaluation. Groundwater and surface-water tests are also done on a selective basis. The technical, administrative, labor, transport and liability costs can be collectively thought of as the transactions costs for a municipality that institutes a sludge utilization program. The farmer and the municipality may also jointly share the costs of transport and application, since the handling equipment serves a dual purpose of wast disposal and agronomic improvement. Using the concepts of theoretical microeconomics, the rational farmer would use a marginal analysis for including sludges as a priced input in his production process. Under the simplifying assumption that the farmer was producing only one output, he would use extra amounts of sludge until the marginal cost of application just equalled the marginal revenue generated by the last unit of sludge input. In most cases the marginality condition can not be applied to sludge use decisions. To correctly balance benefits and costs for maximizing net returns, the farmer would have to determine the independent technical effect of sludge from his production function. He also would need to overcome the "user cost" measurement problems of estimating the value of sludge-handling equipment. In addition, future price trends in the input and output markets would have to be known with certainty.

When the municipality takes responsibility for the transport and application costs, the farmer simply agrees on the time schedules and land parcels for the sludge program. The surveys conducted for this study indicate that the municipality often bears most of the utilization costs. If the farmer does not have to share in the costs of the application program, he can maximize the net returns from sludge use, subject only to the institutional and technical constraints on the landspreading operation.

Conceptual Economic Issues of Sludge Utilization

The advantages of land application of sludges can be arranged into two basic categories. The capacity of sludges to upgrade soil and crop conditions comprises the first class of benefits. Secondly, an improvement in water quality of the environment is expected to result from reducing the discharge of nutrient-laden effluents into natural waterways.

The soil admendments anticipated from sludge application are primarily the plant nutrient contributions (N-P-K) and the soil-building capabilities of the sludge organics. If the utilization programs are to be valuable to farmers, the sludge input should generate improved crop production and higher returns from the cropping activity. Alternatively, utilization could also result in a fertilizer cost savings, by decreasing the requirement for commercial fertilizer while maintaining crop yields. Due to the difficulty in measuring the independent effect of sludge on the plant growth process, only rough estimates of the input value of sludge are available. To improve these estimates, further research is necessary to establish the crop yield responses to sludge applications. In conjunction with these technical investigations, economic analysis should demonstrate whether sludge is competitive with alternative nutrient sources. One method of approximating the separable costs and benefits of a sludge program is the use of partial budgets. The results of such budgeting techniques provide estimates of the net value of sludge, which can then be compared with the profitability of other fertilizer inputs. For instance, if the partial budgets demonstrate animal manure to be more cheaply employed than sludge, then the municipality has to offer additional incentives to encourage the farmer to take sludges onto his land. Such incentives may include the municipality purchasing application equipment, assuming damage liability or generally operating the entire program at no expense to the farmer.

The second type of sludge management benefit, improved water quality, also presents measurement difficulties.[3] The value of controlling sewage disposal is often measured in purely physical terms, using water pollution indicators such as BOD levels, nitrogen concentrations and bacterial counts.

As mentioned previously, secondary sewage treatments eliminate about ninety-five percent of the BOD causing organics in wastewater. But this gain in removal efficiency has expanded sludge production, because the extracted BOD is just concentrated into additional sludge. So the key to the success of a wastewater pollution control program lies in the effective disposal of increasing sludge volumes.

A closer examination of the water pollution issues can reveal some insights into the economic value of lowering BOD in natural waterways. A crucial assumption of the entire process of upgrading pollutant removal efficiency is that gains will eventially be obtained in the form of cleaner waters. Higher water quality is often referred to as a "public good" or a "joint impact good."[4] A joint impact good is one which, once produced, can be utilized by more than one person.[5] Such "public good" qualities can sometimes be more easily handled by a public sector action. Some of these aspects have been categorized as follows:[6]

1. Negative Externalities or Spillovers

   Pollution is a classic example of a negative externality. Externalities occur when an economic agent causes a cost (or benefit) to be generated, but that agent does not have to account for that cost (or benefit).

2. High Exclusion Cost and Free Riders

   The problems of exclusion and free riders occur with common property resources. The difficulty is that, once the good is produced, it can be consumed by more than one person without a decrease in its usefulness. When the costs of excluding a person from using the product become high the incentive is to consume without paying for the good (free rider).

3. Resolution of conflicts of interestover public goods use-rights

   The decision is to distribute the costs and benefits of using a public good among different groups. The public sector politically and legally decides whose interests count. For instance, the Water Pollution Laws have transferred "water quality rights" to target groups concerned with aesthetics, ecological balance, recreational use, and cleaner water supplies. At the same time, "polluters" have been forced to internalize effluent costs through various abatement procedures.

When Congress passed Public Law 92-500, it proclaimed a goal of eliminating all water pollutants by 1985. Therefore, the political process has already made an evaluation judgement: the benefits of improved water quality exceed the costs of effluent treatment and alternative disposal. It is in this view that sludge management is an activity that is publicly recognized as having a net benefical value. But what can be implied about the institutional changes that this political decision has caused? To understand the significance of the Congressional decision, the legislative process needs to be more closely examined. The lobbies in Congress represent a whole variety of interests, and the passage of the 1972 water law indicates that the groups concerned with higher water quality prevailed in asserting their position. The target groups who most benefit from the improvements which may result from the new law can be categorized as follows:[7]

1. Present and Future "Clean-Water" Users

   A list of the goods and services which can be jointly consumed with improved water quality might include:

(a) Aesthetic values attached to unpolluted or pristine waters promoted

(b) Recreational opportunities enhanced

(c) Ecological balances are allowed to be restored by natural processes

(d) Water supplies less threatened by effluents

(e) By passing national standards, it was the intent of Congress that all users would eventually realize "downstream benefits" of pollution abatement.

2. Option Demanders

Those people (groups) who may not be presently consuming the products but effectively demand that action be taken to preserve those opportunities, should they be desired at a later time.

3. Beneficiaries who experience real economic gains

(a) Downstream water users have decreased treatment costs, which means that less resources are used to produce the same output.

(b) Increased valuation of a "unit of improved water quality" expressed as a higher effective demand. For example, the value attached to recreational and aesthetic qualities may increase as society places a higher significance on amenities.

The enactment of Public Law 92-500 has transferred power (rights) to groups primarily interested in water quality. To assure that these interests are converted into effective action, the Congress has played a role of central coordinator to control pollution externalities. In this case the public sector approach has been to administratively employ a number of "solutions":[8]

1. Regulation - For example, a requirement that at least secondary treatment be installed at all municipal wastewater facilities.

2. Payments - Construction grant program of federal funding for municipalities upgrading their wastewater plants.

3. Prohibition - Setting of deadlines for implementing effluent controls.

4. Directives - Establishing nationwide water quality standards based on technical information (for example, the desired levels of Biochemical Oxygen Demand in waterways).

Those who bear the costs of Congress's initiatives can be identified according to sources of funds. For instance, federal grant monies ultimately originate from federal taxpayers, whereas projects designed to upgrade municipal facilities are also financially supported by local plant users. In a sludge application program, if a farmer pays for sludge as a productive input, he is indirectly bearing some of the treatment costs of effluent controls. The costs of clean water are also being internalized by private industry, since the pollution laws apply to almost all sources of effluent.

Another aspect of abatement is classified into a category known as pecuniary effects, which are neither costs nor benefits in an analytic sense. Pecuniary effects occur when improved water quality causes an increase in effective demand for water activities, which in turn produces a resultant rise in relative prices. If a supplier of water-related services receives higher prices and profits, due to the increased demand of water-users who now have new opportunities, then income is redistributed from buyer to seller.

The cost side of the equation also includes the problems encountered in the enforcement and implementation of environmental legislation. Bureaucratic, informational, and institutional obstacles add to the job of making abatement a workable concept. Sludge disposal costs are merely one facet of the expenditures for effluent control.

Single sludge management is a direct result of Public Law 92-500 and other legislation, it is politically recognized as having a net beneficial value. When the Congress says that the benefits of a project exceed the costs, the work of the economic analyst is reduced to finding the cost-effective (or cheapest) solutions. Techniques such as sensitivity analysis and opportunity cost evaluation can be used to establish a framework for economic decisionmaking between sludge disposal alternatives. In connection with these cost-minimizing criteria, the Congress has also demonstrated its support for alternative disposal technologies such as recycling sewage. The Clean Water Act has given these innovative projects an additional 15% advantage in cost-effectiveness calculations and has also absolutely required municipalities to consider alternative disposal techniques to be eligible for construction grant funds.

The water quality of a lake or stream is a primary factor in determining the type and degree of jointness in use. Unpolluted conditions along a certain section of a river would be conducive for simultaneously supplying domestic, aesthetic and recreational water uses. Polluted water may not be useful to any of these groups, or only at a high treatment cost. In addition, water pollution may upset delicate ecological balances that would directly or indirectly affect economic agents in terms of higher costs of maintaining a desired quality of life.[9] Certain users can tolerate a lower water quality at a lower cost than others, so that the desirable characteristics of water for one activity may be incompatible with those for another activity (for example, wastewater treatment versus recreational use). Domestic consumption, industrial use, recreational opportunities and the ecological balance are each affected differently both in degree and in kind by the impacts of a specific level of water quality. Improvements in water conditions may benefit some users a great deal and others none at all (or even negatively). As implied in P.L. 92-500, the target groups of water users who should most benefit from water pollution abatement are those concerned with the consumptive, recreational, ecological and aesthetic goods to be obtained from having a "cleaner" waterway.

Interested Parties

Besides the jointly participating farmer and wastewater treatment plant operator, there are a number of other interested parties who can influence a sludge utilization program. The presence (or absence) of these groups can markedly affect the final structure and performance of the sludge management scheme. The motivations for these interested groups vary from a federal agency's formally designated responsibilities to a citizen's concern for the program's impact on his personal activities. A list of all the interested parties would include:[10]

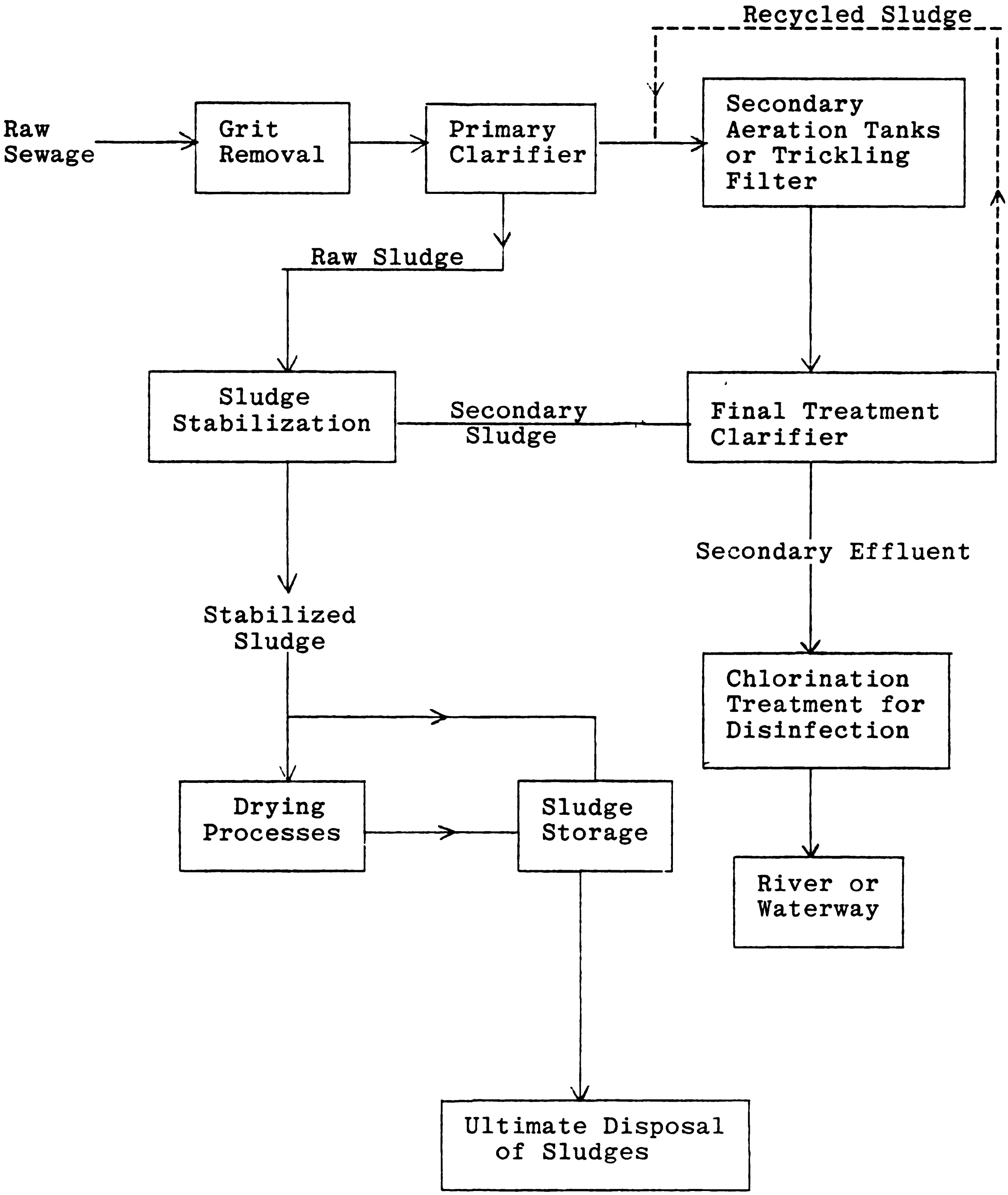
1. wastewater treatment plant operator
2. participating farmer(s)
3. neighbors of the participating farmer, concerned local citizens, and the general public
4. local municipal government (such as the local Health Department)
5. state agencies (such as Michigan's Department of Natural Resources)
6. state land-grant university; for example, at Michigan State University the involvement of:
   a) Agricultural Experiment Station
   b) Agricultural Extension Directors
   c) Departments of Crop and Soil Sciences, Agricultural Engineering, and Agricultural Economics
7. Federal agencies, guidelines, and funding
   a) Environmental Protection Agency
   b) U.S. Department of Agriculture
   c) Food and Drug Administration
8. Private Consulting Firms and Hauling Firms

Due to their diverse backgrounds and intentions, the input of any (or all) of these above-mentioned parties can influence the development and operation of a sludge utilization program. The interactions among the various groups produce working relationships which define the rights and responsibilities of the primary participants, namely the farmer and the plant operator (who represents the municipality). Another factor which affects the institutional relationships is the available state-of-the-art technology for implementing a feasible sludge project.

Technical Characteristics of Sludges[11]

The technical considerations for the spreading of sludges onto agricultural lands involve the evaluation of the physical, chemical and biological characteristics of sludge. Sludge is a generic term for the setteable solids which are coagulated in the wastewater treatment processes to form a semi-liquid mixture (0.25% or > 0.25% solids) of organic matter and microbes. Sludge is categorized by the treatment process from which it originates. Raw (untreated) sludge is composed of the solids directly settled (clarified) from the incoming wastewaters. Activated, chemical and filter sludges are produced from the solids which collect in the secondary treatment processes in the wastewater plant. The raw sludge is often mixed with the other treatment sludges, and this mixture is then circulated to the site of stabilization, as depicted in the flow diagram below.

Figure 2-1. Diagram of a Wastewater Treatment System and Sources of Sludge Generation.[12]



Anaerobic digestion (noted in the above diagram) is the most commonly employed stabilization process for treating raw and secondary sludges. The stabilizing effect of anaerobic digestion is the result of a bacterial fermentation process that breaks down the odorous organic compounds into relatively more inert substances. After digestion, the stabilized sludge is a dark gray to black semi-liquid substance with a granular consistency, a tar-like odor, and a 3 to 5% organic solids content. The physical characteristics of digested sludge are compatible with dewatering processes which decrease the volume and mass of sludges for on-site storage processes at the treatment plant. Dewatering reduces the moisture content of stabilized sludge, and this "drying" process can be accomplished with open-air drying beds, centrifuges or vacuum-filter devices. Dewatering produces a 60% moisture, pastelike material which is known as "dry filter cake sludge," as distinguished from "liquid sludge" which is directly generated by stabilization processes. The importance of the distinction made between liquid and dry sludges becomes more apparent when selecting the proper transportation and application equipment. Hauling and spreading of liquid sludge usually involves the use of modified tank-wagons, while dry sludges may require the use of a manure spreader.

Before consideration of sludge handling equipment becomes a matter of decision, the initial evidence for sludge as a valuable crop input should be established. Sludge applications provide plant nutrients and can improve the properties of the soil. But sludge also possesses pathogenic threats. The severity of the disease vector problem is modified by a number of factors: the kind and degree of stabilization, the types of microbes in the sludge and the survival time of pathogens in the soil environment.

Other important constraints on sludge application are the build-up of heavy metals in the soil and the prevention of nitrogen excesses and nitrate groundwater contamination. Proper control of the potential damages caused by faulty application methods is also essential if programs are to be successful and begin to receive public acceptance (another constraint).

Categorizing the Significant Factors in Farmland Sludge Application[13]

An understanding of the influences affecting the performance of sludge utilization can be found through an identification of the independent and dependent variables in a sludge management system. As a specific strategy, private farmland sludge application programs are jointly implemented by a municipality and a participating farmer. From the point of view of these primary participants, the controllable and uncontrollable variables can be outlined as follows in Table 2-1.

The distinctions made in Table 2-1 are useful for

Table 2-1. Categorizing the Controlled and Uncontrolled Variables of a Sludge Utilization Program from the Perspectives of the Participating Farmer and Municipal Sewage Plant Operator.

Uncontrolled (or Independent) Variables	Controlled (or Dependent) Variables
1. Population density and growth a) partial determinant of wastewater inflow to the treatment plant and influences the volume of sludge to be disposed	1. Choice of the appropriate treatment and application technology a) economic aspects b) technical aspects c) institutional aspects
2. Distance between treatment plant and available farmland a) influences transport costs	2. Institutional arrangements a) terms of the land-spreading agreement b) ability to influence restrictions, e.g., obtain a variance from local zoning ordinance for sludge application.
3. Environmental conditions for land-spreading a) climate, weather b) type of soil c) topography d) hydrogeology	3. Economic considerations a) decision among the disposal alternatives b) benefits: how much and to whom c) costs: how much and who bears them
4. Nutrient content and soil benefits of stabilized sludge a) technical characteristics of sludge	
5. Pathogenic disease vectors and heavy metals content of sludges a) type and number of pathogens b) estimated survival time of pathogens in the soil c) concentration of heavy metals	

Table 2-1 (cont'd.).

6. Social factors a) influence of interested parties on the program b) public attitudes 7. Available technology for sludge utilization a) transport and application equipment b) stabilization techniques c) sludge and soil analyses d) estimation of crop yield responses to sludge use	4. Control of potential risks and the ability to promote sludge utilization benefits a) use of proper management practices to ensure environmental and health protection b) proper management or application procedures to enhance the sludge nutrient values for crop production c) safeguards against longer-term risks through monitoring and testing procedures.

describing the static situation faced by the farmer and treatment operator. The designations 'controlled' and 'uncontrolled' are intended to be very general. In certain cases, variables such as 'social factors' may in fact be dynamically influenced, or controlled, by the municipality and the farmer. Or, the use of a certain technology may be locked-in (no control), at least in the short run.

The municipality and farmer can manipulate the control variables in an attempt to achieve the goals of the sludge program. But changes in either type of variable can effect performance. A complicating factor is that the altering of program conditions causes a number of interrelated consequences. This variety of impacts on the technical, legal and economic aspects of sludge use are difficult to identify and evaluate. A broader approach is necessary to better assess the outcomes which flow from decisions and changes. One of the objectives of this thesis is to widen the scope of analysis to improve the process of solving the multi-faceted problems of sludge utilization.

This chapter has briefly outlined the major components of a sludge management program. In the following Chapter Three, a more detailed description of the legal and economic issues is presented.

ENDNOTES

[1]The idea for employing the analysis in Chapter Two is taken from R.H. Pantell, Techniques of Environmental Systems Analysis (New York: John Wiley and Sons, 1976), pp. 1-45.

[2]The information on farmer-municipality arrangements if obtained largely from private conversations and survey answers provided by actual program participants.

[3]This discussion takes ideas from A. Allan Schmid, AEC 811, Spring, 1978.

[4]A. Allan Schmid, Property Power and Public Choice: An Inquiry into Law and Economics (New York: Praeger Publishers, 1978), p. 70.

[5]Ibid., p. 79.

[6]A. Allan Schmid, pp. 37-57, 70-87.

[7]These concepts of beneficiaries are taken from discussions with Robert S. Manthy, R.D. 809, Winter 1978.

[8]Otto A. Davis and Morton I. Kamien, "Externalities, Information and Alternative Collective Action,." Public Expenditure and Policy Analysis (Chicago: Rand McNally Pub. Co., 1977), pp. 94-104.

[9]Roger Blabaum, Larry C. Holcomb, Sarah Fast and Larry Swanson, "An Assessment of the Potential for Applying Urban Wastes to Agricultural Lands," Urban Wastes Project (Omaha: National Science Foundation Program, 1978), p. 47.

[10]The information on the interested parties is obtained primarily from the surveys conducted with farmers and sewage treatment plant operators.

[11]Clarence G. Golueke, Biological Reclamation of Solid Wastes (Emmaus: Rodale Press, 1977), pp. 117-150.

[12]Mark J. Hammer, Water and Waste-Water Technology, (New York: John Wiley and Sons), p. 346.

[13]R.H. Pantell, pp. 16-17.

CHAPTER III

LEGAL, INSTITUTIONAL AND ECONOMIC ASPECTS OF SLUDGE UTILIZATION

Dealing with the New Problem: Sludge Management

The language of the legislation and policy statements on sludge has increasingly reflected the concern for conservation and recycling efforts, rather than just simple disposal.[1] Alternative technologies have been endorsed, and funding has been provided to do technical research on sludge utilization methods. The phrase "sludge management" is used to emphasize the role of proper decision-making in successfully confronting the sludge problem. Proper sludge management involves acquiring and organizing the knowledge of the legal, institutional, economic and technical information into a workable program. This study now proceeds to examine the legal structure that provides a foundation for sludge utilization projects.

The Legal Characteristics of Sludge Management

Legislative and Regulatory Responses to the Sludge Problem

The U.S. Congress designated the Environmental Protection Agency (EPA) as the primary enforcement organization for administering the pollution control directives of Public Law 92-500. Authority was to be transferred to individual state environmental agencies, under the condition that the state would enforce requirements at least as strict as the federal regulations. In Michigan, the Department of Natural Resources (DNR) serves in the role of enforcer, in addition to numerous other environmental services.

The FWPCA of 1972 also called for the construction of improved sewage treatment facilities for municipalities, and financing of these projects were to be up to 75 percent federally funded. Sludge management systems also had to be upgraded and their costs can vary between 30 to 50 percent of total plant expenditures.[2] However, the construction grant system was structured so that sludge treatment investments were primarily made in capital intensive equipment. Municipalities also had to rely upon consulting firms for wastewater treatment design expertise, and these firms were composed largely of sanitary and civil engineers who endorsed the use of more sophisticated equipment for sludge management. This situation occurred despite the clauses in Title II of Public Law 92-500 which designated recycling and land application as options to be seriously examined. In 1976, the EPA's Office of Water Program Operations (the OWPO administers the construction grant funding) altered the application procedure to increase the possibilities of receiving federal aid to be used in the purchase of land for sludge and wastewater applications purposes.[3] Also, as the Congress became aware of the increasing magnitude of sludge management problems, it enacted new environmental legislation which contained provisions designed to deal with sludge disposal. The following list comprises federal statutes which have sections on sludge management practices. Some of the impacts of new requirements are explained below, following the list of federal laws in Table 3-1 on the next page.

Federal Legislation Pertaining to Sludge Use[4]

Public Law 92-500--The Federal Water Pollution Control Act Admendments of 1972

In order to provide adequate funding of the comprehensive aims of P.L. 92-500, the U.S. Congress initially authorized the expenditure of 24.7 billion dollars. Such an outlay was unprecedented in the field of pollution abatement. Out of this sizable federal budget, some 18 billion dollars were allotted for the construction of treatment plants and secondary facilities. As mentioned previously, the approval of grant applications was supposed to be partially dependent upon the municipality's consideration of recycling and recovery alternatives for waste disposal. Regretfully, the ultimate disposal of sludges was a question which was left largely unanswered by P.L. 92-500. Municipalities proceeded to

Table 3-1. List of Federal Laws Which Contain Provisions on Sludge Management.

1.	Public Law 92-500	Federal Water Pollution Control Act of 1972 (FWPCA of 1972)
2.	Public Law 95-217	Clean Water Act of 1977 (Amends WPCA of 1972)
3.	Public Law 93-523	Safe Drinking Water Act of 1974
4.	Public Law 94-469	Toxic Substances Control Act of 1976
5.	Public Law 94-580	Resource Conservation and Recovery Act of 1976
6.	Public Law 95-153	Marine Protection, Research and Sanctuaries Act of 1977 (Amends P.L. 92-532 of 1972 on Marine Protection)
7.	Public Law 95-192	Soil and Water Resources Conservation Act of 1977

individually define the strategies which would fulfill the minimum requirements for "disposing of sludges in an environmentally safe manner." The information upon which to make such disposal decisions was for the most part incomplete, and cost-effective alternatives of land application were absent from consideration in numerous cases. Another difficulty involved the lack of cooperation beetween adjacent counties and townships for land application alternatives. The movement of sludges across political boundaries was interpreted as one area "dumping" at the expense of another, even if the program was designed to enhance the organic content of soils and recycle nutrients back into the ecosystem. Preconceived notions about the undesirability of human wastes often dominated over any efforts to introduce the concept of utilizing treated wastes in a beneficial manner. Such episodes highlighted the need for educational workshops on the magnitude of the wastewater sludge disposal problem and the options available for communities. The implications of P.L. 92-500 were not clearly understood by local officials and the general public, which resulted in an atmosphere of distrust of any landspreading activities proposed by wastewater authorities.

The 1972 Admendments faced some additional difficulties in their implementation, among which were the impoundment of construction grant funds by President Nixon and the reluctance of municipalities to begin any projects during the inflationary recession of 1974. However, a recent survey of water quality conducted by the EPA revealed that pollution indicators had significantly improved since 1972. Such findings were encouraging news for the proponents of effluent controls, although the results were not conclusive evidence of the success fo the program. By 1977 the funding allotments for construction grants were exhausted, and when the Congress confronted this new fiscal spending decision, much debate began to center on the relative merits of the entire 1972 law. The new legislation which emerged from this debate became known as the Clean Water Act of 1977. This law was labelled in the media as a "compromise between environmental and industrial interests, with neither side gaining an overall advantage as a result of the new legislation."

Public Law 95-217--The Clean Water Act of 1977*

The passage of the Clean Water Act of 1977 was generally a renewed commitment by the Congress for eventually eliminating water pollution. But the measure also extended the deadlines for attaining desired treatment levels to give the regulated industries the necessary additional time to comply. The Clean Water Act (hereafter referred to as "the Act") authorized 24.5 billion dollars more to continue the construction grant program for the next five

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*Public Law 95-217 further amended the 1972 admendments in P.L. 92-500.

years. With specific reference to this report, the Act contained a number of new provisions on sludge management and the use of innovative and alternative** technologies for waste treatment. In emphasizing the recycling option, the Act prohibited the financing of grant programs unless the municipal applicant demonstrated why alternative treatment was not suitable. Other financial incentives in the Act for recycling included giving an edge of 15 percent in cost effectiveness to warranted innovations and a federal grant that would cover 85 percent (rather than the standard 75%) of the alternative's construction costs. As a result of the congressional efforts to promote recovery concepts for waste treatment in the Act, the issue of sludge management was accorded greater attention. Specifically, the Act contained clauses on the following aspects of sludge disposal:

Sludge Disposal Provisions[5]
Clean Water Act, P.L. 95-217
(Amends P.L. 92-500 of 1972)

1. Maintained the section of P.L. 92-500 that encourages facilities provide for... "the ultimate disposal of sludge in a manner that will not result in environmental hazards." (under section 201 (d) (4).)

2. Placed sludge disposal practices under the National Pollutant Discharge Elimination System (known as the NPDES permit program). In states which have approved NPDES programs, the appropriate

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**The terms "innovative and alternative" are defined as processes which provide for the reclaiming and reuse of water,..., and utilize recycling techniques, land treatment,..., for municipal waste..." Title II, Section 201 (g) (5) of P.L. 95-217.

state water pollution control agency was delegated primary enforcement responsibilities. Michigan's NPDES program is approved and the Department of Natural Resources (DNR) has the regulatory responsibility. (Sludge placed on NPDES by section 405 (b) of P.L. 95-217.)

3. Required the EPA to set toxic and pretreatment effluent standards for industries which utilize the services of publicly-owned treatment works (or POTW). The EPA regional administrator or the appropriate state agency can require the POTW operator to design a pretreatment program to control pollutants which may contaminate sewage sludge. (under sections 307 (b) (1) and 402 (b) (8).)

4. Required the EPA to set guidelines and criteria for sludge for various purposes. The regulations were to "...

   1. identify uses for sludge, including disposal;
   2. specify factors to be taken into account in determining the measure and practices applicable to each such use or disposal (including publication of information on costs);
   3. identify concentrations of pollutants which interfere with each use or disposal.

   The EPA Administration is authorized to revise any regulation issued under this subsection (under section 405 (d)).

5. The sludge disposal option is to be locally determined, but the locality must comply with any guidelines which the EPA sets for the disposal strategy. Compliance is the responsibility of the owner or operator of the wastewater facility. (under Section 405 (e).)

6. Construction grant funding would be provided for alternative and innovative processes of waste treatment which meet set criteria. Sludge landspreading projects would be eligible for such support. (under Section 201 (j) and Section 201 (g) (5).)

7. The EPA was required to submit a report to the Congress on the status of the "use of municipal secondary effluent and sludge for agricultural and other purposes that utilize the nutrient value of treated wastewater effluent." (under Section 516 (d).)

On February 6, 1978, the EPA released a proposal on the sludge criteria requested by Section 405 (d) of the Clean Water Act.[6] These guidelines were narrowed down to five basic areas of concern:[7]

1. analyze the sludge for cadmium and other toxic substances;

2. assure that the sludge has been appropriately stabilized;

3. determine the appropriate application rates and assure that these rates are compiled with;

4. determine what monitoring is required and assure that it is performed;

5. develop any necessary contingency plans and assure that they are followed.

The EPA proposal also restated that the responsibility for adherance to the above criteria under Section 405 (e) lies with the owner or operator of the publicly owned treatment works. The above sludge guidelines were also designed to jointly satisfy requirements of the Clean Water Act and the Resource Conservation and Recovery Act of 1976, also known as the RCRA of 1976. The RCRA will be examined next for the relevant clauses on sludge management.

<u>Resource Conservation and Recovery Act of 1976 (RCRA)</u>
<u>Public Law 94-580</u>

In amending the Solid Waste Disposal Act of 1965,* the RCRA of 1976 expanded the authority of the federal and state governments to cope with the troublesome problems of garbage and sludge. Recognizing solid waste generation

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*The RCRA of 1976 amended the 1965 Solid Waste Disposal Act (P.L. 89-272), which had been strengthened by the Resource Recovery Act of 1970 (P.L. 91-512).

as an undesirable by-product of technological and economic growth, the Congress drafted the RCRA with the intent of providing technical and financial assistance in developing long-range plans for solid waste management. The RCRA also acknowledged that sludge and other pollution residues were occurring in greater quantities as a result of Water Pollution Control Act, Clean Air Act and accompanying environmental legislation (section 1002 (b) (3)).

The sludge related provisions of RCRA included a formal classification of sludge as solid waste. Also sludge was defined in P.L. 94-580 as "any solid, semi-solid or liquid waste generated from a municipal, commercial, or industrial wastewater treatment plant,..." (Section 1004, Subsections 26A and 27). The RCRA established an Office of Solid Waste in the EPA and directed this office to develop criteria to ensure that solid waste disposal facilities" pose no reasonable probability of adverse effects on health or the environment..." (Section 4004 (a)). The EPA interpreted the term "disposal facility" to include land application of sludges for use as a soil conditioner and fertilizer. In response to the RCRA directive for establishing criteria, and in coordination with the requirements fo the Clean Water Act, the EPA proposed guidelines for the application of solid waste to land for the production of food chain crops. In the proposal of February 6, 1978, these criteria centered on the following aspects:[8] (Part 257.3)

1. Set Cadmium levels allowable in solid wastes such as sludge, taking account of site soil conditions such as Cation Exchange Capacity and pH.

2. Concern over Pathogens in solid waste requires that the sludge be stabilized and food crops normally eaten raw should be delayed until at 18 months after application.

3. Application of solid wastes (such as sludge) contianing residues in excess of the tolerances established by the Federal Food, Drug, and Cosmetic Act.

4. Solid wastes (such as sludge) which are of concern due to their pathogen, toxic organic or heavy metal content must not be applied to a site where the waste may be directly ingested by animals raised for milk or by humans.

The EPA proposal also contained more generalized criteria for protecting surface waters, groundwaters, public safety and environmentally sensitive areas.

An important feature of these above criteria is that responsibility for compliance lies with the "solid waste disposal facility." Such a provision can be interpreted to mean that the private landowner in a landspreading program can be held accountable for proper adherance to solid waste disposal criteria. Recalling that the Clean Water Law of 1977 designated that the owner or operator of a wastewater plant be responsible for fulfilling regulatory requirements, one can theorize a legally-indicated joint obligation for compliance. However, the degree of joint "liability" between the two parties is not clear within the language of the federal laws. Deciding the relative responsibilities is an institutional issue that is likely to be determined in the framework of state and local administrative processes.

The RCRA also set up a grant program of federal funding, but limited the eligible projects to those which were part of a state plan for area-wide solid waste disposal. In addition, the project must promise to advance the state of knowledge in waste management by either reducing environmental impacts achieving recovery of energy or resources, or recycling of useful materials.

A specific provision of RCRA also instructed the EPA to undertake a comprehensive study and publish a report on sludge. The report was to cover at least the following topics:[9] (Section 8002 (g))

1. what type of solid waste is to be classified as sludge;
2. the effects of air and water pollution legislation on the creation of large volumes of sludge;
3. the amounts of sludge originating in each State and each industry producing sludge;
4. methods of disposal of sludge, including the cost, efficiency and effectiveness of such methods;
5. alternative methods for the use of sludge, including agricultural applications of sludge and energy recovery of sludge; and
6. methods to reclaim areas which have been used for the disposal of sludge or which have been damaged by sludge.

To avoid any duplication in the completion of requested projects and regulations as listed above, the Congress required that the RCRA be properly integrated with related Acts such as the Water Pollution Control Act. RCRA also added another institutional dimension to the attack on solid wastes by authorizing private citizens to sue violators of the solid waste law or to sue the EPA for failure to enforce it. Provisions on sludge recovery also brought on the involvement of two additional federal agencies, the Food and Drug Administration (FDA) and the Department of Agriculture (USDA). Government concerns over Cadmium and pesticide concentrations and their transferral up the food chain have traditionally been the administrative responsibilities of FDA and USDA. Extra authority on potentially harmful chemicals was also granted to by the EPA by the Toxic Substances Control Act of 1976, which is the next topic of discussion.

<u>Toxic Substances and Control Act of 1976</u> (TSCA)
<u>Public Law 94-469</u>

The TSCA is a legislative action primarily aimed at preventing public exposure to any hazardous chemicals which could adversely affect health or the environment. The language of P.L. 94-469 is broad enough to be interpreted in a manner that could place more restrictions on sludge utilization. Part of the TSCA is a testing program to be conducted on ".....processing, use or disposal of a chemical substance or mixture or that any combination of such activities, may present an unreasonable risk of injury to health or the environment." (Section 4 (a) (1.A.) The results of such tests must indicate the absence of such risks. However, the toxic substances law is tempered by a provision which states that:[10]

> "If the Administrator of the EPA determines that a risk to health or the environment could be eliminated or reduced by actions taken under the authorities contained in other Federal laws, the Administrator shall use such authorities,... unless... it is in the public interest to protect against such risk by actions taken under this Act." (Section 9 (b))

As a result of the above subsection, the EPA released a statement in the solid waste disposal criteria of February 6, 1978, which reads as follows:[11]

> "The EPA will continue to explore and reevaluate its authority under the Solid Waste Disposal Act, the Safe Drinking Water Act, the Toxic Substances Control Act in order to determine the best regulatory approach...to assure the adequate control of the disposal of wastes...."

The effect on sludge management of the broad powers of the TSCA can be contrasted with the specific requirements of the last three federal laws examined in this report.

<u>The Safe Drinking Water Act of 1974
Public Law 93-523</u>

The main purpose of the SDWA of 1974 was to ensure that procedures were being followed to guarantee the safety of public water systems. The particular section of this water law that relates to sludge disposal is a request for information on storage practices such as pits, ponds and sewage lagoons. The EPA was instructed to begin a study on the impacts of surface storage impoundments on underground water recharge areas. One purpose of the study was to analyze for any potential hazards to public water supplies caused by sludge treatment techniques. The EPA was to coordinate the study to satisfy the requirements of other laws such as the Resource Conservation Act of 1977.

Soil and Water Resources Conservation Act of 1977
Public Law 95-192

During 1977 the Congress was alerted to "land quality issues" as being important in an environmental improvement policy which had already focused on air and water quality. The main thrust of P.L. 95-192 was to create a continuing plan for improving and protecting soil-related resources for sustained use.

This soil and water law contained a clause which authorized the Soil Conservation Service of the Department of Agriculture to conduct an investigation of sludge utilization as a method "to improve soil tilth and fertility." (Section 6 (a) (5))[12] Other investigations were also required, and the input of other agencies (such as EPA) was encouraged to promote coordination of information and projects.

The Marine Protection, Research and Sanctuaries Act of 1972
P.L. 92-532, (MPRSA) Amended in 1977 By Public Law 95-153

In 1972, the interest in upgrading water quality generated by the Water Pollution Control Act gave impetus to the congressional attack on marine pollution problems. The Marine Protection Act was designed to set federal guidelines for dumping of materials into the oceans. The law also called for the development of alternative technologies which would eventually supersede the need for ocean dumping. The 1977 admendment to MPRSA set a deadline of December 31, 1981 after which ocean dumping of municipal sludges would be prohibited. The largest cities affected by the ban were New York, Philadelphia and Camden. The wastewater authorities of these ocean dumping municipalities have now been literally forced to examine alternatives, such as large sludge composting facilities. Such a facility would produce significant quantities of a sludge soil-conditioner and fertilizer substitute.

SUMMARY OF THE FEDERAL REGULATIONS ON SLUDGE MANAGEMENT

The federal acts examined in this report indicate a rising national interest in controlling the hazards of sludge as well as attempting to exploit the "recycling benefits." Although the directives and authorities were created with good intentions by the Congress, the job of coordinating a sludge management policy is complicated by the regulations set by six different laws. The Environmental Protection Agency has been delegated most of the responsibility for decisionmaking and analysis on sludge problems. The EPA needs to organize the required studies and reports on sludge use to prevent any unplanned overlaps. In like manner, the influence of the USDA, FDA, and other agencies must be properly integrated to develop an acceptable policy. The input of a State agency, such as Michigan's Department of Natural Resources is also extremely important for properly implementing the desired sludge practices.

Sludge Disposal Policy in Michigan

State Public Acts and Administrative Agencies Which Are Concerned with Sludge Management

At the state government level, there are also a variety of legal structures which pertain to sludge and wastewaters. State regulations have been steadily changing in recent years due to the flood of federal laws which have requested states to meet new guidelines. In Michigan, the administrative duties of wastewater control have primarily been the responsibility of the Wastewater Section of the State's Department of Natural Resources (hereafter referred to as DNR). The DNR acts under the authority granted by both state and federal statutes. In most cases, the DNR performs in the role which would otherwise be occupied by the Federal Environmental Protection Agency. Whereas the DNR acts in an administrative capacity, the policy formulation function is the work of the Water Resourc-s Commission (WRC) of Michigan. The WRC was established in Public Act 245 of 1929 (as amended up to 1973), and was to consist of seven permanent members.[13] The commission is empowered to initiate state permit programs and promulgate regulations to fulfill its broad purpose of "protecting and conserving the water resources of the state, and to have control over the pollution of any waters of the state, and the Great Lakes." The formal interrelationships among government agencies at the state, county and municipal levels in wastewater matters are designated by a number of state laws in Michigan. A brief listing of these relevant laws follows:[14]

PUBLIC ACTS OF MICHIGAN

1) Public Act 98 of 1913, as amended
   - Established role of Michigan Department of Public Health in sewage disposal.
   - Administrative powers originally delegated to Public Health Commissioner, then transferred responsibility to the Wastewater division of DNR in 1973.

2) Public Act 245 of 1929, as amended
   - Created Water Resources Commission and designated the conservation and pollution control duties of that Commission
   - Directed the Commission to establish a state permit system for Water Pollutant Discharges.
   - Gave the Commission the right to act in a court of law in the name of the people of Michigan for violations of water-protection laws.

3) Public Act 342 of 1939
   - Known as a County Public Improvement Act
   - Authorizes counties "to establish and provide connecting water, sewer and/or sewage disposal improvements within or between cities, villages and townships...or any other duly authorized combinations thereof."

4) Public Act 185 of 1957
   - Authorized the establishment of a Department and Board of Public Works in counties
   - Granted special powers and duties to county public works, such as special assessments and condemnation; and contracting rights.

5) Public Act 233 of 1955
   - Gave municipalities the official right to acquire, own and operate sewage disposal and water supply systems
   - Authorized municipalities to contract with other governmental units for the system's operation

- Allowed municipalities to issue bonds to finance activities
- An area water authority can be established by two or more municipalities.

6) Public Act 329 of 1966, as amended
   - The purpose of this Act was to prevent the discharge of untreated or inadequately treated sewage or other liquid wastes into state waters.
   - Established a fund for state grants to assist in the financing of projects designed to accomplish reduced waste discharge.

7) Public Act 641 of 1978
   - Known as the Solid Waste Management Act
   - Defined municipal sewage sludge as a solid waste
   - Required that transport equipment for sludges be watertight and maintained properly
   - Placed sludges under county-wide solid waste management plans.

8) Public Act 64 of 1979
   - Known as the Hazardous Waste Management Act
   - Hazardous waste does not include solid or dissolved material in domestic sewage discharge
   - Some sludges might be classified as hazardous, depending upon criteria established under the Act.

The DNR participates in the execution of various disposal-related laws, and in the process of completing its tasks, the DNR issues its own regulations and policies. With reference to the uses of wastewater sludge, the state laws have been interpreted by the Wastewater Section of DNR in the following manner:[15]

1) The DNR is to encourage sludge utilization practices wherever they are practicable. Landspreading operations are recognized as having the potential to yield benefits of amending the soil, while lowering environmental, public health and energy costs.

2) The DNR administers sludge disposal permits under the National Pollutant Discharge Elimination System of Public Law 92-500, as amended in 1977 by the Clean Water Act. There is also a separate state permit system, which is designed to protect groundwaters. Sludge utilization and other agricultural management practices are employed.

3) The DNR obligates itself to providing informational, educational, and coordinational services to ensure the understanding and compliance with regulatory standards. In addition, DNR is to act as an agency for monitoring wastewater disposal throughout the state.

4) The DNR has issued a policy stance on the participating parties' responsibilities in sludge use programs. The contention of DNR is that the municipality bears primary responsibility in meeting guidelines and ensuring the successful operation of a sludge disposal system, and that the responsibility for any failures cannot be delegated to another private party. (Such as a participating farmer or a sludge hauler.)

In the last opinion issued above, the DNR has adopted a policy similar to the one established in the Clean Water Act of 1977, by placing the responsibility of regulatory compliance with the treatment plant operator. Many of the standards that DNR establishes, as well as the program guideance services that it provides, are of a technical nature. Knowledge of proper application rates and equipment, sludge nutrient content and heavy metals tolerance is important to the success of the sludge operation, and DNR has been working to provide such information. The DNR employs soil scientists and civil engineers who use their expertise in confronting the municipal sludge problem at the state level. One of the jobs of Basin Engineers employed by the State is to monitor the sewage disposal practices, and to act as an information source for officials in the county and municipal subdivisions of government.

Regulation of Sludge Utilization Practices at the County and Municipal Level of Government in Michigan

Public Act 342 of 1939 (as amended in 1959), authorizes counties to provide for sewage disposal systems. Although many wastewater treatment plants are operated by smaller townships, there are also some county-wide operations. In Michigan, the Muskegon County Wastewater System and the Monroe County Drain Commission are examples of county-level involvement. The Muskegon Project has attracted much attention to the recycling concept and the system operates on publicly-owned farm and forest land. The Monroe County Drain Commission (MCDC) has been dealing with the sewage disposal problem on a less grand scale, but has been directly involved in the encouragement of utilizing sludge on private farmlands.[16] In recognizing the cost-savings and potential soil benefits of sludge utilization as compared to other disposal options, the MCDC has been an early initiator of practicing the recovery concept. Under the contracting rights granted by Public Act 342, the MCDC has entered into a number of written agreements with farmers, specifying the conditions under which sludges would be spread onto farmer's cropland.

The content of such written contracts is characterized by a variety of stipulations, among which are guidelines issued by the wastewater authorities at the federal, state and local level. The actual form in which these legal requirements appear on a sludge landspreading contract is not only determined by the participating farmer and plant operator, but also by other interested parties. A coordinated sludge program might include a number of interrelationships. For instance, the County Cooperative Extension Office may make initial contacts with potentially interested farmers. Extension agents also aid in organizing workshops for explaining the relative benefits and costs of landspreading sludges. Others who may be involved include soil science and agronomy scientists at Michigan State University, who recommend practices and conduct biochemical sludge analyses. Consulting engineering services may also be called upon to give advice and perform technical tests. Furthermore, if the program is to meet state approval, the participants should confer with DNR and its representatives (such as Basin Engineers).

Regulations at the Municipal Level-Local Ordinances and Sludge Utilization Agreements

A written contract for sludge application is generally recognized as a formal commitment between the farmer and the municipality. However, in real world circumstances, there is some reluctance by both parties to formalize a landspreading agreement, especially at the beginning of a new program. The reluctance stems from uncertainty about the interpretation of local laws, the reaction of area citizens, and the actual benefits to be obtained. The participating farmer does not desire to become partially liable under a written contract, if he believes the sludge program may be subject to complaints which eventually lead to court action under nuisance and/or zoning ordinances. Adverse opinions on landspreading can originate with neighbors' concern over odors, pathogens, runoff and groundwater contamination which might result from use of improper practices. So until the viability of a sludge project can be demonstrated, the participants often choose to proceed with caution. Early efforts to use private farmlands are on a tentative basis, under verbal or handshake agreements, and are designed to maintain a "low profile." In the surveys conducted for this research, participating farmers and operators commented on the need for "some shake down time" before entering any formal commitments. Such a loose agreement allows for maximum flexibility to meet changing conditions, but also involves a greater chance for slack compliance with technical standards and could lead to more undesirable consequences.

The Contractual Agreement as an Institutional Arrangement

As referred to in this research, a contract is a written or oral agreement which can be thought of as mutually desirable exchange of use-rights between two parties. In general, it can be assumed that both participants expect to benefit from the freely entered-upon transaction. In addition, the two parties agree to respect the conditions (or restrictions) placed upon each other within the contract. But the essence of the agreement is not perceived as coercive by either party, but rather as an activity which furthers each party's individual interests.

An oral agreement which is clearly understood and respected by both parties can be successful in promoting the desired transaction, and has the advantage of a high degree of flexibility. The disadvantages of oral contracts include the absence of a legally-binding document and the misinterpretation of contract conditions. In this study, the majority of the surveyed Michigan municipalities engaged in private farmland application were operating on verbal contracts. Such a preference for the loosely-structured "handshake" agreements may be indicative of the degree of confidence that municipalities currently have for utilization as a viable and long-run sludge disposal option. Participants may desire a temporary arrangement which has low exit costs, as opposed to a more permanent written commitment which may carry a high costs of legal liability under circumstances of a program failure.

Despite the trend towards loose verbal agreements, some Michigan communities have approached sludge utilization in a formal manner. Written contracts have a slightly different set of characteristics which may be preferred by municipalities who are convinced a well-planned sludge application program is workable and desirable. The written agreement contains the legally-binding rules under which the program will operate. Formulation of the specific provisions to be placed on the document also forces the participants to carefully consider the implications of the contract, and thereby eliminates ambiguities. Examples of written sludge application agreements from Monroe County, Michigan and Bad Axe, Michigan both have similar structures and content, but some clauses are naturally site specific.

The social dynamics which occur between the participants and the "third parties" have an impact on the division of responsibilities that appear on the written contract.[17] For instance, it is particularly interesting to trace the development of the landspreading arrangements of Monroe and Bad Axe. In Monroe County, the officials of the Drain Commission have been the primary initiators of the program and have made special efforts to attract potential farmers. A typical Monroe County contract stipulates that the Drain Commission is responsible for a variety of technical and administrative services and also carries an insurance policy as evidence of the county's liability in case of damages. But the manner in which the Bad Axe sludge application project has evolved differs, and the resulting contract conditions reflect that difference. In Bad Axe, an informed farmer has been the primary instigator in starting sludge use on his land. A number of extra arrangements had to be made before the program could proceed, because the farmer lived in Colfax township, an adjacent but politically-separate entity from the city of Bad Axe. In cooperation with the farmer, the wastewater treatment operator convinced the City of Bad Axe to employ an engineering consulting service to investigate the feasibility of using the farmer's land for sludge application. The report of this firm was then submitted to Colfax Township, which in turn passed a resolution to allow the transport and application of sludges within its boundaries. The actual contract between the city of Bad Axe and the farmer contained many of the same technical provisions which appeared in the Monroe agreements. But an important difference was that the farmer was "to assume liability if damage or crop loss occurred." Such a stipulation seems "unfair" to the farmer, but the City still must perform sludge testing and inform the farmer as to the potential hazards of the material. Also, in this specific case, the farmer owns the transport equipment, is being paid transport costs by the city, and is a knowledgeable person. It can be speculated that since the farmer "forced the issue, and expressed a fairly high interest in obtaining the sludge, that he was willing to take some extra risks. An example of a sample contract for sludge application is in Appendix A.

The basic characteristics of sludge utilization contracts can be summarized in seven general areas of agreement:

1) Provision and responsibility for technical services

    a) Testing and monitoring of soils, sludges, groundwaters, and surface waters
    b) setting of sludge application rates and runoff protection requirements
    c) deciding on the proper transportation and application equipment
    d) biochemical and metals analysis of plant leaf and fruit samples to monitor uptake of crops on sludge amended soils.

2) Liabilities of each party established in case of damages to crops and/or surrounding environment as a result of faulty sludge practices.

3) Financial arrangements and source of funds

    a) Agreement of parties on who purchases transportation/application equipment and or the operating expenses (labor, gasoline, maintenance, etc.)
    b) agreement on who purchases liability insurance
    c) farmer receives any increased revenues which might result from sludge amended soils.

4) Agreement on third party influences

    a) Involvement of the following organizations and agencies:

        1) Michgian's Department of Natural Resources
        2) Private Consulting Firms
        3) Future landowners through tenant leasing and conditions for sale of land which has been utilized for sludge application.

5) Administrative Responsibilities of the Municipality

    a) Record keeping of amounts and frequency of application
    b) Agreeing upon mutually acceptable times for application

6) Sets the time of duration of the sludge program

    a) the number of years that contract is binding.

7) Establishes the conditions for exiting or terminating the contract.

The major advantage of having a written document as opposed to an oral agreement appears to be in the clarity of the contract stipulations. An explicit statement of each party's responsibilities can aid in creating a greater incentive to fulfill the articles of agreement. If each party is more certain of the other's realized intent to meet a specified set of obligations, then each recognizes the development of a mutually-beneficial transaction.

Formalized contracts are also usually more acceptable at a public-opinion level, since the document's legally binding nature is believed to motivate the participants to take actions to reduce the probability of damages by negligence. Favorable impressions by the public are an important aspect of sludge management. The reaction of neighbors and local citizens is often modified by their perception of the sludge program's organization and legitamacy. Because the written contract is enforceable, it is an accepted institution which guides the behavior of the participants.

Sludge Utilization and its Controversial Issues: The Need for an Acceptable Sludge Disposal Solution

If the media are a reflection of public opinion, then there has recently been a rising distrust of waste disposal practices of both private and public facilities. Especially in Michigan, in the aftermath of the PBB incident, the political setting for developing sludge utilization programs is particularly sensitive.

It is important to recognize that an improperly controlled sludge project has the potential for producing some adverse environmental and health effects. Specifically, sludge may contain dangerous pathogens and cumulatively harmful concentrations of metals. If the soil conditions are not sufficient to absorb and filter the sludge, there may be a potential for runoff problems or groundwater contamination with nitrates. Difficulties and accidents can also occur in the movement of sludges from the treatment plant onto the farmer's land. Odors of inadequately treated sludges can be particularly offensive, and cause a citizen reaction which questions the safety of the sludge program (and perhaps rightfully so).

To answer these concerns, the participants need to demonstrate that sludge recycling is a workable concept and that the proper precautions are taken to ensure a successful and damage-free program. In addition, the local people need to be informed of the constraints under which the municipal treatment plant must work. By constraints are meant the government regulations, the technical requirements, the feasible disposal options and the financial budget allocated for this purpose. The most important elements of a sludge disposal strategy need to be identified, and the tradeoffs between the various options should be clear enough to make a relative value judgement.

Evaluative criteria and rules for decision are necessary if a specific sludge management program is to be chosen. If farmland application is taken to be the optimal choice under these criteria and decision rule, then additional action is necessary to implement the utilization option. For instance, when establishing a private farmland sludge program, the municipality needs to coordinate both the technical and institutional arrangements. Under such situations when constraints, alternatives, value-tradeoffs and decision-making are being considered, a role develops for an economic analysis to specify the distributive and efficiency impacts of the available options.

Economic Aspects of Sludge Utilization

To begin an economic evaluation of sludge utilization, it is useful to identify the involved participants, the inputs to the project and the desired outputs. For the purposes of analysis, the private farmland application of sludges can be modelled as a contractual arrangement between two primary parties (farmer and treatment plant operator). But it can also be viewed as an activity which both impacts on and is influenced by third parties. The various economic interdependencies between these agents are categorized under the headings of costs and benefits. The costs of sludge utilization are more readily measured and are classified as follows:

1) Implementation Costs.

   a) Transportation and Application Activities

      1) Equipment Purchase and Maintenance
      2) Labor Time
      3) Energy Requirements

4) Licensing and Liability
5) Additional treatment costs
6) Management
7) Costs of Contingency Arrangements

b) Administrative

1) Personnel management
2) Public Relations
3) Monitoring, testing and record keeping

2) Opportunity Costs

a) The concept of opportunity cost applies to both the farmer and the municipality. For the farmer, there may be better nutrient sources in the farm of animal manure or commercial fertilizer. The treatment plant must consider other disposal options such as landfills, incineration or use of public lands.

b) If sludge utilization is not the least cost alternative, then an effective demand for recycling would have to be established to economically justify its choice.

3) Institutional and Social Costs

a) Legislation and regulation restrict the number of disposal alternatives that are available. Such constraints can be thought of as an institutionally chosen opportunity cost.[18]

b) Local citizen reaction can prevent the implementation of sludge programs. Uncertainty over potential risks and the lack of information can significantly alter public opinion.

c) The possibility of the primary participants having to bear court costs of liability suits and nuisance claims.

d) The costs of obtaining and organizing information.

4) Costs of Potential Environmental or Health Risks

a) The extra costs of safeguarding sludge use to prevent pathogenic threats, heavy metal buildups or nutrient overloads.

b) Costs of management and administration. This includes program supervision, public relations and contracting.

In a similar manner, the potential benefits of utilizing sludges can be categorized:

1) Economic Benefits of Sludge Use Assoicated with Improved Crop Production

   a) Increased crop yields can result from the technical capacity of sludge as a soil amendment and fertilizer. The economic benefit is theoretically the value of the extra amount of crop output produced by the last unit of sludge applied that is, the marginal value product.

2) The Value of Sludge Management as Pollution Avoided: Joint Impacts of Improved Water Quality Resource Recovery

   a) The political process has declared that the benefits of avoiding water pollution exceed the costs. The public sector has also encouraged land utilization of sludges whenever it is feasible and acceptable.

   b) "Clean" Water is a joint-impact good since once it is produced it can be used by more than one person without appreciably decreasing its value. An example would be any joint recreational, ecological and aesthetic opportunties made available by removing pollution from a stream.

   c) The real benefits of improved water quality, which may differ from the politically-intended benefits, need to be adequately measured. To determine whether a pollution control program makes a difference, tests should be designed to eliminate the doubts of causality between the law's intent and the actual abatement that occurs.

3) Cost Savings

   a) Under the economic conditons of full employment and effective demand, the extra costs avoided by not pursuing another more expensive alternative may be recognized as a cost-savings or benefit.

Three basic groups of people are impacted by the costs and benefits listed above. These are the farmer, the municipality and the "general public." The latter group is included in terms of the downstream effects attributable to improved waste treatment. The distribution of the incomes and outflows which result from implementation of new waste controls and sludge programs is a subject for analysis. The farmer may receive net benefits from utilizing sludges, but the program's profitability depends largely on the crop and soil conditions and also the contractual arrangements. In addition, the farmer must evaluate the opportunity costs of using other nutrient sources such as animal manure that might be more economically desirable. Sludge use can increase crop yields for the farmer, but these gains might be offset by expenses for equipment, fuel and labor time. The second affected group, the municipality, may bear a greater part of the cost burden in a sludge utilization plan. From an economic point of view, it is advantageous for the municipality to select the least expensive mode of disposal. Farmland application is not necessarily the lowest cost choice, and a municipality might be better off placing sludge in a sanitary landfill. But again, the contractual arrangements may be a deciding factor in determining cost bearing. Another consideration is that certain utilization plans may be eligible for federal funding, and the municipality may be able to minimize its own costs by apportioning some of the expenses to the "general public."

This third group is supposed to benefit from better water quality which results from decreasing wastewater pollution (and increasing sludge production). The "general public" includes people who are option demanders, clean water user, etc. who derive utility (or avoid costs) associated with less pollution.

Some of the costs and benefits accruing to the above groups are difficult, if not impossible to measure. But the more readily identified costs usually are paid by the municipality. In a utilization plan, a measureable and important expense is for the transport of sludges. The distance between the treatment plant and the farm accepting sludge has a dominant impact on labor fuel and equipment needs. For instance, a longer transport distance may require a higher capital investment in vehicles and machinery. Application and hauling equipment must generally meet the following technical standards:

1) travel the required distances
2) carry the types of sludges being produced (either liquid or filter cake) and apply sludges at controlled rates
3) prevent spillage and/or other accidents
4) prevent soil compaction on farmer's land*

The experience in Michigan communities with transport and application costs for sludge utilization varies

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*The Soil Compaciton Problem - This refers to when the wheels of a heavy vehicle can compress the soil structure. Newer tires have been designed to distribute the vehicle's weight over a greater surface area.

considerably. In some cases municipalities have invested in new sophisticated vehicles, while others have reconvertted dump trucks and oil tankers to suit their specific purposes. Capital expenditures on equipment ranged from as low as $1,000 and up to $37,000. But insome instances, the farmers have purchased the necessary vehicles themselves, and the municipal treatment plant has then paid a transport price to the farmer, usually measured in dollars per thousand gallons of sludge hauled. In contrast, one community owns and operates a transporter/applicator known as "Big Wheels," and the wastewater facility charges the farmer a per mile moving and spreading cost. Finally, some municipalities own the necessary equipment and spread sludges onto the farmer's land at no pecuniary charge to the farmer. In a non-payment situation, the farmer simply must agree to the application site, and may be asked to disk in (incorporate) the sludges into the soil after the sludges have been spread.

Another municipal cost of farmland application programs is the provision of storage capacity or "contingency arrangements." The treatment plant may need a "sludge holding capability" when scheduling of spreading times becomes a cumbersome problem. Opportunities for sludge spreading are reduced by adverse weather conditions and the seasonal availability of uncultivated crop sites. For instance, the winter and crop-growing seasons can limit sludge application to the early Spring and late Fall in northern areas similar to Michigan. But sludges are being continuously produced at the treatment plant throughout the year. When open lands are only available at certain times, the municipality may have to confront storage problems and higher costs. Liquid sludges are troublesome to store since their volume usually requires the construction of retention ponds, storage basins, lagoons or large holding tanks. If the treatment plant is equipped with a vacuum filter, or centrifuge devices or drying beds, the volume of sludges can be considerably reduced. When drying processes are employed, storage problems can be diminished, but sometimes at higher energy costs.

In addition to the above considerations are the liability insurance costs to protect the participants in case a mishap does occur. There are also outlays for labor time (e.g., vehicle operators), management time and skills, testing and monitoring of sludges and soils, and groundwater and surface water analyses. In this perspective, sludge utilization appears to be an expensive option. But despite these problems, more municipalities are instituting "back to the land" programs because they are less costly than other alternatives.

Although some of the costs of utilization are readily identifiable, the benefit measures have been vague or difficult to validate. The agronomic value of sludges to farmers might be recognized as a resultant increase in net farm income. But the problem of analyzing the separate contribution of sludge in producing higher crop yields (and hopefully higher income) is the establishment of any cause and effect relationship over repeated trials. The surveys conducted for this report indicated that little or no quantitative evidence was available in Michigan, although farmers did perceive visual differences in crop quality and crop yields on sludge amended soils. The surveyed farmers who generally noticed the most positive plant growth effects were those who applied sludges to organically deficient soils. One surveyed Michigan farmer performed a rough "with and without" experiment on adjacent fields of corn, and recorded an average increase of thirty bushels per acre on the sludge amended plot. Other interviewed farmers noted little or no change in crop response, but these farmers remained in sludge programs because of soil tests and personal judgements of sludge as an input which promotes favorable soil conditions for crop growth. Such data can not be generalized, but when coupled with the results of soil science research on sludge agronomic benefits, there is sufficient evidence to encourage further investigation and trials. More information will become available as programs continue to progress and as incentives develop to maintain better records.

Troublesome problems are also encountered in measuring the value of improved water quality and in establishing cause and effect between effluent treatment and receiving waterway improvement. Current indicators of the benefits of water pollution control include technical characteristics such as dissolved oxygen content, newly created recreational opportunities and revived aesthetic appeal. However, it is beyond the scope of this thesis to appropriately address these measurement and causality issues in a thorough manner. Although evidence of a water quality trend was not solicited in the surveys, interviewed waste treatment operators said that the local waters appeared to have improved over the last five years. The operators referred to the better visual appearance of the rivers as well as to the renewed community interest in beginning stocking programs for game-fish.

The beneficial value of a sludge utilization program to a municipality might also be measured as its cost efficiency. The economic welfare of treatment plant users is enhanced if their sewage fees are minimized or reduced by a farmland application solution to the sludge problem. (Such a criterion would be a relative one, measured against all other available and acceptable alternatives). When agricultural lands are within a fifteen mile radius of a treatment plant, the transport costs are relatively low, and sludge utilization should be an option that receives consideration.

The results of the survey conducted for this thesis were not intended to provide comparative cost information. But the questionaires do have data that is useful for designing an outline of the essential components that would comprise a well managed "back to the land" program.

Some Characteristics of a Well-Managed Sludge Utilization Program for Private Farmlands

Recalling the analytical framework from the second chapter, it is possible to design a guide for examining the feasibility of a sludge application project. A municipality considering sludge utilization might examine this option in the manner outlined below.

An Outline for Evaluating a Private Farmland Application Program as an Option for Managing Municipal Sludges

A. Specify the Objectives of the Program
- 1) Goals for the municipality
  - a) Minimize the budgetary costs of disposal of sludges
  - b) Avoid environmental risks in accordance with legal requirements and local citizen expectations and health protection
  - c) Establish a long term strategy that will assure proper disposal in the future, as well as the present
- 2) Goals for the Participating Farmer
  - a) Enhance the potential for increased crop production and higher net farm income by utilizing the soil admendment and nutrient qualities of sludges
  - b) Decrease fertilizer costs by using less costly sludges as a partial substitute input, and also have a positive effect on income

B. Investigate the Technical Feasibility of Sludge Utilization
- 1) Determine the type of stabilization procedures necessary to apply sludges to land
  - a) Conventional stabilization facilities at treatment plants include:
    - 1) Aerobic Digestion
    - 2) Anaerobic Digestion
    - 3) Chemical Treatment
    - 4) Heat Stabilization
    - 5) Heat Drying
  - b) Determine whether additional treatment may be required
    - 1) Contact Michigan DNR or MSU's Department of Soil Science

2) Analyze the nutrient value of sludges and the potential hazardous content of sludges
    a) Employ testing services of private consulting firm, MSU Department of Crop and Soil Sciences or local chemcial laboratory to analyze sludge samples
    b) Use test results to estimate the nitrogen-phosphorus-potassium value of the sludges and to set constraints for heavy metal content and pathogen threats.
    c) Determine compatibility of sludges with local soils, consult with the appropriate scientists when necessary

3) Evaluate the type of farmlands which are within a fairly clsoe proximity of the treatment plant
    a) Gain knowledge of the soil characteristics and cropping practices; set sludge application rates accordingly
    b) Determine runoff and infiltration problems which may be peculiar to the application sites
    c) Investigate transportation routes and application sites for distance from higher-density population areas
    d) Evaluate available lands in a long-term view

4) Determine the necessity for contingency or standby plans
    a) Examine the seasonal nature of open farmlands for application
        1) Weather conditions
        2) Cultivation and crop growing seasons
        3) The frequency and timeliness of application may be a limiting factor
    b) Estimate the storage capacity for sludges available at the treatment plant
        1) Need to answer question, "Is the sludge holding capability sufficient to contain the sludge accumulation in between applications?"
        2) Design and capacity of sludge stoarge facilities should control against environmental damages (such as seepage to groundwaters)
        3) Examples of storage include:
            a) Lagoons
            b) Retention Ponds
            c) Holding Tanks
            d) Compost Piles
            e) Sludge Drying Beds

4) Need to gain a contractual agreement with participating farmers
    a) Verbal or "handshake" contracts have greatest flexibility and seem to be advantageous for the initial short-term trial period of starting a sludge utilization program
    b) Written contracts are preferable for a number of reasons
        1) Still have considerable flexibility but also indicate both parties willingness to meet specific obligations of an agreement
        2) Clarity of a written contract tends to eliminate ambiguities over the distribution of responsibilities between parties
        3) Public acceptance is usually greater for a formalized program

5) Management of a Sludge Utilization Program
    a) Monitoring technical aspects by regularly performing:
        1) Tests of soil samples, sludge samples, groundwaters and surface water runoff
        2) Leaf and seed, grain fruit analyses of plants grown on sludge amended soils
        3) Maintenance of transport and application equipment to ensure safety and proper spreading rates.
    b) Administration
        1) Make sure that contract stipulations are fulfilled on past and current agreements with farmers
        2) Set up new agreements with other farmers as contracts with current landowners expire
        3) Decisionmaking on all other aspects of the program, such as third party influences, legal constraints, labor time, etc.
        4) Public relations - education and information

D. Categorize the Financial Costs of a Sludge Program
    1) Transportation and Applications Costs
        a) Equipment capital costs
        b) Labor time (for example, vehicle operators)
        c) Energy expenditures
        d) Licensing permits
        e) Costs of any additional treatment processes
        f) Any financial costs of contracting with farmers
        g) Repairs and maintenance
        h) Management

    2) Contingency costs
        a) Storage facility investments
        b) Liability insurance

5) Obtain or utilize transport and application equipment necessary to move sludges from treatment plant
   a) Vehicles should be designed to:
      1) Travel the required distance
      2) Carry the type of sludges being produced (either liquid or filter cake) and apply sludges at controlled rates
      3) Prevent spillage and/or other accidents
      4) Prevent soil compaction on the farmer's land
   b) Examples of liquid sludge transport and application equipment include
      1) Converted oil tankers with applicator attachments
      2) Liquid manure spreaders
      3) Big wheels transport/applicator
      4) Soil injection vehicles
      5) Pipeline irrigations (highly capital and intensive; costly)
   c) Examples of filter cake spreaders
      1) Converted dump trucks
      2) "Dry" manure spreader or compost spreader

C. What Arrangements are Necessary to Make A Sludge Utilization Program Workable?

1) Contact farmers who would be responsive to sludge use idea
   a) Employ services of county extension agent for initial contacts and also educational/informational workshops

2) Investigate legal constraints
   a) Federal legislation and enforcement policies
   b) State regulations
   c) Local zoning laws and nuisance ordiances
   d) Licensing and liability requirements
   e) Contact state DNR and local officials for interpretations of laws

3) Communication with any or all of the following people may be necessary
   a) Wastewater authorities at county-level
   b) Participating farmers
   c) Neighbors and local citizens in participating farmers' area
   d) Local governments
   e) State agencies (DNR in Michigan)
   f) State Land-Grant University
   g) Federal agencies
   h) Private consulting firms and sludge hauling firms

3) Costs of technical guidelines
   a) Testing and monitoring costs
   b) Records keeping
   c) Management costs of preventing damages due to technical negligence

E. Investigate Financial Sources for Funding the Costs of Sludge Utilization
   1) For municipalities in the process of upgrading treatment facilities, up to seventy-five percent of capital costs may be covered by the federal construction grant funding program of the Water Pollution Control Act of 1972 (P.L. 92-500) and its successor, the Clean Water Act of 1977 (P.L. 95-217).
      a) Federal financing of up to 85% of construction costs is available to municipalities who demonstrate the use of innovative technologies, which have been interpreted to include sludge recycling schemes
      b) The construction grant program is administered by the Federal Environmental Protection Agency's office of water program operations
      c) Facility costs of sludge stabilization and storage necessary for land treatment programs have been funded (up to 75%) by construction grants

   2) Municipal bond issues may be another debt financing alternative

   3) Costs of sludge disposal are also reflected in treatment plant user fees (that is the amount of local citizen cost bearing).

   4) Contract arrangements with local farmers may include opportunities for joint cost sharing of transport and application costs
      a) Farmer can have an incentive to employ or modify his own equipment for moving and spreading sludges, due to the value of a potential productive input to cropping activities
      b) Joint cost sharing occurs since utilization satisfies the dual objectives of safe disposal and enhanced crop production.

Private farmland application of municipal sludges is a program that can be summarized in terms of three basic characteristics: technical feasibility, institutional arrangements and economic desirability. First, research and experience have established a technology for implementing the utilization concept. But sludge recycling is a sufficiently complex activity that it requires the management skills of a well-informed decision-maker. (Usually the greatest weight of responsibility falls upon the wastewater treatment plant operator). Secondly, the institutional arrangements are comprised of interactions among the primary participants and the interested third parties. All of the involved groups play a role, either collectively or individually, in determining the legal, social and contractual constraints on a sludge program. Lastly, the costs of sludge utilization on private farmlands need to be compared to the expenses of alternative disposal options, while the questions of cost sharing and budget allocations are simultaneously resolved.

The measure of the potential success of sludge utilization lies in the ability of the participants to meet the disposal and agronomic goals. The three basic program characteristics just mentioned above constitute the general structure within which a farmland sludge operation develops, and therefore influence whether a "real difference" is made in pollution control, resource recovery and crop producition. This thesis has examined some of the institutional and financial aspects of sludge utilization. The focus now proceeds to a more in depth discussion of the technical characteristics of a "back to the land" program.

ENDNOTES

[1]"Solid Waste Bill," Congressional Quarterly Almanac, XXXII (Washington: Congressional Quarterly Inc., 1976), p. 199.

[2]"In Search of A National Sludge Management Policy," Sludge Magazine, 1, (Jan-Feb. 1978), p. 13.

[3]Ibid., p. 13.

[4]The information on federal laws pertaining to sludge disposal is from the Environment Reporter (Washington: Bureau of National Affairs, Inc., 1979), p. 71:5101-5301.

[5]These sections of P.L. 95-217 were obtained from Environment Reporter, (Washington: Bureau of National Affairs, Inc., 1979), pp. 71:5114, 5160, 5168.

[6]"Solid Waste Disposal Facilities - Proposed Criteria," The Federal Register, 43, (Feb. 6, 1978), pp. 4941-4955.

[7]Ibid., p. 4943.

[8]Ibid., p. 4943.

[9]Resource Conservation and Recovery Act of 1976, Environment Reporter (Washington: Bureau of National Affairs, Inc., 1979), pp. 71:3113-14.

[10]Toxic Substances Control Act, Environment Reporter (Washington: Bureau of National Affairs, Inc., 1979), p. 71:8510.

[11]"Solid Waste Disposal Facilities - Proposed Criteria," p. 4945.

[12]Soil and Water Resources Conservation Act of 1977, Environment Reporter (Washington: Bureau of National Affairs, Inc., 1979), p. 71:8402.

[13]Members shall consist of: Director of DNR, Director of the Department of Public Health, Director of the Department of State Highways, Director of the Department of Agriculture, one representative of industrial management, one representative of municipalities, and one representative of conservation interests. This information is from Public Act 245 of 1929, as amended, Environment Reporter (Washington: Bureau of National Affairs, Inc., 1979), p. 811:0101.

[14]Lee A. Christensen, Douglas G. Lewis, Larry W. Libby and Larry J. Connor, Land Treatment of Municipal Wastewater (East Lansing: Center for Rural Manpower and Public Affairs, 1976), No. 41, pp. 18-27.

[15]Richard T. Sprague, "Municipal Wastewater Sludge Application to Land: Pertinent Legislation and Regulations," (Lansing: Wastewater Division of Department of Natural Resources, 1978).

[16]Paul J. Fleming, "A Program for Land Disposal of Stabilized Wastewater Treatment Sludges," The Monroe County Drain Commission, 1975, pp. 1-4.

[17]Most of the information on these written contracts is obtained from personal communication, documents and the surveys.

[18]Discussion notes from A. Allan Schmid, AEC 811, Spring 1978.

CHAPTER IV

TECHNICAL ASPECTS OF SLUDGE UTILIZATION

Introduction to the Agronomic Value of Sludge Use

The benefits of utilizing sewage wastes as a soil addition have been recognized since the early stages of civilization. Even from a more current perspective, soil scientists have been able to identify the potential of sludge as a soil admendment. An important reason for the resurgence of interest in the agronomic value of sewage (and of sludge in particular) is the renewed concern for recycling and conservation practices. But when the situation of most municipal wastewater treatment plants is examined, the primary reason for considering farmland application of sewage residuals stems from the need for acceptable disposal techniques.

The organic and inorganic contents of municipal wastewaters can be removed by various treatments at a sewage facility. The water pollutants removed from sewage inflows are further concentrated to form the sludge material. The composition of sludges is variable, even for separate samples obtained from the same treatment plant. However, some general characteristics can still be identified, and the actual proportions of various constituents are related to:[1]

1) the sources of waste inflows

2) the types of treatment processes from which sludges are generated

3) the sludge stabilization technique employed

4) the variety of the thickening, dewatering and drying methods used.

The value of sludge as an agronomic aid is dependent on its nutrient content and organic matter. Sludges are variable in their make-up, but information does exist on the range of measured constituents contained in sludge. The following three tables provide some data on the physical and chemical contents of typical wastewater sludges.

Table 4-1. Solid Content of Sludges[2]

Treatment	Percent Solids	Tons of Water/ Ton of Sludge Solids
Primary Sedimentation	5	19
Chemical Precipitation	7	13
Trickling Filters		
Humus-low rate	7	13
Humus-high rate	3	32
Activated Sludge	1-2	~66
Well-Digested Sludge		
Primary treatment	10-15	~7
Activated sludge	6-10	~12

Table 4-2. Range and Median of N, P and K Contents of Digested Sewage Sludge[3]

Component	Range %	Median* %	Median* lbs/ton
Total Nitrogen	2.0-5.0	3.3	66
Organic Nitrogen	1.6-3.0	2.0	40
P (Phosphorus)	0.5-4.0	2.3	46
P_2O_5 (Phosphate)	1.1-9.2	5.3	106
K (Potassium)	0.1-2.0	0.3	6
K_2) (Potash)	0.12-2.40	0.4	7

*The median is that value for which 50% of the observations, when arranged in the order of magnitude, lie on each side.

Table 4-3. Trace Element Concentrations in Digested Sewage Sludge[4]

Element	Range (ppm*, dry wt.)	Median
Boron	6-1000	50
Cadmium	3-3000	15
Chromium	20-30,000	1000
Cobalt	2-20	10
Copper	50-11,000	1000
Nickel	10-5000	100
Manganese	60-7000	300
Mercury	0.5-10,000	5
Molybdenus	20-30	30
Lead	50-20,000	500
Zinc	100-28,000	2000

*Parts per million.

Ref: Unpublished data, North Central Regional Committee 118, report entitled "Utilization and Disposal of Municipal, Industrial and Agricultural Processing Wastes."

The quantities of sludge produced at a sewage plant generally increase with the amount of treatment that wastewaters receive at the plant. As more facilities come into compliance with water quality standards, larger volumes of sludge are produced. Farmland application of these sludges has led to some speculation on the potential of substituting sludge for petroleum-based fertilizer. But even at the projected increase in sludge production rates, the fertilizer value of all municipal sludges combined would comprise one to two percent of the crop nutrients used for agricultural purposes each year in the U.S.[5] A quantitative approximation of the total municipal sludge production rate is about 4.8 million tons per year, compared to the expected rate of 6.7 million tons per year by 1985. The following tables illustrate the average amounts of sludge produced by processes at wastewater plants.

Table 4-4. Typical Quantities of Sludge Produced in Wastewater Treatment Processes[6]

Treatment	Keefer	Imhoff & Fair	Babbitt	M & E
Plain Sedimentation	2,950	3,530	2,440	3,000
Trickling Filter Humus	745	530	750	700
Chemical Precipitation	5,120	5,100	5,250	5,100
Activated Sludge	19,400	14,600	18,700	19,400

(Given as gallons/million gallons sewage treated)

Table 4-5. Sludge Masses[7]

Treatment	% Suspended Solids Removal	lb/day/mg Removed	% of Volatile Materials Removed	Specific Gravity Suspended Solids
Plain Sedimentation	60	1,020	65	1.33
Trickling Filter Humus	30	510	45	1.52
Activated Sludge (excess)	92	1,563	65	1.33
Imhoff Tank Dig.	60	1,020	50	1.47

Table 4-6. Trends in Production of Municipal Wastewater Sludge[8]

Sludge Type	Population Served (millions)	Dry tons per year X 10^6 **	Population Served (millions)	Dry tons per vear S 10^6
Primary (0.12 lb/cap-da)*	145	3.2	170	3.7
Secondary (0.08 lb/cap-da)	101	1.5	170	2.5
Chemical (0.05 lb/cap-da)	10	0.1	50	0.5
TOTALS		4.8		6.7

*lb X 0.454 = kg.

**ton X 0.908 = metric ton.

Sludge is a semi-liquid (or semi-solid) mixture of organic and inorganic matter and microbial organisms. During wastewater treatment at a sewage plant, settleable and suspended solids are concentrated (clarified) into a sludge slurry. The sludges are collected from the primary and secondary treatment processes and then circulated to sites of stabilization thickening and storage. The entire system can be depicted as in the diagram on page 27 of chapter two.

Sludge is categorized according to the treatment process from which it originates. Raw sludge (also known as primary or untreated sludge) is composed of solids directly clarified from incoming wastewaters. Activated, filter and chemical sludges are the byproducts of their respective treatment processes. Stabilized sludge is the substance which results from the techniques designed to reduce the odors and volume of raw and secondary sludges. At a stabilization site, various sludges are usually mixed and then processed. Other sludges which require further processing may also be produced by tertiary effluent treatments at a sewage facility.[9]

Most land application programs require that the sludges receive stabilization before landspreading. This extra treatment of sludges serves a variety of purposes, among which are:[10]

1) converting the bulky and odorous sludges which result from primary and secondary treatments, to substances which possess qualities better suited to disposal and storage needs.

2) decomposing the odor-causing organics into more inert compounds.

3) decrease the potential of sludges for disease transmission by destroying most pathogens during stabilization.

4) reduce the water content (and the mass and volume) of sludge.

Anaerobic Digestion and other Sludge Stabilization Processes

Anaerobic digestion is the most commonly used stabilization process for treating raw and secondary sludges. This digestion process primarily involves the breakdown of volatile organic materials to more inert substances by a bacterial fermentation process. This biological digestion occurs in the absence of oxygen and at heated temperatures of 85° - 95° F over a period of about thirty days. Following digestion, the stabilized sludge is a dark gray to black, semi-liquid (10 percent solids - 90 percent water), with a granular, batter-like consistency. In addition, digested sludge has a tar-like odor and a 3 percent to 5 percent organic solids content. The physical qualities of this type of stabilized sludge are suitable for further thickening and dewatering as well as for direct farmland application as a liquid sludge.[11]

There are some other accepted methods of stabilization. The processes for sludge treatment include:[12]

1) aerobic stabilization

2) pond stabilization and lagoons

3) chemical and lime treatments

4) heat stabilization

Aerobic stabilization and lagoons also rely upon biological decomposition to stabilize sludge, but the last two options listed above are classified as physical-chemical methods of sludge treatment. These latter techniques are designed to separate the suspended solids from the water content and reduce the volatility of the solids. This separation produces a sludge with less mass, decreased volume and increased handleability.

Sludge Thickening, Dewatering and Drying Processes

The available techniques for reducing the amount of water in sludge vary considerably in the degree of sophistication employed. Small-scale sewage treatment plants can use relatively simple open-air drying beds to separate the water from the solids in digested sludge. After open-air drying, the sludge is a paste-like substance of 40 to 60 percent solids content. This "dried" sludge can be handled with auger and conveyor systems and subsequently applied to land with conventional manure spreading equipment.[13]

Other techniques for concentrating and dewatering sludge may be necessary for larger scale treatment plants. Sludge thickening processes include chemical conditioning, air flotation and gravity-baffle processes. Dewatering can be accomplished by techniques known as centrifugation, vacuum filtration and filter presses. If large volumes of sludge must be reduced in a short period of time due to storage constraints, then one or more of these water-removal processes may be necessary.[14]

Storage, Transport and Application of Sludges

Farmland utilization programs for sludge disposal may require additional facilities for the storage of sludge. Application can be prohibited when weather, soil or crop conditions are not suited for landspreading. A storage capability is necessary to hold sludges during these sometimes extended interim periods between applications. A sludge holding capacity can consist of stabilization tanks, drying beds, stockpiles and lagoons. But storage time can create problems for a plant operator because of the tendencies for natural destabilizing of the sludge, overloading the holding capacity and diminishing the nutrient content of sludge by leaching and volatilizing processes.[15] Because of these troubles, plant operators desire to minimize storage time and costs. From the viewpoint of sewage plant efficiency, the use of farmlands for sludge disposal is a valuable practice only if the availability for spreading coincides with the need to periodically rid the plant of sludge. The focus of most concern for a sludge manager is the proper balance among sludge production rates, sludge holding capacity and the costs of implementing a specific disposal strategy.

When farmland utilization becomes a desirable sludge disposal choice, the treatment plant must be capable of properly transporting and spreading the sludges. The movement of sludge from a sewage plant to an application site can be accomplished with a variety of equipment. Pipelines and vehicles are both technically feasible options, but the latter is most commonly (and cheaply) employed. Tankers, dump trucks and soil-injectors are a few of the various machines used for sludge handling. All such vehicles possess some similar characteristics, but the techniques for moving liquid sludge (< 5 to 10 percent solids) differ from those for drier sludge (> 30 percent solids).[16]

The transport and application of liquid sludge can be completed with the use of a single vehicle. Often a tank truck can be modified with various attachments to spread liquid sludge on the soil at controlled rates. Water-tight tanks can be fitted with gravity flow equipment, mechanical pumps, or below-surface soil injection instruments. Except when soil injection methods are used, surface application of sludge often requires a follow-up discing or tilling activity to incorporate the sludge into the soil. The incorporation serves to facilitate the entrance of sludge components into the soil structure, and also to prevent any nutrient loss by runoff, leaching or volatilization.[17]

Dried and filter-cake sludges have been handled with dump trucks, portable storage bins and manure spreaders. The higher percentage solids content calls for equipment which can mechanically apply dried sludge at acceptable rates. The common type box-spreader, which is used to apply animal manure, can be mounted on a dump truck for spreading solid and semi-solid sludge. Other adaptive equipment has been developed for direct incorporation of dried sludges by employing a disc plow or moldboard.

There are a number of tradeoffs between the use of dried and liquid sludges. The advantages of using semi-solid dry sludges are simply the result of the decreased water content. Dried sludges can be stored more easily for prolonged periods of time and with smaller storage capacity requirements. The transport problems are also somewhat alleviated since more sludge (in dry weight) is carried per truckload. The threats of liquid ponding on the soil surface caused by slow infiltration of the sludge's water content into the ground, are also greatly reduced. But the costs of drying constitute the major disadvantage of utilizing the semi-solid sludge. These costs are largely the energy and equipment necessary for obtaining a dried sludge. Also, the correct hauling and application equipment needs to be available in order to spread the dried sludge. But the equipment requirements for the liquid slurry-form sludge also constitute a considerable investment, since some type of water-tight tank must be used for transport. The main advantages of applying liquid sludge are the avoidance of costly dewatering procedures and the relative ease of spreading liquid sludges using gravity flow or mechanical pumping methods. The disadvantages of tank trucks are the maintenance needs as well as soil compaction difficulties with wet soils. These compaction problems are being somewhat remedied by the use of trucks with tractor-like tires known as "big wheels tank-trucks."[18] The operation of sludge spreading vehicles must be conducted so as to avoid uneven applications and undesired dumping. Proper maintenance of equipment and the training of vehicle drivers lends to greater assurances that the application occurs at desired rates and with beneficial results.

Farmland Application of Sludges

Agronomic Values, Application Rates and Constraints

The agronomic benefits of sludge application have been identified in three roughly equivalent manners. The most important measures of the sludge value, from the farm-firm point of view, are the contribution to higher crop yields or the reduction of fertilizer cost. The most commonly cited values of sludge utilization practices are:[19]

1) The nitrogen and phosphorus additions to soil which are attributed to sludge use. The nutrient content of sludge is generally known as its fertilizer valued. Sludges also contain small amounts of potassium and sparse quantities of micronutrients, such as boron.

2) Sludge applications can improve soil tilth or soil humus. Sludge is composed of carbon and nitrogen based organic compounds which tend to be incorporated into the soil structure. The potential soil improvements have been noted as better soil

aggregation, water holding capacity, cation exchange capacity, gas exchange and water infiltration rates. Heavy soils with high clay content can become more friable and loose, while sandy soils achieve improved soil structure, with sludge additions.

3) As a result of the two agronomic values mentioned above, farm crops may react favorably by bringing forth higher yields.

New information on the benefits of sludge use is originating from the records of programs currently in operation as well as from data on test plots of soil science experiments. The determination of crop yield response as a function of sludge application rates is still an area of much research.

Application rates (sludge loading rates) to the soil are calculated on a technical basis, and actual rates may be an issue for contractual agreement between the farmer and plant operator. Typically, loading rates are determined by considering the following factors:[20]

1) Nutrient content of the sludge.

2) The fertilizer recommendations obtained from soil tests.

3) The heavy metals content of the sludge and the soil.

When application rates are being computed, usually the limiting nutrient is nitrogen. The reasons for the nitrogen (N) limit include: The high N content of sludge, the rate at which organic N is converted to inorganic forms that are conducive to plant growth, and the problems associated with excess nitrogen in the soil. (Please note that the heavy metals' constraints on loading rates are to be discussed after the aspects of nitrogen loadings are more fully explained.)

Although the specific amounts of nutrients in sludge are variable, the N-P-K* contents have been statistically observed to have values which range over relatively small intervals for samples taken at smaller wastewater treatment plants. If nitrogen is determined to be the limiting nutrient, some simple calculations of N loading rates can be made. A hypothetical example would be the application of a sludge with a 3 percent nitrogen content at a rate of 3 dry tons per acre of sludge. The total loading would be 180 poinds per acre of nitrogen. But of this 1,500 pounds of N, only 54 pounds would be in the readily plant-available forms of ammonia (NH_3) and nitrate (NO_3). The remaining 126 pounds of N would consist of organic compounds and not be immediately usable for plant growth. This organic N becomes a type of resevoir of nitrogen which is slowly converted to NH_3-N and NO_3-N for plant use. The decomposition of the organic N occurs due to a bacterial process known as nitrification. Another series of reactions known as denitrification, acts to slightly deplete the organic N "resevoir" by converting N compounds to nitrogen gas (N_2), which is released to the atmosphere. Nitrogen additions to the soil by sludge application should therefore be calculated by estimating the available N,

*N-P-K = (Nitrogen-Phosphorus-Potassium) as well as the release rates from the organic N in the sludge. In general, both mineral N and the portion of the organic N that breaks down is the "available N." In relation to these considerations on the nitrogen in sludge, the uptake rate of the crop and the natural soil N content should be used in determining the proper sludge application rate. Excess availability of nitrogen can have a number of adverse effects. When too much nitrogen is available to plants, the maturation of flowering and fruiting growth may be delayed or overwhelmed by stem and leaf growth. Also, when the soil is overloaded with nitrogen, the nitrates may leach to grounwaters, and cause contamination of water supplies. With regard to grounwaters, the depth to the water table is an important factor in choosing sites of application and loading rates.[21]

The limits placed on sludge spreading rates due to heavy metals content can be more restrictive in some cases. There are a number of significant considerations with reference to the heavy metals in sludge. First, high levels of heavy metals in sludge are mostly due to industrial inflows of waste to the municipal sewage plant. When sewage facilities treat only domestic (human) wastes, then the problem of heavy metals diminishes. But even with industrial flows eliminated, a wastewater plant still must monitor for metals such as zinc, copper and cadmium that generally exist in sludge at concentrations too high to ignore for crop production. Another aspect is that much research is currently in progress to obtain information on:[22]

1) the uptake rate of metals by plants

2) the concentration levels which should be considered as harmful

3) the effects of animals further down the food chain

4) metals reaction with the soil under various conditions.

Some general experimental results indicate that the plant uptake of heavy metals is proportional to the metals concentration in the soil. Also, plants tend to collect greater proportions of metals in the leafy and vegetative parts of the plants, rather than in the grain, seeds or fruits. Soil conditions are a major factor in uptake of metals by plants, and the relationship between soil pH and metal contamination has been strongly researched. An acidic level of pH 5.5 or less does permit higher uptakes by causing metals to be more soluble in the soil solution. But under neutral or slightly alkaline conditions (pH 6.5 to 7.5) metals tend to be less soluble and available in soil solution for plants. Other factors which tend to retard uptake and availability of these trace metals are a high cation exchange capacity and a high organic content. Overall, different crops do not have the same uptake rates and also differ in their tolerance for concentrations of metals.[23]

Suitability of Sludge Use for Selected Crops

To avoid the adverse effects of excess heavy metals and nitrogen loadings, sludge applications need to be coordinated with the choice of the cultivated crop. Sludge utilization programs are modified by the different requirements of each crop. For example, sludge can be applied to sites for annual crops such as corn, grain or soybeans, either before planting in the spring or after harvest in the fall. But incorporation procedures must be followed more closely when cultivating soybeans, because the seed germination of soybeans is more sensitive to changing soil conditions. Perennial crops used for forage or sod production can utilize sludge, but there are difficulties due to soil clogging from surface applications, plants damaged by equipment traffic and the costs of any subsurface injection techniques. Small grain crops such as wheat, oats, barley and rye can benefit, although these grains tend to have lower nutrient uptake rates and produce excessive vegetative (stalk) growth in the presence of high nitrogen availability. But the small grains (and forages) also tend to minimize erosion and are tolerant of salts which may exist in sludge.[24] A listing of the desirable and undesirable crop characteristics for sludge applications can be shown as follows:[25]

Desirable Crop Conditions for Sludge Spreading

1) Greater number of time periods available for application.

2) Higher tolerance of salts and heavy metals.

3) High nutrient uptake rates and low metals uptake rates.

4) Extensive acreage opportunities for spreading.

5) High infiltration rates, erosion control, and minimal soil clogging.

Undesirable Crop Conditions

1) Reverse characteristics to those listed above. For example, low nutrient uptake rates and high metals uptake.

2) Vegetable crops for human consumption are not allowed to be grown on sludge-amended soils due to potential for health hazards.

3) Animal grazing on sludge-amended soils should be prevented for at least one month, provided the sludge has been stabilized by an acceptable process.

4) Nitrogen excesses can have adverse effects on germination and plant growht of crops, especially the sensitive varieties. Releases of available nitrogen from sludges (nitrification) may delay fruiting or otherwise adversely alter the growth of some crops.

5) Marketing of animal feed products grown on sludge-amended soils may be prohibited or very difficult.

When the benefits of sludge use are measured only in terms of yield responses, the record exhibits mostly favorable results. Crops such as corn and soybeans have been tested with varying application rates, and the results have shown significant yield increases when sludges are spread and incorporated on formerly marginal soils. Although there is a limit to which the sludge application will encourage productivity, soils with lower potentials are generally improved by higher spreading rates. The incorporation of sludge in the soil tends to raise its natural productive capacity by strengthening the soil structure, and restoring nutrient content.

Measuring and Monitoring Sludges and Sludge-Amended Soils

To apply sludges at a desired loading rate, a knowledge of the N-P-K contents, heavy metals and other constituents is necessary. Approximating the average content of these elements in sludge is usually accomplished by subjecting a collection of sludge samples to chemical analyses. The equipment and expertise required to perform such tests may not be available at the treatment plant. Municipalities can employ the services of privately-owned laboratories or the facilities of large universities. (Michigan State University's Department of Crop and Soil Science provides a complete sludge analysis service.)

Although the results of sludge tests are helpful in determining the fertilizer values and in setting spreading rates, these analyses should be complemented by soil tests. If soil samples are taken both prior to and after sludge applications, a more accurate measure of the contribution of sludge to soil fertility can be obtained. When they are performed on an annual (or semi-annual) basis, soil tests can give useful information on the release and buildup of plant-available nitrogen. A soil analysis may also measure Cation Exchange Capacity and soil pH, both of which influence nutrient (and metals) availability to plants. Soil tests also reveal any nutrient deficiencies or excesses, and can be used to predict fertilizer requirements for various crops which might be cultivated.

Finally, there is also considerable concern for the infiltration and runoff rates of sludge-amended soils. A well conceived utilization plan includes periodic testing of groundwaters and surface-waters which might be contaminated by sludge residuals.

The question of monitoring sludge application also raises the issues of health hazards, odor problems and public acceptance. The primary health concern with sludge is the pathogenci population of micro-organisms which exist in wastewater sludges. The pathogen problem is characterized by two main concerns:[26]

1) the type and number of micro-organisms
    a) In sludge, the four dominant pathogens are:
        1) bacteria
        2) protozoa
        3) helminth parasites
        4) viruses
2) the length of survival time of various pathogens
    a) stabilization techniques and environmental conditions influence survival.

Anaerobic digestion greatly diminishes the pathogen populations, so that a stabilized sludge is generally less hazardous. Another important factor which tends to alleviate the potential for disease is that most sludge pathogens cannot successfully compete with soil micro-flora, so that pathogens usually perish in the soil environment. There are some remaining questions on the survival rates of some viruses and parasitic worm ova. Some studies indicate that these particular organisms (viruses and worm ova) are highly resistant to most adverse environmental conditions.

The uncertainties over pathogens have been reason enough to institute a policy of using sludge on food crops not intended for humans. But the record with spreading of treated sludges (stabilized) has had little or no evidence of adverse health effects.

The obnoxious odors which emanate from untreated sludge are the source of much public opposition to land application programs. Undesirable smells can be considerably eliminated from sludge by stabilization processes. An anaerobically digested sludge has a bearable tar-like odor. But the isolation of sludge application sites is generally a good rule to follow when possible. Destabilizing processes can cause putrescent odors even from digested sludges when they are applied to land but not immediately incorporated in the soil. The manager of a sludge program should not only isolate sludge applications from more densely populated areas, but also conduct workshops to instruct local people as to the alternative sludge disposal options available, and to the reasons for choosing a specific strategy (for example, landspreading on farms).

Summarizing the Technical Aspects of Sludge Utilization

The general perspective on farmland application of sludges is favorable, despite some reservations over the potential hazards. Digestion or other forms of stabilization are a requirement for any landspreading schemes. Stabilization is capable of reducing odor, minimizing pathogen threats and increasing the handleability. Equipment is available for the application of either liquid or dry sludges, and the choice of vehicles is often a decision which is specific to the situation of each treatment plant. The application rates must be determined by estimating the nutrients in the sludge and soils, the nutrient demands of the crops, and the environmental conditions which influence the interrelationships of sludge, soil and plants. Testing and monitoring become an integral part of a well-planned program designed to spread sludges to enhance crop growth and simultaneously dispose of sludge in a safe manner. Actual operations are primarily concerned with meeting these twin goals of disposal and agricultural enhancement. The next chapter examines the results of surveys conducted on Michigan rural communities which have participated in landspreading programs. These surveys provide some factual information on the benefits and problems of sludge utilization.

ENDNOTES

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[8]Ibid., table 2.

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[17]R.H. Dowdy, R.E. Larson and E. Epstein, pp. 144-46.

[18]Personal conversation with municipal wastewater operator while conducting surveys.

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[20]Clarence G. Golueke, pp. 124-129.

[21]C.M. Gilmore, F.E. Broadbent and S.M. Beck, "Recycling of Carbon and Nitrogen through the Land Disposal of Various Wastes," Soils for Management of Organic Wastes and Wastewaters, pp. 181-192.

[22]G.W. Leeper, Managing the Heavy Metals on the Land, (New York: Marcel Dekker, Inc., 1978), pp. 11-12.

[23]Harry M. Galloway and Lee W. Jacobs, pp. 10-12.

[24]Chris J. Johannsen, "Site Selection and Land-Use Considerations," Utilizing Municipal Sewage Wastewaters and Sludges on Land for Agricultural Production, pp. 37-39.

[25]Ibid., pp. 38-39.

[26]Harry G. Geyer, "Health Aspects," Utilizing Municipal Sewage Wastewaters and Sludges on Land for Agricultural Production, pp. 48-51.

CHAPTER V

SUMMARY AND INTERPRETATION OF SLUDGE UTILIZATION SURVEY RESULTS

Farmland Application of Sludges in Rural Michigan

The operation of a sewage treatment plant is often provided as a public service by local government. At the present time, municipal authorities are being required by federal and state laws to upgrade existing sewage disposal systems. Many wastewater facilities are being redesigned to incorporate advanced treatment processes to meet the new water quality standards. The improved waste removal techniques are capable of controlling sewage outflows and preventing water pollution. But these advanced methods are also more costly and generate larger volumes of sludge, which is a solid waste pollution problem.

As discussed earlier, the growing difficulties of sludge management are being confronted by all municipalities. But the purpose of the present chapter is to examine sludge programs only as they pertain to selected communities in Michigan. In general, the responsibility for developing sludge disposal plans has been delegated to state and local levels of government. Federal directives are carried out by agencies such as Michigan's Department of Natural Resources. As a result, sludge programs are not uniform.

The surveys conducted for this analysis focus on just one of the available disposal alternatives: the application of stabilized sewage sludges to privately-owned farmland in Michigan. Those communities which employ public lands for utilization purposes are not included in this study. Due to the difficulty in addressing all the issues of sludge disposal, the survey objectives are limited. The questionaires are primarily designed to obtain information on utilization agreements in Michigan. Upon examining the sludge disposal practices throughout the state, it was found that private farmland programs tend to be located in rural settings. Less populated areas have utilization programs which are facilitated by the close proximity of the treatment plants to cropland.

The primary agents involved in implementing a private farmland application plan are the farmer and the sewage treatment plant operator. To analyze sludge programs from the perspectives of both participants, separate surveys were conducted with the farmers and operators involved in landspreading operations. The Michigan Department of Natural Resources (DNR) provided the necessary information on the wastewater facilities which currently spread sludges on private cropland. When the surveys were conducted, twenty Michigan municipalities were actively pursuing utilization programs with local farmers. A total of 37 farmers were interviewed about their participation in sludge programs.

The time of the survey was June 1978, and since then a number of additional communities and farmers have initiated utilization agreements.

The survey communities are generally located in the southern half of the lower peninsula of Michigan, as indicated by the map on page 108. Most landspreading programs in these municipalities have only been operating for one to three years, but a few locations have been recycling sludge on croplands for about eight years. The farmland option has been adopted by about seventy percent of the studied communities as the sole method of ultimate sludge disposal. The relationship between the physical quantity of sludge produced at the treatment plant and the percentage of this total production applied to farmland is illustrated in Table 5-1 on page 107.

Characteristics of Sludge Utilization Programs

Population Size, Program Goals and the Related Costs of Land Application

As Table 5-1 indicates, a majority of the current utilization programs meet the disposal needs of the surveyed municipalities. Land application programs seem to have the potential for solving the sludge problems of rural areas. To gain a better idea of the quality of sludge being managed by communities using landspreading programs, Tables 5-2 and 5-3 present the association between sludge production, population size and the sewage treatment plant design size.

As might be expected, the larger the population or

Table 5-1. Comparison of the Treatment Plant's Sludge Production with the Percent of Sludge Output Applied to Private Farmland[a]

Quantity of Sludge Produced in Dry Tons Per Day[b]	Percentage of Total Sludge Production Applied To Land			
	100%	80-90%	50-60%	Row Total
0 - 0.15	5	1	1	7
0.16 - 1.10	4	2	1	7
1.11 - 6.00	2	0	0	2
Column Total	11	3	2	16

[a]Survey of Municipal Sewage Treatment Plant Operators

[b]Dry Tons Per Day are Calculated Using one of the Following Equivalent Formulas:

$$\text{Dry Tons Per Day} = \frac{\text{Gallons}}{\text{Day}} \times \%\ \text{Solids} \times \frac{8.34\ \text{Lbs.}}{\text{Gallon}} \times \frac{\text{Ton}}{2000\ \text{Lbs.}}$$

$$\text{Dry Tons Per Day} = \text{Wet Tons Per Day} \times \frac{\%\ \text{Dry Solids}}{100}$$

sewage plant size, the greater the amount of sludge that is generated. The population size ranged from 750 to 25,000 people, and sixty-five percent of the surveyed municipalities lie within the 2,000 to 12,000 population interval. The communities having larger and more densely settled areas also tended to be further away from cropland. Table 5-4 shows the influence of population size on the distance between spreading sites and the treatment plant.

Transport and application of sludges constitute the major portion of utilization costs. Land application may not be a feasible alternative when the costs rise above

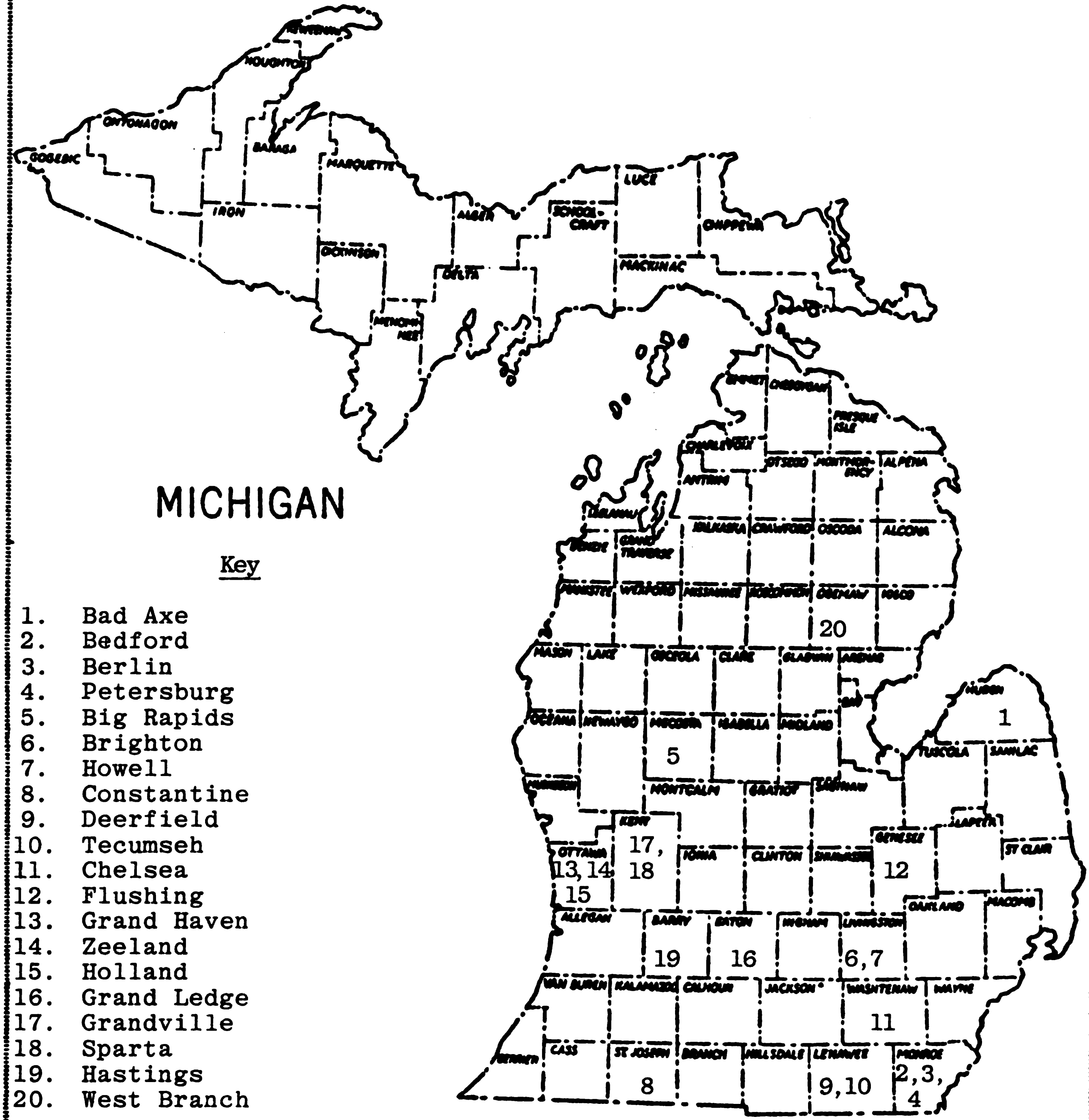

Figure 5-1. Location of Surveyed Communities.

Table 5-2. Comparison of the Treatment Plant's Sludge Production with Population Size[a]

Dry Tons Per Day of Sludge Produced[b]	Population Size Intervals[c]				
	0-2000	2001-6000	6001-12,000	12,000	Row Total
0 - 0.15	4	2	1	0	7
0.16 - 1.10	0	1	4	0	5
1.11 - 6.00	0	1	2	2	5
Column Total	4	4	7	2	17

[a]Survey of municipal sewage treatment plant operators. From this point forward, referred to as "Survey of sewage plant operators."

[b]Dry tons per day are calculated using the formulas given for Table 5-1.

[c]Data on Population Size obtained from "The Superlist" which is a listing of information on all Michigan Municipal Wastewater Treatment Facilities. Compiled by the Wastewater Division of the Department of Natural Resources.

Table 5-3. Comparison of Treatment Plant Sludge Production with the Design Wastewater Flow of the Plant[a]

Dry Tons/Day of Sludge Produced[b]	Design Flow of Sewage Plant[c]			
	0 -0.60 MGD	0.61-1.20 MGD	1.21-5.00 MGD	Row Total
0.00-0.15 DT/D	5	2	0	7
0.16-1.10 DT/D	0	3	3	6
1.11-6.00 DT/D	0	1	3	4
Column Total	5	6	6	17

[a]Survey of municipal sewage treatment plant operator.

[b]Dry tons per day are calculated using the formulas given for Table 5-1.

[c]Design flow data obtained from "The Superlist."

Table 5.4. Comparison of Population Size with Distance that Sludge is Transported.

Size of Population[b]	Average Distance Sludge Transported[a]			
	1-5 Miles	6-10 Miles	11-15 Miles	Row Total
0-2000	4	0	0	4
2001-6000	5	2	0	7
6001-12,000	3	4	0	7
12,000	0	0	2	2
Column Total	12	6	2	20

[a]Survey of municipal sewage treatment plant operators.

[b]Data from "The Superlist."

budgeted amounts or when another alternative can achieve disposal less expensively. More densely populated areas tend to have longer transport distances and, therefore, higher labor and energy costs to move sludges to application sites. In addition, the costs of finding transport routes and controlling contingencies are higher when the treatment plant is not conveniently located close to farmlands. But utilization may still be desirable if higher costs can be spread over a greater number of treatment plant users. The survey data on transport and application costs exhibit variability, especially with the expenditures for equipment and vehicles. The range in outlays for machinery to move sludges is influenced by a number of factors:

1. The source of funds for purchasing equipment (or use of that equipment) may either be local, federal or both.
   (a) Federal aid can defray the cost borne by the municipality for purchasing equipment. If federal funds are plentiful, more expensive (and hopefully better) equipment can be obtained.
2. The ownership of the transport and/or the application equipment can lie with:
   (a) The treatment plant
   (b) The farmer (s)
   (c) A private hauler.

3. The existence or non-existence of differences between the transport and application vehicles.
   (a) In the case of liquid sludges, one tank-truck can accomplish both the transport and application procedures. Dried sludges may require the use of a hauling truck as well as a manure spreader.
4. The management objectives and the technical requirements for a sludge utilization program
   (a) The desire to use improved technology (equipment) to enhance the agricultural usefulness, rather than accomplish just simple disposal, may require higher investment costs.
5. Cost sharing arrangements with farmers and/or haulers for moving the sludges onto the land.
   (a) The farmer or hauler may own the transport and application equipment, and the municipality pay for hauling services
   (b) The municipality may perform both application and transport activities in exchange for a payment from the farmer (for example, a per mile charge).

Only twelve of the municipalities reported cost figures for the sludge-moving equipment. But the cost data still provide some useful information on the arrangements made for procuring the necessary equipment (See Table 5-5).

The results from Table 5-5 contain some interesting

Table 5-5. Comparison of Population with Costs and Arrangements for Sludge-Handling Equipment[a]

Population Size[b]	Expenditure on Equipment (in Thousands)			Source of Funds For Equipment			Municipality Owns Equipment		Municipality Pays Farmer or Hauler for Moving Sludge	Farmer Pays Municipality for Sludge
	0-15	15-30	30-70	Local Users	Federal	Local+ Federal	Yes	No		
0-2000	0	0	2	3	1	0	3	1	0	1
2001-6000	1	1	1	5	0	0	3	4	1	0
6001-12,000	2	3	1	5	1	1	6	0	0	0
12,000	0	1	0	2	0	0	0	2	2	0
Column Totals	3	5	4	15	2	1	12	7	3	1

NOTE: Entries are the number of communities.

[a]Survey of municipal sewage treatment plant operators

[b]Data from "The Superlist."

relationships. For example, two of the lowest populated communities purchased the most expensive hauling vehicles. But a closer examination of these same two municipalities shows that their funding strategies differed from the other surveyed areas. One of the two small treatment plants had purchased the equipment with a federal grant, while the other was charging farmers for transporting and landspreading the sludges. In contrast, another three communities have a reverse cost arrangement: the farmer (or hauler) owns the equipment and the municipality pays a transport charge for the movement of the sludge. The various contracting arrangements influence the participants' incentives to minimize expenditures, to obtain technically superior machinery, or to satisfy some other objectives.

Another type of transport cost to recognize is socio-political. If the treatment plant is located where township or county boundaries must be crossed to reach available application sites, the program can be complicated by local opposition, licensing requirements and extra fees. The problems of obtaining vehicle and route permits may be more costly to resolve than the technical issues of sludge utilization.

Further Influences on Equipment Choice and Program Arrangements

A number of technical factors affect decisions on the operation of a landspreading project. Considerations such as physical capacity, stabilization processes and drying techniques can alter a program's requirements. As elaborated upon in Chapter 4, a number of stabilization methods may be employed to condition sludges. Anaerobic digestion is the most commonly used stabilization procedure. Successful stabilization is important to any landspreading program, since sludge conditioning reduces threats of pathogens and odors, and also improves handleability. Digestion and other sludge treatments are also preparatory for drying procedures. Sludge drying usually reduces the water content of stabilized sludges from a slurry of 95 percent moisture down to a paste consistency of 60 percent water.

The transport and application requirements differ for dry and liquid sludges. To handle the high water content sludges, a single tank-truck can be modified with spreading attachments and be able to perform both application and hauling activities. In cases where a municipality obtains a tank-wagon designed for liquid sludges, no further application equipment need be provided by the farmer. However, any incorporation of sludges into the soil still requires the landowner to do some additional discing-in or plowing of the application site.

Dry sludges can often be applied to the land with a manure spreader, leaving the opportunity open for the farm to control the application procedure. Tables 5-7 and 5-8 seem to indicate that the characteristics of dry sludges can partially determine how program arrangements develop

Table 5-6. Comparison of Treatment Plant Sludge Production with Methods of Stabilization[a]

Method of Stabilization	Quantity of Sludge Produced in Dry Tons Per Day[c]			
	0-0.15	0.16-1.10	1.11-6.00	Row Total
Anaerobic	2	5	0	7
Aerobic	3	0	0	3
Heat or Chemical	0	0	3	1
Combination[b]	2	1	1	4
Column Total	7	6	4	17

[a]Survey of sewage plant operators.

[b]Some municipalities employ a combination of processes to stabilize sludge. For instance some used anaerobic digestion, aerobic digestion and chemical conditioning processes.

[c]Dry tons per day as calculated in Table 1.

Table 5-7. Comparison of the Moisture Content of Sludge with the Farmer's Use Of His Own Equipment to Spread Sludge[a]

Farmer Uses His Own Equipment	Form of Sludge Being Spread on Land: Liquid	Dry	Liquid + Dry	Row Total
Yes	3	5	0	8
No	26	1	2	29
Column Total	29	6	2	37

[a]Survey of farmers utilizing sludge on their land. From this point on, simply referred to as "Survey of Farmers."

Table 5-8. Comparison of Differences in Sludge Application and Transport Equipment with Farmer's Use of His Own Equipment to Spread Sludge[a]

Farmer Uses His Own Equipment	Any Difference Between the Transport and Application Equipment?: Yes	No	Row Total
Yes	6	0	6
No	3	11	14
Column Total	9	11	20

[a]Survey of sewage plant operators.

Table 5-9. Comparison of Differences in Sludge Application and Transport Equipment with Municipal Ownership of the Transport Equipment.[a]

Municipality Owns the Transport Equipment	Any Difference Between The Transport and Application Equipment		
	Yes	No	Row Total
Yes	6	7	13
No	3	4	7
Column Total	9	11	20

[a]Survey of sewage plant operators.

Table 5-10. Comparison of Municipal Ownership of the Transport Equipment with the Farmer's Use of His Own Application Equipment to Spread Sludge.[a]

Municipality Owns the Transport Equipment	Farmer Uses his Own Equipment to Apply Sludges		
	Yes	No	Row Total
Yes	4	9	13
No	2	5	7
Column Total	6	14	20

[a]Survey of sewage plant operators.

between farmer and municipality.

Table 5-7 shows that sludges are applied most often in the liquid form with municipal or hired vehicles. But when dry sludges are available, farm-owned equipment (manure spreaders) perform the task of application. The responses of the treatment operators in Table 5-8 show a close correlation between vehicle difference and use of the farmer's equipment. The farmer's use of his own vehicles is a stronger display of his incentive to utilize sludge. Because municipalities are willing to supply and transport free of charge, sludge is a low-priced input for the farmer.

Municipal ownership of the sludge transport vehicle might also be expected to influence the farmer's decision to supply his own application vehicle. But the surveys indicate that ownership does not exhibit any relationship to either the equipment differences or to the farmer's supply of his own machinery (See Tables 5-9 and 5-10).

When the farmer and the municipality do not supply the sludge handling equipment (a "no" answer to both questions in Table 5-10), then a private firm provides the necessary link in an application program. The independent sludge hauling business can perform the two activities (transport and spreading) and may even charge both the landowner and the municipality for the services. But the firm is also placed under restrictions, mainly in the form of state and local licensing and in the contract agreements with the farmer and/or municipality.

Contracting Arrangements for Sludge Utilization in Michigan

The farmland application of sludges is not a new idea, but for many municipalities utilization is a relatively novel practice. Landspreading programs in Michigan are largely characterized by informal or "handshake" agreements between the municipality and the farmer. Only two of the surveyed communities use written contracts for conducting their land application programs. A number of reasons can be hypothesized for the looseness of arrangements for sludge utilization:

1. A need for maximum flexibility to adjust for the timing and land availability constraints on application.
2. The newness of the program causes a need for some "shakedown time" to work out the problems of running a successful operation.
3. Sludge utilization agreements are conducted as a trade made in kind: the farmer allows the municipality onto his land in exchange for the nutrient value of the disposed sludge.
4. Any restrictive commitments might preclude the farmer from utilizing more desirable sources of nutrients, such as animal manure.

Verbal agreements which are well understood by both parties are suitable for establishing a new program. The absence of any binding commitment allows both the farmer and the municipality to experiment with the applications. At the outset, the municipality needs to develop a record of successfully running a landspreading operation. The treatment authority also has to continually evaluate utilization as the desired management option for their sludges. On the other hand, the farmer recognizes that the nutrient benefits are associated with some potential risks. Because of the possibility of groundwater contamination or other threats, the farmer may only be willing to spread sludges on a trial basis.

Whether the contract is oral or written, part of the process of establishing a workable utilization plan is an agreement on the management practices to be followed. With regard to technical considerations, agronomists have made some specific recommendations for the maintenance of the program:

1. Incorporation into the soil of sludges as soon as possible after application. The plowing or discing in of sludge prevents nutrient loss, runoff and health threats.
2. Maintaining a neutral pH of about 6.5 to facilitate nutrient uptake by plants and to minimize heavy metal availability to plants in the soil structure.
3. Periodically conduct tests on sludge, soil, groundwaters and surface waters as a management control on the application program.

4. One of the municipality's responsibilities should be to inform the farmer of loading limits on heavy metals and nitrogen from sludge.

In the two cases where contracts existed, the various management, testing and application practices were clearly specified in writing. If these written agreements have any discernible advantages over oral contracts, it is in the designation of the responsibility for testing and monitoring. As Tables 5-11, 5-12 and 5-13 illustrate, some of the more important technical information is not being collected by a relatively high proportion of the communities.

Table 5-11. The Frequency of Conducting Testing and Monitoring by Municipalities.[a]

Municipality Employs the Procedure	Types of Monitoring and Testing Procedures			
	Ground Water	Surface Water	Sludge Sample	Soil Sample
Yes	7	8	12	9
No	13	12	8	11
Column Total	20	20	20	20

[a]Survey of sewage plant operators.

Table 5-12. Comparison of the Frequency of Groundwater and Surface Water Testing with the Frequency of Sludge Sample Analysis by Municipalities.[a]

Groundwater and Surface Water Tests Conducted	Sludge Sample Analysis Conducted		
	Yes	No	Row Total
Yes	8	1	9
No	4	7	11
Column Total	12	8	20

[a]Survey of sewage plant operators.

Table 5-13. The Frequency of Following Management Practices and Testing Procedures by Farmers.[a]

Farmer Employs the Procedure	Types of Management Practices and Testing Procedures			
	Advised of Heavy Metals	Maintained a pH of 6.5	Any Tests or Monitoring	Knew Sludge Application Rate
Yes	8	1	14	16
No	26	34	22	19
Column Total	34	35	36	35

[a]Survey of farmers.

In the tables directly preceding, some of the shortcomings of the new sludge programs are noticeable. Table 5-11, which is obtained from the treatment operator questionnaire, indicates an overall lack of testing procedures. Table 5-12 shows that municipalities which have conducted at least one test, have also performed additional monitoring as well. Conversely, those municipalities who did not conduct one test, tended also to skip others. The implication of Table 5-12 is that some programs fulfill the recommended standards to a greater degree than others. In Table 5-12, drawn from the farmer's survey, the evidence also demonstrates that technical controls are being used in a minority of the programs. The omission of such practices from utilization plans implies a lack of incentives to perform the tests. Without an explicit designation of the responsibility, the farmer or operator would prefer that the other participant pay for monitoring services. Also, the length of time for which the programs have been operating is another consideration. Neither of the participants may want to "invest" in testing if the program begins only on a trial basis. Test results are often used to make future application decisions, so that the usefulness of such technical information depends on the continuing operation of the program. If the utilization plan proves to be successful over a longer period, then there maybe greater interest in obtaining some data on nitrogen loadings, metals buildup and changes in other available nutrients caused by sludge applications.

Table 5-14. Comparison of the Number of Years Participation in the Sludge Program with the Frequency of Testing Procedures by Farmers.[a]

Farmer employs testing procedures	Years of Farmer's Participation in Utilization Program			
	1-2 yrs.	3-4 yrs.	5-8 yrs.	Row Total
Yes	3	7	4	14
No	15	4	3	22
Column Total	18	11	7	36

[a]Survey of farmers.

Table 5-15. Comparison of the Number of Years Participation in the Sludge Program with the Future Plans to Utilize Sludge by Farmers.[a]

Farmer has Future Plans to Use Sludge	Years of Farmers's Participation in Utilization Program			
	1-2 yrs.	3-4 yrs.	5-6 yrs.	Row Total
Yes	11	12	3	26
No	5	2	1	8
Unsure	2	1	0	3
Column Total	18	15	4	37

[a]Survey of farmers.

Table 5-14 is consistent with a positive relationship between program longevity and use of monitoring procedures.

Despite the trend towards more comprehensive utilization programs with time and experience, it should be a matter of policy to encourage the necessary monitoring. As Table 15 indicates, the majority of farmers who have used sludge for any length of time are planning to continue the landspreading programs.

One interpretation of Table 5-15 is that utilization is an alternative with longer term potential. The positive response of farmers towards the future use of sludge demonstrates an interest in maintaining the program. This favorable outlook for the prospects of farmland application should be a primary reason for encouraging the actual practice of testing and other management controls. New policies are necessary if the process of improving programs is to develop more quickly and easily. One prescription is to provide more educational workshops on utilization for the participants. The farmer and treatment operator can use such informal learning sessions to better evaluate the operation of their program. Another policy approach to upgrading sludge use plans is to set stiffer regulations. But instituting new rules may not change these participants' incentives, resulting in programs which are only more difficult to enforce.

The decisions made on which elements are actually included in a sludge program are only part of an ongoing adjustment process between the participants. The farmer-municipality relationship seems to evolve from a trial basis to a more permanent commitment. This "evolutionary" process can only continue as long as the program is mutually advantageous. When the incentives exist for both participants, the farmer and treatment operator usually cooperate to resolve most of the program difficulties. But as had been noted, some aspects may be overlooked. Other sources of information can act as positive inputs for improving the operation of a sludge management plan. The impact of third parties on sludge programs is the next topic of discussion.

Third Party Participants in Sludge Utilization Programs

Sludge disposal problems are public concerns which can involve a number of interest groups. Often the farmer and treatment plant operator require outside advice on the technical aspects of landspreading sludges. In addition, the desirability of farmland application may be questioned by neighbors, local citizens and county health officials. A typical program also includes representatives of state level government, usually for regulatory and advisory purposes.

The public nature of utilization is twofold. First, sewage treatment is provided as a service by local government. Second, there are potential impacts such as odors, runoff and health threats which may result from faulty sludge practices. One of the primary considerations for any land application program is the community's reaction to these potential risks. Opposition can easily form due to people's perceptions of the undesirable consequences of a full scale plan for recycling sewage. In some cases, the idea of returning nutrients to the land is not argued, but doubt is cast upon the municipality's ability to implement the program successfully. Some localities may be particularly sensitive to any disposal strategy because of previous harmful experiences. In Michigan, the PBB incident and chemical dumping controversies have raised citizen awareness of disposal issues. Preventing the occurrence of similar situations should be the aim of policy makers and program participants. For sludge utilization, a coordinated effort needs to be organized for encouraging the institution of proper practices.

The various parties involved in a sludge application program are placed into three categories:

1. People who serve in an advisory or participatory capacity.
2. The agents who have power to regulate sludge programs.
3. The local citizens and neighbors who influence the program in accordance with perceived impacts such as nuisance or health.

The survey results lend to an examination of the three types of interested parties. The interaction (or lack of it) between the participants can greatly affect the operation of a program.

Parties Consulted for Advice on Utilization

The farmer and treatment operator can jointly implement the greater part of a sludge application program. But these two primary participants may require additional expertise to set application rates, conduct testing and provide updates on new technology. The sources of information include the DNR, County Extension Director, County Health Sanitarian and the Department of Crop and Soil Sciences at Michigan State University. All of the surveyed treatment operators received input from the DNR. But contacts to the other agents were more selective. As Table 5-16 illustrates, the municipalities who obtained extension advice also tended to employ the services of the County Health Department.

The impact of outside consultation on a sludge plan may be difficult to evaluate. But a proxy measure can be developed to estimate the contribution of county health and extension. In this case, the presence or absence of monitoring practices are used as an indicator of the controls being exercised on a sludge program. Both the sanitarian and the extension director seemed to have a positive influence on the inclusion of recommended procedures in a sludge plan. Tables 5-17 and 5-18 below demonstrate a correlation of testing activities and the advise of county personnel.

Table 5-16. Comparison of the Frequency of County Extension Involvement with the Frequency of County Health Department Participation in a Sludge Utilization Program.[a]

County Health Department Participation	County Extension Involvement		
	Yes	No	Row Total
Yes	8	3	11
No	1	5	6
Column Total	9	8	17

[a]Survey of sewage plant operators.

Table 5-17. Comparison of the Frequency of County Health Department Participation with the Frequency of Following Testing Procedures by Municipalities.[a]

Was the County Health Sanitarian Contacted?	Characteristics of Sludge Analyzed		Surface-and-Groundwater Tests		
	Yes	No	Yes	No	Row Total
Yes	10	1	7	4	11
No	1	5	1	5	6
Column Total	11	6	8	9	17

[a]Survey of sewage plant operators.

Table 5-18. Comparison of the Frequency of County Extension Involvement with the Frequency of Following Testing Procedures by Municipalities.[a]

County Extension Director Contacted	Sludge Characteristics Analyzed		Soils Analyzed		Row Totals
	Yes	No	Yes	No	
Yes	9	0	5	4	9
No	2	7	3	6	9
Column Total	11	7	8	10	18

[a]Survey of sewage plant operators.

At the state-level of government, the DNR of Michigan can provide input on technical and administrative details of a program. Special efforts are being made by DNR to communicate information for sludge disposal plans through educational workshops and seminars. But although all surveyed treatment operators have received advice from DNR, only seven percent of the interviewed farmers have had any direct contact with the state agency. Many of DNR's recommendations are communicated to the operator, who is then supposed to transfer the knowledge to the farmers. But a good working relationship between the operator and the farmer is necessary for "second-hand" information to be relayed. When possible, greater emphasis should be placed on the advisory capacity of DNR, as opposed to its regulatory responsibilities.

Parties With Regulatory Powers Over Sludge Programs

Constraints can be placed upon sludge programs by regional, state and federal authorities. General policies usually originate with upper government levels (DNR), whereas specific controls take the form of local licensing, ordinance and zoning requirements.

In actual programs, the enforcement of regulations is often lax, except in cases where opposition arises to landspreading. Tables 5-19 and 5-20 below indicate a relationship exists among three variables: local opposition to the program, enforcement of clearance permits, and the role of the county health sanitarian.

Table 5-19. Comparison of the Frequency of Local Opposition to Utilization Programs with the Frequency of the Need for Clearances to Approve Landspreading.[a]

Farmer Needed Clearance to Approve Sludge Use	Local Opposition to Landspreading Sludges		
	Yes	No	Row Total
Yes	7	2	9
No	0	5	5
Column Total	7	7	14

[a]Survey of farmers.

Table 5-20. Comparison of the Frequency of County Health Department Participation with Frequency of Local Opposition to the Utilization Program.[a]

County Health Department Contacted	Any Local Opposition to Spreading Sludges		
	Yes	No	Row Total
Yes	5	6	11
No	0	6	6
Column Total	5	12	17

[a]Survey of sewage plant operators.

In the two tables directly above, local controversy over utilization apparently influences the establishment of a formal permit procedure for regulating the spreading of sludges on farmland. The county health official may participate in the approval process. Responses on the municipality survey indicate that the sanitarian may either help determine application suitability on a site-by-site basis or decide on the appropriateness of the entire program.

When the opportunities and incentives exist for omitting certain practices, regulation and enforcement may be necessary to ensure that the minimum safeguards are instituted. The potential hazards of a faulty sludge program can be serious and should be prevented. To restructure the incentives of the primary participants to comply with standards, the regulators first need to explain the consequences of non-compliance. In other words, the farmer and operator must be made aware of the purposes behind the guidelines. Practices such as monitoring and soil incorporation have definite values which are readily defended as necessary and beneficial for a well-run program.

When they are informed of the purposes of the guidelines, the farmer and treatment operator may be apt to comply. But if the incentives are still lacking, pressures from local citizens may force the enactment of a more comprehensive utilization plan.

Parties In Opposition To Sludge Utilization Programs

As exhibited in Tables 5-19 and 5-20 above, community reaction can effect the operation of a utilization program. The interest of local citizens in disposal stems from the public nature of sewage treatment issues and the potential external effects of land application. Under certain nuisance laws, third parties have rights to either block the implementation of a program or to set restrictions on land application. As a result, a utilization plan may be technically feasible but socially unacceptable. If the community is not included in planning the sludge disposal strategy, then a strong negative response can occur with a program which appears to be a concealed operation. But organized participation of people in the program can achieve beneficial outcomes. In the early stages of developing a disposal scheme, the various alternatives available should be explained and the choice of a specific option should receive local consent. The enlistment of outside experts can greatly aid in interpreting technical issue, while the extension director and DNR can assist in information dissemination and public relations. Extension personnel have closer contacts with farmers who might be interested in utilizing sludge. DNR spokesman are responsible for evaluating environmental aspects of sludge disposal and have information on the experience of other communities with land application.

The municipality survey results show the extension director to be especially involved in a program when local opposition arises. As Table 5-21 illustrates below, there is a stronger need for extension to help deal with a controversy over sludge use. In Table 5-22, the municipalities appear to institute monitoring controls more often when confronted with program opposition.

Table 5-21. Comparison of the Frequency of County Extension Involvement with the Frequency of Local Opposition to the Utilization Program.[a]

Any Local Opposition To Sludge Application	Local Extension Director Contacted		
	Yes	No	Row Total
Yes	4	1	5
No	5	8	13
Column Total	9	9	18

[a]Survey of sewage plant operators.

Table 5-22. Comparison of the Frequency of Following Testing Procedures with the Frequency of Local Opposition to the Utilization Program.[a]

Any Local Opposition To Sludge Application	Groundwater and/or Surface Water Testing Conducted		Sludge Sample Analysis Conducted		Row Totals
	Yes	No	Yes	No	
Yes	5	1	5	1	6
No	4	8	6	6	12
Column Total	9	9	11	7	18

[a]Survey of sewage plant operators.

Local opposition might also be expected to discourage farmers from entering or continuing in a sludge program. But the interviews conducted with farmers do not indicate that they are dissuaded by the controversy. It appears that if the farmer recognizes sludge to be a valuable nutrient source for crop growth, then the incentives are strong enough to utilize sludge despite other's opinions. The following Tables, 5-23 and 5-24, show the relationship between farmers' utilization plans and local opposition.

Table 5-23. Comparison of the Frequency of Local Opposition to the Utilization Program with the Plans of Farmers for Landspreading Sludges in the Future.[a]

Any Local Opposition To Spreading Sludges	Any Future Plans to Use Sludges				Other Farmers Plan to Use Sludge Due to Participant's Experience			
	Yes	No	Unsure	Row Total	Yes	No	Unsure	Row Total
Yes	9	4	1	14	4	5	1	10
No	16	4	2	22	5	12	4	21
Column Total	25	8	3	36	9	17	5	31

[a]Survey of farmers.

Table 5-24. Comparison of the Frequency of Local Opposition to the Utilization Program with the Years of Participation in Landspreading by Farmers.[a]

Local Opposition To Spreading Sludges	Number of Years in Sludge Utilization Program			
	1 to 2	3 to 4	5 to 8	Row Total
Yes	5	6	3	14
No	13	5	4	22
Column Total	18	11	7	36

[a]Survey of farmers.

The interest in utilization by farmers most likely stems its potential as a fertilizer substitute and its ability to increase crop yields. The survey results imply that the farmer does perceive sludge as a productive input and desires to remain in the program.

Sludge Utilization, Crop Yields and Fertilizer Reductions

The spreading of sludges on agricultural lands can accomplish dual objectives: effective disposal and increased crop production. The latter of these two goals is the primary incentive for the farmer to participate in a sludge program. Utilization has initially been attractive to farmers when sludges have relatively lower costs or greater availability than other nutrient sources. But most of the current application plans have only become operational in the last ten years. A more important question is whether agricultural utilization has favorable long term prospects. If future programs are to be perceived as worthwhile, the agricultural potentials must be realized (e.g., observed increases in yields and returns) and the risks must be properly managed (or minimized).

Because of the concerns over the uncertainties of sludge use, additional restrictions and greater incentives are necessary to both monitor and encourage utilization. As an extra inducement, municipalities often assume all costs of transport, testing and liability. But these attempts to stimulate farmer participation are tempered by the restrictions placed on cropping practices. In order to participate, the farmer may be required to incorporate sludges into the soil immediately or shortly after application. Another factor is the social reaction of local citizens, where strong opposition might terminate the program.

As illustrated in Table 5-23, controversy did not overly discourage farmers' future plans to use sludge. The implication of these results is that the farmer has a motive to continue landspreading despite neighbors' complaints. A positive relationship between crop yields and sludge application was observed by a majority of the surveyed farmers, as illustrated in Table 5-25 below.

Table 5-25. Comparison of Reported Crop Yield Effects of Sludge Use with the Years of Participation in Landspreading by the Farmer.[a]

Increase in Crop Yields Associated with the Sludge Use	Number of Years in Sludge Utilization Program			
	1 to 2	3 to 4	5 to 8	Row Total
Yes	9	6	7	22
No	4	2	0	6
Unsure	4	4	0	8
Column Total	17	12	7	36

[a]Survey of farmers.

A major difficulty in evaluating the yield effects of sludge is the lack of any data or records. The impact of applications on crop productivity is largely based on the subjective judgement of the farmer. In a few instances, farmers had estimated approximate yields. One farmer conducted his own "with and without" experiment on sludge use. In this particular case, two adjacent twenty-acre plots of field corn were raised under similar conditions (e.g., inorganic fertilizer additions, soil types, irrigation, etc.). But one tract had 3.2 dry tons of sludge applied, while the other received no sludge. The results were an increase of twenty to twenty-five bushels per acre on the sludge amended plot. While such a yield outcome is encouraging, this trial represents only one point on a production function. Information on yield responses over a wide range of application rates needs to be researched. When equipped with the response function, the farmer can better estimate the optimal spreading rate to maximize returns.

The volume of sludge applied to cropland needs to be coordinated with the farmer's inorganic fertilizer decision. Because of the high nitrogen content of sludge, the amount of anhydrous ammonia or other commercial fertilizer used can be lowered. But careful planning of these reductions is important because part of the organic nitrogen complement in sludge is not readily available for plant uptake. Organic nitrogen is slowly broken down into plant-usable inorganic compounds by soil microorganisms. The nitrogen in organic form therefore represents a resevoir which releases plant available nitrogen over time. The upshot of these technical considerations is that sludge utilization should be planned along with other fertilizer additions to provide ample nutrients for plant growth.

The two tables which follow demonstrate the actions taken by surveyed farmers on fertilizer use. In Table 5-26, only about thirty percent of the farmers reduced their fertilizer requirement on sludge-amended soils. But it is interesting to note that farmers with more years in the sludge program have a higher tendency to reduce inorganic fertilizers. This relationship of sludge use and fertilizer reductions over time is consistent with the "nutrient resevoir" idea, and also implies an improved productive capacity of the land. As Table 5-27 illustrates beneath, there is some correlation between increased crop yields and fertilizer reductions with sludge applications.

Table 5-26. Comparison of the Frequency of Fertilizer Use Reductions with the Years of Participation in Landspreading by the Farmer.[a]

Reduced Fertilizer Application with the Use of Sludges	Number of Years in Sludge Utilization Program			
	1 to 2	3 to 4	5 to 8	Row Total
Yes	3	4	3	10
No	14	8	3	25
Column Total	17	12	6	35

[a]Survey of Farmers.

Table 5-27. Comparison of the Frequency of Fertilizer Use Reductions with the Frequency of Observed Changes in Crop Yields.[a]

Farmer Reduced Fertilizer Use On Sludge - Amended Soils	Observed Increase in Crop Yields			
	Yes	No	Unsure	Row Total
Yes	7	1	2	10
No	15	5	5	25
Column Total	22	6	7	35

[a]Survey of Farmers.

There is only a weak association between crop yield response and fertilizer use in Table 5-27. A closer examination of the practices employed by the farmer reveals some reasoning for this lack of a substantial relationship. As has been described, the relative amounts of fertilizer and sludge must be applied in the proper proportions to assure a sufficient nutrient complement. Knowledge of the N-P-K content in the sludges and the approximate application rates should be in the farmer's plan for crop fertilization. But as indicated in Tables 5-28 and 5-29 below, some farmers change their strategy on the basis of incomplete information.

Table 5-28. Comparison of the Frequency of Fertilizer Use Reductions with the Frequency of Using a Sludge Analysis on which to Base the Fertilizer Requirement.[a]

Reducing Fertilizer on Basis of a Sludge Analysis	Reducing Fertilizer Usage Where Sludges are Applied		
	Yes	No	Row Total
Yes	5	0	5
No	5	25	30
Column Total	10	25	35

[a]Survey of farmers.

Table 5-29. Comparison of the Frequency of Fertilizer Use Reductions with the Frequency of Farmer Knowing the Sludge Application Rate.[a]

Farmer Knew Sludge Application Rate	Farmer Reduced Fertilizer Usage Where Sludges Were Applied		
	Yes	No	Row Total
Yes	7	9	16
No	3	16	19
Column Total	10	25	35

[a]Survey of Farmers.

When either the nutrient composition or application rate for sludge are unknown, the results of a spreading operation are highly variable. If utilization programs are to achieve the goals of proper disposal and soil productivity enhancement, the basic technical controls must be available. The looseness of application agreements is a probable cause for the farmer's lack of incentive to appropriately manage the sludge operation.

Despite the trial and error basis of new programs, emphasis needs to be placed by the participant on realizing the potentials of utilization. In most cases, the burden of responsibility for instituting the warranted controls lies with the municipality which initiates the plan. The treatment operator should have the sludge analyzed and become knowledgeable on application rates. In addition, the operator needs to stress to the farmer that technical management is a prerequisite to achieving the desired outcome of higher crop yields. Reductions in fertilizer use based on sludge and soil analyses have a much better chance of reducing nutrient input costs while maintaining crop productivity.

Future Prospects for Sludge Utilization

A central issue for all utilization programs is whether landspreading is a worthwhile option over the longer term. One criterion for evaluating the prospects is the participants' interest in maintaining the programs. For utilization to remain a viable alternative, the incentives should be structured so that the farmer and the municipality cooperate.

A primary motive for the municipality to continue landspreading is the ability to meet disposal objectives. From the municipal point of view, the capacity of utilization to fulfill disposal goals is complicated by regulatory, monetary and "social reaction" constraints. Treatment authorities may try to avoid the problems of restrictions by shifting responsibilities to the participating farmer. However, the incentive for the farmer is to obtain the nutrient value in sludges at a minimal cost. Striking a balance on the areas of conflict is a necessary condition for improving the long-term potential of farmland application. For instance, a utilization agreement must resolve the cost sharing arrangements for transport, application and monitoring.

Often a municipality is required to quickly implement an acceptable disposal strategy and is placed in a "forced" bargaining position. To induce participation in a utilization program, the treatment authority may have to assume most of the costs. Extra efforts by the municipality are also necessary to "lure" the farmer to use sludge rather than just additional fertilizer or animal manure. But even if the farmer is willing to begin a sludge program, his continued participation depends on whether a net value is attributable to the sludge.

In Table 5-30 below, the future plans of the surveyed farmers indicate a long-run potential for the utilization alternative. Similar positive responses were obtained from the surveyed treatment operators on the question of expansion plans for utilization. Approximately eighty percent of the sewage treatment operators arranged for sites which are suitable for continuing a full utilization program.

Table 5-30. Comparison of Frequency of Increased Crop Yields with Future Plans of Farmers to Participate in Utilization Programs.[a]

Does the Farmer Have any Future Plans to Use Sludges?	Was There An Increase In Crop Yields Associated with the Sludge Use?			
	Yes	No	Unsure	Row Total
Yes	17	2	7	26
No	3	4	1	8
Unsure	3	0	0	3
Column Total	23	6	8	37

[a]Survey of farmers.

CHAPTER VI

ESTIMATING THE COSTS OF SLUDGE UTILIZATION ON FARMLANDS

Introduction to the Representative Case Studies

Aside from technical and social concerns, municipalities and farmers are interested in the expenses of running a sludge application program. The purpose of this chapter is to outline the costs of sludge utilization under varying conditions. Although landspreading is only one of a number of sludge disposal alternatives, cost estimates are presented on just the utilization option. As a result, no attempt is made to perform cost comparison analysis for disposal.

The aims of this chapter are further narrowed by the lack of available data on the input-output relationships between sludge use and crop yield response. Agronomists have identified the potential of sludge for soil and crop enhancement, but the specific production functions are still being actively researched. As discussed in the technical chapter of this thesis, sludge application builds up the organic content and nitrogen reserves of the soil. Although there are some immediate benefits of improving these soil qualities, the dominant effect is to produce some long run advantages. Over time, soil amendments may yield a stream of benefits in the form of improved productive capacity. For instance, sludge application to an organically deficient soil can increase its natural fertility and promote crop growth over successive growing seasons. From an economic point of view, it becomes important to conceptualize a means for evaluating the benefits of sludge use. One measure of the returns might be the cost savings of the reduced fertilizer requirement on sludge-amended soils. But to estimate the long-run value of utilization, it becomes necessary to calculate the discounted value of the future benefit stream flowing from improved soil fertility. The economic desirability of sludge for the farmer lies in the net returns from utilization. That is, the present discounted value of the anticipated benefits should exceed the current costs of using sludges.

As already stated, the present objective is only to outline the costs of a farmland utilization program. The design of this chapter is to set up a number of cases which are constructed with information obtained from the surveys. The cost data for these cases are drawn from several sources, and are designed to represent the typical expenses for a utilization program in a rural municipality. The types of contractual arrangements examined are exemplary of the agreements presently operating in Michigan municipalities. There are roughly four general kinds of arrangements which communities have adopted.

Case 1

In this first utilization plan, the municipality owns and operates a vehicle which both transports and spreads the sludges on the farmer's land. The treatment plant may haul the sludge at no charge to the farmer or it collects a per mile transport fee. The sludge is available in a liquid form (5 percent solids content), and the municipality uses a tanker-truck for hauling and applying purposes.

Case 2

The municipality has facilities to convert liquid sludge to a lower moisture "filter cake" sludge (40 percent solids content). When these partially dried sludges are available, the municipality and farmer share the transport and application duties. The treatment plant moves the sludge out to the farmer's land and the farmer uses a manure spreader to apply it. The farmer pays no user fees for the sludge nor for its transport, a condition observed to hold in the surveys when an equipment sharing arrangement exists.

Case 3

In this third general situation, the farmer owns and operates all the sludge-handling equipment. In exchange for the farmer's services, the municipality pays him a per unit sludge fee. Such an arrangement places more control and responsibility in the hands of the farmer. The municipality avoids some of the equipment and management costs of operating its own vehicle. Liquid or dry sludges can be managed under this arrangement.

Case 4

A private hauler is employed to perform the transport and application functions for liquid or dried sludges. In this case the municipality pays an intermediary a fee per unit of sludge hauled. Under these conditions, the farmer receives the sludge on his land free of charge, but such payment arrangements may vary between municipalities and circumstances.

General Overview of the Case by Case Approach

Each of the above-mentioned cases has two major sub-categories:

1) Distance that sludge is transported.

2) The use of liquid or filter cake sludge.

In the first instance, increasing mileage between the treatment plant and the application site causes larger variable costs in fuel, labor and maintenance. Secondly, the distinction between liquid and dried sludges lie in the costs (or cost-savings) of placing sludge through different treatment processes. Liquid sludge use avoids the expense of drying sludges, but has relatively higher costs of transport due to its much larger mass and volume. Filter cake sludge is just the reverse situation, with higher energy costs of drying and lower hauling expenses.

The costs borne by the farmer vary with the contractual arrangements. If the municipality performs both transport and application, the farmer may only incur the expense of incorporating sludge into the soil. But when filter cake sludges are available, the farmer may also use a manure spreader for application followed by an incorporation activity. Or the farmer can manage all three operations of transport, application and incorporation.

Different agreements for utilization are a source of variation in costs and cost-bearing. One way to estimate the expense for a farmland application program is the use of an enterprise (or block or activity) budget. A block budgeting approach is a simple and direct way of getting at the separate cost of a utilization plan. Each enterprise budget shows the breakdown of costs for the individual activities which comprise the program.[1] A useful modification of an enterprise budget is obtained when one or more of the activities in a program are varied. When a change occurs, such as an increase in transport mileage or fuel price, a "partial budget" can be used to determine the additional costs and reutrns. The use of a partial budget assumes that there are no major organizational changes in the program or the treatment plant operation resulting from the fluctuation in the activity or its price.[2] Partial budgets are valuable as a method for estimating the degree to which utilization costs can change with variations in the components of a program such as labor requirements or wages. Using different assumptions about prices and activity levels, a municipality can approximate the sensitivity of farmland application costs to anticipated changes in conditions.

Partial budgets have also been used for the broader purpose of estimating the net change in income with sludge use. Robert L. Christensen of the University of Massachusetts at Amherst employed partial budgeting to investigate the net returns from increased sludge application costs and decreased fertilizer expenditures.[3] In his study, Christensen demonstrated a net benefit to utilization based on fertilizer reductions.

Applying the Budgeting Approach

The advantage of enterprise and partial budgets is the ability to clearly present cost data. An enterprise budget is a type of "static picture" of the utilization costs at a given point in time. Partial budgets can be used to examine the sensitivity of program costs to changes in activities and prices.

A disadvantage of enterprise budgets is the tendency to overlook effects on costs of the larger system (e.g., the sewage plant). For instance, since farmland application usually occurs at specified times of the year, the treatment plant bears higher storage costs to hold sludges over long time intervals. To overcome this problem, a careful look must be taken to include these costs in the enterprise budget.

Case Studies of Farmland Utilization Costs

Each of the following cases takes cost data from several information sources. The purpose is to demonstrate the costs of a typical utilization program in a rural Michigan municipality. The cost data are synthesized from the surveys, research completed in Ohio and Massachusetts, a study by the federal Environmental Protection Agency on land application costs and other sources.

The case studies are representative of situations where a small-sized treatment plant sets up a sludge program with farmers located within a fifteen mile radius of the plant. The sewage facility is assumed to treat an average of one million gallons per day of wastewater for a user population of 7,000. The sludge utilization agreements are made with family-owned farms, and the intent of the arrangements is to promote agricultural production and not just sludge disposal. Sludges are spread at rates appropriate for enhancing organically-deficient sandy soils which commonly exist in the state of Michigan. Restrictions on spreading rates are set according to nutrient or metal loading limits. In these case studies, the serious problems of heavy metals buildup are diminished by the absence of industrial inflows to the rural sewage plant. To prevent adverse health and odor effects, only stabilized sludges are permitted for utilization. The form of sludge applied to the land may be either liquid or filter cake. The crops raised on sludge-amended land are not intended for direct human consumption, but are used as animal feed or left for fallow to rebuild the soil.

The objective here is to construct cases representative of farmland application programs in rural communities by using synthesized cost data. This chapter now proceeds to identify the sources of information used to obtain cost estimates.

Sources of Cost Data

Many sludge utilization plans in Michigan have been operating for only a short number of years. Accurate cost records are just beginning to be developed. Also, the contractual arrangements between farmer and municipality vary from one locality to another. As a result, the information on utilization costs is usually not available in an organized form. A synthetic approach is used in this analysis to resolve the problems presented by the dispersed nature of the cost data. In other words, the case studies combine information from personal communications, the surveys and other research studies. Each case uses the synthesized data to construct representative enterprise budgets of the costs for a typical utilization program in a rural municipality.

Specific information, such as the prices for labor, equipment and testing services, is obtained directly from the surveys and conversations with farmers and treatment plant operators. The size of the sewage plant and the daily sludge production is chosen for being an average of the surveyed municipalities. Other costs, such as vehicle maintenance, storage and depreciation, are taken from reports prepared by researchers in Ohio, Massachusetts and the U.S. Environmental Protection Agency. Information on the operating costs for the farmer's application and incporporation activities is obtained primarily from extension publications distributed by Michigan State University.

Using the above-mentioned data sources, the next section constructs a series of case studies with a budgeting approach. Enterprise budgets outline the separate costs of a utilization program. The partial budgets show the changes in costs under varying case conditions.

Case Analyses

Background Information on Case 1

In this first example, the municipality owns and operates equipment to transport and apply liquid sludges onto private farmlands. Case 1 is further described with the following characteristics:

1) The case is divided into two sub-categories by varying the transport distance.

   Case 1a. A one-way trip of 5 miles from the treatment plant to the farm.

   Case 1b. A one-way trip of 15 miles from the treatment plant to the farm.

2) The treatment plant produces 4800 gallons of liquid sludge per day. The sludge has a 5% solids content and the plant has no sludge drying facilities. The plant services a population of 7,000 and treats one million gallons per day of wastewater.

3) The desired application rate for a sandy loam soil is 3 dry ton equivalents of sludge per acre based on soil fertility tests, the available nitrogen content in sludge and the nutrient uptake of the crop. At this spreading rate, a field of about 125 acres is needed to accept all the sludge produced at the treatment plant.

4) The main transport and spreading vehicle is a 1,600 gallon tanker truck, obtained at a cost of \$37,000.[4] The truck, when loaded has a fuel efficiency rating of 5 miles per gallon of gasoline.

5) Assume that sludge can only be placed on farmland during early spring and late fall. Labor is hired at a wage of \$6.20 per hour plus 40% benefits to drive and operate the turck.[5] In addition the treatment plant operator must devote some of his time to the program at a cost of \$8.00 per hour.[6]

   The labor time of the driver is divided into four categories:[7]

a.	Loading time	30 minutes
b.	Transit time	mileage dependent
c.	Unloading time	5 minutes
d.	Unproductive time	8 minutes

   Using the above labor-time scheme, the time required for a round trip can be calculated. The knowing the output of sludge from the plant and the capacity of the tanker-truck, the number of round trips is approximated. By converting all the transport figures to annual terms, the labor and fuel costs can be estimated.

6) Besides the above mentioned costs, there are also expenses for vehicle depreciation, testing services, storage operation and liability insurance.

Tables 6-1a and 6-1b on the next two pages illustrate that a large proportion of the municipality's costs are for labor time. One way to cut these labor costs is the use of a larger-capacity hauling vehicle. For instance, some treatment plants have converted a 4,500 gallon oil tanker for sludge application activities. When such vehicles are purchased at used prices, these municipalities tend to have lower capital costs but higher maintenance costs. The main advantage of a large tanker is to cut down the number of trips necessary to haul all of the sludge. The primary disadvantage is that the wheels of a large heavy vehicle can cause soil compaction problems for the farmer. Since these compaction costs may not enter the municipality's account, the size of the vehicle may be a point of contention between the farmer and the treatment plant operator.

Table 6-1a. Enterprise Budget of Utilization Costs to the Municipality. The One-way Transport Distance from Treatment Plant to Farm Site is 5 miles. Liquid Sludges with a 5% Solids Content are Hauled.

Annual Capital Costs[8]	
1. Vehicle Depreciation, 10% Declining Balance 1600 Gallon Tanker: Cost, $37,000	3,700
2. Total Annual Capital Cost	3,700
Annual Operating Costs	
Labor	
3. Truck Driver, $6.20/hour	7,694
4. Treatment Plant Operator, $8.00/hr	800
5. Fringe Benefits at 40%	3,474
Vehicle Operation and Maintenance	
6. Gasoline, $1.00/gal	2,409
7. Oil	140
8. Maintenance, Repairs, Licensing	600
Other Costs	
9. Utility Costs of Storage[10]	552
10. Sludge and Soil Testing Services	190
Annual Fixed Costs[9]	
11. Insurance, Vehicle and Liability	650
Total Annual Operating Costs	16,509
Total Average Operating Costs per Dry Ton of Sludge	45.23
Total Annual Costs	20,209
Total Average Annual Costs per Dry Ton of Sludge	55.37

Table 6-1b. Partial Budget of Utilization Costs to the Municipality. The One-way Transport Distance From Treatment Plant to Farm Site is Increased to 15 miles. Liquid Sludges with a 5% Solids Content are Hauled.

Annual Additional Costs[11]	
Labor	
1. Truck Driver, $6.20/hr	3,960
2. Fringe Benefits at 40%	1,584
Vehicle Operation and Maintenance	
3. Gasoline, $1.00/gal	6,789
Total Annual Additional Costs	12,333
Total Average Additional Costs per Dry Ton of Sludge	$33.79
Total Average Annual Cost per Dry Ton of Sludge (See Table 6-1a)	$89.07

Table 6-2. Enterprise Budget of Utilization Costs to the Farmer for the Incorporation Activity. Liquid Sludges (5% Solids) Are Applied

Annual Operating Costs	
Incorporation Costs, 125 Acres	
1. Labor Time, $3.30/hr[12, 13]	180
2. Gasoline[14]	113
Total Operating Costs	293
Total Average Cost per Dry Ton of Sludge	0.83

Table 6-3. Enterprise Budget of Utilization Costs to the Farmer for Incorporation and Transport. One-way Trip is 5 miles, Liquid Sludges (5% Solids) Are Applied.

Annual Operating Costs	
Incorporation Costs, 125 Acres	
1. Labor Time, $3.30/hr	180
2. Gasoline	113
Transport Costs	
3. Mileage Charge, $.05/mile, 11 miles round trip	602
Total Annual Costs	$895

Table 6-4. Partial Budget of Utilization Costs to the Farmer for Incorporation and Transport. One-way trip is Increased to 15 miles. Liquid Sludges (5% Solids) Are Applied.

Additional Operating Costs[15]	
Transport Costs	
1. Mileage charge, \$0.05 mile, 31 miles round trip	1,697
Total Additional Costs	1,697
Total Annual Costs Inclusive of Additional Charges (See Table 6-3)	1,990

As Tables 6-2 and 6-3 illustrate, incorporation costs depend upon the total acreage which is plowed after sludge application. Case 1 above requires about 125 acres to handle all the sludge at a spreading rate of 3 dry tone equivalents per acre. Other variables which affect the incorporation expenses are the value of farm labor time, the price of fuel and the fuel efficiency for a tractor pulling plowing equipment.

The above estimates of farmer's costs are not complete. For instance, the use of commercial fertilizer may be decreased for a cost savings. Or the farmer may spend more for extra soil tests performed on the sludge-applied land. The farmer's economic incentive to incur utilization expenses depends on the opportunity costs of other nutrient sources and on present value of the future benefits from sludge use. If net benefits from sludge application are more desirable than those from other alternatives, then an incentive exists for the farmer to participate in the program. But the determination of the "profitability" of using sludge is made difficult by the problems of measuring the future flow of benefits. Identifying the value of sludge in promoting the soil's productive potential is a main thrust of agronomic research.

Despite the uncertainty of the exact yield responses functions for utilization, farmers have been willing to participate in sludge programs. In the second case presented below, the farmer both applies and incorporates sludges into the soil.

<u>Background Information on Case 2</u>

In Case 2, the municipality owns and operates a transport vehicle for hauling filter cake sludges (40% solids). A manure spreader is used by the farmer to apply the sludge. The other conditions, such as treatment plant size, population and sludge production, are the same as in Case 1. But the following characteristics more fully describe the situation in Case 2:

1) Four sub-categories are considered on the basis of drying techniques and transport distance.

   Case 2a. Sludges are dewatered with open air drying beds. The transport distance is 5 miles one-way from the plant to the farm.

   Case 2b. Sludges are dewatered with open air drying beds. The transport distance is 15 miles one-way from the plant to the farm.

   Case 2c. Sludges are dewatered with a vacuum filter. The transport distance is 5 miles one-way from the plant to the farm.

Case 2d. Sludges are dewatered with a vacuum filter. The transport distance is 15 miles one-way from the plant to the farm.

2) The sewage plant produces one dry ton equivalent of sludge per day. With the drying facilties operating, the filter cake sludges has an average solids content of 30 percent. The actual movement of sludge requires a front end loader for transfer purposes and a 10-yard dump truck for transport. When a vacuum filter is employed, the front end loader is replaced by a conveyor system to transfer the sludge to the dump truck.

3) The labor time of the dump truck driver can be divided as follows:[16]

a.	Loading time	15 minutes
b.	Transit time	depends on mileage
c.	Unloading time	10 minutes
d.	Unproductive time (waiting, etc.)	8 minutes

4) Again assume labor is hired at a wage of $6.20 per hour plus 40% benefits.[17] The treatment plant operator devotes some time at a cost of $8.00 per hour. When the treatment plant uses drying beds, the truck driver also operates the front end loader. When a vacuum filter dries the sludge, the municipality must hire a filter operator at a cost of $6.00 per hour.

5) Using the above labor time schedule, and that the truck averages a speed of thirty miles per hour in transit, the time required for a round trip can be calculated. Then knowing the output of sludge from the plant and the capacity of the dump truck, the number of round trips is approximated on an annual basis. By converting all the transport figures into value terms, the labor and fuel costs can be estimated.

Table 6-5a. Enterprise Budget of Utilization Costs to the Municipality. The One-way Transport Distance from Treatment Plant to Farm Site is 5 miles. Filter Cake Sludges with a 40% Solids Content are Obtained from Open Air Drying Beds and Hauled.

Annual Capital Costs	
1. Vehicle Depreciation, 10% Declining Balance[18]	1,265
10-Yard Dump Truck: Cost $12,648	
2. Structure Depreciation[19]	2,450
Sand Drying Beds	
3. Total Annual Capital Costs	3,715
Annual Operating Costs	
4. Dump Truck Driver, $6.20/hr	740
5. Treatment Plant Operator	800
6. Fringe Benefits at 40%	616
Vehicle Operation and Maintenance	
7. Front End Loader, rented at $6.22/hr[20]	250
8. Gasoline ($1.00/gal.) and Oil for Hauling	455
9. Maintenance, Repairs, Licensing	600
Other Costs	
10. Drying Bed Maintenance[21]	2,200
11. Sludge and Soil Testing	190
Annual Fixed Costs	
12. Insurance, Vehicle and Liability	650
Total Annual Operating Costs	6,501
Total Average Operating Costs per Dry Ton of Sludge	17.81
Total Annual Costs	10,216
Total Average Annual Costs per Dry Ton of Sludge	28.00

Table 6-5b. Partial Budget of Utilization Costs to the Municipality. The One-way Transport Distance From Treatment Plant to Farm Site is Increased to 15 miles. Filter Cake Sludges with 40% Solids Content are Obtained from Open Air Drying Beds and Hauled.

Annual Additional Costs [22]	
Labor	
1. Truck Driver, $6.20/hr	591
2. Fringe Benefits at 40%	236
Vehicle Operation and Maintenance	
3. Gasoline for Transport, $1.00/gal	543
Total Annual Additional Costs	1,370
Total Average Additional Costs per Dry Ton of Sludge	3.75
Total Average Annual Costs per Dry Ton of Sludge (See Table 6-5a)	31.36

Table 6-5c. Enterprise Budget of Utilization Costs to the Municipality. The One-way Transport Distance from Treatment Plant to Farm Site is 5 miles. Filter Cake Sludges with a 40% Solids Content are Obtained from a Vacuum Filter and Hauled.

Annual Capital Costs	
1. Vehicle Depreciation	1,265
10-Yard Dump Truck: Cost, $12,648	
2. Equipment Depreciation[23]	10,111
Vacuum Filter and Conveyor: Cost, $101,110	
3. Total Annual Capital Costs	11,376
Annual Operating Costs	
Labor	
4. Truck Driver, $6.20/hr	740
5. Treatment Plant Operator, $8.00/hr	800
6. Vacuum Filter Operator, $6.00/hr[24]	9,988
7. Fringe Benefits at 40%	4,611
Vehicle Operation and Maintenance	
8. Gasoline ($1.00/gal.) and Oil for Hauling	455
9. Maintenance, Repairs and Licensing	600
Other Costs	
10. Maintenance and Chemicals for Vacuum Filter[25]	7,100
11. Electricity and Vacuum Filter[26]	1,270
12. Sludge and Soil Testing Services	190
Annual Fixed Costs	
13. Insurance, Vehicle and Liability	650
Total Operating Costs	26,404
Total Average Operating Costs per Dry Ton of Sludge	72.34
Total Annual Costs	37,780
Total Average Annual Costs per Dry Ton of Sludge	103.51

Table 6-5d. Partial Budget of Utilization Costs to the Municipality. The One-way Transport Distance from Treatment Plant to Farm Site is Increased to 15 miles. Sludges with a 40% Solids Content are Obtained from a Vacuum Filter and Hauled.

Annual Additional Costs [27]	
Labor	
1. Truck Driver	591
2. Fringe Benefits at 40%	236
Vehicle Operation and Maintenance	
3. Gasoline for Transport, $1.00/gal	543
Total Annual Additional Costs	1,370
Total Average Additional Costs per Dry Ton of Sludge	3.75
Total Average Annual Costs per Dry Ton of Sludge (See Table 6-5c)	107.26

In the enterprise and partial budget for Case 2 above, there seems to be some economic advantages to using air dried sludges as opposed to liquid sludges. But there are some hidden costs to sand drying beds. The beds are susceptible to technical problems of clogging (drainage), seepage into surrounding soil strata and freezing during the winter months. When these adverse drying conditions develop, the solids content of the sludge may remain relatively low (about 10 to 20 percent) and the job of hauling more difficult. New developments in air drying technology or much higher maintenance costs may be necessary to make the drying beds operative. The comparison of utilizing air dried versus liquid sludge illustrates the tradeoffs between capital costs, storage difficulties and future demands on the sewage system. In the long run it may be cheaper for the municipality to spread air-dried sludges if the capacity of fully-operative beds can be expanded. The transport costs of using air-dried sludges are less and the capital costs decrease over time. But the beds must be designed to hold the accumulation of sludge between farmland applications. Liquid sludge utilization is advantageous where the sand beds have insufficient capacity and adequate storage is provided by digesters and holding ponds.

As Tables 6-5c and 6-5d demonstrate, the costs of running a vacuum filter are extremely high. In general, the use of energy-intensive technologies for drying sludge are not economical for small size treatment plants. Vacuum filters are better suited to large-scale wastewater facilities which realize economies of size and spread fixed costs over a larger output.

In addition to the municipal costs of utilizing filter sludges, the farmer incurs costs for application and incorporation. A manure spreader is used to apply the dried sludge, while some type of discing operation is employed to combine it with the soil. Other equipment includes some conveyor machinery to transfer the sludges to the manure spreader. The following Table 6-6 outlines labor and machinery costs to the farmer for utilizing sludges.

Table 6-6. Enterprise Budget of Utilization Costs to the Farmer for Application and Incorporation. Filter Cake Sludges with a 40% Solids Content are Utilized.

Annual Capital Costs	
1. Equipment Depreciation, 10% Declining Balance[28]	700
Manure Spreader: Cost, $3,000	
Bobcat Conveyor: Cost, $4,000	
2. Total Annual Capital Costs	700
Annual Operating Costs	
Application Costs[29]	
1. Labor Time, $3.30/hr	883
2. Fuel Requirements for Machinery	69
Incorporation Costs[30]	
3. Labor Time, $3.30/hr	180
4. Fuel Requirements for Machinery	113
Total Operating Costs	1,245
Total Average Operating Costs per Dry Ton of Sludge	3.41
Total Annual Costs	1,945
Total Average Annual Costs per Dry Ton of Sludge	5.33

As Table 6-6 illustrates, the farmer plays a larger role both technically and economically when applying filter cake sludges. In terms of the effect on net income, the farmer's willingness to incur expenses depends upon the size of the benefits associated with sludge use. The surveys indicate that the farmer has incentives to spread sludges due to decreased fertilizer costs and perceived increases in crop yields.

The third case about to come under consideration transfers the primary responsibilities for the program away from the municipality. Control of the transport, application and incorporation activities is placed with the farmer. In exchange for his sludge-moving services, the farmer receives a fee per unit of sludge transported from the treatment plant.

Background Information on Case 3

In this third situation, the farmer purchases transport and application equipment for hauling sludges. The municipality avoids administrative and machinery costs, but pays the farmer an agreed-upon fee for transporting the sludges. The enterprise budgets for this case show how the costs of the utilization arrangements are shared between the farmer and municipality. The assumptions about population size, sludge production, application rates, etc. remain the smae as in the previous two cases. Specific characteristics of Case 3 can be outlined as follows:

1) Using information from the surveys for this report, two sub-cases are examined for the fee payment arrangements. In one case, the municipality pays $2.00 per thousand gallons of sludge hauled. The second situation is where a $13.00 per thousand gallons fee is paid. For both sub-cases only liquid sludge (5% solids) is handled and desired application rate is 3 dry ton equivalents per acre.

Table 6-7a. Enterprise Budget of Utilization Costs to the Municipality. The Treatment Plant Pays the Farmer a $2 Per Thousand Gallon Fee for Hauling Liquid Sludge (5% Solids).

Annual Capital Costs	
1. Depreciation on Transport Equipment	0
2. Total Annual Capital Costs	0
Annual Operating Costs	
Labor	
3. Sewage Treatment Operator	800
Other Costs	
4. Fee for Sludge Hauling, $2.00/1000 gal.[31]	3,504
5. Sludge and Soil Testing Services	190
6. Utility Costs of Sludge Storage	552
Total Annual Operating Costs	5,046
Total Average Operating Costs per Dry Ton of Sludge	13.82
Total Annual Costs	5,046
Total Average Annual Costs per Dry Ton of Sludge	13.82

Table 6-7b. Enterprise Budget of Utilization Costs to the Farmer. The Treatment Plant Pays the Farmer a $2 per Thousand Gallon Fee for Hauling Liquid Sludge (5% Solids). One-way Transport Distance is 5 miles.

Annual Capital Costs	
1. Depreciation on Equipment[32]	1,200
4,500 Gallon Tanker: Cost, $10,000	
Liquid Manure Spreader: Cost, $2,000	
2. Total Annual Capital Costs	1,200
Annual Operating Costs[33]	
Labor	
3. Value of Farmer's Time in Transport, Application and Incorporation , $3.30/hr	3,525
Equipment Operation and Maintenance	
4. Fuel and Oil Expenses	1,474
Transport, Application and Transportation	
5. Insurance, Vehicle and Liability	650
6. Maintenance Repairs and Licensing	600
Total Operating Costs	6,249
Total Average Operating Costs per Dry Ton of Sludge	17.12
Total Annual Costs	7,449
Total Average Annual Costs per Dry Ton of Sludge	20.41
Total Annual Fee Received for Hauling Sludge	3,805
Total Annual Costs Less Fee Received	3,644
Total Average Annual Costs (Less Fee Received) for Dry Ton of Sludge	9.98

Table 6-7c. Partial Budget of Utilization Costs to the Farmer. The Treatment Plant Pays the Farmer a $2 Per Thousand Gallon Fee for Hauling Liquid Sludge (5% Solids). One-way Transport Distance is Increased to 15 miles.

Annual Additional Costs[34]

Labor
1. Value of Farmer's Extra Time in Transit........782

Vehicle Operation and Maintenance
2. Fuel for Extra Transport Distance............1,560

Total Annual Additional Costs.........................2,342
Total Average Annual Additional Costs Per Dry Ton of Sludge..6.42
Total Average Annual Costs Per Dry Ton of Sludge.....16.42
(See Table 6-7b)

Table 6-8a. Enterprise Budget of Utilization Costs to the Municipality. The Treatment Plant Pays the Farmer a $13 Per Thousand Gallon Fee for Hauling Liquid Sludge (5% Solids).

Annual Capital Costs

1. Depreciation on Transport Equipment................0
2. Total Annual Capital Costs.........................0

Annual Operating Costs
Labor
3. Sewage Treatment Operator........................800

Other Costs
4. Fee for Sludge Handling, $13/100 gal[35].........22,776
5. Sludge and Soil Testing Services.................190
6. Utility Costs of Sludge Storage..................552

Total Annual Operating Costs. 24,318
Total Average Operating Costs Per Dry Ton of Sludge..66.63
Total Annual Costs...................................24,318
Total Average Annual Costs per Dry Ton of Sludge.....66.63

Table 6-8b. Enterprise Budget of Utilization Costs to the Farmer. The Treatment Plant Pays the Farmer a $13 Per Thousand Gallon Fee for Hauling Liquid Sludge (5% Solids). One-way Transport Distance is 5 miles.

Annual Capital Costs	
1. Depreciation on Equipment[36]	1,200
4,500 Galoon Tanker: Cost, $10,000	
Liquid Manure Spreader: Cost, $2,000	
2. Total Annual Capital Costs	1,200
Annual Operating Costs[37]	
Labor	
3. Value of Farmer's Time in Transport, Application and Incorporation, $3.30/hr	3,525
Equipment Operation and Maintenance	
4. Fuel and Oil Expenses	1,474
Transport, Application and Incorporation	
5. Maintenance, Repairs and Licensing	600
Annual Fixed Costs	
6. Insurance	650
Total Operating Costs	6,249
Total Average Operating Costs per Dry Ton of Sludge	17.12
Total Annual Costs	7,449
Total Average Annual Costs per Dry Ton of Sludge	20.41
Total Annual Fee Received for Hauling Sludge	22,776
Total Annual Costs Less Fee Received	(15,327)
Total Average Annual Costs (Less Fee Received) per Dry Ton of Sludge	$42.00)

Table 6-8c. Partial Budget of Utilization Costs to the Farmer. The Treatment Plant Pays the Farmer a $13 Per Thousand Gallon Fee for Hauling Liquid Sludge (5% Solids). One-way Transport Distance is Increased to 15 miles.

Annual Additional Costs[38]	
Labor	
1. Value of Farmer's Extra Time in Transit, $3.30/hr	782
Vehicle Operation and Maintenance	
2. Fee for Extra Transport Distance at $1.00/gal	1,560
Total Annual Additional Costs	2,342
Total Average Annual Additional Costs Per Dry Ton of Sludge	6.42
Total Annual Costs (Less Fee Received) Per Dry Ton of Sludge (See Table 6-8b)	(35.57)

In Tables 6-7b and 6-7c, the fee paid by the municipality does not cover all the costs to the farmer. This lower hauling rate only offsets the transport costs. But Tables 6-8b and 6-8c show the farmer receiving a net income from the $13 per thousand gallon fee. As noted previously, these two sludge removal fees were obtained directly from the surveys conducted for this thesis. The wide margin between the prices can be explained in terms of incentives and bargaining position. When the lower fee exists, the farmer may be one of a number of persons interested in utilizing sludge. The farmer with the lowest bid is given the right to be the sole recipient of the sludge. In the second case, the municipality may be having trouble finding any farmer willing to use sludge. The bid (fee) offered by the treatment plant may be having trouble finding any farmer willing to use sludge. The bid (fee) offered by the treatment plant may be higher to attract and maintain the interest of the farmer. Differences in the perception of utilization by farmers are influenced by social constraints, variability in access to information and individual attitudes.

In the final Case 4 which follows, neither the municipality nor the farmer are directly involved in the transport of sludges to the farm site. The municipality pays a per unit fee to a private hauling firm, which then moves the sludge onto the farmer's land. The farmer does not usually incur any additional charges when the municipality hires the hauling services. But the farmer may still be incorporating and/or applying the sludges.

Background Information on Case 4

The primary characteristic of this fourth case is that the treatment plant hires a private hauling firm. The assumptions about the population size, sludge production, application rates, etc. are the same as for the previous three examples. The specific conditions for Case 4 are as follows:

1) There are two sub-categories based on the types of sludge (liquid or dry) being transported:

Case 4a. Open air drying beds are used to produce filter cake sludges (40% solids). The hauling firm charges $40 per 20 cubic yards of sludge transported.

Case 4b. Liquid Sludges (5% Solids) are produced. The hauling firm charges $16.5 per thousand gallons of sludge transported.

2) The farmer pays the hauler no fees for the services of transport. The costs of application and incorporation are borne by the farmer.

The prices charged by the hauling firms in Tables 6-9a and 6-9b on the next two pages are incongruous. The fee for the liquid sludge transport was obtained form an E.P.A. bulletin on landspreading costs. The price for moving filter cake sludge was observed in the surveys. The charge for transporting the liquid sludges seems almost prohibitive. If a municipality were to choose a utilization plan on a cost basis, the hauling charge would have to be about $8 per thousand gallons or less before a private firm would be employed. A municipality may be willing to pay a little extra for the private hauler to avoid the direct and indirect costs of operating its own equipment. It may also be more productive to employ transport services due to the treatment plant operator's opportunity costs and the comparative advantage of the specialized firm. If the operator is better suited to just running an efficient wastewater facility, then an advantage exists to shift the problems of sludge transport to a private firm with the appropriate skills.

Table 6-9a. Enterprise Budget of Utilization Costs to the Municipality. The Treatment Plant Pays $40 per 20 Cubic Yards of Filter Cake Sludge to a Private Hauler. Sludge has 40% Solids.

Annual Capital Costs	
1. Structure Depreciation[39] Sand Drying Beds	2,450
2. Total Annual Capital Costs	2,450
Annual Operating Costs	
Labor	
3. Sewage Treatment Plant Operator	800
Other Costs	
4. Charge for Sludge Hauled, at $40/20 cubic yards[40]	2,862
5. Sludge and Soil Testing Services	190
6. Maintenance of Filter Beds[41]	2,200
Total Operating Costs	6,052
Total Average Operating Costs Per Dry Ton of Sludge	16.58
Total Annual Costs	8,502
Total Average Annual Costs Per Dry Ton of Sludge	23.30

Table 6-9b. Enterprise Budget of Utilization Costs to the Municipality. The Treatment Plant Pays $16.5 Per Thousand Gallons of Sludge Hauled to a Private Firm. Sludge has 5% Solids.

Annual Capital Costs	
1. Vehicle Depreciation	0
2. Total Annual Capital Costs	0
Annual Operating Costs	
Labor	
3. Sewage Treatment Plant Operator	800
Other Costs	
4. Charge for Sludge Hauled, at $16.50 Per Thousand Gallons.[42]	28,908
5. Sludge and Soil Testing	190
6. Utilities for Sludge Storage	552
Total Operating Costs	30,450
Total Average Operating Costs Per Dry Ton of Sludge	83.42
Total Annual Costs	30,450
Total Average Annual Costs Per Dry Ton of Sludge	83.42

Table 6-10. Enterprise Budget of Utilization Costs to the Farmer. A Private Hauler Transports Liquid Sludge (5% Solids). Farmer Applies and Incorporates the Sludges.

Annual Capital Costs	
1. Depreciation on Equipment[43]	200
Liquid Manure Spreader: Cost, $2,000	
2. Total Annual Capital Costs	200
Annual Operating Costs	
Application Costs44	
1. Labor Time, $3.30/hr	1,642
2. Fuel Requirements for Machinery	363
Incorporation Costs	
3. Labor Time, $3.30/hr	180
4. Fuel Requirements for Machinery	113
Total Operating Costs	2,298
Total Average Operating Costs Per Dry Ton of Sludge	6.30
Total Annual Costs	2,498
Total Average Annual Costs Per Dry Ton of Sludge	6.84

Table 6-11. Enterprise Budget of Utilization Costs to the Farmer. A Private Hauler Transports Filter Cake Sludges (40% Solids). Farmer Applies and Incorporates the Sludges.

Annual Capital Costs	
1. Equipment Depreciation[45]	700
Manure Spreader: Cost, $3,000	
Bobcat Conveyor: Cost, $4,000	
2. Total Annual Capital Costs	700
Annual Operating Costs [46]	
Application Costs	
1. Labor Time, $3.30/hr	883
2. Fuel Requirements for Machinery	69
Incorporation Costs	
3. Labor Time, $3.30/hr	180
4. Fuel Requirements for Machinery	113
Total Operating Costs	1,245
Total Average Operating Costs Per Dry Ton of Sludge	3.41
Total Annual Costs	1,945
Total Average Annual Costs Per Dry Ton of Sludge	5.33

<u>Evaluating the Usefulness of the Cost Estimates</u>

The four cases examined above are not intended to include all the possible arrangements for a utilization program. The goal has been to outline the costs for the types of application agreements which prevailed in the survey of Michigan municipalities. In Table 6-12 below, the estimated costs are summarized for the different cases and conditions. The expenses calculated for each program are summarized for the different cases and condtiions. The expenses calculated for each program are roughly representative of the costs faced by a rural municipality. The average costs in the summary Table 6-12 are taken directly from the enterprise budgets in this

Table 6-12. Summary Table of Utilization Costs Under Alternative Contractual Arrangements[a]

Case 1. Municipality Hauls Liquid Sludge	Municipality	Farmer	Total
5-Mile Transport, No Fee	$55.37	$0.80	$56.17
5-Mile Transport, $0.05/Mile Fee	53.72	2.45	56.17
15-Mile Transport, No Fee	89.07	0.80	89.87
15-Mile Transport, $0.05/Mile Fee	83.62	5.45	89.87
Case 2. Municipality Hauls Filter Cake Sludge			
5-Mile Transport, Air Dried	28.00	5.33	33.33
5-Mile Transport, Vacuum Dried	103.51	5.33	108.84
15-Mile Transport, Air Dried	31.36	5.33	36.69
15-Mile Transport, Vacuum Dried	107.26	5.33	112.59
Case 3. Farmer Hauls Liquid Sludge			
5-Mile Transport, $2/1000 gal. Fee	13.82	9.98	23.80
5-Mile Transport, $13/1000 gal. Fee	66.63	(42.00)	24.63
15-Mile Transport, $2/1000 gal. Fee	13.82	16.40	30.22
15-Mile Transport, $13/1000 gal. Fee	66.63	(35.57)	31.06
Case 4. Private Firm Hauls Sludge			
Private Hauling Firm, $16.5/1000 gal. Fee	83.42	6.84	90.26
Private Hauling Firm, $40/20 Cu. Yd. Fee	23.30	5.33	28.63

[a]These are average annual costs in dollars per dry ton. This table compiles the average annual costs for utilization from the case studies in this chapter. The "total" column is simply the summation of the municipality's and farmer's costs.

chapter.

Although the budgets provide a "snapshot" of the program's expense, the costs need to be viewed in light of thw whole sewage disposal system. For instance, in the short run, a municipality may be in a forced position of utilizing only liquid sludges when cheaper air dried sludges can not be produced. A treatment plant may have malfunctioning sand beds, inadequate facilties to dry the increasing sludge volumes or land and funding restrictions placed on the use of drying beds. In cases where the choices are limited, the treatment plant engaged in utilization may desire to know the trade-offs among the various options. That is, the comparative costs of owning equipment, paying a farmer to transport the sludge or hire a private hauling firm.

Another important element in these costs estimations is the farmer's incentive to participate in the program. Missing from the enterprise budgets is a calculation of the net benefits of sludge use to the farmer. The technical input-output relationships between sludge application and crop growth are being researched. When equipped with the knowledge of the production function for utilization, the farmer's enterprise budget can be made more complete. That is, changes in fertilizer usage, current crop yield responses and future productive capacity can be converted into value terms. The sludge benefits are then compared to the budget costs to approximate the farmer's net returns to the sludge application activity.

Enterprise budgets provide information on cost conditions at a single point in time. But current decisions on sludge disposal also have future consequences. The dynamic concerns for a sludge program are the anticipated changes in sewage plant service population, the future availability of farmlands and the prospects for utilization as a long-run alternative. If a municipality is experiencing rapid growth, alterations in plans may be needed to account for changes in the present value of the future costs. In other words, a treatment plant operator may have to adapt the present disposal strategy for a smooth transition over the longer term. A municipality may switch from an entirely liquid sludge plan to a filter cake sludge operation by combining a liquid and dry application program in the short run.

Another dynamic consideration is the adoption of new technologies for sludge treatment and utilization. Each new development should be reviewed in light of its economic feasibility. Certain techniques have associated scale economies. Vacuum filtration, centrifugation and other sludge drying techniques involve both high capital and operating costs. Large urban treatment facilities can fully use the capacity of this drying equipment and can distribute the costs over a large volume. Unless the smaller municipality is expanding the treatment plant to meet an anticipated rise in demand, the selection of more "appropriate technology" is probably in order.

One of the looming problems for all sludge disposal strategies is the continual rise in transport costs. If fuel prices continue to rise faster than other costs, then there will be impacts on the relative costs of different activities. For example, the disposal of liquid sludges becomes less competitive than utilizing air dried sludges as fuel prices rise. In a sensitivity analysis, a rise of $0.50 per gallon of fuel can raise the cost of a liquid sludge program by $3.30 per dry ton of sludge. The same increase in the price of fuel pulls up the cost of utilizing air dried sludge by only $0.43 per ton. In addition, a rise in labor wages tends to grant the same relative advantage to the application of air dried versus liquid sludges. But an increase in capital costs, such as higher interest rates, creates a disadvantage for air drying due to the large investments needed when sand bed capacity is expanded. A change in the contractual arrangements may have a large effect on utilization costs. In cases where the farmer receives a fee for transporting and applying the sludges, the total cost of the program may be lowered due to decreased labor and administrative costs. A final note on fuel cost changes should be noted by municipalities: The general climb in energy prices tends to make the vacuum filter and other energy intensive options less and less viable.

In addition to rising fuel expenses, the general inflationary trend in the economy can affect sludge programs. A jump in labor wages tend to favor the use of air-dried over liquid sludges in the same proportions as when fuel prices go up. But an increase in capital costs, such as higher interest rates, creates a disadvantage for air drying due to the larger investment costs of constructing sand beds. The sensitivity of utilization costs to changes in other variables, such as the contractual arrangements. If farm labor wages are relatively lower and if the treatment plant can cut personnel costs, then an agreement to pay the farmer a fee in exchange for transport services can decrease the total expense for a utilization program. However, a key feature of this fee payment arrangement is the farmer's willingness to share in a larger percentage of the program's costs and responsibilities. When the farmer perceives a net gain from utilizing sludge, then such an arrangement can develop.

ENDNOTES

[1]Emery N. Castle, Manning H. Becker and Frderick J. Smith, Farm Business Management (New York: Macmillan Publishing Co., 1972), p. 86.

[2]Ibid., p. 107.

[3]Robert L. Christensen, The Feasibility of Application of Municipal Sewage Sludge on Agricultural Land in Massachusetts (Amherst: Massachusetts Agricultural Experiment Station, 1977), sec. 5, pp. 24-29.

[4]Information on the characteristics of the liquid sludge hauling truck obtained from a conversation with a treatment plant operator. The vehicle is known as a "Big Wheels Sludge Applicator" which is designed to transport and apply liquid sludges to farmland.

[5]Data on the wage and benefits for operating the disposal vehicle from conversations with two wastewater treatment operators.

[6]R. Kent Anderson, Cost of Landspreading and Hauling Sludge From Municipal Wastewater Treatment Plants: Case Studies (Cincinnati: Solid Waste Information of U.S. Environmental Protection Agency, 1977), p. 85.

[7]Information on loading and unloading times obtained by conversation with treatment plant operator. Transit time is calculated with knowledge of mileage and vehicle speed. Estimation of the unproductive time (waiting, etc) is obtained from Robert L. Christensen, sec. 5, p. 20.

[8]Selection of the depreciation rate is from Robert L. Christensen, sec. 5, p. 18.

[9]Insurance costs obtained from a conversation with a treatment plant operator.

[10]The utility cost of storage was estimated using information from Stephen L. Ott and D. Lynn Forster, "Economic Analysis of Recycling Sewage Sludge on Agricultural Land," (Syracuse: Cornell University Waste Management Conference, 1977), p. 15.

[11]Note that these additional costs should be adjusted upwards for increased maintenance and insurance costs.

[12]The wage rate is average for a field worker as reported in Michigan Agricultural Statistics, July 1979 (Lansing: Department of Agriculture, 1979), p. 17.

[13]The labor time for incorporation was taken from Robert G. White, "Determining Capacities of Farm Machines," (East Lansing: Cooperative Extension Service of Michigan State University, 1978), Bulletin E-1216, p. 5.

[14]The fuel costs are calculated using Robert G. White, "Fuel Requirements for Selected Farming Operations" (East Lansing: Cooperative Extension Service of Michigan State University, 1974), Bulletin E-780, p. 2.

[15]These costs do not include extra expenses for maintenance and insurance.

[16]Information on the labor time requirements for filter cake sludges is obtained from Robert L. Christensen, Section 5, p. 19.

[17]Information on wages and benefits obtained form conversations with sewage treatment plant operators.

[18]Cost of the dump truck obtained from the utilization surveys. Depreciation rate taken from Robert L. Christensen, Section 5, p. 18.

[19]Depreciation costs of sand drying beds obtained from R. Kent Anderson, p. 102.

[20]Ibid., p. 72.

[21]Ibid., p. 102.

[22]These costs do not include extra expenses for maintenance and insurance.

[23]Cost outlay for the vacuum filter is obtained from R. Kent Anderson, p. 37.

[24]Ibid., pp. 53, 75

[25]Ibid., p. 75.

[26]Ibid., p. 54.

[27]The costs do not include the extra expenses for maintenance and insurance.

[28]Information of equipment costs acquired form the utilization surveys.

[29]The labor time and fuel requirements for application of filter cake sludge estimated with data from P.H. Southwell and T.M. Rothwell, Report on Analysis of Output/Input Ratios of Food Production in Ontario (Guelph: School of Engineering, 1977), p. 160.

[30]Labor time requirement acquired from Robert G. White, Bulletin E-1216, p. 5. The fuel needs are obtained from Robert G. White, Bulletin E-780, p. 2.

[31]Information on fee acquired from utilization surveys.

[32]Data on equipment costs taken from utilization surveys. Depreciation rate acquired from Robert L. Christensen, Section 5, p. 18.

[33]Labor time and fuel requirements estimated from data in P.H. Southwell and T.M. Rothwell, pp. 160-162. The wage rate is obtained from Michigan Agricultural Statistics, 1979, p. 17.

[34]These costs do not include extra expenses for maintenance and insurance.

[35]The data on this fee is taken from the utilization surveys.

[36]Cost data for the equipment acquired form utilization surveys. Depreciation rate taken from Robert L. Christensen, Section 5, p. 18.

[37]Labor and fuel costs estimated with data from P.H. Southwell and T.M. Rothwell, pp. 160-62.

[38]These costs do not include the extra expenses for maintenance and insurance.

[39]Depreciation on sand drying beds acquired from R. Kent Anderson, p. 102.

[40]The data for this fee obtained from the utilization surveys.

[41]R. Kent Anderson, p. 102.

[42]The data on this fee acquired from R. Kent Anderson, p. 127.

[43]Cost data on the application equipment acquired form the utilization surveys.

[44]Labor and fuel costs are estimated using data in P.H. Southwell and T.M. Rothwell, pp. 160-162.

[45]Cost data on application equipment acquired form the utilization surveys.

[46]Labor and fuel costs are estimated using data in P.H. Southwell and T.M. Rothwell, pp. 160-162.

CHAPTER VII

SUMMARY AND CONCLUSIONS

A Reexamination of Farmland Utilization As An Alternative For Sewage Sludge Management

The Water Pollution Control Act Amendments of 1972 set a national goal of eliminating effluent discharges by 1985. One part of this ambitious legislation required municipalities to upgrade their sewage treatment facilities. With the aid of a federal funding program, communities have complied with the new regulations and have installed advanced wastewater control technologies. But the abatement of water pollution from sewage plants has been gained at the expense of intensifying the solid waste problem of sludge disposal.

Municipal sewage sludge is the organically-concentrated residual of wastewater treatment processes. Increased sludge volumes have been produced as a result of improved wastewater control, and communities need an acceptable means of coping with the growing sludge problem. Farmland utilization has recently received increased attention as a potential method of sludge management. This research has examined the feasibility of sludge application to private farmlands to solve the disposal problem and to promote agricultural production.

There are a number of other alternatives for sludge management, such as landfills, incineration and spoiled-land reclamation. The choice of a specific management option is complicated by the interplay of economic, social and environmental tradeoffs. Municipalities are requesting that more information be made available on the advantages and disadvantages of each option, so that a more knowledgeable decision can be made.

Research Objectives

The purpose of this study was to research the potential of private farmland utilization as a solution to the sludge management problems of rural municipalities in Michigan. Other options, such as landfills and incineration, were not examined and no comparative cost analyses were performed. Instead, the intent was to provide a descriptive analysis of the broad multidisciplinary issues of sludge utilization. This research was specifically designed to be applicable to small municipalities in Michigan, since no previous study has fully documented the experience with farmland utilization in the State.

Methodology

When a sludge utilization program is being established by a municipality and participating farmers, a variety of arrangments must be coordinated. For instance, the participants need to agree on the terms for transporting and applying the sludges. In addition, a farmland application plan is often influenced by government regulations, technical constraints, economic concerns and local opinion. To sort out the various aspects of sludge utilization, this study was organized in the following manner:

1. Investigated the institutional framework which shapes the development of sludge utilization plans. The relevant federal, state and local laws were examined in terms of their influence on land application as a sanctioned and feasible alternative. Also, the various types of utilization agreements between the farmer and the municipality were described and analyzed.
2. Briefly reviewed the technical aspects of sludge utilization. A description of stabilization processes, adequate monitoring procedures and proper application techniques was presented, and the importance of these safeguards were explained. Information was presented on the capacity of sludges to improve the productivity of the soil. Also, the problems of pathogens, odors and heavy metals were examined, and the managment practices to minimize these risks were described.
3. Interpreted the results of surveys conducted with farmers and treatment plant operators who jointly participated in sludge programs. The surveys revealed information about the contractual arrangements, the interested third parties, the perceived benefits and costs and the future prospects for

utilization.

4. Performed some representative case studies which approximated the utilization costs to municipalities and farmers. Enterprise and partial budgets were employed to determine the cost differences under alternative contractual arrangments.
5. Summarized the private farmland alternative as a potential solution to the sludge managment problem in Michigan.

Results and Implications

This research is particularly applicable to municipalities with small-sized treatment plants and with available farmland in a close proximity. The sewage facilities in this study have little or no industrial inflows, so that the disturbing problem of heavy metals is largely avoided. In the surveyed communities, all the sludges are stabilized prior to land-spreading in order to control odors and pathogens.

The results of this study indicate that sludge utilization should receive serious consideration as a management alternative, especially for rural municipalities. The sludge recycling concept has been encouraged in federal legislation. State and local authorities have also taken an initiative in developing sludge application programs. Farmland application has been shown to be technically beneficial as a soil amendment and a fertilizer source for crop growth when proper management practices are employed. There are also some important results from the surveys conducted on the participating farmers and sewage treatment plant operators. With reference to the contractual arrangments, most of the surveyed utilization programs operated under verbal or "handshake" agreements. The advantages of such loosely structured arrangments are the flexibility of the program, the allowance for trial periods and the foundation for more permanent plans. The weakness of an informal agreement is the greater chance for misunderstood or non-binding contractual terms. Written agreements can formally specify the rights and responsibilities of either party for monitoring and cultural practices. Such details of a utilization program are more easily overlooked in a verbal contract. The informal arrangments also exhibited a noticeable dichotomy in the degree of program organization. Either a sludge utilization plan was well designed to include technical practices and contractual arrangments or the program was too loosely structured and lacking in monitoring and cultural techniques. The incentives to comply with these minimum standards were influenced by the participation of interested third parties. The various interest groups could be differentiated by their roles in advising, regulating or opposing the utilization programs. Local opinion, state officials, health and extension personnel and consulting firms contributed in varying degrees by pressuring for better-run programs. The influence of these third parties, or the lack of it, did make a difference in the operation of the programs.

A majority of the surveyed municipalities were applying all of their sludge production to agricultural lands. In addition, about seventy-five percent of the plant operators planned to continue utilization as a viable future program. The interviewed farmers reported higher yields and improvements in soil quality. But little hard quantitative evidence on the sludge use benefits was available. When questioned about their evaluation of the future prospects for utilizing sludge, about seventy percent of the farmers expressed a preference for continuing participation in the programs.

The results of the representative case studies on the costs of utilization indicate that air-dried sludges are the cheapest alternative in an expenditure sense for municipalities. But the prevalence and trend towards the use of liquid sludges in application programs suggests otherwise. Air-drying beds have hidden costs in terms of physical handleability and variable drying capacity. Liquid sludge utilization is physically easier to employ, and current transport costs are not prohibitively high. But as the relative cost of energy continues to rise, incentives may develop for municipalities to decrease the costs of hauling the larger volumes of liquid sludges.

The costs to the farmer varied mostly with the contractual terms. The acceptance of responsibility by the farmer for any or all of the transport, application and incorporation activities directly affects his expenditure. The farmer would need to estimate the value of reduced fertilizer costs or increased crop yields in order to determine economic desirability of incurring utilization costs.

The conclusions have meaning for both rural municipalities and farmers. From an overall perspective, farmland utilization deserves attention from municipalities as a means for managing sewage sludges. Landspreading also merits consideration from farmers who are interested in alternative nutrient sources and soil improvement. But if utilization is chosen as the mode of sludge disposal by the community, then certain technical and institutional arrangements should be implemented to ensure the success of the program. For instance, proper testing practices and explicit utilization contracts can promote the benefical aspects of applying sludges to land while minimizing costly errors. The utilization agreement should be structured so that the participants have incentives to comply with technical standards and the contractual terms. Also, a public relations effort may be a crucial part of a workable program.

Municipalities have expressed the need for more information on the economic costs and social aspects of various sludge disposal alternatives. Educational workshops, bulletins and seminars may be one way of distributing knowledge to communities who desire to improve existing programs or to start implementation of new plans.

Areas of Future Research

The aim of this thesis has been to examine farmland application as one sludge management alternative for disposal. Further studies, based on the emerging knowledge of crop responses to sludge applications, are needed to estimate the benefits of utilization for farmers. Municipalities need research to establish the cost-effective (or least cost) methods of sludge disposal under varying conditions. Another area of concern is the effect of changes in fuel, labor and capital costs on the competitive advantage of the disposal strategies. Budgeting and programming techniques can be used to estimate the relative costs of different alternatives in a dynamic framework.

APPENDICES

APPENDIX A

AGREEMENT BETWEEN CITY OF BAD AXE AND HURON COUNTY FARMERS FOR DISPOSING OF STABILIZED SEWAGE SLUDGES OF FARM LAND

GENERAL

WHEREAS, the City of Bad Axe is responsible for operation of the said City's sewage system; and

WHEREAS, the treatment process provides for removal of most of the organics and nutrients from the wastewater, and it ultimately develops a stabilized liquor in which the organics and nutrients have been concentrated; the liquor commonly referred to as sludge, must be ultimately disposed of in such a way that the organics and nutrients do not contaminate surface waters, by employing any of the traditional methods of such disposal including incineration, landfilling, placing on crop land and dumping at sea; and

WHEREAS, the value of sludges for crop land application has long been recognized due to the nutrient content and the favorable soil conditioning characteristics of sludges, allowing a reduction of commercial fertilizer usage in maintaining optimum soil fertility conditions; and

WHEREAS, the City of Bad Axe's Wastewater Treatment Plant is operating near capacity, and disposal of sludge can be performed economically by discharging onto crop land and thus be of benefit to both the City and the recipient of the sludge.

NOW, THEREFORE, BE IT AGREED BETWEEN THE CITY OF BAD AXE (PARTY OF THE FIRST PART), HIS AGENTS AND ______________ ______________________ FARMER AND (AND PARTY OF THE SECOND PART) PROPERTY OWNER, THAT:

THE CITY OF BAD AXE AGREES:

1) To provide sewage sludge and equipment necessary to inject liquid sludge onto tillable land on the premises of the above farmer.

2) To test sludge periodically for the presence of undesirable substance and to take reasonable steps to prevent discharge onto farmland any sludges exceeding recommended maximum levels of undesirable materials.

3) To keep appropriate records of sludge volumes supplied, maps of locations where applied and other pertinent data.

4) To work closely with the Huron County Office of the Michigan State University Cooperative Extension Service and through it receive appropriate scientific information and counsel from MSU, Department of Crop and Soil Sciences, that will enable the City of Bad Axe to:

A) Develop a management program to insure the environmental concerns are considered and to insure that the best interests of the farmer relating to these concerns are met.

B) Develop a cropping program agreeable to both parties and make sludge applications on the basis of the nutrient requirements of certain crops.

C) Develop a soil testing program and advise farmers on the proper amounts of supplemental commercial fertilizers that should be used to balance the crop nutrients requirements not completely supplied by the sludge applications.

D) Test soils for pH and for buildup of undesirable materials.

E) Test tissue cultures of crops for buildup of undesirable materials if such becomes desirable.

5) That all proceeds from sale of crops grown on land which has had sludge applied shall be the farmer's.

THE FARMER AGREES:

1) To cooperate as fully as possible with the City of Bad Axe in scheduling the discharge of sludge onto crop land.

2) To assume the liability should damage or crop loss occur as a result of sludge application.

3) To pickup sewage sludge at pre-arranged times suitable to both parties.

4) To spread the material onto the land to be treated with sludge in an uniform manner and at specified rates as described in item 6 below.

5) To apply sludge in such manner so as not to result in runoff of sludge to streams or to render fields unworkable due to excess moisture or to cause excessively deep rutting due to equipment movement.

6) To follow the recommendations of the County Extension Service and MSU, Department of Crop and Soil Sciences, with regard to application rates of supplemental commercial fertilizer and lime to be applied with regard to the crop that is planned. It is the intent of this paragraph that the cropping details and procedures be agreed to annually by both parties prior to the placing of sludge on the land.

7) To lime any fields to which sludge has been applied to pH indicated by soil tests any time the pH falls, liming, to be applied as soon as possible after discovery that the pH has fallen below desirable levels. The desirable pH levels shall be 6.5 to 7.0. This requirement will be valid for a three year period from the date of the last sludge application.

8) To allow persons representing the City of Bad Axe, the County Extension Service, MSU, Department of Crop and Soil Sciences, and the Michigan Department of Natural Resources, access to fields to which sludge has been applied at any reasonable time for testing of soils and any materials grown on the soils.

9) To construct at his own expense any runoff retention ponds and/or dikes to protect streams to control runoff and erosion of sludge constituents, if agreed to by both parties prior to further sludge application. If it is determined that runoff from any certain field must be controlled prior to further sludge applications and

the farmer refuses, no more sludge will be allowed to be applied to that field.

10) That if he should sell his land he will advise the purchaser of said land that sludge has been applied to it for cropping purposes, and that paragraph 7 above, concerning maintenance of soil pH, and paragraph 8 concerning access, will be made a stipulation of said title transfer, provided that this item looses its legal binding force three years following the last sludge application.

11) To not use land to which sludge has been applied for growing crops for direct human raw consumption within one year of the time sludge has been applied.

12) To maintain in adequate operating condition all equipment necessary to properly handle sludges.

EXTENT OF AGREEMENT

The terms of this agreement shall be binding upon the heirs, executors, administrators and assigns of the City of Bad Axe, the Farmer, and any tenants using the land in a like manner as upon the original parties.

If the land is sublet at any time during the agreement period, or sublet prior to the date of this agreement so that the period of the lease overlaps any portion of the period of this agreement, all the above terms of the agreement will apply to the lessee as well as the owner - farmer.

It is mutually understood and agreed that no one will be coerced by the terms of this agreement to put sludge on his property against his will, nor will be coerced to take such material at any time against his will.

The term of this Agreement shall be two (2) years from November 3, 1975 to November 3, 1977. This Agreement shall continue in effect from year to year thereafter until written notice of termination is given by either party on or before the 1st day of October of any year after expiration of this Agreement.

SPECIAL PROVISIONS

It is further understood by the parties hereto that the farmer shall provide a sealed tank truck for transporting and will furnish liability coverage on same in case of spill.

In case of spill within the City of Bad Axe, the City will provide the necessary fire equipment to flush streets of spillage.

In case of spill outside of the City of Bad Axe, a joint effort will be made by the parties herto to contain sludge from spreading and said farmer will vacuum up with a spreader unit as soon as possible.

The farmer will be reimbursed by the City of Bad Axe for fuel costs at the rate of $2.00 per 1,000 gallon of sludge transported. Should fuel cost increase or decrease, this figure may be negotiated at any time upon written request of either the farmer or the City of Bad Axe.

HEREBY CERTIFIED AND AGREED TO:

FARMER

____

OWNER

____

OWNER

____

LESSEE (IF ANY)

____

LESSEE (IF ANY)

CITY OF BAD AXE

____

MAYOR, CITY OF BAD AXE

DATE: ________________________

APPENDIX B

DEPARTMENT OF AGRICULTURAL ECONOMICS
MICHIGAN STATE UNIVERSITY
EAST LANSING, MI 48824

MICHIGAN SURVEY OF SLUDGE UTILIZATION ON FARMLAND-MUNICIPALITIES

1. Is your treatment plant currently disposing of any sludges on privately-owned farmlands?

   Yes_____ No_____

   a. Which of the following land application alternatives (if any) are also being used for sludge disposal?

      1. airport land ______________
      2. forest land ______________
      3. publicly-owned farm land ______________
      4. other (please specify) ______________

   b. If you answered "yes" to question one, please complete the rest of this questionnaire.

   c. If you answered "no" to question one, then this questionnaire is completed. Please place the questionnaire in the enclosed envelope for mailing. Thank you for your cooperation.

2. What percentage of the total sludge production is applied to farmland?_________%

   a. What quantity is this?_______dry tons/day

      If dry tons/day not known, please specify units (e.g., gallons/week)

3. What method is utilized to stabilize the sludges? Check one or more of the following:

   a. aerobic digestion ______________
   b. anaerobic digestion ______________
   c. chemical treatment ______________
   d. heat stabilization ______________

e. heat drying ______________

f. other (please specify) ___________________________

4. What are the sludge characteristics?

<u>Nutrient values</u> (percent)*

Nitrogen _________

Phosphorus _________

Potassium _________

<u>Physical characteristics</u>

% volatile solids _______

% Total solids _______

<u>Heavy metal content</u> (parts per million)*

Lead _________

Zinc _________

Cadmium _________

Copper ___________

Nickel ___________

Chromium ___________

Other ___________

(specify) ________

5. What type of transportation equipment is being used to get the sludge to the application site?

____

____

____

a. Does the treatment plant own the equipment?

Yes _________ No _________

6. How much does the transportation equipment cost?

Equipment	Initial Cost
__________________________	_________________________
__________________________	_________________________

*On a dry solids basis.

a. Is there any difference between the transportation equipment and application equipment?

Yes_________ No__________

If yes, briefly describe the difference:__________

____

7. Who pays for the transportation equipment?

a. Municipality____________

If the municipality pays for the equipment, is the origin of funds:

1. Local tax base___________

2. State funds ___________

3. Federal funds ___________

b. Does the farmer supply his own application equipment?

Yes_________ No_________

8. What is the average distance that the sludge is transported?

______________ 1 to 5 miles

______________ 6 to 10 miles

______________ 11 to 15 miles

______________ greater than 15 miles

a. Is there a charge to the farmer for transporting the sludge?

Yes_________ No_________

b. If yes, is the charge

1. flat rate_______

2. per mile _______

c. What is the rate or charge?_________________________

9. How was the farm(s) selected as a sludge utilization site?

____

____

____

10. If the soils were analyzed, which tests were run? (check one or more)

Available nutrients (N, P, K, Ca, Mg)____________

Soil pH; include value if known ____________

Soil organic matter; include % if known ____________

Soil cation exchange capacity; include value if known

____

11. What are the application rates for the sludges?

__________ ____________ dry tons/acre
or
__________ ____________ wet tons/acre plus % total solids

12. Have any provisions been made to maintain a soil pH of 6.5 with the sludge application program?

Yes________ No________ Don't know________

13. Are there monitoring and testing procedures for:

a. ground water Yes________ No________

b. surface water Yes________ No________

c. How often are monitoring and testing procedures used?

______________(e.g., times/year)

14. Were any state agencies, such as the Department of Natural Resources, contacted or consulted for the sludge application program?

    Yes_________ No_________

    a. If yes, what agencies?___________________________

    ____

    b. Was the local Extension Director contacted?

       Yes_________ No_________

15. Was the county health department contacted or consulted for the sludge application program?

    Yes_________ No_________

    a. If yes, do they approve of this sludge management alternative?

       Yes_________ No_________

       If not, why are they opposed?________________________

       ____

    b. If yes, is the county health sanitarian approving each land application site?

       Yes_________ No_________

       Does he approve the total program?

       Yes_________ No_________

16. Is there a written contract between the municipality and the farmer for the land application of sludge?

    Yes_________ No_________

    a. If yes, please specify the major responsibilities of each party. Also, please enclose a xerox copy of the contract, if it is available.

       ____

       ____

       ____

17. Is there a contract with a private firm for sludge removal and transport?

    Yes__________ No__________

18. Are the application sites suitable for expansion of the sludge utilization program?

    Yes__________ No__________

    a. If yes, has additional stand-by acreage been identified for unanticipated needs to insure long-term viability of this alternative?

       Yes__________ No__________

19. Has there been any local opposition to the application of sludges to farmlands?

    Yes__________ No__________

    a. If yes, did the Cooperative Extension Service assist in informing the general public about this sludge management alternative?

       Yes__________ No__________

20. If there are any special problems with sludge application to farmlands in your municipality, briefly describe them below:

    ____

    ____

    ____

    ____

21. Name of Municipality______________________________

Thank you for your cooperation. Please place the questionnaire in the enclosed envelope for mailing.

APPENDIX C

DEPARTMENT OF AGRICULTURAL ECONOMICS
MICHIGAN STATE UNIVERSITY
EAST LANSING, MI 48824

CONFIDENTIAL: For Research Purposes Only

MICHIGAN SURVEY OF SLUDGE UTILIZATION ON FARMLAND - FARMERS

Your Name:____(Optional)

Address: ____

1. Have you used stabilized sludge from wastewater treatment plants as a soil conditioner fertilizer on your farmland?

   ( ) Yes
   ( ) No

   a. Have you used raw sewage sludge, as opposed to the treated stabilized sludge, on your farmland for fertilizer purposes?

      ( ) Yes
      ( ) No

If you answered No *to questions 1 and 1 (a), then this questionnaire if completed. Thank you for your cooperation.*

If you answered Yes *to either questions 1 or 1(a), please complete the rest of this survey.*

2. How many years have you used sludge on your land?

   ______________Years

3. Which municipality(ies) is(are) the source(s) of this sludge?__________________________________

   a. Have you considered other sources of sludge?

      ( ) Yes ( ) No

4. Did you have a written contract with the municipality for accepting the sewage sludge on your farmland?

   ( ) Yes ( ) No

   a. If you answered Yes to question 4, what management practices did you agree to undertake as part of of sludge use program?

      ____

      ____

      ____

   b. If you answered Yes to question 4, did the contract require you to accept a certain amount of sludge?

      ( ) Yes ( ) No

      Also, did the contract specify the time of year for spreading the sludges?

      ( ) Yes ( ) No

5. Are you spreading liquid-form sludges or sludge filter cake on your fields?

   ( ) Liquid sludge

   ( ) "Dry" filter cake sludge

   a. If you are spreading liquid sludge, are you:

      ( ) Injecting sludges into the soil

      ( ) Applying onto the soil surface

6. If you are applying sludge on the surface of the soil (liquid or cake), how long after the application is the sludge actually incorporated (or tilled) into the soil?

   ( ) Usually immediately after application or on the same day

   ( ) Two to six days after application

   ( ) One to two weeks after application

   ( ) More than two weeks after application

7. Did you apply the sludges with your own equipment?

   ( ) Yes ( ) No

   a. If you answered No to question 7, did the municipality transport and apply the sludges to your farmland?

      ( ) Yes ( ) No

   b. If you are using your own equipment, did the municipality pay you for taking and spreading the sludge?

      ( ) Yes ( ) No

      If you were paid, what was the rate that they paid you? (For instance, did they pay you per ton of sludge on per acre spread over your farm?)

      ____

   c. If you are using your own equipment, what type did you use and what were the additional costs to you? (That is, did you purchase some equipment especially for spreading the sludges?)

Equipment	Cost
____________________	____________
____________________	____________
____________________	____________

   d. If you do not use your own equipment for spreading the sludge, and the municipality does not apply the sludge, then who performs this service?

      ( ) Private contractor

      ( ) Other (Please specify:__________________________)

8. If the municipality owns the equipment to transport and apply the sludges to your farmland, did you have to pay for the costs of transporting the sludges?

   ( ) Yes ( ) No

   a. If you answered Yes to question 8, was there a charge on a per mile basis?

      ( ) Yes ( ) No

b. What was the rate charged? (Per mile, per gallon, per cubic yard, etc.)

____

9. What other cost sharing arrangements did you have with the municipality (if any) besides sharing equipment?

____

____

____

a. Are you happy with the cost-sharing arrangements that you have with the municipality?

( ) Yes ( ) No

If not, what arrangements would have been more preferable? ______________________________

____

____

10. Do you have storage capacity on your land for holding sludges until they are applied to your farmland?

( ) Yes ( ) No

a. If you do have storage capacity, how is the sludge stored? (For example, storage tanks, compost piles, etc.)

____

____

11. What farmland was used for the sludge application? (Type of soil, crops grown, crop rotations, etc.)

____

____

____

a. Has there been any increase in crop yields?

( ) Yes ( ) No

b. Please explain any effect on yields.

____

____

____

c. What was the application rate of sludges on your farmland? Please choose the unit of measurement that applies to your program.

____________________ dry tons/acre

____________________ wet tons/acre

____________________ cubic yards/acre

____________________ gallons/acre

____________________ (   ) please specify

d. If it is known, what is the approximate moisture content of the sludge?

________________% moisture

12. Are you reducing fertilizer usage where sludges are applied?

( ) Yes ( ) No

a. If you answered Yes to question 12, what was you basis for the reduction, that is, how much nitrogen, phosphorus, and potassium were you expecting from the sludge?

____

____

b. Were these amounts of nutrients based on a sludge analysis?

( ) Yes ( ) No

13. Were there any testing or monitoring procedures conducted with the sludge application program?

( ) Yes ( ) No

a. If you answered Yes to question 13, please check which of the following were used?

( ) Soil fertility tests

( ) Sludge samples analyzed for plant nutrients (N, P, K)

( ) Sludge samples analyzed for heavy metals

( ) Other (Please specify)____________________

b. In relation to these tests, did you have to make any special contacts or receive a clearance for using the sludges?

( ) Yes ( ) No

c. Where did you get your information and advice for correctly using sludges on your land? Check one or more of the following:

( ) Agricultural Extension Director

( ) Wastewater Treatment Plant Operator

( ) Officials from Michigan Department of Natural Resources

( ) Department of Crop and Soil Sciences, Michigan State University

( ) Other (Please specify)____________________

d. Were you advised of the maximum heavy metal loadings that could be made to your fields from sludge applications?

( ) Yes ( ) No

If you were so advised, is the municipality keeping a record of the annual heavy metal loadings to your fields?

( ) Yes ( ) No

14. As part of your commitment to the sludge application program, were you asked to maintain a soil pH at 6.5?

( ) Yes ( ) No

15. Did you encounter any opposition from your neighbors due to the sludge application program?

( ) Yes ( ) No

16. Did you have any problems with local zoning laws due to the sludge application?

( ) Yes ( ) No

17. Do you have any future plans for applying sludges to your land?

( ) Yes ( ) No

18. Do you plan to have sludge applied to your land on a continuous annual basis?

( ) Yes ( ) No

19. When are the sludges applied to your land? Please check one or more of the following:

( ) January	( ) May	( ) September
( ) February	( ) June	( ) October
( ) March	( ) July	( ) November
( ) April	( ) August	( ) December

a. When are the sludges incorporated in the soil?

20. Do you plan to expand your use of sludges on your farm-land?

( ) Yes ( ) No

a. If you answered Yes, where would it be applied? (Type of soil and crops)

____

____

____

21. Are there other farmers in your area who are planning to use or thinking about using sludges on their land as a result of your experience?

( ) Yes ( ) No

22. If you have had any specific problems or suggestions with applying sewage sludges on your land, briefly describe them below:

Thank you for your cooperation!

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BIBLIOGRAPHY

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