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ALTERNATIVES FOR MANAGING WASTEWATER FOR CLEVELAND - AKRON METR--ETC(U)
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ALTERNATIVES FOR MANAGING WASTEWATER

FOR CLEVELAND — AKRON METROPOLITAN AND THREE RIVERS WATERSHED AREAS.

SUMMARY REP[redacted]T.

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75p.

A FEASIBILITY STUDY

PREPARED BY THE

BUFFALO DISTRICT OF

THE U. S. ARMY CORPS OF ENGINEERS

IN COOPERATION WITH

REGION V OF THE ENVIRONMENTAL PROTECTION AGENCY

AND

THE STATE OF OHIO

ALTERNATIVES FOR

MANAGING WASTEWATER

IN

CLEVELAND-AKRON METROPOLITAN

AND

THREE RIVERS WATERSHED AREAS

SUMMARY REPORT

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NON-TECHNICAL GLOSSARY OF TERMS

Activated Sludge - a process by which organisms such as bacteria remove organic matter.

Adsorption - adherence of dissolved or finely divided solids on surfaces of solid material such as carbon.

Advanced Treatment - processes following secondary treatment which tend to remove the last traces of BOD and suspended solids.

Aerobic - conditions in which oxygen is present.

Amenity - the attractiveness and aesthetic, or non-monetary, value of things.

Anaerobic - condition in which oxygen is absent.

Biochemical Oxygen Demand (BOD) - amount of oxygen needed by organisms while consuming organic material in water.

Chemical Oxygen Demand (COD) - amount of oxygen used in the chemical oxidation of organic matter.

Coagulation - collecting colloidal or finely divided suspended matter by chemical means in order to produce a settleable mass.

Coliform - group of bacteria, predominantly inhabitants of the human intestine.

Compatible Industrial Waste - industrial wastes that can be treated along with domestic wastewater without adversely affecting biological treatment processes. Antonym - non-compatible.

Denitrification - removal of nitrates in wastewater by biological means.

Detritus - relatively heavy inorganic and organic settleable solids.

Dissolved Solids - solids which are present in solution.

Domestic Wastewater - water-carried waste from household drains.

Ecology - science of relationships between organisms and their environment.

Ecosystem - the combination of organisms and their environment.

Effluent - wastewater discharge from a point source.

Environment - the surroundings of an organism which influence it and which are influenced by the organism.

Eutrophication - process of progressively becoming richer in dissolved nutrients. Nuisance growths of algae and aquatic weeds are produced.

Evapo-transpiration - the process through which water is returned to the atmosphere as a vapor, either after having been evaporated from a surface or after having been transpired, or expelled, by a biological organism.

Flocculation - collecting precipitated materials into a settleable mass.

Flotation Unit - a tank in which materials lighter than water rise to the surface and are skimmed off.

Grit - heavy inorganic settleable solids.

Hypolimnion - the uniformly cold and deep layer of a lake that is thermally stratified during summer.

Industrial Wastewater - water-carried waste from manufacturing establishments.

Iterative Process - one in which evaluation causes modifications to be made. The modified alternative is again evaluated and altered. The process is repeated until an alternative evolves.

Lagoon - man-made lakes or ponds in which biological organisms decompose wastewater. Aerated lagoon - one in which processes are aerobic.

Land Disposal System - system in which wastewaters are applied to land for treatment using a number of possible methods.

Mixed Media Filtration - process for removing solids from liquid by a straining process using a mixture of sands.

Municipal Wastewater - combination of domestic, industrial, and commercial wastewaters collected in a municipal system.

Nitrification - oxidation of ammonia nitrogen into nitrates through biological action.

Nutrient Removal - processes which remove materials that serve as fertilizer to aquatic plants.

Pathogenic - disease producing.

Percolation - downward flow of liquids through soils.

Percolating Basin - bed of sand and gravel that filters suspended solids and removes nitrogen by biological activity.

pH - a qualitative means of expressing acidity and alkalinity on a scale of 0 to 14. Numbers less than 7 indicate an acid condition, 7 is neutral, numbers greater than 7 indicate an alkaline condition.

Primary Treatment - settling tanks and flotation units remove solids, some suspended solids and associated BOD.

Secondary Treatment - removal of dissolved organic solids, some suspended solids and nutrients by biological means.

Settleable Solids - suspended solids which will settle in still water usually within an hour. Antonym - non-settleable.

Settling Tank - tank in which water containing settleable solids is retained for sufficient time to remove by gravity a part of the suspended matter. Also sedimentation tank.

Sludge - the accumulated solids deposited from sewage or industrial wastes in tanks or basins, containing enough water to form a semi-liquid mass.

Suspended Solids - the solid material held in suspension in wastewater.

Tertiary Treatment - See Advanced Treatment.

Underdrains - Porous drain tiles placed under soil or sand to collect filtered water.

Unit Process - one of a coordinated series of steps used to treat wastewater.

Water Disposal System - system in which wastewaters are treated in plants. The purified effluent is usually released into receiving waters.

I - INTRODUCTION

This study developed a number of alternative approaches for the management of wastewaters in the Cleveland-Akron Metropolitan and Three Rivers Watershed Areas, in Northeast Ohio and assessed their feasibility. It is one of five such regional studies combining the technical and planning capabilities of the Environmental Protection Agency (EPA) and the Corps of Engineers. The area was selected for study because of its relationship to environmental changes in the Great Lakes. Early management of wastewaters in this region is expected to lead to early improvements in the quality of Lake Erie. Furthermore, the concepts developed in this study will provide a base for solving wastewater problems in other important source regions.

The contaminated condition of Lake Erie and its tributaries, has been nationally publicized. Among the most prominent problems are bacterial contamination, premature eutrophication, and mercury pollution. Overall, large quantities of untreated wastes have been discharged, seriously degrading many of the tributary streams.

Problems such as these led the United States and Canada on 10 June 1971 to undertake to negotiate an agreement to control pollution of boundary waters. Their aim was to reach agreement by the end of the year on water quality criteria and standards and on the international organization to exercise control. Such recognition of the pollution problem will influence the respective governments to act in improving the quality of the contiguous waters.

In addition, the increasing demands being placed on this nation's critical water resources require their increased recycling and reuse. President Nixon stated the problem clearly when he presented to Congress the first report of the Council on Environmental Quality: "We can no longer afford the indiscriminate waste of our natural resources; neither should we accept as inevitable the mounting costs of waste removal. We must move increasingly toward closed systems that recycle what are now considered wastes back into useful and productive purposes."

Current efforts in water quality management appear to be unnecessarily limited in scope with an emphasis placed on conventional wastewater treatment methods. In the past 15 years, more than $6 billion have been spent for construction and improvement of sewage treatment facilities across the nation. Present plans call for doubling that amount in the next 3 years and undoubtedly even more will be spent in the future. Future programs must encourage the most effective use of these funds.

Regulations published on 2 July 1970 require that any municipal waste treatment facilities or interceptor sewer projects receiving grant support under Section 8 of the Federal Water Pollution Control Act must be included in a basin plan and, when necessary, a metropolitan regional plan. The States are developing water quality management plans to comply with these current regulations. These basin and metropolitan regional plans will provide systematic and coordinated development of measures to protect and enhance the quality of waters of each specific area.

This feasibility study is designed to reinforce the efforts of the EPA, the State of Ohio, and local jurisdictions to develop long range strategies which will go beyond the time period required by current regulations dealing with grants for water pollution control, and to explore alternatives that may not have been considered in the current plans.

There is a need to develop wastewater management alternatives to complement and expand currently employed local pollution abatement programs. The approach must be regional in nature, free of restraints imposed by political boundaries, adaptable to local financing capabilities and phased into existing programs.

The approach must be aimed toward the highest achievable levels of wastewater collection and treatment. Coordination and centralization of the many pollution control efforts, and management of all phases of water resources are essential. And, it must evaluate a full range of alternative solutions, assessing not only techniques of wastewater disposal but also the value of wastewater as a resource in meeting public, agricultural, and industrial needs.

Nature and Scope of the Study

The nature of the feasibility study was primarily exploratory. Problems were initially defined and a variety of alternatives were proposed for further, more detailed study. In carrying out this study it was first necessary to discover the magnitude of pollution problems in the region, the sources of pollution and how much was contributed by each source. Future conditions from now to the year 2020 were projected. Concurrently, a wide variety of alternatives to solve the problems were developed. These included, among others, conventional methods of treatment with disposal of the treated effluent to streams and lakes, specialized techniques for nutrient removal, and techniques of land treatment, such as filtration and spray irrigation. Those which were judged representative of the techniques were selected for more detailed evaluation. The evaluation process involved predicting the changes which these alternatives would have on the environment, the general health and well-being, and the economy of the region. Finally, the strategies were analyzed for flexibility, completeness, effectiveness and institutional realism.

In making the study, views of local interests and the public were sought and included. From its earliest stages this study has been coordinated through representatives of State and regional agencies. Their previous studies have provided the base on which possible comprehensive programs have been investigated. Representatives of the Ohio Departments of Natural Resources and Health, the Three Rivers Watershed District and the Cleveland Department of Utilities have attended the staff monitoring sessions and a larger number have received drafts of interim portions of this study. They have been encouraged to provide an input to the study as it progressed and comments on the content as it developed. Approximately 80 persons attended a public information meeting on 8 July 1971 which outlined the study procedures and described the selected alternatives. As the studies progress, the role of local governments will be substantially expanded. Opportunities will be provided for participation by the general public through contact with other organizations and additional public meetings.

Section II of this report describes the study area and its present and projected pollution problems. Section III presents the representative alternatives selected for evaluation. Section IV describes the changes, both good and bad, which might be expected from each alternative. Discussion of the findings and conclusions are developed in Sections V and VI. Three Appendices contain the detailed information on which this Summary Report is based. Where necessary these Appendices are referenced in this report.

Havens and Emerson, Ltd., Consulting Engineers, Cleveland, Ohio, studied current conditions, projected future needs, and developed alternative solutions on which Sections II and III are based. Battelle Memorial Institute, Columbus, Ohio, assessed and evaluated the effects of the different approaches, as described in Section IV.

Authorization

This report is submitted as an initial interim response to Section 102 of the River and Harbor Act of 1966 (Public Law 89-789, approved 7 November 1966), which authorized and directed the Secretary of the Army "to cause surveys to be made at the following named localities and subject to all applicable provisions of Section 110 of the River and Harbor Act of 1950: ...Great Lakes, particularly Lake Ontario and Lake Erie, in connection with water supply, pollution abatement, navigation, flood control, hydroelectric power, and related water resources development and control."

II - THE STUDY AREA TODAY AND IN THE FUTURE

Statement of the Problem

According to preliminary results of the 1970 census, the population of the Cleveland-Akron area was 2,420,000. The region is highly industrialized with nearly 5,000 factories and plants. Pollution control and water resource management are among the most crucial problems of large metropolitan areas.

The pattern of development of wastewater disposal facilities in this area has been typical of growing metropolitan and suburban areas. Many of the municipalities have extended their old sewer systems far beyond the corporate boundaries to serve additional areas, thus overloading both sewers and treatment plants. The old practice of combining storm and sanitary sewers results in overflows of raw sewage directly into waterways. Some residential and business developments have been constructed with small "package" treatment plants which are seldom properly maintained and operated. In unsewered areas individual septic tanks have been installed, often in poorly drained soils. These may be inadequate and contribute to the pollution of local drainage courses. When the quality of the receiving water becomes intolerable, the responsible governmental agency takes steps to install a local treatment plant. As the area develops, the cycle repeats itself, resulting in a proliferation of small treatment plants, many of which are in some stage of construction or enlargement. Few of these can produce quality effluents as economically or consistently as large plants.

The central cities of Cleveland and Akron have long-standing pollution problems. Improvement of treatment facilities has not kept pace with growth, and the major treatment plants are only now being enlarged and improved. The Cleveland combined sewer system contains at least 530 sewer overflows which discharge raw sewage to the waterways during periods of storm flow. Similar discharges occur in Akron and many of the suburban areas.

Description of the Study Area

The Three Rivers Watershed Basin, shown in Figure 1, consists of three river systems, the Chagrin, the Cuyahoga and the Rocky. In addition there are several small streams which drain directly into Lake Erie. The headwaters of the main rivers lie along the St. Lawrence-Mississippi divide, and flow generally northward to Lake Erie. Elevations range from 1300 feet inland to 570 feet above sea level at Lake Erie. The rivers flow through areas of unconsolidated surficial glacial deposits and have relatively well-defined and deep valleys in their lower reaches. Much of the upland soils were deposited by glacial action and have silt or clay loam textures with slow internal drainage. Coarser soils exist in relatively few locations, such as flood plains, glacial outwashes, and ancient lake beds.

Some 22% of the area's 1500 square miles can be classified as urban, and 38% as farmland. The remaining 40% is rural, non-farmland. Cleveland, with a population of 750,900, is the largest urban center in Ohio, one of the nation's largest industrial cities and one of the largest Great Lakes ports. Industrial products manufactured in the area include steel, automotive products, machine tools, petroleum products, chemicals, rubber goods and wearing apparel. Akron, population 273,000, is a major tire and rubber center.

Dairy farming is a principal agricultural activity. General farm crops include timothy and clover hay, oats, corn, wheat and potatoes. Fruit and nursery stock are grown in the northern part of the region. Food processing is important.

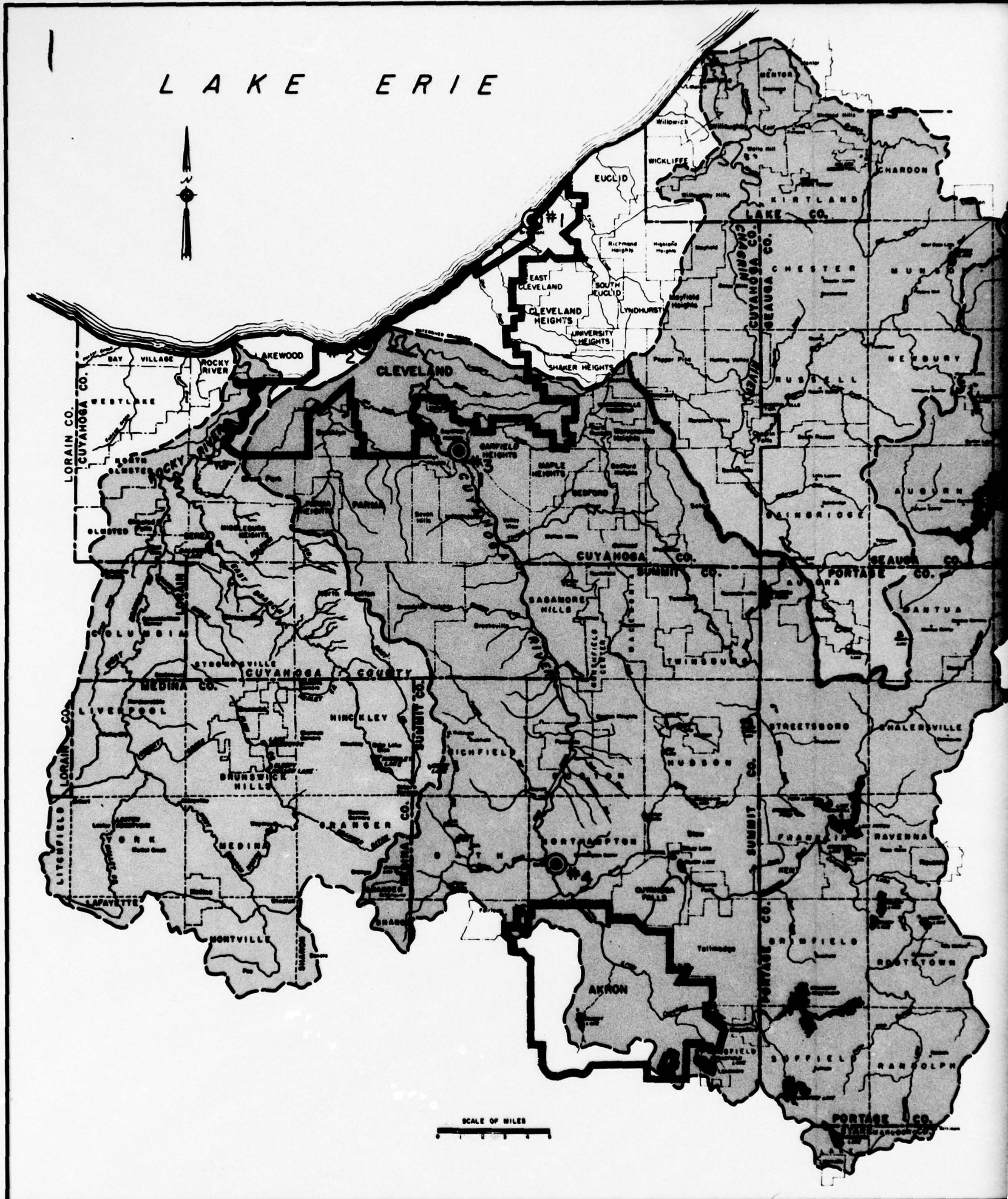
Average annual precipitation ranges from 31 to 46 inches and averages 37 inches. Monthly mean temperatures range from 27^{o} to 75^{o} Fahrenheit with an average of 49^{o} Fahrenheit. Mean temperatures above freezing occur during the period of March through November.

<u>Current Wastewater Problems</u>

Wastes collected in the municipal systems constitute the largest single source of wastewaters within the area. Most are inadequately treated. The 122 treatment plants, each with a capacity greater than 20,000 gallons per day (gpd), discharge as treated effluent about 118,000 pounds per day (lb/day) of biochemical oxygen demand (BOD) and 140,000 lb/day of suspended solids (SS). Effluent flow is approximately 380 million gallons per day (MGD). Of those plants, 5 discharge their effluent directly into Lake Erie, accounting for about one-half the load, 21 into Rocky River, 23 into Chagrin River, and 73 into the Cuyahoga River. Backwash sludges from water filtration plants add significantly to the pollution loads in several areas.

An inventory of industrial waste loads indicated that a wide variety of constituents were present, including heat, acids, alkalies, toxic materials, radioactivity, and organic chemicals. The treatment provided varies, although the most common process is settling. Little of this industrial effluent is adequately treated before discharge.

The 7-mile reach of the Cuyahoga River above its mouth experiences especially concentrated and severe pollution problems.


LAKE ERIE
EUCLID
WICKLIFFE
MENTOR
CHARDON
KIRTLAND
LAKE CO.
EAST CLEVELAND
CLEVELAND HEIGHTS
SOUTH EUCLID
LYNDHURST
UNIVERSITY HEIGHTS
SHAKER HEIGHTS
CHESTER
NEWBURY
RUSSELL
AUBURN
BAINBRIDGE
LAKEWOOD
ROCKY RIVER
BAY VILLAGE
WESTLAKE
CLEVELAND
GARFIELD HEIGHTS
MAPLE HEIGHTS
PARMA
LORAIN CO.
CUYAHOGA CO.
CUYAHOGA CO.
SUMMIT CO.
GEAUGA CO.
PORTAGE CO.
MANTUA
COLUMBIA
STRONGSVILLE
CUYAHOGA COUNTY
MEDINA CO.
LIVERPOOL
HINCKLEY
RICHFIELD
HUDSON
STREETSBORO
SHALERSVILLE
BRUNSWICK HILLS
GRANGER
NORTHAMPTON
FRANKLIN
RAVENNA
LITCHFIELD
YORK
MEDINA
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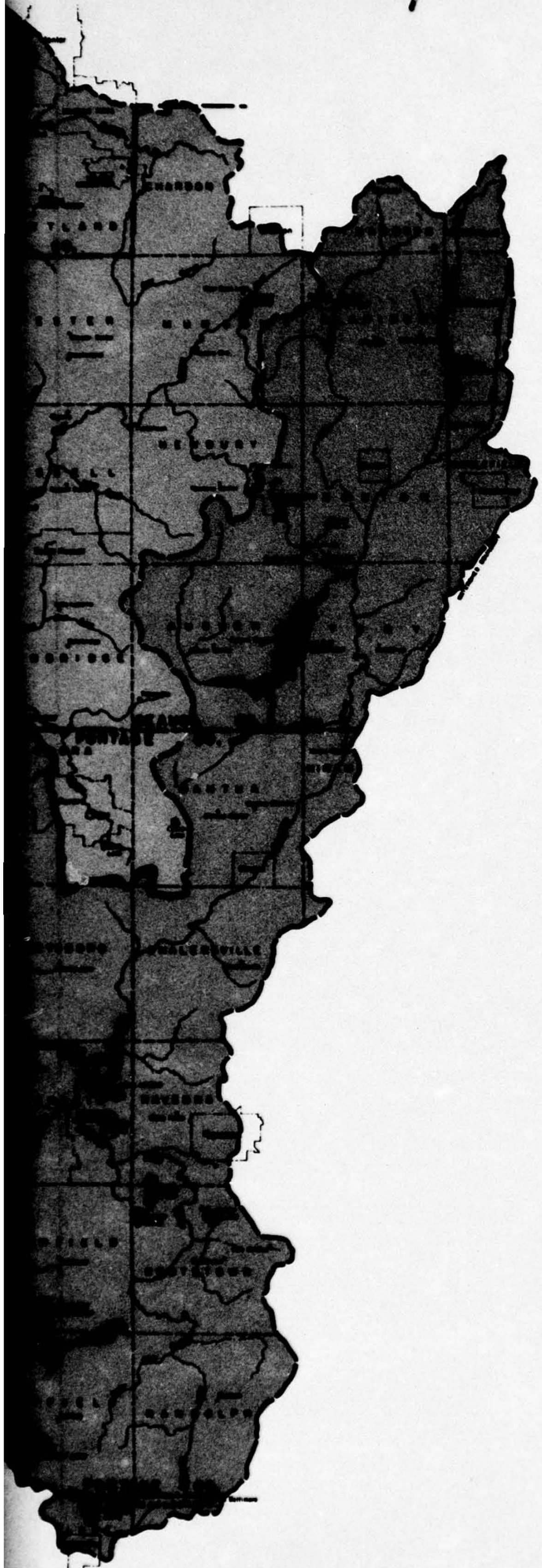
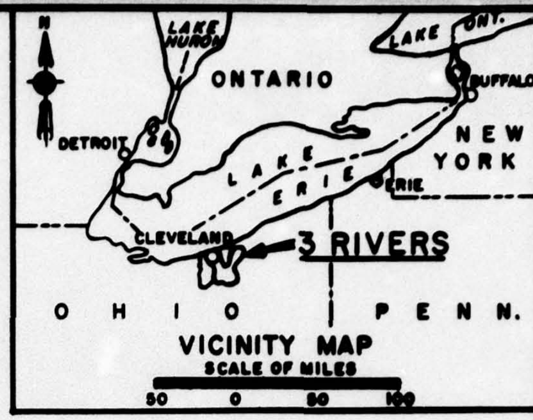




LEGEND:

◉ WASTEWATER TREATMENT PLANTS

- #1 CLEVELAND EASTERLY PLANT
- #2 CLEVELAND WESTERLY PLANT
- #3 CLEVELAND SOUTHERLY PLANT
- #4 AKRON PLANT

FEASIBILITY STUDY

WASTEWATER MANAGEMENT PROGRAM

STUDY AREA

U. S. ARMY ENGINEER DISTRICT, BUFFALO

JULY 1971

FIGURE 1

Total oxygen demand has recently been estimated at about 500,000 lbs/day. Temperatures exceed 95° Fahrenheit and dissolved oxygen approaches zero during critical low flow periods. Floating oil, scum, and debris are evident. Although industrial firms have reduced discharges of raw wastes within the past two years, substantial quantities are still being discharged, including ammonia, phenols, cyanides, pickling liquors, acids, heavy metals, plating wastes, oil, unoxidized iron compounds, solids, paint residues and solvents.

Another significant source of pollution is runoff from precipitation. Runoff can be analyzed in two categories: the average sustained flow from streams and drains which occurs in dry weather or from normal low intensity precipitation, and intermittent high flows from infrequent intense storms.

Runoff contributes large pollutant loads, particularly of suspended solids and chlorides. A storm occurring on the average of once a year would contribute 14 billion gallons of flow. The first flush of storm runoff may provide relatively large quantities of organic nutrient and high BOD loadings. Average sustained flows provide especially high loads of suspended solids and chlorides. The latter constituent may pose health hazards when concentrated in water supplies and, at present, is relatively costly and difficult to treat.

A number of important constituents originating from domestic, industrial, and average sustained runoff are summarized in Table 1 shown on page 12. These loads are the quantities of pollutants produced in the study area which must be treated.

Current Institutional Arrangements

Three major classes of agencies provide wastewater treatment in Northeast Ohio: local cities under the constitutional home rule right, county sanitary engineering departments, and the Ohio Water Development Authority. Communities may decide upon suitable methods of wastewater treatment and provide this treatment individually or with other municipalities. Counties can set up sewer districts or can contract with municipalities to provide wastewater treatment service. The Water Development Authority so far has acted principally as a financing agency. However, under Ohio law, the Authority has the right to operate and maintain facilities as well. The law also permits the formation of Water and Sewer Districts.

In addition to the local planning done by each agency that treats wastewater within the area, there are other agencies that provide overall regional planning for all or part of the study area. These are the Ohio Department of Natural Resources; the

Three Rivers Watershed District; the Regional Planning Commission, Cuyahoga County; and the Tri-County Planning Commission.

The "Water Pollution Control Act of Ohio," effective September 27, 1951, created a Water Pollution Control Board with broad powers to prevent, control, and abate pollution of the waters of the state. In order to discharge effluents, permits must be secured from the Board. The permit system is regarded as a mechanism which protects the waters of the state by making illegal any discharges that do not meet certain standards of quality.

Present Water Quality Standards

The Ohio Department of Health set minimum standards in 1967 which must be met by all waters everywhere in the State. There are specific requirements for water which is to be used for public, industrial, and agricultural water supplies; recreation; and aquatic life.

As minimum conditions, waters must be free from substances which form objectionable sludge deposits, produce color, odor or other conditions to a nuisance degree, or contain toxic concentrations or combinations of substances. These minimum conditions must be met everywhere and every reach of stream has additional criteria that must be met which are related to the most beneficial uses for that reach as established after public hearings.

For public water supplies the criteria are concerned with odor, content of solids, chemicals, radioactivity, and bacterial count. For instance, coliform counts must not exceed 5,000 per 100 milliliters (ml) as a monthly average. Water to be used for industrial supplies must have a temperature less than 95^{o} Fahrenheit and a pH between 5 and 9. The criteria also include minimum permissible concentrations of dissolved oxygen and maximum permissible concentrations of solids. Waters to be used for recreation must not have a coliform group count exceeding 1,000 per 100 ml as a monthly average. The aquatic life "A" standard is designed to maintain a well-balanced warmwater fish population, while the aquatic life "B" standard is directed toward maintaining desirable biological growths and permitting the passage of fish.

Comparison of Water Quality with Present Water Quality Standards

In general, Lake Erie and all of the major rivers and their tributaries within the study area contain pollutants to some degree. Failure to meet the established standards occurs with varying frequency and severity at different points within the watershed. In general, the headwaters and tributaries meet the required standards most of the time, while the lower reaches of the main rivers fail to meet criteria much of the time.

The Cuyahoga River above Lake Rockwell Dam is used as the principal water supply of the City of Akron. Downstream of Akron, the Cuyahoga becomes increasingly degraded, and the final 6-mile reach through the navigation channel in Cleveland's industrial valley is one of the nation's most severely polluted waterways.

The Chagrin River is used for recreation and as a source of municipal supply for the City of Willoughby. However, the area is growing rapidly and severe degradation of the river is expected unless extensive pollution control accompanies development.

The Rocky River is used for recreational purposes and as a source of water supply for the cities of Medina and Berea. However, BOD, phosphorous, and nitrogen levels, in particular, are high and potential for further degradation is great.

The inshore waters of Lake Erie within the Three Rivers Watershed Area are polluted by four major sources of discharge: polluted surface streams and drainage courses, combined sewer overflows, effluents from wastewater treatment plants and water entering the inshore zone from Cleveland Harbor. These inshore waters seldom meet standards for recreational waters.

Offshore waters in the study area approach quality of the water in the central basin of Lake Erie. Water quality generally meets the standards for all uses. However, periods of very low dissolved oxygen occur in the hypolimnion, and intermittent algae blooms attest to nutrient excess. Seasonal turnovers promote vertical circulation which causes cyclic deterioration in quality.

In December 1970, the Environmental Protection Agency warned Cleveland to halt alleged violations of water pollution standards within 180 days or face a possible suit by the Justice Department. The warning stated that the city was well behind the schedule in the building of primary and secondary treatment works for sewage. In June 1971 the Environmental Protection Agency and the Mayor of Cleveland agreed to a program of treatment and collection facilities and a timetable of construction. This is subject to agreement by other interested parties.

Description of Probable Growth and Changes in Land Use

The total population of the study area is estimated to grow to 3.3 million in 1990 and 4.2 million by the year 2020. The majority of the population growth will be the result of the expansion of the ring of suburban communities centering around Cleveland and Akron, and the gradual consolidation of these two cities into a single metropolitan area.

Population is expected to grow within these two rings by increasing the density within built-up areas and by filling in the undeveloped property. Zoning will be a critical issue and a major factor in future development. The outer ring in the zone between Cleveland and Akron will probably disappear altogether except perhaps for the area around Richfield, Peninsula, Remindersville, and southwestern Streetsboro.

Projected Wastewater Loads

Wastewater loads for the years 1990 and 2020 were projected for domestic, industrial, and runoff sources. These are summarized in Table 1. Current water use trends were the basis for estimating domestic contributions. The industrial waste loads were based on projected employment growth. Estimates of future waste load from runoff took into account the increased volume which is expected to result from continuing urbanization. The incremental load from combined sewer areas was considered to be constant for the next fifty years since it is not expected that presently combined sewer systems will be separated. By 2020 the one year storm will produce 16 billion gallons of flow, an increase of 2 billion. This flow will generate more than 26,000,000 pounds of suspended solids, almost 400,000 pounds of BOD, 8,000,000 pounds of chloride, 260,000 pounds of nitrogen, as N, and 26,000 pounds of phosphorus, as P.

Effects of Continuing Present Wastewater Management Strategies

The general goals of existing wastewater management strategies are to collect and treat all waterborne wastes. Implementation of current plans should lead ultimately to meeting existing standards in streams and lakes.

Several public agencies in the Three Rivers Watershed have a number of specific environmental engineering projects currently underway or planned within the 1970-1980 decade. The first decade plan of the Northeast Ohio Water Development Plan is being prepared by the Ohio Department of Natural Resources, and additional phases of water management through the year 2020 are being considered in the Plan.

Within the next 5 years a number of new treatment facilities will be constructed and existing plants modernized. This will include addition of nutrient removal and tertiary treatment, and expansion of Cleveland's Southerly and Easterly plants. New advanced treatment plants will be built at Cleveland Westerly and Akron. The trend towards regionalization and more effective treatment has been strongly emphasized in projects planned through 1980.

However, some problems now exist which may impede the development of the wastewater management system best suited for the region. For example, current planning has been oriented toward meeting existing water quality standards. These standards will undoubtedly be upgraded within the next decade, necessitating modifications in the plans. These changes may have to be made in a piecemeal fashion. The resulting mixture of partly independent plants of varying sizes will be expensive to build, operate and maintain compared to a flexible regional system based on needs projected ahead for 50 years.

Current programs also emphasize improving the degree of treatment and expanding the capacity of municipal and industrial treatment plants. However, refinement of sewage treatment processes to achieve efficient removal rates cannot be effective if substantial quantities of wastewater are allowed to bypass treatment plants and be discharged into waterways without treatment. Therefore, improvements to sewer collection systems are needed soon in order to prevent combined sewer overflow and discharge of polluted storm runoff.

Present planning is severely hampered by lack of accurate information on the sources of wastes, their composition, and how waste discharges vary under different conditions. Better monitoring and surveillance systems are urgently needed to permit the development of useful water quality models and enforcement procedures.

Other problems include safety, completeness of system, and distribution of effluents. The failure of a Cleveland sewage treatment plant in July 1971, allowing 120 MGD of sewage to be by-passed for a week directly into Lake Erie, indicates that additional safety features, perhaps cross-connections, back-up systems, or reserve storage, need to be considered, further complicating present planning. Some areas will continue to lack treatment facilities. If the untreated areas comprise only 3% of the regional population, the effect will be similar to that

TABLE 1 - CURRENT AND PROJECTED WASTE LOADS

Constituent	Waste Loads - 1000 lbs/day								
	Current Waste Loads Year 1970		(1)	Projected Waste Loads Year 1990		(1)	Projected Waste Loads Year 2020		(1)
	Domestic	Industrial	Runoff	Domestic	Industrial	Runoff	Domestic	Industrial	Runoff
Waste flow (MGD)	338	91	539	492	96	563	672	105	599
BOD	340	211	52	516	235	55	698	264	60
Suspended Solids	500	176	441	715	192	440	934	216	439
Sulfate, SO_4	357	82	86*	502	89	86*	636	102	86*
Chloride, Cl	424	86	429	596	96	465	755	111	520
Total Nitrogen, N	54	8	14	76	9	15	96	10	16
Total Phosphate, PO_4	79	56	14	111	60	15	141	64	15
COD	N/A	582	156	N/A	632	164	N/A	696	176
Total Solids	N/A	1,335	804*	N/A	1,421	804*	N/A	1,578	804*
Total Volatile Solids	N/A	310	N/A	N/A	348	N/A	N/A	392	N/A
Oil and Grease	N/A	18	N/A	N/A	19	N/A	N/A	22	N/A
Phenols	N/A	1.2	N/A	N/A	1.3	N/A	N/A	1.6	N/A

* In excess of

(1) Annual runoff quantities have been translated to an equivalent daily average.

N/A - Data not available.

of a small city. Today, effluent discharges from sewage treatment plants in some areas are greater in volume than the natural flow of the streams. Current plans consider only point discharge of effluents from plants, but do not distribute flows.

Therefore, while present strategies may solve many of the problems of wastewater management, alternatives which are aesthetically better, environmentally more suitable, and more flexible should be explored on a regional basis.

This section is based on information presented in Appendix I.

III - WASTEWATER MANAGEMENT ALTERNATIVES

General

The basic goal in developing alternative strategies was to attain the best level of pollution control compatible with present and anticipated technology. Achievement of this goal in most instances would result in better water quality than now exists. To accomplish this, certain specific treatment objectives must be met:

1. Treatment for high-level removal of BOD and suspended solids.

2. Controlled nutrient removal.

3. Separation and special treatment of toxic materials.

4. Increased control and more effective treatment of industrial wastes.

5. Control of combined sewer overflows and polluted surface runoff.

The objectives were approached by looking at methods of treating municipal wastewater, industrial wastewater, and storm runoff. These are described below.

Municipal Wastewater Treatment

There are two categories of systems for treating municipal wastewater, the "water disposal" system and the "land disposal" system.

Water based disposal methods are almost universally used in the United States. Most large urban plants rely on a water based treatment system and discharge the effluents to watercourses, lakes or the ocean. This results from the fact that sewage has historically been collected in an aqueous medium.

In the "water disposal" system, waterborne wastes are collected and treated in plants, the purified effluent being released into receiving waters or recycled for re-use. The separated solids are disposed of on land either with or without incineration.

The unit processes commonly employed include:

1. Preliminary treatment - Racks, screens, grit chambers and detritus tanks remove materials hazardous to plant equipment.

2. Primary treatment - Settling tanks and flotation units remove detritus, some suspended solids, and associated BOD.

3. Secondary treatment - Activated sludge tanks, aerated lagoons or trickling-filter beds remove dissolved organic solids, remaining suspended solids and some nutrients by biological action. This treatment normally removes 80-95% of the BOD and 90% of suspended solids.

4. Advanced treatment

   a. Chemical coagulation - Removes colloidal materials, commonly using coagulation with alum followed by settling tanks.

   b. Nutrient removal - Removes phosphates by chemical coagulation and settling using metal salts or lime for precipitation. Biological nitrification and denitrification units remove nitrogen.

   c. Filtration - Mixed media filtration and microstrainers remove fine suspended solids.

5. Disinfection - Treatment with chlorine, ozone and other chemicals removes pathogenic organisms.

Distillation, freezing, ion exchange, electrodialysis, reverse osmosis and carbon adsorption are advanced treatment processes which can be incorporated into treatment systems.

Land disposal techniques for wastewater treatment are used in over 1300 communities and industries in the United States. Most of these are relatively small facilities, although recently, Muskegon County, Michigan, with a population of nearly 200,000 commenced design of a land disposal system employing spray irrigation.

In the "land disposal" system, the wastewaters are applied to the land for treatment using a number of possible methods. The treated effluent is returned to the hydrological cycle either through underground aquifers or surface streams.

The unit processes commonly employed include:

1. Preliminary Treatment - as in water based plants.

2. Primary Treatment - as in water based plants.

3. Secondary Treatment - in aerated lagoons or by other processes.

4. Disinfection.

5. Storage - Winter storage is required in northern latitudes.

6. Irrigation - There are two methods of applying treated effluent to land; spray irrigation and ridge and furrow irrigation. Both processes require natural or installed underdrainage to control movement of water, reduce losses, and monitor filtered water. Spray irrigation consists of spraying the pretreated, disinfected liquid on croplands, grasslands or woodlands. The effluent provides nutrients and moisture for growth. Ridge and furrow irrigation consists of distributing liquid through ditches rather than by spraying. An alternative to irrigation is spreading and percolation.

7. Spreading-percolation - These methods consist of applying effluent from the secondary facility to which phosphorus removal must be added, to a bed of gravel and sand. Suspended solids are taken out by filtration and nitrogen is partially removed biologically. This process requires underdrainage and a pumping system sufficient to develop a high rate of percolation.

Industrial Wastewater Treatment

Although some industrial wastes can be released safely into the municipal sewer system for treatment at municipal facilities, a number of them have extremely deleterious effects. Suitable provisions must be made for their collection, treatment and disposal.

The most troublesome industrial wastewaters require segregation and treatment by the individual industry or at a central industrial wastewater treatment plant before release into the municipal sewer system. These materials include heavy metals, inflammables, cyanide, phenols, oil and grease, acids and alkalies and radioactive materials. Treatment can begin with chemical coagulation followed by such physical and chemical processes as precipitation, neutralization, pH adjustment, sedimentation, ion exchange, reverse osmosis, electrodialysis and distillation.

Other unit processes would be added to treat contaminants not removed by those basic techniques. After partial reduction by pretreatment, industrial wastewaters containing high concentrations of organic material or suspended solids could be treated further at municipal facilities. Uncontaminated industrial cooling waters can have excess heat removed through cooling towers by individual industries and then be recycled.

Storm Water Runoff

The general processes used to treat runoff are similar to those previously discussed. Preliminary and primary treatment or spreading percolation removes suspended solids. Biological oxidation reduces organic materials and disinfection removes pathogens.

In older cities wastewaters from households and industries are usually collected along with stormwater runoff in combined sewers. Normally, the flow in the sewers is small enough for the treatment plants to handle. However, rain storms can add more flow than the treatment plant or collection system is designed to take, and the excess flow discharges to nearby watercourses. Large quantities of raw sewage may escape treatment, creating serious health hazards. Modern practice calls for constructing separate stormwater and wastewater collection systems, but it is virtually impossible to prevent plumbing connections from being made to the storm sewer system. Therefore, treatment of combined sewage and of stormwater runoff is a logical step.

Quantity of flow and frequency of occurrence are major problems of runoff. In the development of alternatives, a one year storm was selected for calculation purposes. This would provide storage for the first 50% of the 5-year storm, 30% of the 10-year and 20% of the 100-year storm and treatment of about 90% of the sewage load coming from combined sewers regardless of the frequency of the storm. The remaining 10% would be untreated. Three possibilities of treatment were considered:

1. Basins for settling and biological stabilization could treat all storm flow.

2. Urban runoff could be collected at several discharge points with storage and treatment in aeration basins or at treatment facilities in plants.

3. Runoff could be collected at several points and pumped to storage sites for spreading and percolation treatment.

Sludge and Residue Disposal

In conventional wastewater treatment plants, large quantities of organic sludges are produced in the primary sedimentation and secondary biological treatment processes. Physical and chemical wastewater treatment techniques yield a chemical precipitate sludge combined with organic sludge. Residues from industrial wastewater treatment plants may contain extremely high concentrations of inorganic solids, salts, or metal precipitates. Residues from treating runoff contain mainly inorganic grit.

Possible treatment and disposal methods include:

1. Thickening - Concentrates and reduces the volume of the sludge.

2. Anaerobic digestion - Biologically transforms organic sludge into a form that can be handled more readily.

3. Dewatering - Physically separates and concentrates the sludge to a form that can be handled. Dewatering is done in drying beds or by vacuum filtration.

4. Incineration - Burning dried organic sludge at high temperatures produces gases which escape to the atmosphere and ash which must be disposed of on land. Modern sludge incinerators are capable of meeting current air pollution control standards.

5. Land fill - Dried sludge is placed in suitable locations.

6. Soil conditioning - Spreading and plowing dried sludge into soil can improve moisture and aeration characteristics in certain soils and can add some nutrients.

7. Underground storage - Sludge is deposited in underground cavities. Industrial sludge could be reclaimed if technology creates feasible methods of recovery.

8. Land reclamation - Land can be reclaimed by filling abandoned strip mines or other suitable areas.

9. Other - Sludge irrigation, wet oxidation.

Land reclamation could be a feasible disposal method for this region. There are about 50 square miles in nearby Columbiana, Mahoning, and Stark Counties that have had coal and other materials removed by strip mining operations. These areas could be reclaimed for productive farm use by applying the ash and sludge in a combination landfill-reclamation process. Using 2020 production rates and assuming that material is applied to an average depth of one foot there would be sufficient area to handle the sludge volume generated in the study area for at least the next 200 years.

Choosing Alternatives

The various unit processes that have been described can be combined in many different ways to develop management alternatives. Whether or not some of these would be suitable depended on a number of tests. In the initial evaluation a system had to be both capable of meeting the stated needs and flexible in order that additional, larger, or more efficient treatment processes could be later incorporated. Furthermore, reliability was an important factor. At this early stage, possible problems of a social, environmental, or institutional nature could cause the rejection of an otherwise technically suitable process.

In the first analysis, several strategies and variations were considered but rejected for failing to meet the criteria. Among these were:

1. Disposal of raw sewage or industrial wastes by direct application to land by using irrigation techniques. Rejected because of public health aspects, soil clogging by oil, solids, odors and other problems.

2. Ridge and furrow irrigation. Rejected because terrain at land disposal sites available within a reasonable distance was not suitable. To achieve the flat grades required would require excessive earth grading.

3. High rate spreading or percolation systems using natural soils in place. The heavy clay - silt soils encountered in the area are not suitable for high percolation rates even when underdrained.

4. Release of all treated wastewaters to underground aquifers through percolation, without underdrainage. Both soil characteristics and the very large volumes of water to be handled preclude such a system.

5. Treatment of all runoff water. The enormous quantities of water involved appeared to exclude this possibility. A one year storm frequency has been used to define the quantity of runoff to be treated.

6. Deep well disposal of all municipal wastewater, industrial wastewater, and runoff wastes was rejected on the basis of the enormous storage volumes required and the inability to assure the protection of ground water resources.

7. Segregated industrial wastes were not considered for spray irrigation due to the noxious characteristics of these wastes. High rate spreading basins for these industrial wastewaters were also ruled out due to the poor removals of contaminants that would be expected from such a system.

Eight alternatives were identified as suitable for preliminary analysis based on the tests used in the initial evaluation. These were:

Identification	Description
W-1	Regional System of Advanced Treatment Facilities, Separate Treatment of Runoff. Water Disposal System.
W-2	Regional System of Advanced Treatment. Combined Treatment of Runoff. Water Disposal System.

Identification	Description
L-1	Aerated Lagoons and Spray Irrigation on Croplands. Separate Treatment of Runoff. Land Disposal System.
L-2	Aerated Lagoons and High Rate Percolation from Spreading Basins. Separate Treatment of Runoff. Land Disposal System.
C-1	Secondary Treatment in Regional Plants. Effluent to Spray Irrigation on Croplands. Separate Treatment of Runoff. Combination System.
C-2	Secondary Treatment in Regional Plants. Effluent to High Rate Percolation in Spreading Basins. Separate Treatment of Runoff. Combination System.
C-3	Region north of Cuyahoga-Medina County Line (Inner Ring) Provided with Water Based Treatment. Outer Ring Region Provided with Land Based Treatment. Separate Treatment of Runoff. Combination System.
C-4	Inner Ring Region Provided with Water Based Treatment. Outer Ring Region Provided with Combination of Water-Land Based Treatment. Separate Treatment of Runoff. Combination System.

Three wastewater management alternatives, W-1, L-1 and C-3, were selected in the Feasibility Study as being representative of both the possible range of methods that could be used and judgment of the maximum range of impacts that might occur. Thus the impacts of any modifications or alternatives developed later would fall within these ranges. More detailed study might indicate that some other combination of processes and locations would be more appropriate or that some process not previously evaluated could be used. The locations are not fixes; at this time they represent possibilities on which to base estimates of technical operation and cost.

These three selected alternatives can be broken down into their individual unit processes. Alternative W-1, a water disposal system, employs secondary treatment by activated sludge followed by tertiary treatment and nutrient removal. In alternative L-1, a land treatment system, biological stabilization takes place in aerated lagoons followed by spray irrigation of the chlorinated effluent. Alternative C-3 represents a combination of the processes used in both of the other systems.

Alternative W-1 - Regional System of Advanced Treatment Facilities, Separate Treatment of Runoff

This system would treat and discharge all municipal and industrial wastes into a receiving water, eventually emptying into Lake Erie. It resembles the Northeast Ohio Water Development Plan with regard to location of treatment plants and systems of collection. The best available technology is used and existing treatment plants are consolidated into 28 coordinated regional systems. This approach is summarized in Table 2 and diagrammed in Figure 2.

Municipal wastes would be collected through existing sewer systems and transported to treatment plant sites. To convey the flow to the regional treatment sites, new interceptors, pumping stations and force mains would be needed. Outfalls would be used to disperse the effluent to the Lake from nearby plants. Advanced waste treatment, including coagulation and filtration, at all regional sites could remove 95-98% of the BOD and suspended solids. Phosphate would be removed at all plants. Nitrogen would be removed at Cleveland Southerly and Akron since these plants are the major sources of nutrient loads to the Cuyahoga River.

A small percentage of wastewater could be used to recharge the groundwater aquifers within each watershed. A portion of the Southerly plant effluent could be recycled for use in Cuyahoga Valley industries. Sludges from large municipal operations would be dewatered, incinerated, and then landfilled. Sludge from small plants would be digested and could be used for land reclamation in nearby areas. Compatible industrial wastes would be treated with municipal wastes. Segregated non-compatible industrial wastes, after separate treatment, would be reused wherever possible. Suitable treatment facilities could be constructed at Cleveland and Akron. In order to prevent thermal pollution from the discharge of hot effluents, cooling towers would be used.

This type of treatment alternative offers the advantage of using developed technology and is capable of fairly high degrees of treatment. However, heavy metals and dissolved solids are resistant to treatment. Existing treatment facilities could be used in many cases. Water based treatment is flexible, because unit processes can be added to or deleted from the system fairly easily and the plant loading can be varied.

Implementation of this plan and similar water based plans would be hastened by new institutional arrangements. There is a definite need for authorities having a wide scope of influence. The biggest institutional problem is the funding of interceptor sewers and the purchase of outstanding bond indebtedness of treatment plants which would be phased out.

TABLE 2 - ALTERNATIVE W-1 - REGIONAL SYSTEM OF ADVANCED TREATMENT FACILITIES

	Municipal Wastewater	Industrial Wastewater	Runoff Wastewater
Collection System	Existing sewer systems to collect to local plant sites. New systems collect to regional plants.	Compatible wastes collected with municipal wastes. Non-compatible wastes collected by tank truck or separate pipeline.	New interception and storage systems to collect discharges of combined sewer overflows and urban runoff, along lake-front and rivers.
Transport System	New interceptors, pump stations and force mains convey flow to regional treatment sites.	Compatible wastes transported with municipal wastewater. Non-compatible transported by tank truck from collection points to treatment sites.	Short force mains or inter-ceptors to convey to new treatment and disposal sites.
Treatment System	Secondary and advanced waste treatment at all centralized treatment plants. Phosphate re-moval at all plants, nitrogen removal at Cleveland Southerly and Akron.	Compatible waste treated with municipal. Non-compatible wastes treated at separate facilities at Cleveland and Akron.	Storage and pre-treatment in stabilization basins in Lake Erie or in separate treatment facilities on land with disinfection before release. Excess flows screened and chlorinated before release.
Disposal or Re-Use System	Effluents discharged to surface streams, Lake Erie, or recharged in natural percolation areas. Some effluent recycled as industrial water supply. Sludge disposed of on land, or incinerated, with ash used for landfill.	Pre-treated effluents to municipal systems for advanced treatment. Cooling waters reduced in temperature and recycled. Some wastes reclaimed for recycle, such as pickling liquors, reclaimable oils. Unusable remainder incinerated and landfilled or directly landfilled.	Release to receiving waters. Some treated runoff may be recycled to augment flow in lower Cuyahoga and reduce temperature.

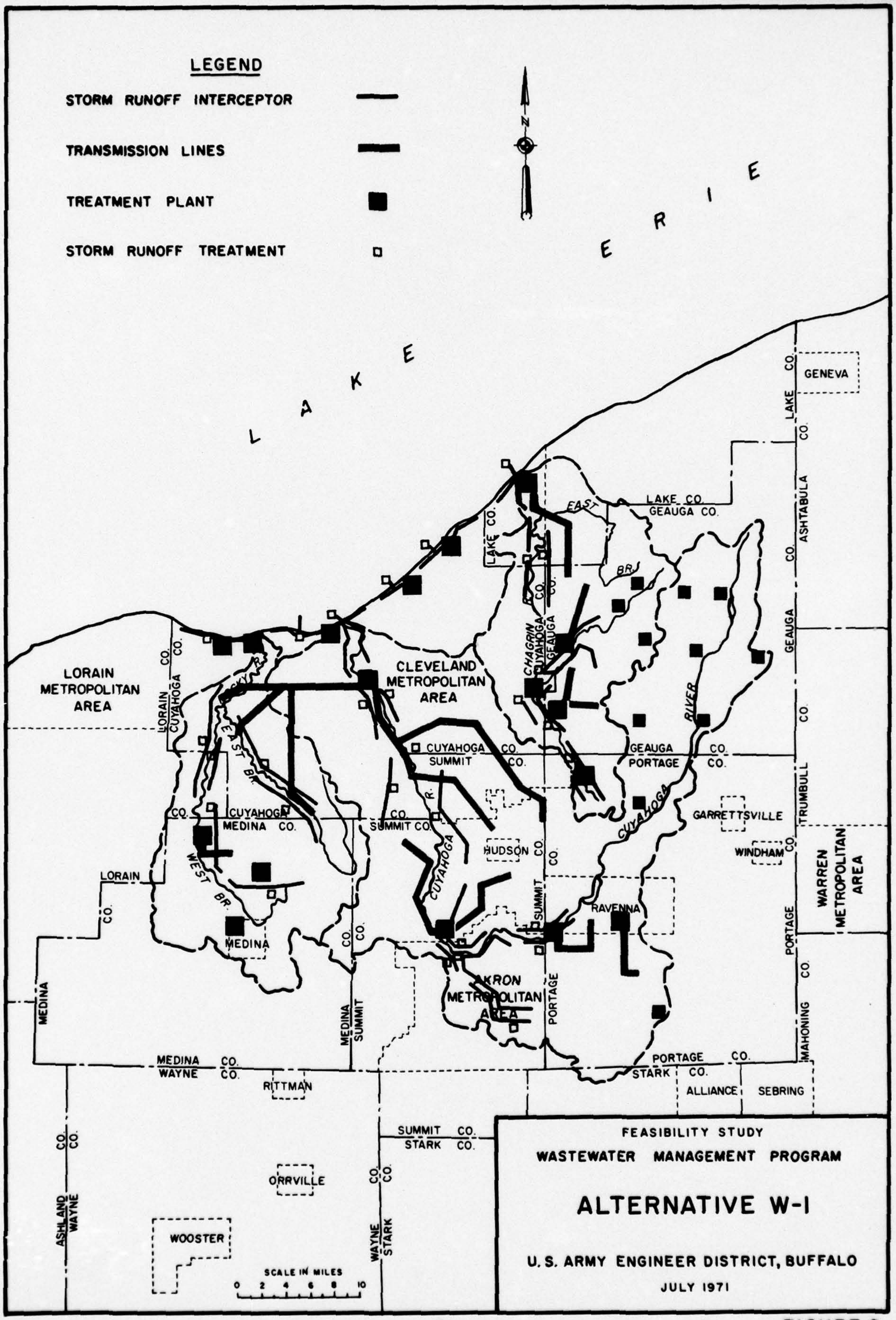

LEGEND
STORM RUNOFF INTERCEPTOR
TRANSMISSION LINES
TREATMENT PLANT
STORM RUNOFF TREATMENT
N
LAKE ERIE
LORAIN METROPOLITAN AREA
CLEVELAND METROPOLITAN AREA
AKRON METROPOLITAN AREA
WARREN METROPOLITAN AREA
GENEVA
GARRETTSVILLE
WINDHAM
HUDSON
RAVENNA
MEDINA
RITTMAN
ORRVILLE
WOOSTER
ALLIANCE
SEBRING
LAKE CO.
GEAUGA CO.
CUYAHOGA CO.
SUMMIT CO.
MEDINA CO.
PORTAGE CO.
CHAGRIN
EAST BR.
WEST BR.
CUYAHOGA R.
CUYAHOGA
RIVER
ASHTABULA CO.
TRUMBULL CO.
MAHONING CO.
STARK CO.
WAYNE CO.
ASHLAND CO.
LORAIN CO.
SCALE IN MILES
0 2 4 6 8 10
FEASIBILITY STUDY
WASTEWATER MANAGEMENT PROGRAM
ALTERNATIVE W-1
U. S. ARMY ENGINEER DISTRICT, BUFFALO
JULY 1971

FIGURE 2

Alternative L-1 - Aerated Lagoon and Spray Irrigation on Croplands

Municipal wastes and compatible industrial wastes would be given primary treatment, given secondary treatment in aerated lagoons, stored and used for spray irrigation of cropland in areas outside the study region. Runoff water would be treated in spreading basins. The return water would be collected and returned to surface streams within the Lake Erie Watershed. Table 3 summarizes the approach and Figure 3 illustrates a possible network.

Municipal wastes would be collected in existing sewer systems. New regional pump stations, as well as interceptor sewers, would be required. The actual treatment would consist of coarse screening, aerated lagoon treatment, disinfection, and spray irrigation to an underdrained cropland. The irrigation waters would be collected by underdrains, monitored, and returned to streams within the Three Rivers Watershed. Some loss of water would occur by evapo-transpiration. Organic sludge would be oxidized in the aerated lagoons and be spread on the irrigation sites.

Compatible industrial wastes could be collected with municipal wastes. Non-compatible wastes would be concentrated by physical and chemical treatment for underground disposal.

Runoff would be collected by new storm water interceptors along Lake Erie and the Cuyahoga River and other streams and rivers. Lift stations and conduits would transport the wastewater to land disposal sites outside the watershed. Highly permeable materials would be used in constructing spreading-percolation basins to yield high percolation rates. Underdraining would be installed to permit the percolant to be returned to surface streams within the Lake Erie watershed.

In the spray irrigation technique, lined basins would hold the treated and disinfected effluent from the aerated lagoons for a maximum of 22 weeks during periods when irrigating lands were frozen or saturated with rainfall. During the irrigation season of at least 30 weeks, the effluent would be applied at about 2 inches per week to grow suitable forage crops. Management would permit maximum removal of nutrients in root zones. Irrigating waters would be collected by underdrains and returned to the basin.

Land requirements for this approach are significant. The 20-foot deep storage basins would require 34.5 square miles of area, 10-foot deep aerated lagoons 1.7 sq. mi. and spray irrigation sites 312 sq. mi. for a total of nearly 350 square miles. These are total requirements in the year 2020; they would be divided among more than one site in order to minimize disruption of existing land uses.

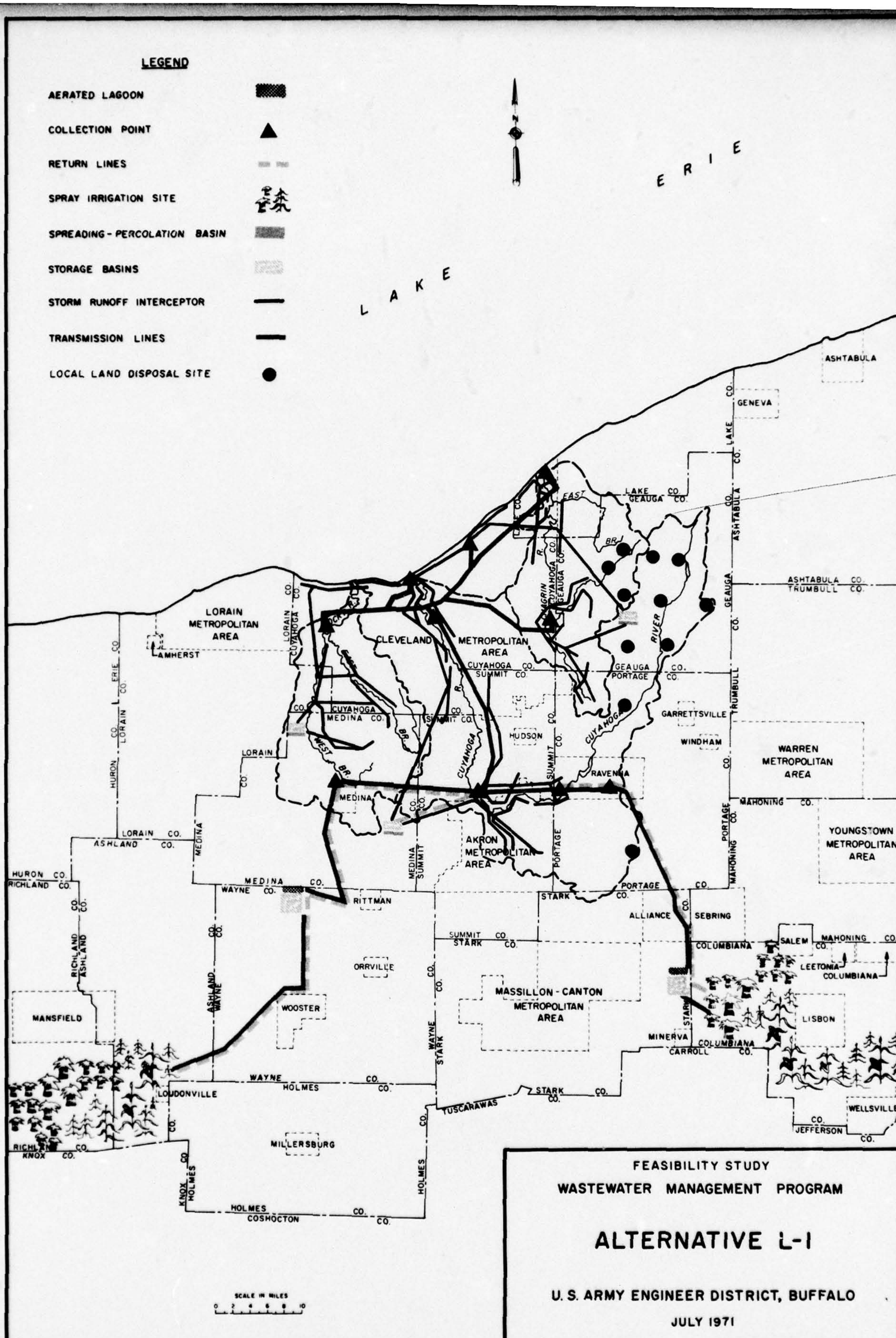
This treatment system offers the advantage of producing potential income from harvestable forage crops. Spray irrigation would involve large land areas and large capital expenditures for new transportation and treatment facilities. The return of collected irrigation water would produce increased flow during the summer months which could be used to augment the flow in rivers in the study area. It is estimated that in this system about 15% of the water would be lost to evapo-transpiration and groundwater recharge and would not be returned. Although domestic and sanitary purposes are given preference in water usage under the 1909 treaty between the United States and Canada this could be an institutional constraint since the losses might not be returned to the Great Lakes Basin. The mechanical equipment used in the irrigation system is relatively uncomplicated and not subject to frequent failure. The treatment efficiency is fairly high although oil and grease, dissolved solids and heavy metals are not removed to a very high degree. Excellent management is essential to grow crops which will effect nutrient removal and control efficient drainage. Irrigation also offers the advantage of creating "green space" which could be used to separate metropolitan areas. In addition, the use of the storage basins for thermal cooling ponds for power facilities would be possible.

Land based systems are relatively flexible since unit processes can be added after irrigation if underdrains are provided. Sufficient storage volume provides a large measure of flexibility and reliability. Deep plowing of the soil is one of the measures that can lengthen the life of the soil filter.

Land based systems present a number of difficult institutional problems. Arrangements would be needed to allocate the returned water among the three watersheds. As outlined, this alternative would require using large tracts of land which are in several political sub-divisions outside the study area. On the other hand, the land disposal system could be expanded to serve outside areas. Careful site selection and layout could enhance the treatment areas.

TABLE 3 - ALTERNATIVE L-1 - AERATED LAGOONS AND SPRAY IRRIGATION ON CROPLANDS

	Municipal Wastewater	Industrial Wastewater	Runoff Wastewater
Collection System	Existing sewer systems convey wastewater to local plant sites. New pump stations and sewers connect to regional pumping stations.	Compatible wastes collected with municipal wastewater. Non-compatible wastes collected by tank truck or pipeline.	Runoff collected by new storm water interceptors along lakefront and Cuyahoga River in Cleveland and other rivers and streams in the rest of the area.
Transport System	New pump stations, force mains and gravity conduits convey flow to winter storage basins and treatment sites.	Compatible wastes transported with municipal wastewater. Non-compatible wastes transported by tank truck and pipeline to disposal sites.	Lift stations and conduits to land disposal sites.
Treatment System	Coarse screening, aerated lagoon treatment, spray irrigation to underdrained croplands without special nutrient removal.	Compatible wastes treated with municipal. Non-compatible wastes concentrated by chemical-physical treatment for underground disposal.	Discharge to spreading basins constructed of permeable materials for high percolation rates.
Disposal or Re-Use System	Effluent from underdrains returned to surface streams within the basin. Some loss to ground water aquifers outside of basin. Sludge disposal on spray irrigation land.	Pumped to isolated underground cavities for permanent storage. Reclamation, where feasible.	Percolate collected by underdrains and pumped to surface streams or stream recharge basins. Suitable for re-use as raw water supply.



FEASIBILITY STUDY
WASTEWATER MANAGEMENT PROGRAM

ALTERNATIVE L-1

U. S. ARMY ENGINEER DISTRICT, BUFFALO
JULY 1971

FIGURE 3

Alternative C-3 - Inner Ring Region Provided with Water Based Treatment, Outer Ring Region Provided with Land Based Treatment

Municipal and compatible industrial wastes from outlying areas such as Akron, Medina, Mantua, Kent and Ravenna, would be treated in aerated lagoons and distributed for spray irrigation as in L-1. Similar wastes from "inner ring" areas, Cleveland and vicinity, would undergo advanced waste treatment as in W-1. Non-compatible industrial wastes would be treated in new facilities, while runoff wastewater would be treated and returned to the Lake and streams. This system is shown on Figure 4 and summarized in Table 4.

Municipal wastewater would be collected by the existing system, and transported to regional sites within both rings. The "inner ring" transport system would require new interceptors, pump stations, and force mains to convey flow to regional treatment plants. The "outer ring" system would require force mains to carry wastes to storage and treatment facilities. Inner ring treatment plants would provide advanced waste treatment, including microstraining or filtration, and nutrient removal. Outer ring treatment would include coarse screening followed by aerated lagoon treatment storage, holding basins and spray irrigation. Irrigation areas would be underdrained and the collected water returned to surface streams in the upland regions of the Three Rivers Watershed.

Sludge from the large treatment facilities would be incinerated and the ash landfilled. Digested sludges from smaller treatment plants would be spread on land. The small amounts of organic sludges not oxidized naturally in the aerated lagoons would be applied to irrigation areas. Compatible industrial wastes could be transported and treated with municipal wastes. Non-compatible wastes would be handled as previously discussed. Cooling waters would have their temperatures reduced before discharge. Some wastes, such as pickling liquors and oils, would be reclaimed.

Force mains and interceptors would carry runoff water to new treatment and disposal sites. Runoff wastes would be treated at the point of discharge as discussed under W-1.

Since only the Outer Ring wastewaters would be treated by spray irrigation, total land required would be about 97 square miles by the year 2020.

Advantages and disadvantages are similar to W-1 and L-1 for the "inner and outer ring" respectively.

TABLE 4 - ALTERNATIVE C-3 - INNER RING REGION PROVIDED WITH WATER BASED TREATMENT; OUTER RING REGION PROVIDED WITH LAND BASED TREATMENT[1]

	Municipal Wastewater	Industrial Wastewater	Runoff Wastewater[2]
Collection System	Use existing sewer system to collect to regional plant sites, both Rings.	Compatible wastes collected with municipal wastes. Non-compatible wastes collected by tank truck or separate pipeline.	New interception and storage systems to collect discharges of combined sewer overflows and urban runoff along the lake front and rivers.
Transport System	Inner Ring: New interceptors, pump stations and force mains to convey flow to regional treatment sites. Outer Ring: New pump stations, force mains and gravity channels to storage and treatment sites.	Compatible wastes transported with municipal wastewater. Non-compatible transported by tank truck from collection points to treatment sites.	Short force mains or interceptors to convey to new treatment and disposal sites.
Treatment System	Inner Ring: Secondary and advanced waste treatment at all inner ring regional plants. Phosphate removal at all plants, nitrogen removal at Cleveland Southerly. Outer Ring: Coarse screening, aerated lagoon treatment, spray irrigation to underdrained croplands without special nutrient removal from underdrainage.	Inner and Outer Rings: Compatible wastes treated with municipal. Non-compatible wastes treated at separate facilities at Cleveland and Akron.	Storage and pre-treatment in stabilization basins in Lake Erie or in separate treatment facilities on land with disinfection before release to Lake and streams. Excess flows screened and chlorinated before release.

TABLE 4 - CONT'D

ALTERNATIVE C-3 CONT'D

	Municipal Wastewater	Industrial Wastewater	Runoff Wastewater[2]
Disposal or Re-Use System	Inner Ring: Effluents discharged to surface streams or Lake Erie or used for recharge in natural percolation areas within district. Some effluent recycled for industrial water supply. Sludge disposed of on land or incinerated with ash used for landfill. Outer Ring: Collected water returned to surface streams within the Three Rivers Watershed. Some loss to ground water aquifers outside of basin. Sludge applied to spray irrigation sites.	Inner and Outer Rings: Pretreated effluents to municipal systems for advanced treatment. Cooling waters reduced in temperature and discharged to receiving waters. Some wastes reclaimed for recycle, such as pickling liquors, reclaimable oils. Unusable remainder incinerated and landfilled or directly landfilled.	Inner and Outer Rings: Release to receiving waters. Some treated runoff may be recycled to augment flow in lower Cuyahoga and reduce temperature.

(1) Inner Ring includes Cleveland and environs, approximately north of Cuyahoga County - Medina County line; Outer Ring includes Akron, Medina, Kent and Ravenna regions.

(2) Treatment of runoff wastewaters under this plan is similar to that stipulated for Plan W-1.

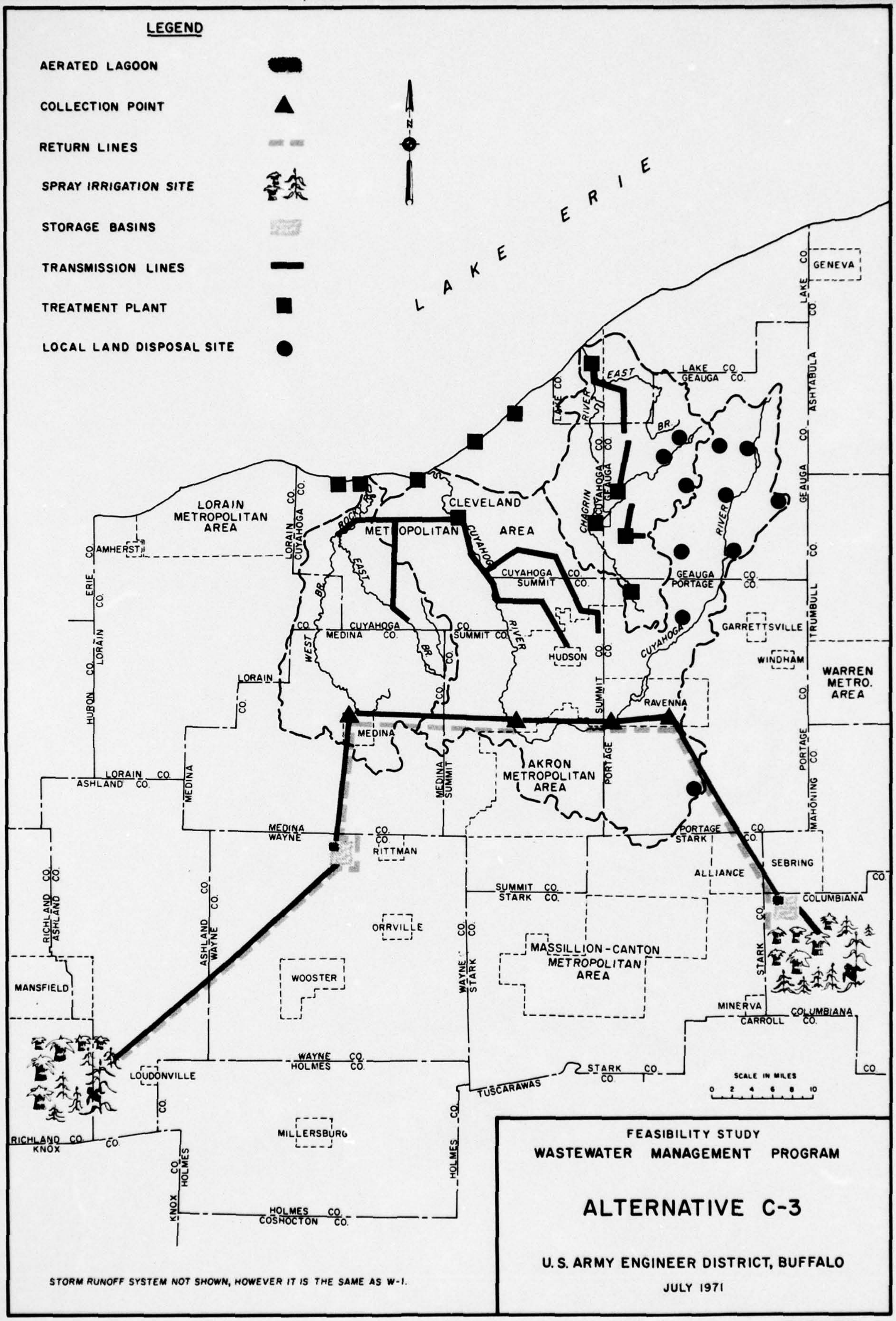

LEGEND
AERATED LAGOON
COLLECTION POINT
RETURN LINES
SPRAY IRRIGATION SITE
STORAGE BASINS
TRANSMISSION LINES
TREATMENT PLANT
LOCAL LAND DISPOSAL SITE
N
LAKE ERIE
GENEVA
LORAIN METROPOLITAN AREA
CLEVELAND METROPOLITAN AREA
AMHERST
HUDSON
GARRETTSVILLE
WINDHAM
WARREN METRO. AREA
RAVENNA
MEDINA
AKRON METROPOLITAN AREA
RITTMAN
ALLIANCE
SEBRING
ORRVILLE
MASSILLION-CANTON METROPOLITAN AREA
WOOSTER
MANSFIELD
MINERVA
LOUDONVILLE
MILLERSBURG
TUSCARAWAS
SCALE IN MILES
0 2 4 6 8 10
STORM RUNOFF SYSTEM NOT SHOWN, HOWEVER IT IS THE SAME AS W-1.
FEASIBILITY STUDY
WASTEWATER MANAGEMENT PROGRAM
ALTERNATIVE C-3
U. S. ARMY ENGINEER DISTRICT, BUFFALO
JULY 1971

FIGURE 4

Sludge Production

Sludge is a major by-product of most treatment processes. In the selected alternatives, runoff sludges, consisting primarily of inorganic grit, would average about 25 tons per day. Industrial sludges would be about 144 tons per day. Alternative W-1 would generate almost 400 tons per day of incinerator ash and 110 tons per day of digested sludge. In the land disposal alternative all sludges would be spread on the treatment areas, and there would be little or no problem in handling or disposal. Inner ring plants in alternative C-3 would produce 285 tons per day of ash and 80 tons per day of digested sludge to be disposed of by landfill.

Effectiveness of the Alternatives

The average efficiencies of the basic alternatives, L-1 and W-1, were estimated and appear in Table 5. The efficiencies of alternative C-3 would be a combination of the other two, calculated by weighting the portion of the loads to be treated by each method.

The figures for alternative W-1 probably reflect the upper levels of efficiencies for plant processes. Careful operation is required to bring about these removal rates, for the treated product of a plant depends on the cumulative effect of all the steps. For instance, if an overload or malfunction occurs in an early stage, and little of the contaminant is removed, then later stages might not make up for this failure and the effluent would be only partly treated.

Plant processes are capable of responding effectively to changes in loads. Dosages of treatment chemicals can be altered to provide the proper reaction rate. To do this, the wastewater quality must be carefully monitored at each step of the process. In general, monitoring can be carried out better in larger plants than smaller ones. However, there are other complications. For instance, five days are required to determine BOD. By the time the results have been obtained the wastewater will have been processed and there will be no need for correcting dosages. Phosphate determination is a complicated analytic procedure also having a significant lag time. Therefore, at present, even the best efforts at monitoring wastewater processing cannot lead to the most effective treatment at all times.

The spray irrigation technique removes nutrients through both adsorption on the surfaces of soil particles and their uptake by plants. If more is applied to a given soil and crop combination than can be taken up, the excess will pass untreated through the system. Design and management of irrigation systems must consider the capacities. As long as nutrient levels are within the capacity of soil and crop there will be complete removal. There are no problems of incomplete chemical reactions.

It is difficult to estimate the amount of phosphorus and nitrogen removal by spray irrigation treatment since much depends on climate and crop management. The assumed uptake of 81 lbs/acre/season of phosphorus was based on a crop uptake of 25 lbs/acre/season and a soil adsorption of 56 lbs/acre/season. The assumed nitrogen uptake of 180 lbs/acre/season is conservative. Other crops and soils would have greater capacity for nutrient extraction. The spray irrigation sites were selected through an appraisal of general capability for irrigation.

Based on the effective area for spray irrigation of 174,000 acres and the assumed uptake rate, alternative L-1 would be capable of removing 218,000 lbs of phosphate (or 71,000 lbs of phosphorus) during each day of the irrigation season. This is 61% of the projected phosphate load in 2020. However, in terms of present phosphate loads in wastewater, the estimated efficiency would be 93%. Furthermore, phosphate loads from detergents, which at present contribute about half of the total, may be eliminated in the next few years. Hence, it is not illogical to expect that alternative L-1 would actually remove 100% of the projected phosphate load for 2020 without reaching capacity.

The estimated removal efficiencies of heavy metals have been given in Table 5. A relatively low efficiency was projected for the land disposal system, since it was assumed that heavy metals would be removed only by the secondary biological treatment taking place in the aerated lagoons. However, soil adsorption and crop uptake are important mechanisms and removal effectiveness again depends upon on many related factors which are difficult to analyze. Thus, the estimated 10% removal is conservative. In addition, the vast majority of these materials would be largely concentrated in the non-compatible industrial wastes which would be treated in segregated facilities. Thus, the heavy metal concentrations in domestic and compatible industrial wastewaters will be very small compared to segregated industrial wastes.

None of the alternatives would remove dissolved solids to a high degree. However, the concentrations of chlorides and sulfates remaining in the effluents after treatment would still be well within present standards for water quality.

TABLE 5 - ESTIMATED AVERAGE EFFICIENCIES OF BASIC ALTERNATIVES STUDIED

Alternative	Selected Processes Employed	Percent Removals from 2020 Loadings: BOD	COD	Susp. Solids	Heavy Metals	Phos-phates	Total Nitrogen	Oils, Grease	Diss. Solids	Bacteria	Viruses
Water, W-1	Preliminary Treatment										
	Primary Sedimentation	35		55		10				50	10
	Activated Sludge	85		90	50	35	30			80	75
	Chemical Coagulation				75						
	Nutrient Removal					95	90				
	Settling										
	Mixed Media Filtration	97		98					10	95	90
	Disinfection									99.9	99+
	Cumulative Removal	97	92	98	75	95	90	95	10	99.9	99+
Land with spray irrigation, L-1	Preliminary Treatment										
	Aerated Lagoon	80		90	10						
	Disinfection									99.9	99+
	Storage										
	Spray Irrigation	98		97		61	79				
	Cumulative Removal	98	96	97	10[a]	61[b]	79[c]	60	0	99.9	99+

a Removal by secondary treatment. Soil and crop uptake not estimated.

b Soil and crop uptake assumed at 56 and 25 lbs/acre/season, respectively, of phosphorus, as P, for a total of 81 lbs/acre/season.

c Crop uptake assumed at 180 lbs/acre/season of nitrogen, as N.

Based on the design efficiencies of the several systems presented in Table 5, the effluent loads to be expected in 2020 from the treatment processes can be calculated. These are presented in Table 6.

TABLE 6 - EFFLUENT LOAD IN 2020 FROM DOMESTIC AND COMPATIBLE INDUSTRIAL WASTEWATERS

		Effluent Loads - 1000 lbs/day					
Alternative	Flow (MGD)	BOD	Suspended Solids	Chlorides	Total N	Phosphates as PO4	Sulfates
W-1[a]	780	28.8	23.0	779	10.8	10.2	664
L-1[b]	1,140	33.4	60.2	1,510	39.0	139.0	1,280
C-3[c]	880	30.8	31.5	958	17.1	31.8	815
C-3[d]	554	19.4	19.8	602	10.8	20.0	512

a Year Round Average Flow and Loads
b Flow and Loads for 30 Weeks - No Return During Remaining 22 Weeks of the Year
c Flow and Loads for 30 Weeks
d Flow and Loads for Remaining 22 Weeks of the Year

Costs

Very preliminary estimates of costs for the alternatives were developed based on 1971 dollar value. These were classified in two categories: construction, and operation and maintenance. Construction costs are those which would be expended over the period of time up to 2020 in order to build a system, while operation and maintenance costs are the maximum required in the year 2020 to run a system. The necessary capability to collect, handle, and treat domestic and industrial wastewater and storm runoff loads for the year 2020, as described in Section III for each alternative, was included in the costs. The process of phasing the construction of the systems over the time period would reduce equivalent annual charges since the total cost would be invested over a 40- to 50-year time period.

As a first approximation construction costs are estimated to be $3.5 billion for alternative W-1. This would include the construction of the primary, secondary, and advanced treatment facilities in the regional plants for municipal and industrial wastes; the collection system and pumping stations in the transport network; and the collection system and stabilization basins for storm runoff. A preliminary value for annual operation and maintenance costs would be $41 million for the total system when completed. The annual operation and maintenance costs for advanced waste treatment are considerably higher than the annual cost for debt service. During the first years of construction of the regional system, operation and maintenance costs would be similar to the total for the present system.

A rough estimate of construction costs for alternative L-1 is $6.6 billion. This would provide for the collection and transmission facilities, aerated lagoon treatment, storage facilities, spray irrigation sites for municipal and industrial wastes and facilities for the return of treated water to the watershed. The collection, storage, percolation and return facilities for treating storm runoff are also included. A rough approximation of the operation and maintenance costs would be about $29 million for the total system when completed. During the initial years the operation and maintenance of a regional land system, similar to L-1, would be of the same order of magnitude as the total for the present system. The land portion of this alternative is a renewable natural resource which would have substantial economic value at the end of the project life. The construction cost has not been reduced to reflect this.

A preliminary estimate of costs for alternative C-3 is $4.4 billion. This would provide collection transport and treatment facilities similar to W-1 for the municipal wastes of the Inner Ring and similar facilities as L-1 for the municipal waste of the Outer Ring. The separate treatment of non-compatible industrial wastes and the interception, collection and treatment system for runoff water is also included. A gross estimate of operation and maintenance costs is $25 million for the complete system. These costs would be in the range of existing costs during the initial years of developing the system.

The cost differential between the alternatives would be largely a result of the storage, transmission, application, and return of the treated wastewater in the land disposal and combination alternatives. Associated with these costs, alternative L-1 would have certain benefits which were not formulated as part of alternative W-1. For instance, return of waters to the upstream areas of the Three Rivers Watershed provides stream flow augmentation benefits, storage provides safety in case of a system malfunction, and spray irrigation provides a potential for producing a useful product. None of these benefits have been evaluated. Furthermore, the alternatives are not fully comparable in reliability or effectiveness.

Since the alternatives were not comparable in effectiveness, reliability, or benefits, a valid comparison of costs cannot be made.

This section is based on material presented in Appendix II.

IV - ASSESSMENT AND EVALUATION OF SELECTED WASTEWATER MANAGEMENT ALTERNATIVES

General

Evaluation is important in developing wastewater management alternatives. By considering the changes, or impacts, which would be expected to occur by carrying out a particular approach, the system initially formulated can be modified so that it not only would fulfill technical requirements but would have maximum benefit to the environmentt, society, and economy. The entire process can be viewed as iterative; that is, evaluation and modification follow one another continuously until an alternative evolves which satisfies, as closely as possible, all the constraints posed by the particular objectives.

The beginning step in evaluation is identifying present conditions. Then based on judgment of trends and relationships, the expected future conditions are predicted. The present and anticipated conditions are compared, and the nature and significance of the expected changes are estimated. To minimize any adverse effects, the alternative is modified and evaluated again. The process is repeated as many times as necessary.

This iterative process was initiated in the Feasibility Study. Three representative alternatives were evaluated to establish general *feasibilities* and to suggest approaches for study in subsequent work.

It is especially important to identify the detrimental changes or negative impacts, because they act as warning signals and point to particular parts of an approach which need modification. Since the negative impacts are so influential, they were strongly emphasized in this study.

Evaluations, which indicate the direction that impacts take, are most useful when they reflect the nature of the study and its objectives and match the detail in which the alternative is developed. For example, in the final design stages of a project very detailed information can be developed and very specific evaluations are needed. In a feasibility study, which is characterized more by breadth of coverage than by depth of detail, broad evaluations of major impacts are desired. In carrying out this study, information was produced which was as specific and detailed as possible. Nevertheless, it was still very general. Geographic locations, for instance, are only representative of possibilities on which to base analyses. The evaluations are not meant to apply generally to treatment systems based on either land or water disposal methods but only to the specific alternative outlined in Section III. It is in this light that the evaluations should be studied.

Classification of Impacts

The impacts of each alternative were evaluated with regard to four major areas of consideration: environmental quality, social well-being, national economic development, and regional development.

Environmental quality, as measured by the health, diversity, and productivity of plants and animals, is important to supporting the quality of human life.

Social well-being impacts deal with the consequences of a strategy on people or groups, on the security of life and health, and on opportunities for educational, cultural, and recreational activities. Changes were categorized under the broad headings of hygienic, aesthetic, recreation, human betterment and life style effects. Hygienic effects relate to health and aesthetic effects to the appearance of the environment. Recreation effects relate to man's leisure activities. Human betterment effects include such things as education, housing, and community, historical and cultural activities. Life style effects are those which result in land use changes, in relocation of individuals, and in changing the general amenities of life.

National economic development is concerned with the Nation's output of goods and services and the national economic efficiency. Regional development is concerned with diversity and stability of income, employment, and economic base.

EVALUATION OF WATER DISPOSAL ALTERNATIVE

ENVIRONMENTAL QUALITY

The most significant ecological effects of the water disposal alternative, W-1, as outlined in Section III are as follows:

1. Increased algal growth could become a problem in the Chagrin River and East Branch of the Rocky River due to reduced flows. Because of a reduction of nutrients, algae should decrease elsewhere, including the nearshore area of Lake Erie.

2. Removal of water from the Chagrin River would result in its change to a warm water fishery, to the detriment of current populations of salmon and trout. A significant improvement in diversity and productivity of aquatic life should result elsewhere from the reduction of BOD and suspended solids.

3. The environment for aquatic life would improve throughout the region due to the reduction of such pollutants as BOD and nitrogen, and to the increase in dissolved oxygen.

4. Diversity of aquatic species should improve significantly for the Cuyahoga and Rocky Rivers and the nearshore area of Lake Erie adjacent to the mouth of the Cuyahoga River.

5. Lower flow conditions in the Chagrin River would adversely affect fish life, and in the East Branch of the Rocky River would cause a change in species composition. Elsewhere there should be a significant improvement.

6. Spawning of sport and commercial fish species could be reestablished in the Rocky and Cuyahoga Rivers.

7. Disposal of incinerator ash.

SOCIAL WELL-BEING

Hygienic Concerns

Specific hygienic effects were identified:

1. Current bacterial and viral problems from untreated sewage would be virtually eliminated.

2. Inefficient operation, a malfunction, a breakdown of a major sewage treatment plant, or failure of a major trunkline sewer could create serious health or environmental problems.

3. After a storm large amounts of bacteria, viruses and round-worms could concentrate in the storm water holding basins, although many would be destroyed after subsequent treatment.

4. Breeding grounds for mosquitoes and other disease carriers would be decreased by the improved control of septic tank discharges. However, breeding places for such pests would possibly be increased in storm water treatment basins in Lake Erie, and in the East Branch of the Rocky River.

5. Toxic heavy metal discharges from industries would be eliminated and present levels in sediments dissipated in time. Mercury vaporized by high temperature incineration of sludges could possibly enter terrestrial and aquatic food chains.

Aesthetic Impacts

Certain aesthetic impacts were identified:

1. The natural appearance of the Lake Erie coast would be changed by the basins for holding storm water. Algae might grow in them, creating an adverse aesthetic impact.
2. The East Branch of the Rocky River is set in a park providing a natural landscape of trees and vegetation and the composition of this river would change drastically. Stagnant pools with associated color and odor problems could be created.
3. Elsewhere the physical characteristics of the water in the area, such as color, odor, and taste, would be greatly improved. The quality of natural vegetation and wildlife would be enhanced.
4. The possibility of increased air pollution from incineration would exist creating adverse impacts on the value of housing and amenities.

Recreation Impacts

Water quality improvement in the region would benefit recreation. Sport fishing would generally increase except possibly in the East Branch of the Rocky and the Chagrin Rivers. Boating would be more pleasant. Swimming should improve. The development of passive recreation areas would be encouraged along the main stem of the Cuyahoga, the Chagrin, and the Upper Cuyahoga Rivers.

Human Betterment Impacts

There would be little effect on education, housing, the community, and historical and cultural activities.

Life Style Impacts

1. The construction of new regional treatment plants and additions to existing plants would involve minor relocation of individuals, homes and businesses.

2. There would be a change in the general amenity value of the community. This alternative would result in cleaner and more attractive water and therefore in a more pleasant life for members of the community.

ECONOMIC DEVELOPMENT

1. Land values should increase along the lakefront and the rivers due to improved water quality and recreation potential. However, the storm water holding ponds would adversely affect some lakeshore homes and apartments if the ponds were unattractive. Viewed from a high-rise apartment building, the holding ponds would change the view of the lake, probably decreasing the value presently placed on those apartments.

2. To the extent that the returns from fishing are a function of the quality of the fish in the lake, those returns should increase.

3. The changes in cost for consumers of water would likely be very small, despite the improved quality of treated wastewaters.

4. Investments in plants and processes would not be fully recoverable.

EVALUATION OF LAND DISPOSAL ALTERNATIVE

ENVIRONMENTAL QUALITY

The primary ecological effects of the land-based alternative, L-1, outlined in Section III, were identified as follows:

1. Improved water quality in the Rocky, Chagrin, Cuyahoga Rivers and nearshore waters of Lake Erie would result in a significant improvement in the productivity and diversity of bottom organisms and fish species.

2. There would be a significant increase in phosphate loadings in the upper rivers which could result in increased algae blooms. There would be a significant reduction in nutrient loadings to Lake Erie, leading to a reduction in algae blooms in the nearshore waters.

3. A potential for increased water runoff and soil erosion exists in the treatment areas because of the rolling topography of the selected sites. Such erosion would adversely effect crop management as well as contribute to the reduction of bottom organisms and fish species in local streams.

4. Potential problems exist for crop management on disposal sites, such as high ammonia content of the liquid wastes retained over winter in storage lagoons.

5. Large areas would be converted from a given terrestrial ecology to either pond-oriented ecosystems in lagoon area or significantly wetter ecosystems in the irrigation areas.

6. The loss of water in the Chagrin and East Branch of the Rocky River would lead to similar changes as produced in the water alternative.

7. Power requirements to transport the water to and from the irrigation sites would be about 750,000 kilowatts, which could cause air and thermal pollution problems.

SOCIAL WELL-BEING

Hygienic Concerns

1. Current bacterial and viral problems from untreated sewage would be virtually eliminated.

2. A malfunction or breakdown of the wastewater transportation system could create serious health problems.

3. The aerated and storage lagoons, irrigation sites, storm water infiltration sites and the East Branch of the Rocky River could provide ideal sites for breeding habitats for mosquitoes and flies.

4. Hazardous wastes from industries would be eliminated. If underground storage of toxic industrial wastes were adopted possible contamination of water supplies could result from failure of such a system.

5. Aerosol transmission of pathogens from spray irrigation would be a potential threat.

Aesthetic Impacts

1. The improved water quality in the Three Rivers area would be beneficial and pleasant in many respects related not only to enjoyment of the water and shore areas, but also to the parks and land use improvements which would be stimulated. The additional flows in the Cuyahoga River would increase its scenic value. The reduced flow in the East Branch of the Rocky River would detract from this existing scenic location.

2. Land use changes in the land treatment areas would have considerable effects on their appearance. The change in the natural landscape of trees and steep sloping valleys to spray irrigated fields and lagoons would be aesthetically objectionable.

3. Both adverse and beneficial impacts on the physical characteristics of color, odor, taste and movement of water would result. Existing color problems would be eliminated on the Cuyahoga River and along the shores of Lake Erie. In the areas where algae blooms would increase, there would be negative aesthetic impacts.

4. Should the storage lagoons turn anaerobic during the winter months under an ice cover, a noticeable odor could be produced in the spring.

5. The construction of large spray irrigation fields and lagoons could possibly affect local meteorological conditions, such as by increasing fog.

Recreation Impacts

1. Improvement in water quality in the Rocky and Cuyahoga Rivers and the shoreline of Lake Erie would have beneficial effects on the recreation in the Basin. New or improved fisheries would probably be established in these waters. Passive recreation would be stimulated. Additional parks could be developed along the Cuyahoga and other rivers in the basin. However, water transfers could cause the Chagrin to lose its cold water fishery and decrease quality in the East Branch of the Rocky River.

2. Most of the positive impacts on recreation in this basin would be small. They would be negated by the adverse impacts caused in the spray irrigation areas where many recreation areas would be eliminated. The loss could amount to 11,000 acres, or 60 percent of the existing public recreation lands in those areas.

Human Betterment Impacts

1. The storage lagoons and spray irrigation areas proposed in this alternative would have an adverse effect on historical and cultural features in the area.

2. The percolation basins and storage lagoons could have bad odors; nearby housing could be adversely affected.

Life Style Impacts

The storage lagoons and spray irrigation areas would replace the existing land uses of recreation and agriculture. The growth of nearby cities and towns would be restricted by the presence of the lagoons and spray irrigation areas. Homes, farms and businesses would have to be abandoned or relocated.

ECONOMIC DEVELOPMENT

1. Flow changes because of the transfer of wastewater and

the collection of storm water runoff could affect land values for nearby property.

2. Land acquisition would require the displacement of a portion of the population. Individuals residing near basins or lagoons might notice displeasing odors, and, as a result, land values could decline. Removal of purchased land from tax rolls would cause income loss to local governments.

3. Because of the slopes, spray irrigation would generally be limited to non-row crop farming. The potential and existing truck-crop farming capabilities of the area would be diminished.

4. To the extent that the returns from fishing are a function of the quality of the fish in the lake, those returns should increase.

5. Positive economic impacts could be additional water supply for use by industry in the Lower Cuyahoga.

6. Investments in land could be favorably recovered when desired.

7. Power requirements to transport the water to and from the irrigation sites would require substantial generating capacity.

EVALUATION OF

COMBINATION LAND AND WATER DISPOSAL ALTERNATIVE

ENVIRONMENTAL QUALITY

The effects of the combination land and water disposal alternative, C-3, are similar to the other two strategies. The primary ecological effects are:

1. An overall improvement in the water quality of the area would significantly improve the diversity and productivity of most aquatic and bottom organisms.

2. As with the land alternative, there is a concern for erosion and stream siltation in the spray irrigation area, possibilities for system failure and compatibility of irrigation with crop management.

3. Power for transmission of the wastewater to and from the spray irrigation fields will require about 200,000 kilowatts, which could cause air and thermal pollution problems.

SOCIAL WELL-BEING

Hygienic Concerns

The major hygienic considerations of the combination alternative are:

1. Current bacterial and viral problems from untreated sewage would be virtually eliminated.

2. Off-shore sewage and storm water holding basins would have some contamination potential, as described in the evaluation of the water alternative, W-1.

3. Inefficient operation, a breakdown of a major sewage treatment plant, or failure of a major trunkline sewer or transmission line could create serious health or environmental problems.

Aesthetic Impacts

1. Major beneficial improvements would occur in water color and odor in the Cuyahoga River from Kent to Cleveland and in the Chagrin River. Because the return flows from irrigation fields would contain nutrients, the Rocky and the Cuyahoga would increase their potential for algae blooms.

2. The improved water quality in the Rocky, Cuyahoga, and Chagrin Rivers and the shoreline of Lake Erie would improve the aesthetic settings. Additional park lands adjacent to the Cuyahoga and Chagrin Rivers, could be purchased and developed. Reduced flow in the East Branch of the Rocky would detract from the value of this existing scenic location.

3. The natural composition of Lake Erie water and open space would be changed by the storm water holding basins and their possible color, odor, and algae problems.

4. The areas suggested for spray irrigation and lagoons would affect a number of scenic areas and parks now used for both active and passive recreation. This would affect the aesthetic composition of the areas unfavorably.

5. The biota in the Three Rivers Area would be improved by new park land. In the spray irrigation areas the existing landscape would change.

<u>Recreation Impacts</u>

1. The improved water quality in the Three Rivers Basin would improve its recreation potential. The East Branch of the Rocky would suffer a decrease in its sport fishery. Boating would be more pleasant. Swimming in Lake Erie, especially east of the Cuyahoga River, would be improved. Passive recreation opportunities would also increase on the tributaries and lake shore.

2. In the spray irrigation areas active and passive recreation opportunities amounting to over 7,000 acres would be lost.

3. The effect on the distribution of recreation activity in the Three Rivers area except for possible lakefront swimming and impetus for park improvements, is expected to be negligible. In the areas proposed for waste treatment, the distribution effect is adverse.

Human Betterment Impacts

Human betterment impacts within the spray irrigation areas would not differ greatly from those of the land alternative.

Life Style Impacts

1. Changes in land use would result from the construction of new treatment plants, from additions to existing ones, and from the closing of some small plants. Land needed for new construction and additions would be taken from other uses.

2. Existing land uses of agriculture and recreation would be replaced by storage lagoons and spray irrigation fields. The growth of nearby towns would be restricted by the areas taken up by the storage lagoons and for spray irrigation.

3. The construction of new regional treatment plants and additions to existing plants would result in minor relocation of individuals, homes, and businesses.

4. The storage lagoons and spray irrigation areas would cause major problems due to the number of homes, farms and businesses which would be relocated.

5. As with the other alternatives, the study area would benefit by better water quality and sewage treatment. There would be negative impacts on amenities in the spray irrigation areas.

ECONOMIC DEVELOPMENT

1. Although less land would be used for lagoons and spray irrigation areas than in the land alternative there would still be considerable effect on land values. The spray irrigation fields would be located in areas used for the truck-crop farming industry serving the Youngstown-Alliance-Canton area. The treatment area also represents one of the major growth sites for that complex.

2. The costs of treating water would not appear significantly different from the treatment costs for the other alternatives.

3. The impacts on commercial fishing would be similar to those previously discussed.

4. Power for transmission of the wastewater to and from the spray irrigation fields would require substantial generating capacity.

Summary of Impact Evaluations

The major impacts are summarized in Table 7 on page 51. The improved water quality resulting from any of the various alternatives would have broad beneficial effects. For example, hygienic problems from sewage disposal would be solved, the discharge of toxic industrial wastes would be eliminated, and a more pleasant life would result for people in the study area. However, each alternative would produce negative impacts.

In the water disposal alternative, W-1, one of the major problems is that wastewater would not necessarily be distributed effectively after treatment. This would create a number of environmental, aesthetic, and hygienic impacts. Possible malfunction of a component of the treatment system would pose severe health hazards. Land use changes would be minor. Investments in fixed plants and processes are not fully recoverable.

Although the specific land disposal alternative described, L-1, would return irrigation water to the Three Rivers Watershed, the indicated points of distribution would not be the most effective. Possible malfunction of the transport system would pose severe health hazards. Rolling terrain would create problems for crop management. The extensive amount of land acquisition would pose major institutional, economic and social problems. Large amounts of electric power would be needed to transport the wastewaters. Further, the long term effectiveness and related impacts of land disposal are not completely known for many pollutant constituents, so that there would be some risk of system failure under long term operation.

The combination alternative, C-3, would return irrigation water to the Three Rivers Watershed, but the indicated points of distribution would not be the most effective. Due to selection of the spray irrigation sites the negative impacts on recreation would be nearly as severe as for the land alternative. Other impacts would be similar to those of both other alternatives.

Several common features could cause problems in any of the alternative systems:

a. Incineration of sludges could create air pollution problems, including release of mercury vapors.

b. Storm water holding basins would have negative effects in several respects.

c. Health hazards and system complexities require special safeguards.

d. The selection of points at which return waters are returned to the originating basin to avoid excessive high, low or sporadic flows.

This section is based on material presented in Appendix III.

TABLE 7 - SUMMARY OF IMPACTS

CATEGORY	ALTERNATIVE					
	W-1		L-1		C-3	
	Favorable	Unfavorable	Favorable	Unfavorable	Favorable	Unfavorable
Environmental Quality	Improvement in species, diversity, health, and population	Changes in East Branch of Rocky and Chagrin	Improvement in species, diversity, health, and population	Upstream nutrients Changes of quality in treatment areas Changes in E. Br. Rocky and Chagrin Large power requirements	Improvement in species, diversity, health, and population	Changes of quality in treatment areas Changes in E. Br. Rocky and Chagrin Power requirements
Social Well-Being	Improvement in aesthetics, recreation, and amenities	Possible malfunctions at plants	Improvement in hygiene, recreation, and amenities	Major recreation changes Possible malfunction of transport system	Improvement in hygiene, recreation, and amenities	Major recreation changes Possible malfunction of plants or transport system
National and Regional Economic Development	Land value increases along streams and lakes Increased fishing income	Holding basins decrease land values locally Investments difficult to recover	Land investment could be favorably recovered Additional water supply	Large power requirements Major land use changes	Land investment could be favorably recovered Additional water supply Land value increases	Major land use changes Power requirements

V - DISCUSSION

General

Representative approaches to the regional management of wastewaters were studied. Preliminary alternatives were developed which were technically feasible and the impacts of three of those alternatives on environmental quality, social well-being, and national and regional economic development were evaluated. Evaluation revealed that these could be modified so as to significantly reduce the magnitude of many of the negative impacts.

No concerted effort was made to develop alternative systems which were technically comparable. In this way significant differences were produced in the impact evaluations.

Water Disposal Alternative, W-1

In this alternative, wastewater would be collected and treated in plants. The purified effluent would be released into receiving waters or reused. The separated solids would normally be deposited on land, possibly after incineration, although there would be a number of other feasible approaches. The following evaluation is based on the alternative W-1 and might not apply in all respects to water disposal in general.

a. Advantages

1. Existing technology for conventional treatment is well established and new technologies for more advanced processes are being developed.

2. Effluent quality is generally consistent due to the close control possible in a plant situation.

3. The treatment method is flexible since it is made of unit processes which can be removed or added as the need arises.

4. The method is effective in removing a variety of pollutants, especially with the flexibility of adding units.

5. Land acquisition would be minimal since much of the system could use present sites. Existing investments would be used to the fullest extent, being easily phased into the regional system.

6. Environmental quality in terms of health, diversity, and population of aquatic and bottom life would be improved in most parts of the Three Rivers Watershed.

7. Positive social impacts would include the elimination of hygienic problems from sewage disposal. The aesthetic appearance of waters in the study area would be generally improved. The general amenity value of the community would increase.

b. Disadvantages

1. Some plants would be located in areas where it would be difficult to add storage capacity to increase reliability.

2. Storage basins for runoff could be unsightly and cause health hazards.

3. Water would not be returned to the stream system in the most effective way, thereby influencing environmental quality and social well-being.

4. New technologies used in advanced wastewater treatment have not been fully tested in large capacity plants for a broad range of constituents.

5. Incineration could cause air pollution problems.

6. Investments in plants and processes would not be fully recoverable at the end of their useful life.

7. Sludge disposal transfers nutrients and pollutants to another medium or location where runoff and decomposition can leach them into ground and surface waters.

8. A malfunction of a component of the system would lead to severe health hazards.

c. Evaluation

This alternative would be highly effective, depending on careful operation and monitoring, in removing most pollutants except dissolved solids. It would not effectively treat process sludges. Reliability of the processes should be high, although further study of this is needed. The system would consist of unit processes providing a great deal of flexibility. No emergency storage would be provided in case of malfunction. Treated wastewater would not be returned to streams in an effective way.

Aesthetic, social, and economic impacts of the storm water storage system were negative. Apart from these, life style and land value impacts appeared comparatively minor as did impacts on existing economic development.

Water disposal as represented by alternative W-1 would meet regional objectives with some modifications.

d. Implementation

Although present plans call for implementing projects which would become part of this alternative, no institutional arrangement now exists to bring about a regional program, The existing sites and collection systems would be used as a base. Thus, the alternative could be fully implemented by 1990 with updating required after that time.

e. Possible Modifications

Modifications to W-1 which would alleviate some of the disadvantages of this alternative, and make it more suitable as a regional water disposal system, are:

1. Return of the treated water to the three watersheds at selected sites to provide for useful distribution of water.

2. Safety and reliability can be increased by adequate operator training, provision of storage at or close to plant sites, and provision of back-up components.

3. Alternate methods of storm water treatment and sludge disposal should be considered.

Land Disposal Alternative, L-1

In this alternative, the wastes would be pretreated, then applied to land where soils and crops would provide final treatment. The renovated water from the land treatment would be returned to the Three Rivers Watershed. Solid material would be deposited on the same land without incineration. The following evaluation is based on the alternative L-1 and might not apply in all respects to the land disposal concept in general.

a. Advantages

1. Wastewater has a value as a source of nutrients as well as moisture for crops. A useful product can

be produced. The initial land investment could be favorably recovered.

2. High summer return flows would increase flows in rivers which could provide additional water supply.

3. Unit processes are uncomplicated, reliable and flexible.

4. Environmental quality in terms of health, diversity, and population of aquatic and bottom life would be improved in most parts of the Three Rivers Watershed.

5. Positive social impacts would include the elimination of hygienic problems from sewage disposal. The aesthetic appearance of waters in the study area would be generally improved. The general amenity value of the community would increase.

6. Sludge disposal on land treatment areas provides for treatment of nutrients and pollutants contained in the sludges.

7. Storage lagoons provide a large measure of safety.

b. Disadvantages

1. Extensive land areas would be necessary. The particular sites identified would create problems of crop management because of rolling terrain.

2. There would be wide seasonal fluctuations in return flows.

3. A malfunction of the transportation lines carrying untreated wastewater would cause health hazards.

4. Return water would not be distributed to the stream system in the way most effective for the enhancement of environmental quality and social well-being.

5. There would be major land use changes with resulting environmental, social, and economic impacts.

6. Nutrient uptake is difficult to calculate because the crop-growing process cannot be precisely controlled.

7. Large amounts of energy would be required to transport the wastewater to and from the irrigation sites.

c. **Evaluation**

This alternative would be very effective for removing BOD and suspended solids. Nutrient removal wan be efficient but not precisely controlled because of climate, soil, and crop conditions. The large storage and land areas would provide a reliable system. Flexibility would be good since all the flow would be concentrated in few sites which would allow for the addition of future treatment processes. Major drawbacks of the alternatives would involve extensive land requirements and high pumping costs. There would be major negative environmental and social impacts in the treatment areas.

The land disposal system as represented by this alternative would requize considerable modification to meet regional objectives.

d. **Implementation**

The principal implementation problem is timing, especially in the early 1970's. Planning, design and even some construction are already underway for extensive upgrading of existing systems. During this period local agencies face frequent decisions on the plans and designs for these systems, yet for both technical and administrative reasons no decision can be made on any other alternative plan before about late 1972.

Implementation could be begun by construction of land systems for treatment of wastes generated in outer areas. Lagoons for the metropolitan areas would be built next and phased in as present plants became obsolete. Final transmission lines could be completed for a full land disposal system by 2000. No institutional arrangement exists at the present time to implement this program.

e. **Possible Modifications**

Modifications to L-1 which would alleviate some of the disadvantages of this alternative and make it more suitable as a regional land disposal system are:

1. Different irrigation sites, rates, and cropping patterns should be investigated to overcome the negative environmental and social impacts.

2. Treated water should be distributed so as to provide managed stream flow. The impacts of possible water

exchange between the Great Lakes and Ohio River basins should be studied.

3. Irrigation sites and storage lagoons should be planned for most effective land use and favorable aesthetic impact.

4. Irrigation waters could be distributed on public forest lands or used, where desirable, on existing farm land, rather than solely on special irrigation sites. Possible sites within the study area should be investigated.

5. Existing public rights-of-way should be used, where possible, for the transportation pipe lines. Pipe lines could be cross-connected at intervals to provide additional safety.

6. Other populated areas outside the study region and near the treatment sites could be added to the system, providing more benefits with fewer liabilities.

7. Providing secondary treatment with phosphate removal capability at regional sites, and pumping the treated effluent to storage and land treatment sites would reduce hazards of sewage pumping, provide positive phosphate removal, and reduce some of the negative psychological factors.

8. Advanced treatment could be provided at plants in the non-growing season with discharge to watershed streams to eliminate winter storage and year-round pumping to and from the irrigation sites.

9. There is the possibility of placing sludge on other lands rather than the irrigated areas. This would increase the pollutant removal in the system but require additional facilities at the sludge disposal site.

The evaluation of alternative L-1 pointed out serious disadvantages of land and power needs. Apart from the several modifications there is another possible land disposal technique which should be considered. This is secondary treatment, possibly in aerated lagoons, with subsequent percolation of the treated effluents at high rates through spreading basins. This alternative was originally designated as L-2. Since the needed area would be 26 square miles, or 7% of the land requirements of L-1, the treatment sites could be situated closer to collection points, perhaps within the study area. Considerably less power would be needed for transmission. Construction costs would be lower.

Combination Land - Water Disposal Alternative, C-3

In the combination alternative, the "inner ring" of the region would be provided with treatment by a water disposal system while the remainder of the region would have treatment based on a land disposal system. Impacts of this alternative are inherently a combination of the impacts of the elements of its components.

a. Advantages

The advantages of the alternative in the "inner ring" would be essentially those of alternative W-1. The advantages in the "outer ring" would be essentially those of L-1.

b. Disadvantages

Disadvantages in the "inner ring" would be essentially those of alternative W-1 and in the "outer ring" those of L-1.

c. Evaluation

This alternative requires a large land area for its implementation and the postulated treatment sites would include most of the recreation land in those areas. There would be accompanying major environmental and social impacts. There would be a more effective return of water to the stream system and institutional problems would be less.

A combination system as represented in this alternative would require modification to effectively meet regional objectives.

d. Implementation

Although no institutional arrangements exist at the present time to implement this program, the "inner ring" could possibly be an extension of an existing metropolitan or county authority. Phasing could be accomplished by starting the irrigation sites for the outer areas in the near future. The transmission lines to these sites as well as transmission lines to the regional sites could be completed by 1990 with updating occurring as needed. However, the problem of timing, in the early 1970's, would exist with this alternative as with L-1.

e. Possible Modifications

Modifications which would alleviate some of the disadvantages of this alternative and make it more suitable as a regional disposal system are:

1. Different irrigation sites, rates, and cropping patterns should be investigated to overcome negative environmental and social benefits.

2. Treated water should be distributed so as to provide managed stream flow. The impacts of possible water exchange between the Great Lakes and Ohio River Basins should be studied.

3. Irrigation sites and storage lagoons could be planned for most effective land use and favorable aesthetic impact.

4. Irrigation waters could be distributed on public forest lands or used, where desirable, on existing farm land, rather than solely on special irrigation sites.

5. Existing public rights-of-way should be used, where possible, for the transportation pipe lines. Pipe lines could be cross-connected at intervals to provide additional safety.

6. To avoid the high power requirements of pumping wastewaters a combination alternative could be developed in which treatment would be based on the general elevation of source. This would also permit possible enlargement of the upland region to include population centers from Youngstown to Mansfield.

This alternative would have major disadvantages of large power and land requirements. Another land disposal technique should be considered for the "outer ring" in combination with a water disposal system for the "inner ring". The "outer ring" would be provided with secondary treatment either in regional plants or in aerated lagoons. The treated effluent would be distributed to spreading basins for percolation at high flow rates. Land requirements might be on the order of 10 square miles, possibly within the study area. Another variation could consider that land disposal technique applied to individual basins so that return of treated waters would be simpler.

Costs

Rough estimates of the construction costs and the ultimate operation and maintenance costs were developed for each of the three alternatives. These costs have a value within themselves since they do give an order of magnitude, although very preliminary, of the costs involved in regional wastewater management for the study area. The costs shown in Section III are not comparable between alternatives, however, because the alternatives were not fully comparable as to reliability, effectiveness, and value of renewable resources. The costs of some alternatives would be partly offset by certain additional benefits. The discussion of the evaluation of the alternatives in Section IV shows that there are positive and negative benefits which would accrue to each that would have to be considered and included in any valid economic comparison. Some of the possible modifications listed for each alternative would undoubtedly result in a decreased total cost for an equal or better system. Neither the construction costs nor the operation and maintenance costs, as developed, should be used as a basis for decision or selection of one of the alternatives or concepts over the others. Before this can be done sufficient studies must be made to develop alternatives that are fully comparable in efficiency, reliability and flexibility and economic analyses must be made to evaluate the positive and negative benefits developed by each.

Information Needs

In order to continue effectively with further studies, information is needed on several aspects of wastewater management. These can be listed within several general categories, as follows:

1. Technical data

   a. Detailed data to use in mathematical system models for the watershed. These would relate effluent discharges and effects of system changes to stream flow and storm events.

   b. Identification of flow, constituents, and variability of pollutants in outfalls. The new discharge permit program would be an initial step.

   c. Soil studies to determine best sites for land disposal.

   d. Determination of best source of power for land system requirements.

   e. Baseline surveys to assess current environmental and social conditions, considering the effect of construction currently underway and planned for implementation in the near future.

2. General Research

   a. Examination of the characteristics and impact of runoff wastes, particularly rural runoff.

   b. Studies to determine best soils for land disposal sites and effects of dissolved solids on land and crop.

   c. Methods to remove dissolved solids.

   d. The effect of storm water fluctuations on treatment capabilities and efficiencies.

   e. Methods to maximize disinfection techniques.

   f. Further examination of expected effectiveness of advanced treatment processes on a large scale.

   g. Reuse of inorganic sludge to reduce treatment costs, and as for fuel to furnish some of the power required.

   h. Opportunities for reclamation, recycling and disposal of industrial wastewaters.

   i. Refinement of design criteria.

3. Social and Economic Studies

   a. Developing a market for crops grown on irrigation areas.

   b. Evaluation of the recreational value of properly planned storage and other areas required for land disposal system.

4. Institutional Problems

   a. Methods of funding.

   b. Formation of agencies with authority and resources to design, construct, operate and maintain.

   c. Enforcement.

   d. Restraints on interbasin transfers of water.

   e. Public acceptance.

   f. Phasing alternatives into existing systems.

VI - CONCLUSIONS

Each of the wastewater management alternatives examined would provide the region with a program that would virtually eliminate pollution in surface waters and reduce pollutant inflows to Lake Erie. Nevertheless, each of the selected alternatives exhibits distinct characteristics and problems, although most of the problems can be solved by modifications.

More detailed analyses are needed to develop within each approach the combination of treatment and transmission facilities best suited for the area. For the water disposal system these might include storage at regional plants to increase reliability and improvement of the distribution of treated effluents. For the land disposal system control of phosphorous removal could be added at irrigation sites. Because of smaller land requirements, spreading-percolation basins could be provided within or near the study area; the costs of transmission, storage, application and return flow could be reduced. Combinations incorporating water disposal for the inner ring and land disposal with spreading-percolation basins might provide the ideal balance.

Institutional problems and timing are major concerns. The number of political subdivisions and current abatement programs complicate the development and implementation of a new regional management approach. A major effort will be needed to coordinate further and work closely with local governments and agencies.

There would be strong negative local reaction to losing large amounts of real estate to irrigation and treatment sites. This reaction could be reduced by better understanding of how these sites could be blended into the surrounding landscape. Additional studies are needed to fit treatment sites into pleasant land use patterns, which could include forest areas, green belts, buffer zones, crop areas, and recreational facilities. Additional study will also be required on such things as nutrient benefits, possible crops, production rates and marketability.

There are several information needs that must be addressed in a further, more detailed study. The most critical of these are: Methods of handling storm runoff, sludge disposal, locations of suitable irrigation areas, development of a watershed model to predict effects of discharges on tributaries, characterization of industrial wastewaters, environmental and social baseline surveys, land use planning of treatment sites, and solution of institutional problems.

Estimates of construction and operation costs were made as first approximations. More detail is necessary for estimating construction, operation, and maintenance costs, especially if cost comparisons are to be based on approaches having comparable effectiveness, flexibility and reliability.

Although the majority of the pollution problems of the Cuyahoga River can be rectified by adequate wastewater management, a number of the problems result from natural and other conditions. Such problems as erosion, sedimentation, and floating debris will not be solved by wastewater management. These and other water resource problems are included in the Cuyahoga River Restoration Study, which deals with all phases of water management. The Cuyahoga River has a great potential for recreation, scenic appeal, and other outdoor leisure activities to provide for the needs of the growing population of the study area. The potential of the river, particularly in the lower reaches, for these water-oriented interests cannot be fully recovered even with the construction of recreation and park facilities unless the present quality of the water is considerably improved. Close coordination is necessary between the two studies.

An important part of this study procedure was that development, evaluation, and modification were used as integral parts of an iterative study process. This process identified impacts which signaled the need for modifications to improve the alternatives. Additional modifications were identified which should help evolve the approach best suited to the area.

Since no single disposal method exhibited a clear advantage, several alternatives must be investigated as soon as possible so as to provide additional assistance to State and local governments to enhance environmental quality and meet the Federal requirements for planning.

Further studies would be required to investigate alternatives which are as equal as possible with respect to effectiveness, reliability, and flexibility. In this way, technical comparisons would be essentially eliminated and impacts could be based on systems having equal performance. Environmental, social, institutional, and economic evaluations would be more meaningful.

The regional systems for treating domestic and compatible industrial wastewaters which should be studied in more detail are:

1. Water disposal system of advanced treatment facilities. Special emphasis on distribution of treated wastewaters to watershed and on added safety features.

2. Land disposal system of aerated lagoons and spray irrigation on croplands employing different treatment sites. Special emphasis on distribution of return water.

3. Land disposal system of secondary treatment in regional plants, filtration, and spray irrigation on croplands. Possible advanced treatment in plants during non-irrigation season. Distribution of return water to region.

4. Land disposal system of aerated lagoons and high rate spreading-percolation basins. Distribution of return water to watershed.

5. Combination system. Inner region provided with water based treatment. Outer region provided with land disposal treatment employing secondary treatment, filtration, and spray irrigation. Inner and outer regions defined by elevation of source and outer region expanded to include larger service population. Return water to be distributed.

6. Combination system. Inner ring provided with water based treatment and outer ring with land based treatment employing aerated lagoons and spreading-percolation basins. Return water to be distributed.

In addition, studies must be made of separate systems to handle both non-compatible industrial wastewaters and stormwater runoff.