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WASTEWATER MANAGEMENT STUDY FOR CHICAGO-SOUTH END OF LAKE MICHI--ETC(U)
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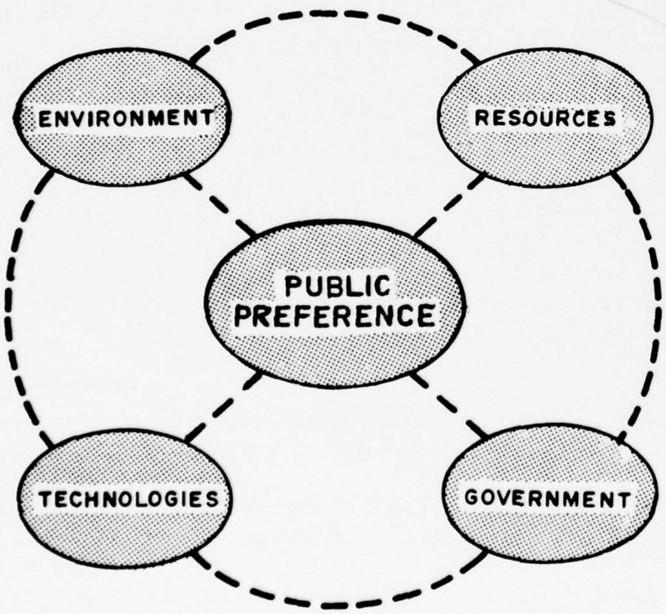
WASTEWATER MANAGEMENT STUDY FOR

CHICAGO-SOUTH END *of* LAKE MICHIGAN



DATA ANNEX
APPENDIX B.

BASIS OF DESIGN AND COST.

(12) 202p.

DEPARTMENT OF THE ARMY
CHICAGO DISTRICT CORPS OF ENGINEERS
219 SOUTH DEARBORN STREET
CHICAGO, ILLINOIS 60604
(11) JULY 1973

410 079

REPORT COMPOSITION

The survey report is divided into a Summary, and 9 Appendices. A charge for each appendix and summary report to cover the cost of printing will be required, should purchase be desired. The appendices each contain a different category of information. Alphabetically identified, the appendices are:

A. Background Information - This appendix includes the population and industrial projections, wastewater flows and the engineering data used as a basis for planning.

B. Basis of Design and Cost - This appendix contains the criteria and rationale used to design and cost the final alternative wastewater treatment system components.

C. Plan Formulation - The appendix presents the planning concepts and procedures used in developing the alternative wastewater management plans that were examined during the study.

D. Description and Cost of Alternatives - This appendix contains a cost description and construction phasing analysis for each of the final five regional wastewater management alternatives. Components of these alternatives are described in detail in Appendix B.

E. Social - Environmental Evaluation - This report provides an assessment of the social and environmental impacts likely to arise from the implementation of the final five alternatives.

F. Institutional Considerations - This report presents an assessment of the institutional impacts likely to arise from implementation of the final five alternatives.

G. Valuation - This appendix presents a broad evaluation of the implications and use potential inherent in the final five alternatives.

H. Public Involvement/Participation Program - This appendix documents the program used to involve the public in the planning process.

I. Comments - This appendix contains all of the formal comments from local, State and Federal entities as the result of their review of the other appendices and the Summary Report. Also capsulized are the views of citizens presented at public meetings.

The Summary document presents an overview of the entire study.

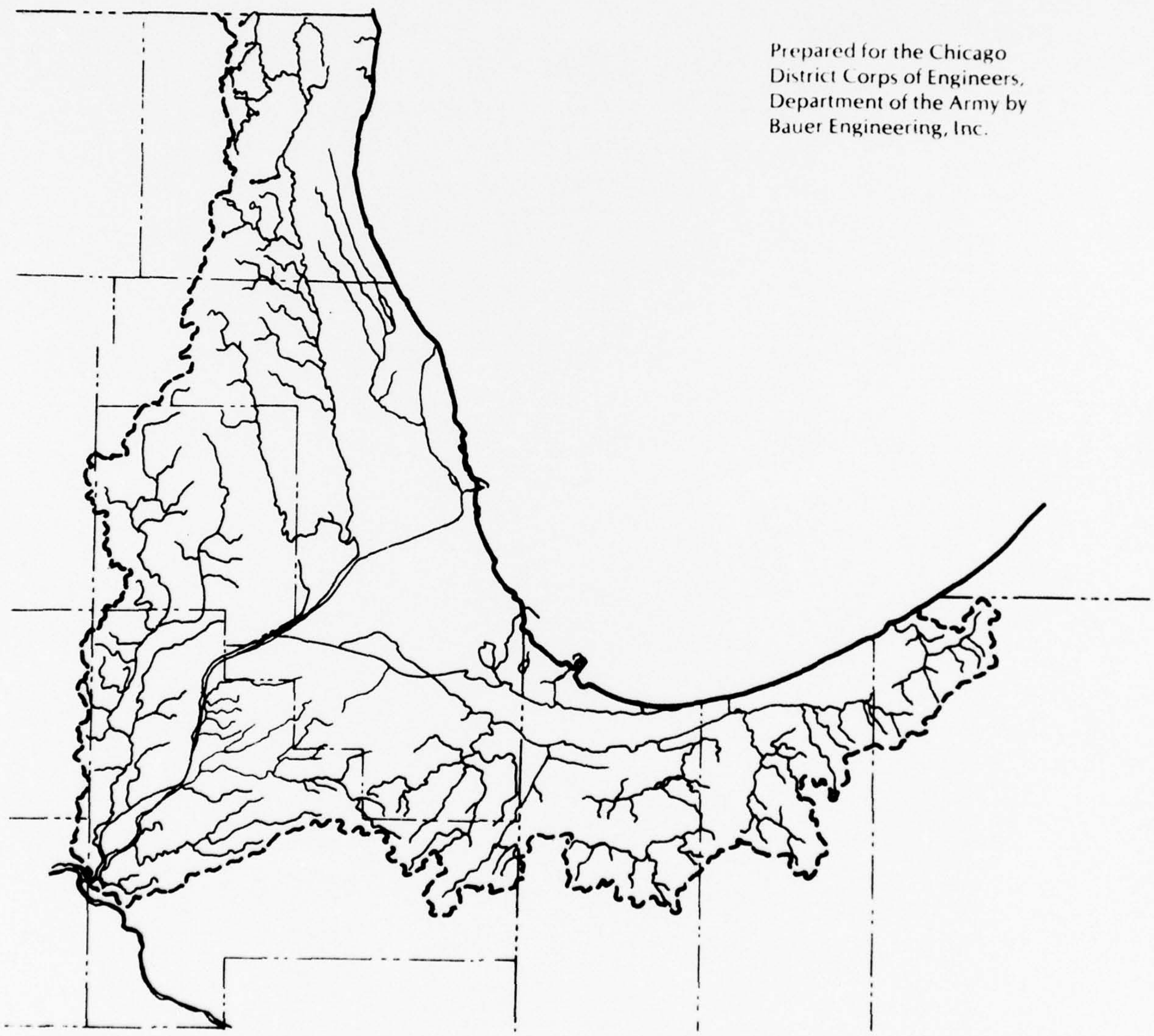
WASTEWATER MANAGEMENT STUDY
CHICAGO-SOUTH END OF
LAKE MICHIGAN AREA

DATA ANNEX B
BASIS OF DESIGN AND COST

DEPARTMENT OF THE ARMY
Chicago District, Corps Of Engineers
219 South Dearborn Street
Chicago, Illinois 60604

MAY 1973

WASTEWATER MANAGEMENT STUDY
CHICAGO-SOUTH END OF LAKE MICHIGAN AREA



Prepared for the Chicago District Corps of Engineers, Department of the Army by Bauer Engineering, Inc.

DATA ANNEX B
BASIS OF DESIGN AND COST

DATA ANNEX B

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PREFACE

GENERAL

This volume is a part of the United States Army, Chicago District, Corps of Engineers, Survey Scope Study for Regional Wastewater Management in the Chicago-South End of Lake Michigan area. The overall Survey Scope Study report consists of a Summary volume and a number of supporting appendices. This appendix, Appendix B - Basis of Design and Cost, contains the basis of the design and costs for five regional wastewater management systems presented in the Summary volume, and detailed in Appendix D, Description and Cost of Alternatives.

Appendix B is divided into two parts, a formal volume and a data annex, Data Annex B - Basis of Design and Cost, which presents more detailed, supporting information pertinent to the formal presentation. Appendix B and Data Annex B are bound under separate cover. This volume is the Data Annex.

The Data Annex is structured parallel to the Appendix, with corresponding roman-numeraled sections and upper case, lettered subsections. Specific information is referenced in the Appendix and is placed in the parallel Data Annex section and subsection. There are a number of subsections which do not have material referenced in the Data Annex.

DATA ANNEX LABELING

Page numbering and Figure and Table identification are referenced by a four place designation. An example of each is presented below:

<u>Table Labeling and Referencing</u>

Table BA - IV - A - 3

Table — Identifies reference as a table

3 — Identifies table number, numbered consecutively from beginning of subsection

A — Identifies subsection of section

IV — Identifies section of data annex

BA — Identifies Appendix, then data annex

Figure Labeling and Referencing

Figure BA - III - C - 5

- Figure: Identifies reference as a figure
- BA: Identifies Appendix, then data annex
- III: Identifies section of data annex
- C: Identifies subsection of section
- 5: Identifies figure number, numbered consecutively from beginning of subsection

Page Numbering and Referencing

BA - VII - D - 14

- BA: Identifies Appendix, then data annex
- VII: Identifies section of data annex
- D: Identifies subsection of section
- 14: Identifies page number, numbered consecutively from beginning of subsection

REFERENCES

Reference numbers for bibliographic references are listed chronologically at the end of data annex subsections.

DATA ANNEX B

INTRODUCTION

I. INTRODUCTION

B. DESCRIPTION OF REGIONAL WASTEWATER MANAGEMENT

ULTIMATE WATER QUALITY GOALS

An integral part of the C-SELM study was the formulation of ultimate water quality goals. These goals were developed by the Corps of Engineers and were based on a variety of water uses such as supplemental potable water supplies, primary-contact recreation, healthy aquatic environment and aesthetic considerations. Presented in Table BA-I-B-1 is a list of parameters defined in this study as critical pollutants. The concentrations of these parameters which reflect the ultimate water quality goals of the study are also presented.

The purpose of the technical goals of the C-SELM wastewater management study is the prevention of water resource degradation by waterborne wastes together with efficient reuse of the renovated wastewater and its separate constituents. Since the characteristics of the majority of the C-SELM streams are dependent on sewage treatment plant and stormwater runoff discharges, the achievement of the ultimate water quality goal requires a goal geared to maximum reasonable purity of sewage effluent and stormwater runoff. Thus, the ultimate water quality goals of this study are translated to a "No Discharge of Critical Pollutants" (NDCP) effluent goal. This NDCP effluent goal was formulated by the Corps of Engineers for this study. It does not represent an accepted or adopted standard by the EPA. The critical levels for the wastewater-stormwater constituents of the NDCP goal are based upon the natural background levels of the receiving stream or aquifer, with specific expections of constituents that are highly toxic or otherwise injurious to the environment at trace levels. As a basis of design three groups of constituents and acceptance levels of each are established:

1. Constituents that should be absent from the wastewater effluent as discharges

2. Constituents that comprise the minimum acceptance list that must be considered

Table BA-I-B-1

ULTIMATE WATER QUALITY GOALS

Critical Pollutant	Controlling and Ultimate Quality Criteria	Controlling Water Use	Reference Source
COD, mg/l	3-6	Healthy Aquatic Environment	Background Concentration of Relatively Unpolluted Natural Waters
BOD, mg/l	1-2	Healthy Aquatic Environment	"
Suspended Solids, mg/l	0	Potable Water Objective	Water Quality Criteria, FWPCA
Dissolved Solids, mg/l	500	Potable Water Objective	"
Soluble Phosphorus, mg/l	0.01	Healthy Aquatic Environment and Recreation	"
NH_3-N, mg/l	<1	Healthy Aquatic Environment	European Inland Fisheries Advisory Commission, Rome, 1970
NO_3+NO_2-N, mg/l	10	Potable Water Objective	Water Quality Criteria, FWPCA
Organic N, mg/l	<0.3	Healthy Aquatic Environment	Background Concentration of Relatively Unpolluted Natural Waters

Table BA-I-B-1 (Continued)

ULTIMATE WATER QUALITY GOALS

Critical Pollutant	Controlling and Ultimate Quality Criteria	Controlling Water Use	Reference Source
Heat, Temp. °F	3 to 5°F Increase Above Background	Healthy Aquatic Environment	Water Quality Criteria, FWPCA
Oils, Greases, mg/l	<0.3	Healthy Aquatic Environment	"
Phenols, mg/l	<0.1	Healthy Aquatic Environment	"
Pathogens, Virus, mg/l	~ 0	Potable Water Objective and Recreation	"
Trace Metals[a], mg/l	See Individual Criteria Below	Potable Water Objective, Healthy Aquatic Environment, Agricultural	"
Boron, mg/l	0.5-1.0	Potable Water Objective and Agricultural	"
Arsenic, mg/l	0.01	Potable Water Objective	"
Cyanide, mg/l	0.02	Potable Water Objective	"

[a] Aluminum-1.0 mg/l, Cadmium-0.005 mg/l, Chromium-0.02 mg/l, Copper-$<$1.0 mg/l, Lead-0.05 mg/l, Nickel-$<$0.1 mg/l, Zinc-4 mg/l, Iron-0.3 mg/l, Manganese-0.05 mg/l, Mercury-$\sim$0.

3. Constituents that should be given particular consideration as warranted by their impacts on the region

Thus, on this basis, together with considerations concerning performance levels that can presently be achieved by application of the best available technology, the NDCP goal was formulated as shown in Table BA-I-B-2. Performance data, in this table, for advanced biological treatment was based primarily on small-scale operating systems, and for physical-chemical and land treatment on limited small scale operating experience and on pilot plant, engineering and laboratory studies. Higher performance may be technically attainable by each process. The extrapolation of the performance data to large size processing facilities is considered reasonable for the scope of this Study. Prototype facilities would be provided during the implementation period in order to develop the required large scale operating experience.

Table BA-I-B-2

NO DISCHARGE OF CRITICAL POLLUTANT EFFLUENT GOAL

Treatment Type	COD mg/l	BOD mg/l5	Suspended Solids mg/l	Dissolved Solids mg/l	Soluble Phosphorus mg/l	NH_3-N mg/l	NO_3-N NO_2 mg/l	Organic N mg/l
Conventional a/	60	20	25	600-635	4-8	13-17	0.5-1.5	2
Advanced Biological	10	3	1	500	0.1-0.2	0.3	2-5	0
Chemical-Physical	10	3	1	535	0.1-0.2	0.5	2	0
Land Treatment	6	2	0	500	0.01	0	2	0

a/ Not a part of the NDCP goal, presented for reference purposes.

Table BA-I-B-2 (Continued)

NO DISCHARGE OF CRITICAL POLLUTANT EFFLUENT GOAL

Treatment Type	Heat, Temp. °F	Oils Greases mg/l	Phenols mg/l	Pathogens, Viruses	Accumulative Trace Metals[a] mg/l	Boron mg/l	Arsenic mg/l	Cyanide mg/l
Conventional	53-78	10	0.2	Present[b]	3	1.0	0.3	0
Advanced Biological	53-78	1	0.01	Present[b]	0.1	1.0	0.03	0
Chemical-Physical	53-78	1	0.01	Present[b]	0.1	1.0	0.03	0
Land Treatment	55-70	0	0	0	~0	0.8	0	0

[a] Trace Metals: Aluminum, Cadmium, Chromium, Copper Lead, Nickel, Zinc, Iron, Manganese, Mercury.

[b] Present with Current Disinfection Practice.

EXISTING EFFLUENT AND WATER QUALITY STANDARDS

In the development of the list of water quality and effluent standards and requirements the following materials were utilized to provide the needed information.

1. Illinois Pollution Control Board:
   a. Newsletter No. 36, November 15, 1971
   b. Newsletter No. 39, December 27, 1971
   c. Newsletter No. 40, January 10, 1972
   d. Newsletter No. 44, March 8, 1972

2. Indiana Stream Pollution Control Board:
   a. Regulation SPC IR-2, September 18, 1970
   b. Regulation SPC 4-R
   c. Regulation SPC 7-R
   d. Regulation SPC 9, June 13, 1967
   e. Regulation SPC 10, June 13, 1967
   f. Regulation SPC 12

3. Summary of Conference, Pollution of the Interstate Waters of the Grand Calumet River, Little Calumet River, Calumet River, Wolf Lake, Lake Michigan and their tributaries (Indiana-Illinois):
   a. March 2-9, 1965
   b. January 4-5, 1966
   c. March 15, 1967
   d. December 11-12, 1968 and January 29, 1969

4. Summary of Conference, Pollution of Lake Michigan and its Tributary Basin (Wisconsin-Illinois-Indiana-Michigan):
   a. January 31, February 1-2, 5-7, March 7-8, 12, 1968
   b. February 25, 1969
   c. March 31, April 1, May 7,
      September 28-30, October 1-2, 29, 1970
      March 23-25, 1971

Illinois Water Quality Standards (Adopted)

A. Lake Michigan waters

1. Freedom from unnatural sludge or bottom deposits, floating debris, visible oil, odor, unnatural plant or algal growth, unnatural color or turbidity, or matter in concentrations or combinations toxic or harmful to human, animal, plant or aquatic life of other than natural origin.

2. pH (STORET number - 00400) shall be within the range of 7.0 to 9.0 except for natural causes.

3. Radioactivity:

   a. Gross beta (STORET number - 03501) concentration shall not exceed 100 pico curies per liter (pCi/l).

   b. Concentrations of radium 226 (STORET number - 09501) and strontium 90 (STORET number - 13501) shall not exceed 1 and 2 pico curies per liter, respectively.

4. The following levels of chemical constituents shall not be exceeded:

CONSTITUENT	STORET NUMBER	CONCENTRATION (mg/l)
Ammonia Nitrogen (as N)	00610	0.02
Arsenic (total)	01000	0.01
Barium (total)	01005	1.0
Boron (total)	01020	1.0
Cadmium (total)	01025	0.01
Carbon Chloroform Extract (CCE)	32005	0.2
Chloride	00940	12.0
Chromium (total hexavalent)		0.05
Chromium (total trivalent)		1.0
Copper (total)	01040	0.02
Cyanide	00720	0.01
Fluoride	00950	1.4
Iron (total)	01046	0.3
Lead (total)	01049	0.05
Manganese (total)	01055	0.05
Methylene Blue Active Substance (MBAS)	38260	0.5
Mercury	71900	0.0005
Nickel (total)	01065	1.0
Nitrates plus Nitrites as N	00630	10.0
Oil (hexane-solubles)	00550	0.1
Phenols	32730	0.001
Phosphorus	00665	0.007
Selenium (total)	01145	0.01
Silver (total)	01075	0.005
Sulfate	00945	24.0
Total Dissolved Solids	00515	180.0
Zinc	01090	1.0

5. Any substance toxic to aquatic life shall not exceed one-tenth of the 48-hour median tolerance limit (48-hr. TLm) for native fish or essential fish food organisms.

6. Waters shall be of such quality that with treatment consisting of coagulation, sedimentation, filtration, storage and chlorination, or other equivalent treatment processes, the treated water shall meet in all

respects both the mandatory and recommended requirements of the Public Health Service Drinking Water Standards - 1962

7. Dissolved oxygen (STORET number - 00300) shall not be less than 90% of saturation except due to natural causes.

8. Based on a minimum of five samples taken over not more than a 30-day period, fecal coliforms (STORET number - 31616) shall not exceed a geometric mean of 20 per 100 ml.

9. Temperature (STORET number - (°F) 00011 and (°C) 00010):

a. (1) All sources of heated effluents in existence as of January 1, 1971 shall meet the following restrictions outside of a mixing zone which shall be no greater than a circle with a radius of 1,000 feet or an equal fixed area of simple form.

(a) There shall be no abnormal temperature changes that may affect aquatic life.

(b) The normal daily and seasonal temperature fluctuations that existed before the addition of heat shall be maintained.

(c) The maximum temperature rise at any time above natural temperatures shall not exceed 3°F. In addition, the water temperature shall not exceed the maximum limits (°F) indicated in the following table:

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
45	45	45	55	60	70	80	80	80	65	60	50

(2) The owner or operator of a source of

heated effluent which discharges 0.5 billion British Thermal Units per hour (BTU/HR.) or more shall demonstrate in a hearing before the Illinois Pollution Control Board not less than 5 nor more than six years after the adoption of this regulation, that discharges from that source have caused and cannot be reasonably expected in future to cause significant ecological damage to the Lake. If such proof is not made to the satisfaction of the Board, backfitting of alternative cooling devices shall be accomplished within a reasonable time as determined by the Board.

(3) The owner or operator of a source of heated effluent shall maintain such records and conduct such studies of the effluents from such source and of their effects as may be required by the Environmental Protection Agency or in any permit granted under the Environmental Protection Act.

(4) Backfitting of alternative cooling facilities will be required if, upon complaint filed in accordance with Board rules, it is found at any time that any heated effluent causes significant ecological damage to the Lake.

b. Any effluent source under construction as of January 1, 1971, but not in operation, shall meet all the requirements of Section 1 of this regulation and in addition shall meet the following restrictions:

(1) Neither the bottom, the shore, the hypolimnion, nor the thermocline shall be affected by any heated effluent.

(2) No heated effluent shall affect spawning grounds or fish migration routes.

(3) Discharge structures shall be so designed as to maximize short-term mixing and thus to reduce the area significantly raised in temperature.

(4) No discharge shall exceed ambient temperatures by more than 20° F.

(5) Heated effluents from more than one source shall not interact.

(6) All reasonable steps shall be taken to reduce the number of organisms drawn into or against the intakes.

(7) Cleaning of condensers shall be accomplished by mechanical devices. If chemicals must be used to supplement mechanical devices, the concentration at the point of discharge shall not exceed the 96-hour TLm for fresh water organisms.

c. (1) No source of heated effluent which was not in operation or under construction as of January 1, 1971 shall discharge more than a daily average of 0.1 billion BTU/Hr.

(2) Sources of heated effluent which discharge less than a daily average of 0.1 billion BTU/Hr. not in operation or under construction as of January 1, 1971 shall meet all requirements of sections 1 and 2 of this regulation.

B. Restricted use waters

1. Chicago Sanitary and Ship Canal

2. Calument-Sag Channel

3. Little Calumet River from its junction with the Grand Calumet River to the Calumet-Sag Channel

4. Grand Calumet River

5. Calumet River

6. Lake Calumet

7. South Branch of the Chicago River

8. North Branch of the Chicago River from its confluence with the North Shore Channel to its confluence with the South Branch

9. Des Plaines River from its confluence with the Chicago Sanitary and Ship Canal to the Interstate 55 bridge

10. North Shore Channel, except that dissolved oxygen in said Channel shall be not less than 5 mg/l during 16 hours of any 24 hour period, nor less than 4 mg/l at any time.

    a. Freedom from unnatural sludge or bottom deposits floating debris, visible oil, odor, unnatural plant or algal growth, or unnatural color or turbidity.

    b. pH (STORET number - 00400) shall be within the range of 6.0 to 9.0 except for natural causes.

    c. Dissolved oxygen (STORET number - 00300) shall not be less than 3.0 mg/l during at least 16 hours in any 24-hour period, nor less than 2.0 mg/l at any time.

    d. Based on a minimum of five samples taken over not more than a 30-day period, fecal coliforms (STORET number - 31616) shall not exceed a geometric mean of 1,000 per ml, nor shall more than 10% of the samples during any 30-day period exceed 2,000 per 100 ml.

e. The following levels of contaminants shall not be exceeded:

CONSTITUENT	STORET NUMBER	CONCENTRATION (mg/l)
Ammonia Nitrogen (as N)		2.5
Arsenic (total)	01002	0.25
Barium (total)	01007	2.0
Cadmium (total)	01027	0.15
Chromium (total hexavalent)		0.3
Chromium (total trivalent)		1.0
Copper (total)	01042	1.0
Cyanide	00720	0.025
Fluoride (total)	00951	2.5
Iron (total)	01045	2.0
Lead (total)	01051	0.1
Manganese (total)	01055	1.0
Mercury (total)	71900	0.0005
Nickel (total)	01067	1.0
Oil (hexane solubles or equivalent)	00550	15.0
Phenols	32730	0.3
Selenium (total)	01145	1.0
Silver	01077	0.1
Zinc (total)	01092	1.0

f. Temperature (STORET numbers - (°F) 00011 and (°C) 00010) shall not exceed 93° F (34°C) more than 5% of the time, or 100°C) at any time.

C. General use waters

1. Chicago River

2. Little Calumet River

a. Freedom from unnatural sludge or bottom deposits, floating debris, visible oil, odor, unnatural plant or algal growth, unnatural color or turbidity, or matter in concentrations or combinations toxic or harmful to human, animal, plant or aquatic life of other than natural origin.

b. pH(STORET number - 00400) shall be within the range of 6.5 to 9.0 except for natural causes.

c. Phosphorus (STORET number - 00665): Phosphorus as P shall not exceed 0.05 mg/l in any reservoir or lake, or in any stream at the point where it enters any reservoir or lake.

d. Dissolved oxygen (STORET number - 00300) shall not be less than 6.0 mg/l during at least 16 hours of any 24 hour period, nor less than 5.0 mg/l at any time.

e. Radioactivity:

   (1) Gross beta (STORET number - 03501) concentration shall not exceed 100 pico curies per liter (pCi/l).

   (2) Concentrations of radium 226 (STORET number 09501) and stontium 90 (STORET number - 13501) shall not exceed 1 and 2 pico curies per liter respectively.

f. The following levels of chemical constituents shall not be exceeded:

CONSTITUENT	STORET NUMBER	CONCENTRATION (mg/l)
Ammonia Nitrogen (as N)	00610	1.5
Arsenic (total)	01000	1.0
Barium (total)	01005	5.0
Boron (total)	01020	1.0
Cadmium (total)	01025	0.05
Chloride	00940	500.
Chromium (total hexavalent)		0.05
Chromium (total trivalent)		1.0
Copper (total)	01040	0.02
Cyanide	00720	0.025
Fluoride	00950	1.4
Iron (total)	01046	1.0
Lead (total)	01049	0.1
Manganese (total)	01055	1.0
Mercury	71900	0.0005
Nickel (total)	01065	1.0
Phenols	32730	0.1
Selenium (total)	01145	1.0
Silver (total)	01075	0.005
Sulfate	00945	500.
Total Dissolved Solids	00515	1000.
Zinc	01090	1.0

g. Based on a minimum of five samples taken over not more than a 30-day period, fecal coliforms (STORET number - 31616) shall not exceed a geometric mean of 200 per 100 ml, nor shall more than 10% of the samples during any 30-day period, exceed 400 per 100 ml.

h. Any substance toxic to aquatic life shall not exceed one-tenth of the 48-hour median tolerance limit (48-hr. TLm) for native fish or essential fish food organisms.

i. Temperature (STORET numbers (f°) 00011 and (C°) 00010):

(1) There shall be no abnormal temperature changes that may adversely affect aquatic life unless caused by natural conditions.

(2) The normal daily and seasonal temperature fluctuations that existed before the addition of heat due to other than natural causes shall be maintained.

(3) The maximum temperature rise above natural temperatures shall not exceed 5°F.

(4) In addition, the water temperature at representative locations shall not exceed the maximum limits in the following table during more than one percent of the hours in the 12-month period ending with any month. Moreover, at no time shall the water temperature at such locations exceed the maximum limits in the following table by more than 3°F.

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
60°	60°	60°	90°	90°	90°	90°	90°	90°	90°	90°	60°

D. All other waters in the C-SELM region (Public and Food Food Processing Water Supply Use Waters)

1. Freedom from unnatural sludge or bottom deposits, floating debris, visible oil, odor, unnatural plant or algal growth, unnatural color or turbidity, or matter in concentrations or combinations toxic or harmful to human, animal, plant or aquatic life of other than natural origin.

2. pH (STORET number - 00400) shall be within the range of 6.5 to 9.0 except for natural causes.

3. Phosphorus (STORET number - 00665): Phosphorus as P shall not exceed 0.05 mg/l in any reservoir or lake, or in any stream at the point where it enters any reservoir or lake.

4. Dissolved oxygen (STORET number - 00300) shall not not be less than 6.0 mg/l during at least 16 hours of any 24 hour period, nor less than 5.0 mg/l at any time.

5. Radioactivity:

a. Gross beta (STORET number - 03501 concentration shall not exceed 100 pico curies per lite (pc/1).

b. Concentrations of radium 226 (STORET number - 09501) and strontium 90 (STORET number - 13501) shall not exceed 1 and 2 pico curies per liter respectively.

6. The following levels of chemical constituents shall not be exceeded:

CONSTITUENT	STORET NUMBER	CONCENTRATION mg/1
Ammonia Nitrogen (as N)	00610	1.5
Arsenic (total)	01000	0.01
Barium (total)	01005	1.0
Boron (total)	01020	1.0
Cadmium (total)	01020	0.01
Carbon Chloroform Extract (CCE)	32005	0.2
Chloride	00940	250.0
Chromium (total hexavalent)		0.05
Chromium (total trivalent)		1.0
Copper (total)	01040	0.02
Cyanide	00720	0.01
Fluoride	00950	1.4
Iron (total)	01046	0.3
Lead (total)	01049	0.05
Manganese (total)	01055	0.05
Methylene Blue Active Substance (MBAS)	38260	0.5
Mercury	71900	0.0005
Nickel (total)	01065	1.0
Nitrates plus nitrites as N	00630	10.0
Oil (hexane-solubles)	00550	0.1
Phenols	32730	0.001
Selenium (total)	01145	0.01
Silver (total)	01075	0.005
Sulfate	00945	250.0
Total Dissolved Solids	00515	500.0
Zinc	01090	1.0

7. Based on a minimum of five samples taken over not more than a 30-day period, fecal coliforms (STORET number 31616) shall not exceed a geometric mean of 200 per 100 ml, nor shall more than 10% of the samples during any 30-day period, exceed 400 per 100 ml.

8. Any substance toxic to aquatic life shall not exceed one-tenth of the 48-hour median tolerance limit (48-hr. TLm) for native fish or essential fish food organisms.

9. Temperature (STORET numbers (F°) 00011 and (C°) 00010):

   a. There shall be no abnormal temperature changes that may adversely affect aquatic life unless caused by natural conditions.

   b. The normal daily and seasonal temperature fluctuations that existed before the addition of heat due to other than natural causes shall be maintained.

   c. The maximum temperature rise above natural temperatures shall not exceed 5°F.

   d. In addition, the water temperature at representative locations shall not exceed the maxium limits in the following table during more than one percent of the hours in the 12-month period ending with any month. Moreover, at no time shall the water temperature at such locations exceed the maximum limits in the following table by more than 3°F.

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
60°	60°	60°	90°	90°	90°	90°	90°	90°	90°	90°	60°

10. Waters shall be of such quality that with treatment consisting of coagulation, sedimentation, filtration, storage and chlorination, or other equivalent treatment process, the treated water shall meet in all respects both the mandatory and, except for chlorides, sulfate, and total dissolved solids, also the recommended requirements of the Public Health Service Drinking Water Standards - 1962.

Indiana Water Quality Standards

A. Regulation SPC 4-R (Proposed)

1. Lake Michigan Waters

2. Inner Harbor

3. Gary Harbor

4. Burns Harbor

a. Free from substances attributable to municipal, industrial, agricultural or other discharges that will settle to form putrescent or otherwise objectionable deposits.

b. Free from floating debris, oil, scum, and other floating materials attributable to municipal, industrial, agricultural or other discharges in amounts sufficient to be unsightly or deleterious.

c. Free from materials attributable to municipal, industrial, agricultural or other discharges producing color, odor or other conditions in such degree as to create a nuisance.

d. Free from substances attributable to municipal, industrial, agricultural or other discharges in concentrations or combinations which are toxic or harmful to human, animal, plant or aquatic life.

e. Free from substances attributable to municipal, industrial, agricultural or other discharges in concentrations or combinations which will cause or contribute to the growth of aquatic plants or algae in such degree as to create a nuisance, be unsightly or deleterious or be harmful to human, animal, plant or aquatic life or otherwise impair the designated uses.

f. Fecal Coliform Bacteria: (MPN or NF Count/ 100 ml)

(1) Whole-Body Contact: The fecal coliform content at all recognized beach areas shall not exceed 200 per 100 ml as a monthly geometric mean based on not less than five samples per month; nor exceed 400 per 100 ml in more than ten percent of all samples taken during a month.

(2) Partial-Body Contact: The fecal coliform content at all locations in harbor areas other than at recognized beach areas shall not exceed a geometric mean of 1,000 per 100 ml, nor exceed 2,000 per 100 ml in more than ten percent of the samples.

(3) Lake Michigan Open Water: The fecal coliform content in the open water of Lake Michigan shall not exceed a geometric mean of 20 per 100 ml.

g. Toxic Substances: Not to exceed one-tenth of the 96-hour median tolerance limit obtained from continuous flow bioassays where the dilution water and toxicant are continuously renewed, except that other, lower application factors may be used in specific cases when justified on the basis of available evidence or in the case of materials that are persistent, synergistic or that have cumulative effects.

h. Radioactivity (pc/l): The gross beta concentration shall not exceed 100 pico curies per liter respectively.

i. Temperature: Municipal water and wastewater treatment plants and vessels are exempted from the following:

(1) All temperatures are expressed in degrees Fahrenheit. In all receiving waters the points of measurement shall normally be in the surface one meter at such depth as to avoid thin layer surface warming due to extreme ambient air temperatures, but

where required to determine the true distribution of heated wastes, and natural variations in water temperature, measurements shall be made at greater depths and at several depths as a termal profile.

(2) There shall be no abnormal temperature changes so as to be injurios to fish, wildlife, or other aquatic life or the growth or propagation thereof. In addition, plume interaction with the bottom should be minimized and shall not injuriously affect fish spawning or nursery areas.

(3) The normal daily and seasonal temperature fluctuations that existed before the addition of heat shall be maintained.

(4) At any time and at a maximum distance of 1,000 feet from a fixed point adjacent to the discharge and or as agreed upon by the State and Federal regulatory agencies, the receiving water temperature shall not be more than 3 degrees Fahrenheit above the existing natural water temperature nor shall the maximum temperature exceed those listed below whichever is lower.

Month	Temperature - °F
January	45
February	45
March	45
April	55
May	60
June	70
July	80
August	80
September	80
October	65
November	60
December	50

(5) All new waste heat discharges or enlargement of existing facilities exceeding a daily average of 0.5 billion BTU/hour, which had not begun operation as of the effective date of this regulation, and which plan to use Lake Michigan waters for cooling shall be limited to that amount essential for blowdown in the operation of a closed cycle cooling facility. Plants not in operation as of the effective date of this regulation, will be allowed to go into operation provided they are committed to a closed cycle cooling system construction schedule approved by the State and Federal regulatory agencies.

(6) Water intakes shall be designed and located to minimize entrainment and damage to desirable organisms. Requirements may vary depending upon local conditions but, in general, intakes are to have minimum water velocity and shall not be located in spawning or nursery areas of important fishes. Water velocity at screens and other exclusion devices shall also be at a minimum.

(7) Discharges other than those now in existence shall be such that the thermal plumes do not overlap or intersect.

(8) Facilities discharging more than a daily overage of 0.5 billion BTU/hour of waste heat shall continuously record intake and discharge temperature and flow and make those records available to regulatory agencies upon request.

j. Oil: Oil or similar materials shall not be present in such quantities that they will produce a visible film on the water surface, coat the banks bottom of the lake or harbors or in any way be toxic or harmful to fish or other aquatic life.

k. Constituent limitations.

In the following table the criteria for the Inner Harbor Basin are for evaluation of the waters between the shore and a line from the existing Calumet Harbor breakwater to the existing light on the Inland Steel breakwater. The criteria for Gary Harbor and Burns Harbor are for the evaluation of waters enclosed by the Gary Harbor and Burns Harbor breakwaters. The criteria for Lake Michigan are for evaluation of all shore and open waters outside of the specified harbor areas.

Parameter	Criteria: Inner Harbor	Criteria: Gary Harbor and Burns Harbor	Criteria: Lake Mich.
Dissolved Oxygen (percent sat.)			
24-hour avg.	80%	85%	90%
Min. value	70%	75%	80%
pH (range)	7.5-8.5	7.5-8.5	7.5-8.5
Turbidity	No turbidity of other than natural origin that will cause a substantial visible contrast with the natural appearance of the water.	Same	Same
True Color (units)			
Monthly avg.	5	5	5
Single value	15	15	15
Threshold Odor (units) Hydrocarbon and/or chem.			
Daily avg.	6	5	4
Single value	15	10	8
Odor	No obnoxious odor of other than natural origin.	Same	Same

(Continued) Parameter	Criteria: Inner Harbor	Criteria: Gary Harbor and Burns Harbor	Criteria: Lake Mich.
Ammonia Nitrogen (mg/l)			
Monthly avg.	0.05	0.03	0.02
Single value	0.12	0.10	0.05
Chlorides (mg/l)			
Monthly avg.	20	15	10
Single value	30	20	15
Cyanide (mg/l)	Not to exceed 0.025 at any time	Not to exceed 0.01 at any time	Not to 0.01 at any time
Fluorides (mg/l)			
Monthly avg.	Not to exceed 1.01 at any time	Not to exceed 1.0 at any time	Not to exceed 1.0 at any time
Dissolved Iron (mg/l)			
Monthly avg.	0.15	0.15	0.15
Single Value	0.30	0.30	0.30
Phenol-like Substances (mg/l)			
Monthly avg.	0.002	0.001	0.001
Single value	0.005	0.003	0.003
Sulfates (mg/l)			
Monthly avg.	39	26	26
Single Value	75	50	50
Total Phosphorus (P) (mg/l)			
Monthly avg.	0.03	0.03	0.03
Single Value	0.05	0.04	0.04
Filterable Residue (mg/l) (total dissolved solids)			
Monthly avg.	197	185	172
Single value	230	215	200
Arsenic (mg/l)	Not to exceed 0.05 at any time	Same	Same

(Continued) Parameter	Criteria: Inner Harbor	Criteria: Gary Harbor and Burns Harbor	Criteria: Lake Mich.
Barium (mg/l)	Not to exceed 1.0 at any time	Same	Same
Cadmium (mg/l)	Not to exceed 0.01 at any time	Same	Same
Hexavalent Chrome (mg/l)	Not to exceed 0.05 at any time	Same	Same
Lead (mg/l)	Not to exceed 0.05 at any time	Same	Same
Selenium (mg/l)	Not to exceed 0.01 at any time	Same	Same
Silver (mg/l)	Not to exceed 0.05 at any time	Same	Same
Total Mercury (mg/l)	Not to exceed 0.005 at any time	Same	Same

B. Regulation SPC 7-R (Proposed)

1. Grand Calumet River

2. Indiana Harbor Canal

   a. Free from substances attributable to municipal, industrial, agricultural or other discharges that will settle to form putrescent or otherwise objectionable deposits.

b. Free from floating debris, oil, scum, and other floating materials attributable to municipal, industrial, agricultural or other discharges in amount sufficient to be unsightly or deleterious.

c. Free from materials attributable to municipal, industrial, agribcultural or other discharges producing color, odor, or other conditions in such degree as to create a nuisance.

d. Free from substances attributable to municipal, industrial, agricultural or other discharges in concentrations or combinations which are toxic or harmful to human, animal, plant, or aquatic life.

e. Free from substances attributable to municipal, industrial, agricultural or other discharges in concentrations or combinations which will cause or contribute to the growth of aquatic plants or algae in such degree as to create a nuisance, be unsightly or deleterious or be harmful to human, animal, plant, or aquatic life or otherwise impair the designated uses.

f. Dissolved Oxygen: Concentrations shall average at least 3.0 mg/l during any 24-hour period and shall not be less than 2.0 mg/l at any time.

g. pH: No values below 6.5 or above 8.5, except daily fluctuations which exceed 8.5 and are related to photosynthetic activity, may be tolerated.

h. Temperature: The ater temperature shall not exceed 90 degrees Fahrenheit at any time.

i. Fecal Coliform Bacteria: The fecal coliform bacteria content (either MPN or MF count) shall not exceed a geometric mean of 1,000 per 100 ml, nor exceed 2,000 per 100 ml in more than ten percent of the samples, except during periods of stormwater runoff.

j. Filterable Residue (total dissolved solids): The filterable residue content shall not average more than 275 mg/l during any 24-hour period nor exceed this value at any time except in waters flowing westward into Illinois the concentrations shall not exceed 500 mg/l.

k. Chemical Constituents: The following levels of chemical constituents shall not be exceeded at any time.

Constituent	Concentration (mg/l)
Ammonia Nitrogen	1.5
Chloride [a]	35.0
Cyanide	0.1
Fluoride	1.3
Iron (dissolved)	0.3
Mercury (total)	.005
Phenol-like substances	0.010
Sulfates	75.0

[a] In waters flowing westward into Illinois the Concentration shall not exceed 125 mg/l.

l. Toxic Substances: Not to exceed one-tenth of the 96-hour median tolerance limit obtained from continuous flow bioassays where the dilution water and toxicant are continuously renewed, except that other, lower application factors may be used in specific cases when justified on the basis of available evidence.

m. Total Phosphorus: The content of total phosphorus shall not exceed 0.10 mg/l at any time except in waters flowing westward into Illinois.

n. Biochemical Oxygen Demand: The biochemical oxygen demand shall not exceed 10.0 mg/l.

o. Oil: Oil or similar materials shall not be present in such quantities that they will produce a visible film on the water surface, coat the banks and bottom of the stream or in any way be toxic or harmful to fish or other aquatic life. In addition, the total oil concentration, determined by the petroleum ether extration method, shall not exceed 5.0 mg/l.

C. Little Calumet River flowing into Illinois (Regulation SPC 9)

1. Free from substances attributable to municipal, industrial, agricultural or other discharges that will settle to form putrescent or otherwise objectionable deposits.

2. Free from floating debris, oil, scum, and other floating materials attributable to municipal, industrial, agricultural or other discharges in amount sufficient to be unsightly or deleterious.

3. Free from materials attributable to municipal, industrial, agricultural or other discharges producing color, odor or other conditions in such degree as to create a nuisance.

4. Free from substances attributable to municipal, industrial, agricultural or other discharges in concentrations or combinations which are toxic or harmful to human, animal, plant or aquatic life.

5. Coliform Bacteria - MPN/100 ml

   Maximum value 5,000 except during periods of stormwater runoff.

6. Fecal Streptococci - Number/100 ml

   Maximum value 500 except during periods of storm-water runoff.

7. Turbidity

   No turbidity of other than natural origin that will cause substantial visible contrast with the natural appearance of the water.

8. <u>True Color - Units</u>

Annual Average	Not more than 25
Single Daily Value or Average	Not more than 50

9. <u>Odor</u>

No obnoxious odor of other than natural origin.

10. <u>Temperature - °F.</u>

Single Daily Value or Average	Not more than 90

11. <u>Oil</u>

Substantially free from visible floating oil.

12. <u>pH - Units</u>

Annual Median	Within range 6.5-9.0

13. <u>Dissolved Oxygen - mg/l</u>

Average (May through Sept.)	Not less than 4.0
Single Daily Value or Average	Not less than 2.0

14. <u>BOD - mg/l</u>

Single Daily Value or Average	Not more than 10.0

15. <u>Ammonia-Nitrogen (N) - mg/l</u>

Single Daily Value or Average	Not more than 1.5

16. <u>Methylene Blue Active Substance - mg/l</u>

Single Daily Value or Average	Not more than 0.5

17. <u>Cyanides (CN) - mg/l</u>

Single Daily Value or Average	Not more than 0.025

18. <u>Phenol-like Substances - mg/l</u>

Single Daily Value or Average	Not more than 0.02

D. Wolf Lake (Regulation SPC 10)

1. Free from substances attributable to municipal, industrial, agricultural or other discharges that will settle to form putrescent or otherwise objectionable deposits.

2. Free from floating debris, oil, scum, and other floating materials attributable to municipal, industrial, agricultural or other discharges in amounts sufficient to be unsightly or deleterious.

3. Free from materials attributable to municipal, agricultural or other discharges producing color, odor or other conditions in such degree as to create a nuisance.

4. Free from substances attributable to municipal, industrial, agricultural or other discharges in concentrations or combinations which are toxic or harmful to human, animal, plant or aquatic life.

5. <u>Bacteria - Bumber/100 ml by MF Techniques</u>

    a. The number of bacteria shall be the arithmetical average of the last five consecutive sample results.

    b. Satisfactor area if MF coliform are less than 1,000 and MF fecal streptococci are less than 100.

    c. Satisfactory area if MF coliforms are from 1,000 to 5,000 and MF fecal streptococci are less than 20.

    d. A single sample with over 100,000 coliforms shall require immediate investigation as to the cause. Items to be considered in the judgment of cause and action to be taken include the sanitary survey, winds, currents and weather conditions.

7. True Color - Units

Annual Average	Not more than 5
Single Daily Value or Average	Not more than 15

8. Temperature - °F

Not more than 85

9. Oil

Substantially free of visible floating oil.

10. pH - Units

Daily Median	Within range 7.0-9.0

11. Dissolved Oxygen - Percent Saturation

Annual Average	Not less than 90
Single Value	Not less than 80

12. Ammonia-Nitrogen (N) - mg/l

Annual Average	Not more than 0.05
Single Value or Average	Not more than 0.12

13. Methylene Blue Active Substance - mg/l

Annual Average	Not more than 0.02
Single Daily Value or Average	Not more than 0.05

14. Cyanides (CN) - mg/l

Single Value	Not more than 0.025

15. Total Phosphates (PO_4) - mg/l

Annual Average	Not more than 0.03
Single Daily Value or Average	Not more than 0.04

E. Rearing or imprinting areas for salmonid fish (Regulation SPC 12, Proposed).

1. Trail Creek from Black Road on the West Branch and Meer Road on the East Branch downstream to Highway 35.

2. Little Calumet River and tributaries joining it from the southern boundary of the Westville Prison Farm downstream to the Wagner Road Bridge near Chesterton.

3. Black Ditch from Beverly Drive downstream to Lake Michigan.

4. Salt Creek above its confluence with the Little Calumet River.

   a. Dissolved Oxygen: Concentrations shall not be less than 6.0 mg/l at any time or any place. During the spawning season or during periods of rearing or inprinting, the dissolved oxygen shall not fall below 7.0 mg/l at any time or place.

   b. Temperature: No heat shall be added.

   c. Taste and Odor: There shall be no substances which impart unpalatable flavor to fish or taint any of the associated biota; or result in an offensive or unnatural odor of the water or in the vicinity of the water.

   d. pH No values below 6.0 or above 8.5, except daily fluctuations which exceed pH 8.5 and are correlated with photosynthetic activity, may be tolerated. However, any drop below 6.0 or sudden rise above 8.5 not related to photosynthesis indicates abnormal conditions.

   e. Oil: Oil or similar materials shall not be present in such quantities that they will produce a visible film on the water surface, coat the banks and bottom of the stream, or in any way be toxic or harmful to fish or other aquatic life.

   f. Turbidity: No material from other than natural causes shall be added which will cause the turbidity of the water to exceed 10 Jackson turbidity units (JTU).

g. Settleable Solids: No settleable material from other than natural causes shall be added in quantities that will adversely affect salmonid fishes or the natural biota.

h. Color: No material from other than natural causes shall be added which will produce a noticeable change from the natural color or clarity of the water.

i. Floating Materials: Free from floating debris, scum, and other floating materials in amounts sufficient to be unsightly or deleterious.

j. Radioactive Materials: The gross beta concentration shall not exceed 100 pico curies per liter (pc/1). In addition, the concentrations of Radium-226 and Strontium-90 shall not exceed 1 and 2 pico curies per liter, respectively.

k. Toxic Substances: Not to exceed one-tenth of the 96-hour median tolerance limit of salmonid fishes or the natural biota obtained from continuous flow bioassays where the dilution water and toxicant are continuously renewed, except that other, lower application factors may be used in specific cases when justified on the basis of available evidence.

l. Fecal Coliform Bacteria: The fecal coliform bacteria content (either MPN or MF count) shall not exceed a geometric mean of 1,000 per 100 ml, nor exceed 2,000 per 100 ml in more than ten percent of the samples.

m. Plant Nutrients: Free from substances attriutable to municipal, industrial, agricultural or other sources in concentrations or combinations which will cause or contribute to the growth of aquatic plants or algae in such degree as to create a nuisance, be unsightly or deleterious, or be harmful to salmonid fishes or the natural biota.

n. Mercury (Total): The total mercury concentration shall not exceed 0.005 milligrams per liter (mg/1) at any time or place.

F. Migration routes for salmonid fish (Regulation SPC 12, Proposed).

1. Trail Creek from Highway 35 downstream to Lake Michigan.

2. Little Calumet Rive from Wagner Road Bridge downstream to Lake Michigan via Burns Ditch.

   a. Dissolved Oxygen: Concentrations shall average at least 6.0 mg/l during any 24-hour period and shall not be less than 5.0 mg/l at any time. During periods of migration, the dissolved oxygen shall not fall below 6.0 mg/l at any time or any place.

   b. Temperature:

      (1) The normal daily and seasonal temperature fluctuations that existed before the addition of heat due to other than natural causes shall be maintained.

      (2) The maximum temperature rise at any time or place above natural shall not exceed 2 degrees Fahrenheit. In addition, the temperature shall not exceed 70 degrees Fahrenheit at any time or place during periods of migration nor exceed 85 degrees Fahrenheit at any time.

   c. Turbidity: No material from other than natural causes shall be added which will cause the turbidity of the water to exceed 25 Jackson turbidity units.

   d. Settleable Solids: Free from substances that will settle to form putrescent or otherwise objectionable deposits.

   e. Color: Free from materials producing color or other conditions that will create a nuisance or interfere with the normal migration of salmonid fishes.

G. Put-and-take trout fishing (Regulation SPC IR-2).

1. Salt Creek from 150 East to 500 North.

2. Trail Creek, West Branch from U.S. Route 20 to town of Waterford.

a. Free from substances attributable to municipal, industrial, agricultural or other discharges that will settle to form putrescent or otherwise objectionable deposits.

b. Free from floating debris, oil, scum, and other floating materials attributable to municipal, industrial, agricultural or other discharges in amounts sufficient to be unsightly or deleterious.

c. Free from materials attributable to municipal, industrial, agricultural or other discharges producing color, odor or other conditions in such degree as to create a nuisance.

d. Free from substances attributable to municipal, industrial, agricultural or other discharges in concentrations or combinations which are toxic or harmful to human, animal, plant or aquatic life.

e. Dissolved Oxygen: Concentrations shall not be less less than 6.0 mg/l at any time or any place. Spawning areas (during the spawning season) shall be protected by a minimum DO concentration of 7.0 mg/l.

f. pH: No values below 6.0 nor above 8.5, except daily fluctuations which exceed pH 8.5 and are correlated with photosynthetic activity, may be tolerated. However, any sudden drop below 6.0 or sudden rise above 8.5 not related to photosynthesis indicates abnormal conditions which should be investigated immediately.

g. Temperature: Temperature shall not exceed 65°F or a 5°F rise above natural, whichever is less.

h. Toxic Substances: Not to exceed one-tenth of the 96-hour median tolerance limit obtained from continuous flow bioassays where the dilution water and toxicant are continuously renewed, except that other application factors may be used in specific cases when justified on the basis of available evidence and approved by the appropriate regulatory agencies.

i. Taste and Odor: There shall be no substances which impart unpalatable flavor to food fish, or result in noticeable offensive odors in the vicinity of the water.

j. Bacteria: The fecal coliform content (either MPN or MF count) shall not exceed a geometric mean of 1,000 per 100 ml, nor exceed 2,000 per 100 ml in more than ten percent of the samples.

H. All other waters in the C-SELM Region (Aquatic life and partial body contact, Regulation SPC IR-2).

1. Free from substances attributable to municipal, industrial, agricultural or other discharges that will settle to form putrescent or otherwise objectionable deposits.

2. Free from floating debris, oil, scum, and other floating materials attributable to municipal, industrial, agricultural or other discharges in amounts sufficient to be unsightly or deleterious.

3. Free from materials attributable to municipal, industrial, agricultural or other discharges producing color, odor or other conditions in such degree as to create a nuisance.

4. Free from substances attributable to municipal, industrial, agricultural or other discharges in concentrations or combinations which are toxic or harmful to human, animal, plant or aquatic life.

5. Dissolved Oxygen: Concentrations shall average at least 5.0 mg/l per calendar day and shall not be less than 4.0 mg/l at any time or any place outside the mixing zone.

6. pH: No values below 6.0 nor above 8.5, except daily fluctuations which exceed pH 8.5 and are correlated with photosynthetic activity, may be tolerated. However, any sudden drop below 6.0 or sudden rise above 8.5 not related to photosynthesis indicates abnormal conditions which should be investigated immediately.

7. Temperature:

a. There shall be no abnormal temperature change that may affect aquatic life unless caused by natural conditions.

b. The normal daily and seasonal temperature fluctuation that existed before the addition of heat due to other than natural causes shall be maintained.

c. The maximum temperature rise at any time or place above natural temperatures shall not exceed 5°F. In addition, the water temperature shall not exceed the maximum limits indicated in the following table.

Month	Temperature - °F
January	50
February	50
March	60
April	70
May	80
June	90
July	90
August	90
September	90
October	78
November	70
December	57

8. Toxic Substances: Not to exceed one-tenth of the 96-hour median tolerance limit obtained from continuous flow bioassays where the dilution water and toxicant are continually renewed, except that other application factors may be used in specific cases when justified on the basis of available evidence and approved by the appropriate regulatory agencies.

9. Taste and Odor: There shall be no substances which impart unpalatable flavor to food fish, or result in noticeable offensive odors in the vicinity of the water.

10. Bacteria: The fecal coliform content (either MPN or MF count) shall not exceed a geometric mean of 1,000 per 100 ml, nor exceed 2,000 per 100 ml in more than ten percent of the samples.

Illinois Effluent Standards (Adopted)

A. Lake Michigan Waters

1. Deoxygenating Wastes: On or after 12/31/74, no effluent shall exceed 4 mg/l of BOD_5 or 5 mg/l of suspended solids.

2. Bacteria: No effluent shall exceed 400 fecal coliforms per 100 ml.

3. Phosphorus (STORET number 00665): No effluent shall shall contain more than 1.0 mg/l of phosphorus as P.

4. Additional Contaminants: The following levels of contaminants shall not be exceeded by any effluent:

CONSTITUENT	STORET NUMBER	CONCENTRATION (mg/l)
Arsenic (total)	01002	0.25
Barium (total)	01007	2.0
Cadmium (total)	01027	0.15
Chromium (total hexavalent)		0.3
Chromium (total trivalent)		1.0
Copper (total)	01042	1.0
Cyanide	00720	0.025
Fluoride (total)	00951	2.5
Iron (total)	01045	2.0
Iron (dissolved)	01046	0.5
Lead (total)	01051	0.1
Manganese (total)	01055	1.0
Mercury (total)	71900	0.0005
Nickel (total)	01067	1.0
Oil (hexane solubles or equivalent)	00550	15.0
pH	00400	range 5.10[a]
Phenols	32730	0.3
Selenium (total)	01145	1.0
Silver	01077	0.1
Zinc (total)	01092	1.0
Total Suspended Solids (from sources other than deoxygenating wastes)	00530	15.0

a. The pH limitation is not subject to averaging and must be met at all times.

B. All other Waters in C-SELM region

1. Deoxygenating Wastes

a. On and after 7/1/72, no effluent shall exceed 30 mg/1 of BOD_5 or 37 mg/1 of suspended solids except as follows:

(1) No effluent from any source whose untreated waste load is 10,000 population equivalents or more, or from any source discharging into the Chicago River System or into the Calumet River System shall exceed 20 mg/1 of BOD_5 or 25 mg/1 of suspended solids.

b. On or after 12/31/73, no effluent whose dilution ratio is less than five to one shall exceed 10 mg/1 of BOD_5 or 12 mg/1 of suspended solids except as follows:

(1) Sources whose untreated waste load is 500,000 population equivalents or more shall comply by 12/31/77.

(2) Sources whose dilution ratio is two to one or more but less than five to one shall comply by 12/31/74.

(3) Sources employing third-stage treatment lagoons shall be exempt provided all of the following conditions are met:

(a) The untreated waste load is less than 2500 population equivalents.

(b) The source is sufficiently isolated that combining with other sources to aggregate 2500 population equivalents or more is not practicable.

(c) The lagoons are properly constructed, maintained, and operated.

(d) The effluent does not, alone or in combination with other sources, cause a violation of applicable water quality standards.

(d) The effluent does not, alone or in combination with other sources, cause a violation of applicable water quality standards.

c. On or after 12/31/73, no effluent whose dilution ratio is less than one to one shall exceed 4 mg/l of BOD_5 or 5 mg/l of suspended solids, except as follows:

(1) Sources employing third-stage treatment lagoons shall be exempt provided all of the following conditions are met:

(a) The untreated waste load is less than 2500 population equivalents.

(b) The source is sufficiently isolated that combining with other sources to aggregate 2500 population equivalents or more is not practicable.

(c) The lagoons are properly constructed, maintained, and operated.

(d) The effluent does not, alone or in combination with other sources, cause a violation of applicable water quality standards.

(2) Other sources, not having an untreated waste - load of 500,000 population equivalents or more, shall be exempt provided all of the following conditions are met:

(a) The effluent shall not, alone or in combination with other sources, cause a violation of any applicable water quality standard.

(b) The effluent shall not, alone or in combination with other sources, cause dissolved oxygen in the waters of the State to fall below 6.0 mg/l during at least 16 hours of any 24-hour period, or below 5.0 mg/l at any time

(c) The effluent shall not exceed 10 mg/l of BOD_5 or 12 mg/l of suspended solids.

d. On or after 12/31/77, no effluent from any source whose untreated waste load is 500,000 population equivalents or more shall exceed 4 mg/l of BOD_5 or 5 mg/l of suspended solids.

2. Bacteria: No effluent shall exceed 400 fecal coliforms per 100 ml.

3. Ammonia nitrogen as N. (STORET number 00610): No effluent from any source which discharges to the Chicago River System or Calumet River System, and whose untreated waste load is 50,000 or more population equivalents shall contain more than 2.5 mg/l of ammonia nitrogen as N during the months of April through October, or 4 mg/l at other times, after 12/31/77.

4. Additional Contaminants:

a. The following levels of contaminants shall not be exceeded by any effluent:

CONSTITUENT	STORET NUMBER	CONCENTRATION (mg/l)
Arsenic (total)	01002	0.25
Barium (total)	01007	2.0
Cadmium (total)	01027	0.15
Chromium (total hexavalent)		0.3
Chromium (total trivalent)		1.0
Copper (total)	01042	1.0
Cyanide	00720	0.025
Fluoride (total)	00951	2.5
Iron (total)	01045	2.0
Iron (dissolved)	01046	0.5
Lead (total)	01051	0.1
Manganese (total)	01055	1.0
Mercury (total)	71900	0.0005
Nickel (total)	01067	1.0
Oil (hexane solubles or equivalent)	00550	15.0
pH	00400	range 5.10[a]

(Continued)

CONSTITUENT	STORET NUMBER	CONCENTRATION (mg/l)
Phenols	32730	0.3
Selenium (total)	01145	1.0
Silver	01077	0.1
Zinc (total)	01092	1.0
Total Suspended Solids (from sources other than deoxygenating wastes)	00530	15.0

The pH limitation is not subject to averaging and must be met at all times.

(1) Total Dissolved Solids (STORET number 00515) shall not be increased more than 750 mg/l above background concentration levels unless caused by recycling or other pollution abatement practices, and in no event shall exceed 3500 mg/l at any time.

C. Enforcement Conference Requirements: The adopted and proposed Illinois wastewater treatment plant effluent standards meet the requirements of the "Conference in the Matter of Pollution of Lake Michigan and its Tributary Basin (isconsin-Illinois-Indiana-Michigan)" and the "Conference in the Matter of Pollution of the Interstate Waters of the Grand Calumet River, Little Calumet and Their Tributaries (Indiana-Illinois)."

Indiana Wastewater Treatment Requirements

Except for those wastewater treatment requirements given in the recommendations of the "Conference in the Matter of Pollution of Lake Michigan and its Tributary Basin (Wisconsin - Illinois - Indiana - Michigan)" and the "Conference in the Matter of Pollution of the Interstate Waters of the Grand Calumet Rive, Little Calumet River, Calumet Rive, Wolf Lake, Lake Michigan and their tributaries (Indiana - Illinois)", Indiana has no effluent standards. The requirements of the "Lake Michigan" and "Calumet" Conferences are:

1. Secondary Treatment

2. 80% Total Phosphate Removal

3. Disinfection

An approach to additional effluent requirements would be to relate existing low stream flows to effluent flows. In areas where there is no significant natural base flow, the water quality standards could be considered to be the effluent guidelines. Where there is a natural low flow in the streams, dilution potential could be considered and related to comparable Illinois effluent standards. The principal municipal wastewater treatment plants together with the appropriate 7 day, 10 year flow dilution ratios are given in Table BA-I-B-3

The dilution ratio with natural stream low flow is essentially zero for East Chicago, Gary and Hammond. Therefore, the effluent requirements for these plants could be those of Regulation SPC 7-R, examples of which are:

1. Total Phosphorus - 0.10 mg/1 (max.)

2. BOD - 10.0 mg/1 (max.)

3. Ammonia Nitrogen - 1.5 mg/1 (max.)

Dilution is available at the other treatment plants. As an example of the application of Illinois effluent standards to these plants, the following maximum BOD and suspended solids (ss) would be required:

Location	Dilution Ratio	Max. BOD_5 mg/1	Max. SS mg/1
Chesterton	16/1	30	37
Crown Point	0.2/1	4 or 10[a]	5 or 12[a]
Hobart	1.9/1	10	12
Michigan City	0.9/1	4 or 10[a]	5 or 12[a]
Valparaiso	0.8/1	4 or 10[a]	5 or 12[a]

[a]The variation in the BOD_5 and suspended solid parameters reflect the provisions at a specific STP that can effect a variance in effluent requirements.

Any further definition of Indiana effluent guidelines for the purposes of this study must be coordinated with the Indiana State Board of Health.

Table BA-I-B-3

PRINCIPAL INDIANA MUNICIPAL WASTEWATER FLOWS AND DILUTION RATIOS

Treatment Plant	Receiving Stream	Present Effluent Flow-MGD	Natural Stream Low Flow-MGD	Dilution Ratio
East Chicago Sanitary District	Grand Calumet	10.5	~ 0	~ 0
Gary	Grand Calumet	38.2	~ 0	~ 0
Hammond Sanitary District	Grand Calumet	35.9	~ 0	~ 0
Chesterton	Little Calumet	0.7	11.5	16/1
Crown Point	Deep River	1.8	0.4	0.2/1
Hobart	Deep River	1.7	3.2	1.9/1
Michigan City	Trail Creek	8.3	7.2	0.9/1
Valparaiso	Salt Creek	3.1	2.4	0.8/1

DATA ANNEX B

FLOW BASIS OF DESIGN

III. FLOW BASIS OF DESIGN

A. PRESENT DOMESTIC-COMMERCIAL AND INDUSTRIAL FLOWS

WASTEWATER TREATMENT PLANT INVENTORY

The existing municipal wastewater treatment plant operating data is presented in Table BA-III-A-1. The information presented in this table represents a compilation of data from several sources including treatment plant operating reports on file with the Indiana State Board of Health, the 1970 annual operating reports for the Metropolitan Sanitary District of Greater Chicago (MSD) and the Bloom Township Sanitary District, the Northeastern Illinois Planning Commission (NIPC) wastewater plans, State of Illinois Sanitary Water Board's 1970 data book on wastewater treatment works and private correspondence with treatment plant officials.

Municipal effluent waste loadings are estimated using concentrations which typically reflect treatment performances presently encountered in the study area. For example, the typical concentrations used for secondary treatment plant effluent are as follows

Total dissolved solids	=	400 mg/l
Suspended solids	=	25 mg/l
COD	=	60 mg/l
BOD5	=	20 mg/l
Total N	=	20 mg/l
Total P	=	8 mg/l
Fecal coliform bacteria	=	400 MPN/100 ml

Since the three main MSD plants (North Side, West-Southwest and Calumet) are rather unique considering their treatment capacity and proportion of industrial loadings (42%), actual 1970 operating data is reported. These three plants treat some 1,370 MGD which accounts for 86% of the total (1,594 MGD) municipal wastewater flow generated in the C-SELM study area.

In addition to the municipal systems listed above, there exist over 100 miscellaneous systems (i.e. schools, motels, restaurants) treating a total wastewater flow in the range of 3-5 MGD.

INDUSTRIAL TREATMENT PLANT INVENTORY

The significant industrial wastewater discharges to surface waters in the C-SELM study area are presented in Table BA-III-A-2 together with their characteristic influent and effluent parameters in pounds/day. Industrial wastewater treatment operations are considered significant if the total discharge exceeds 5 MGD. The information presented in this table reflects surface discharge records from the Indiana State Board of Health, U. S. Army Corps of Engineers - Chicago District, the Northeastern Illinois Planning Commission wastewater plans, and the State of Illinois Sanitary Water Board's 1970 data book on wastewater treatment works.

The pollutant loadings presented in Table BA-III-A-2 reflect reported data on file with the above agencies. The symbol BL indicates no significant differences in pollutional loading between the background level of the intake waters and the discharge waters. The symbol NA indicates that although actual data is not available, there is a significant difference in quality between the background level of the intake waters and the discharge waters.

Presented in Table BA-III-A-3 are the current waste solids (sludge) management practices for major industries.

Table BA-III-A-1 EXISTING MUNICIPAL WASTEWATER T

Sewage Treatment Plant Name	Location (Receiving Stream, Mile Designation point)	Sewer Type: Sanitary	Sewer Type: Combined	Present Treatment: Primary	Present Treatment: Secondary	Present Treatment: Advanced	Pop. Served (1000's)	Estimated Service Area (Square Miles)	Estimated Present Average Wastewater Flow (MGD)	Estimated Industrial Average Wastewater Flow (MGD)	Estimated Design Capacity Average (MGD)	Total Dissolved Solids	Suspende Solids
DES PLAINES RIVER DRAINAGE BASIN													
Grayslake	Mi 15	X			X		4.5	1.6	0.45	0.09	0.7	1501	94
Grandwood Park U.C.	Mi 8.5	X			X		1.2	NA	0.12	NA	0.2	400	25
Lindenhurst Water Co.	N.Mi 5.6, Des 102	X			X		3.0	2.2	0.3	0	0.25*	1000	63
Gages Lake S.D.	Di, Des 94	X			X		4.1	1.9	0.41	0	0.6	1368	85
Vickory Manor Serv.	Di, Bul 1, Des 91.4	X			X		0.2	NA	0.02	NA	0.1	67	4
LCPWD Countryside Manor	Des 90	X			X		1.0	0.1	0.1	0	0.1	334	21
Libertyville, S.	Des 84.5	X			X		10.0	14.0	1.0	0.1	2.0	3336	209
LCPWD - Sylvan Lake	In 10.9	X			X		0.6	0.3	0.06	0	0.1	200	13
Mundelein	Haw 7.4	X			X		14.4	6.2	1.44	0.2	2.2	4804	300
LCPWD - Vernon Hills	Haw 4, In 3, Des 79.6	X			X		0.72	0.4	0.07	0	0.12	233	15
Lincolnshire	Des 79	X			X		2.0	2.0	0.2	0	0.26	667	42
LCPWD - S.E. Sew.Wks.	Ap 0.4, Des 76.3	X			X		1.0	0.9	0.1	0.01	0.1*	334	21
Chevy Chase S & W Co	Des 75.8	X			X		0.26	NA	0.03	NA	0.03	100	6
MSDGC - Barrington Woods	Bul 11.7	X			X		0.6	NA	0.06	NA	0.1	200	13
Long Grove	Bu 9,	X			X		*	0.1	0.04	0	0.04	133	8
Buffalo Grove	Bu 5.3,	X			X		NA	NA	NA	NA	0.08		
Buffalo Grove U.C.	Bu 3, Des 72.5	X			X		6.0	3.0	0.75	0.1	0.75	2502	156

ated ent rage water w D)	Estimated Industrial Average Wastewater Flow (MGD)	Estimated Design Capacity Average (MGD)	ESTIMATED WASTE LOADINGS (LBS/DAY)									Comments
			Total Dissolved Solids	Suspended Solids	COD	BOD	NH_3-N	Organic N	NO_3-N	P	Fecal Coliform Bacteria (MPN/100 ml)	
5	0.09	0.7	1501	94	225	75	64	8	4	30	< 400	
2	NA	0.2	400	25	60	20	17	2	1	8	< 400	
	0	0.25*	1000	63	150	50	43	5	3	20	< 400	Expanding plant to 0.5 MGD Capacity
1	0	0.6	1368	85	205	68	58	7	3	27	< 400	
2	NA	0.1	67	4	10	3	3	< 1	< 1	1	< 400	
	0	0.1	334	21	50	17	14	2	1	7	< 400	
	0.1	2.0	3336	209	500	167	142	17	8	67	< 400	
5	0	0.1	200	13	30	10	9	1	1	4	< 400	
(	0.2	2.2	4804	300	721	240	204	24	12	96	< 400	
7	0	0.12	233	15	35	12	10	1	1	5	< 400	
	0	0.26	667	42	100	33	28	3	2	13	< 400	
	0.01	0.1*	334	21	50	17	14	2	1	7	< 400	Plans to increase capacity to 2.0 MGD
3	NA	0.03	100	6	15	5	4	1	< 1	2	< 400	
5	NA	0.1	200	13	30	10	9	1	1	4	< 400	
1	0	0.04	133	8	20	6	6		< 1	3	< 400	Services Antique Business Dist., School, and a Few homes
	NA	0.08										
5	0.1	0.75	2502	156	375	125	106	13	6	50	< 400	

Table BA-III-A-1 EXISTING MUNICIPAL WASTEWATER

Sewage Treatment Plant Name	Location (Receiving Stream, Mile Designation point)	Sewer Type: Sanitary	Sewer Type: Combined	Present Treatment: Primary	Present Treatment: Secondary	Present Treatment: Advanced	Pop. Served (1000's)	Estimated Service Area (Square Miles)	Estimated Present Average Wastewater Flow (MGD)	Estimated Industrial Average Wastewater Flow (MGD)	Estimated Design Capacity Average (MGD)	Total Dissolved Solids	Sus So
Subtotal For Des Plaines R prior to confluence with Salt Creek							49.58	32.7	5.15	0.5	7.73	17180	10
<u>Salt Ck. Sub-drainage Basin</u>													
Roselle	Sp 6.5,	X			X		6.0	2.5	0.7	0.1	1.0	2335	
Bloomingdale	Sp 4.8	X			X		1.5	1.2	0.15	0	0.2	500	
DCDPW - Nordic Park	Sp 2.5	X			X		0.28	NA	0.03	NA	0.1	100	
Itasca	Sp 0.5, Sa 28.2	X			X		5.0	8.0	0.5	0.13	0.6	1668	
Wood Dale	Sa 27.6	X			X		4.5	2.8	0.45	0.02	1.0	1501	
Bensenville	Ad 10,	X			X		11.2	6.5	1.1	0.2	2.0	3670	
Citizens County	Ad 9,	X			X		NA	NA	NA	NA	0.09		
N. Elmhurst S.D.	Ad 8.6, Sa 24	X			X		2.4	0.8	0.24	0	0.3	801	
Addison - North	Sa 23.5		X		X		25.0	2.7	1.58	0	2.0	5271	
- South	Sa 22		X		X	X		3.3	2.48	0.5	2.1*	8273	
Elmhurst	Sa 20	X			X		50.0	9.4	5.0	0	6.9*	16680	1
Salt Ck Drainage Basin S.D.	Sa 19.6		X		X		26.0	4.5	3.6	0.2	2.8*	12010	
Highland Hills S.D.	Su 3.5	X			X		1.1	NA	0.11	NA	0.25	367	
York Center Coop.	Su 2.7, Sa 18.8	X			X		0.12	NA	0.01	NA	0.2	33	

ted nt ge ater)	Estimated Industrial Average Wastewater Flow (MGD)	Estimated Design Capacity Average (MGD)	ESTIMATED WASTE LOADINGS (LBS/DAY)									Comments
			Total Dissolved Solids	Suspended Solids	COD	BOD	NH_3-N	Organic N	NO_3-N	P	Fecal Coliform Bacteria (MPN/100 ml)	
	0.5	7.73	17180	1074	2577	859	730	86	43	344	<400	
	0.1	1.0	2335	146	350	117	99	12	6	47	<400	Plans to exp. 1.7 MGD Act sludge w/existing trickling filter
	0	0.2	500	31	75	25	21	3	1	10	<400	
	NA	0.1	100	6	15	5	4	1	<1	2	<400	
	0.13	0.6	1668	105	250	84	71	9	4	34	<400	
	0.02	1.0	1501	94	225	75	64	8	4	30	<400	
	0.2	2.0	3670	229	550	183	156	18	9	73	<400	
	NA	0.09										
	0	0.3	801	50	120	40	34	4	2	16	<400	
	0	2.0	5271	329	791	264	224	26	13	105	<400	
	0.5	2.1*	8273	517	1241	414	352	41	21	165	<400	Plans to include sludge dewatering & expansion of present tertiary (mixed mediafilters) equipment
	0	6.9*	16680	1043	2500	834	709	84	12	334	<400	To install Chemical precipitation equipment which will inc. plant cap 15%
	0.2	2.8*	12010	751	1801	600	510	60	30	240	<400	Plans for expansion up to 12 MGD
	NA	0.25	367	23	55	18	16	2	1	7	<400	
	NA	0.2	33	2	5	2	1	<1	<1	1	<400	

Table BA-III-A-1 EXISTING MUNICIPAL WASTEWATER T

Sewage Treatment Plant Name	Location (Receiving Stream, Mile Designation point)	Sewer Type: Sanitary	Sewer Type: Combined	Present Treatment: Primary	Present Treatment: Secondary	Present Treatment: Advanced	Pop. Served (1000's)	Estimated Service Area (Square Miles)	Estimated Present Average Wastewater Flow (MGD)	Estimated Industrial Average Wastewater Flow (MGD)	Estimated Design Capacity Average (MGD)	Total Dissolved Solids	Susp Sol
Oakbrook Terrace	Sa 16.7	X			X		.7	NA	0.07	0	0.07	233	
Oakbrook U. C.	Sa 13.5, Des 45.2	X			X		10.0	NA	1.0	0.05	0.9	3,336	2
Subtotal For Salt Creek prior to confluence with Des Plaines River							143.8	41.7	17.02	1.2	20.51	56,778	3,5
Willowbrook Rd. Estates	Fl 4.8	X			X		0.13	NA	0.01	NA	0.02	33	
Hinsdale S. D.	Fl 4.5, Des 33.2	X	X			X	32.0	2.6	3.85	0	4.25*	12,844	3
DCDPW-Marion Br. - Brookhaven	Saw 4.5, Des 30.6	X			X		17.0	NA	1.25	NA	1.25*	4,170	2
DCDPW-Space Valley	Des 28	X			X		0.1	NA	0.01	NA	0.01	33	
Romeoville	Des 23.6	X			X		8.5	2.0	0.9	0	1.0	3,002	1
Alexander UC	Des 23.6	X			X		0.3	NA	0.03	NA	1.5	100	
Subtotal Des Plaines River prior to the confluence with Chicago Sanitary and Ship Canal							251.41	79.0	28.22	1.7	36.27	94,140	5,4
<u>Chicago River Sub-drainage Basin</u>													
Great Lakes Naval Training Center Green Bay	Sk 40.5		X		X		12.0	0.7	1.2	0	2.2	4,003	25
NSSD-Clavey Road	Sk 30.2, N. Br. Chi 22.9	X	X		X		30.0	NA	4.5	NA	4.5	15,012	93
Riverwoods S&W Co.	W. Fr. N. Br. Chi 32	X			X		0.1	NA	0.01	NA	0.1	33	2
Deerfield	W. Fr. N. Br. Chi 29, N. Br. Chi 19.3	X			X		18.0	5.8	1.8	0.3	2.25	6,005	375
MSDGC-North Side	N. S. C. 3.3, N. Br. Chi 7.7, SSC 30.8	X	X		X		1424.0	145.0	327.0	96.9	410.0	1,090,872	46,36
Subtotal Chicago River System prior to the Chicago Sanitary & Ship Canal							1484.10	151.5	334.51	97.2	419.05	1,115,925	47,92
MSDGC-West Southwest	SSC 25	X	X		X		3300.0	270.0	844.0	418.0	1200.0	2,815,584	168,93

ted nt ge ater D)	Estimated Industrial Average Wastewater Flow (MGD)	Estimated Design Capacity Average (MGD)	ESTIMATED WASTE LOADINGS (LBS/DAY)									Comments
			Total Dissolved Solids	Suspended Solids	COD	BOD	NH_3-N	Organic N	NO_3-N	P	Fecal Coliform Bacteria (MPN/100 ml)	
07	0	0.07	233	15	35	12	10	1	1	5	< 400	
0	0.05	0.9	3,336	209	500	167	142	17	8	67	< 400	
02	1.2	20.51	56,778	3,549	8,517	2,839	2,413	284	142	1,135		
01	NA	0.02	33	2	5	2	1	< 1	< 1	1	< 400	
85	0	4.25*	12,844	385	963	321	546	64	32	257	< 400	Plans to expand to 9.6 MGD
25	NA	1.25*	4,170	261	626	209	177	21	10	83	< 400	Expanding plant to to 2.75 MGD Cap.
01	NA	0.01	33	2	5	2	1	< 1	< 1	1	< 400	
9	0	1.0	3,002	188	450	150	128	15	8	60	< 400	
03	NA	1.5	100	6	15	5	4	1	< 1	2	< 400	
22	1.7	36.27	94,140	5,467	13,158	4,387	4,000	471	235	1,883		
2	0	2.2	4,003	250	600	200	170	20	10	80	< 400	
5	NA	4.5	15,012	938	2,252	751	709	75	38	300	< 400	
.01	NA	0.1	33	2	5	2	1	< 1	< 1	1	< 400	
.8	0.3	2.25	6,005	375	901	300	255	30	15	120	< 400	
.0	96.9	410.0	1,090,872	46,362	114,540	38,181	16,636	6,545	8,182	16,363	< 400	
.51	97.2	419.05	1,115,925	47,927	118,298	39,434	17,771	6,670	8,245	16,863		
4.0	418.0	1200.0	2,815,584	168,935	337,869	112,623	80,244	20,413	1,408	16,894	< 400	

Table BA-III-A-1 EXISTING MUNICIPAL WASTEWAT

Sewage Treatment Plant Name	Location (Receiving Stream, Mile Designation point)	Sewer Type: Sanitary	Sewer Type: Combined	Present Treatment: Primary	Present Treatment: Secondary	Present Treatment: Advanced	Pop. Served (1000's)	Estimated Service Area (Square Miles)	Estimated Present Average Wastewater Flow (MGD)	Estimated Industrial Average Wastewater Flow (MGD)	Estimated Design Capacity Average (MGD)	Total Dissolve Solids
Little Calumet Drainage Basin discharging into Des Plaines River												
Township U. C.	Pl 18.5	X			X		0.8	NA	NA	NA	NA	
Selym U. C.	Pl 16.8, Har	X					NA	NA	NA	NA	NA	
Schererville	Sc 2.5, Har 3.6	X			X		4.25	9.0	0.37	0	NA	1,234
Dyer	Har 3.5, L. Cal 29.5		X		X		3.3	5.5	0.36	0	NA	1,200
Lansing	L. Cal 25.2		X		X		21.0	5.0	2.1	0.1	2.5	7,006
Bloom Township S. D.	Tho 32.3	X			X		80.0	14.2	9.9	3.0	12.1	33,026
MSDGC-E. Chi. Hts.	De 20	X			X		26.0	0.9	2.6	0	2.4	8,674
Steger	Thi, De 18	X			X		7.0	1.6	0.7	NA	1.0	2,335
Wood Hill U. C.	De 14.4	X			X		1.0	NA	0.1	NA	0.25	334
Crete	De 9.7	X			X		3.8	1.5	0.38	0	0.4	1,268
Crete-Greenbiar	De 7.9	X			X		NA	1.5	NA	0	NA	
Crete-Swiss Valley	De 6.9, Tho 30.3	X			X		NA	1.5	NA	0	0.1	
Glenridge Subd.	But 11.5	X			X		0.4	NA	0.11	NA	0.16	367
Richton Park	But Trib 2.5, Bu 8	X			X		1.5	3.0	0.15	NA	0.3	500
Flossmoor	But 3.5	X			X		6.0	3.0	0.6	0	0.8	2,002
Homewood	But 1.3, Tho 29.5	X				X	20.0	4.5	2.0	0	3.8	6,672
Thornton	Tho 26.4, L. Cal 22.5		X		X		3.7	1.9	0.37	0	0.4	1,234
MSDGC-Hazel Crest	Cal U 4.0, L. Cal 19.4 Cal. Sag 16	X			X		8.0	2.5	0.8	0	1.0	2,669
MSDGC-Calumet	L. Cal 10.5 Cal-S 16	X	X		X		700.0	280.0	198.0	66.0	310.0	660,528
Subtotal Little Calumet River prior to confluence with the Cal Sag Channel							886.75	335.6	218.54	69.1	335.21	729,049
Fernway	Ti 8.7, Cal-S 10.5	X			X		1.9	NA	0.2	NA	0.2	667
MSDGC-Orland Park	McG, Mi5, Cal-S 5.2, SSC 13.1	X			X		7.5	4.0	0.75	0	0.8	2,502

ıd t e ıter	Estimated Industrial Average Wastewater Flow (MGD)	Estimated Design Capacity Average (MGD)	ESTIMATED WASTE LOADINGS (LBS/DAY) Total Dissolved Solids	Suspended Solids	COD	BOD	NH_3-N	Organic N	NO_3-N	P	Fecal Coliform Bacteria (MPN/100 ml)	Comments
	NA	NA										
	NA	NA										
7	0	NA	1,234	77	185	62	52	6	3	25	< 400	
5	0	NA	1,200	75	180	60	51	6	3	24	< 400	
	0.1	2.5	7,006	438	1,051	350	298	35	18	140	< 400	
	3.0	12.1	33,026	2,064	4,954	1,651	1,404	165	83	660	< 400	
	0	2.4	8,674	542	1,301	434	369	43	22	173	< 400	
	NA	1.0	2,335	146	350	117	99	12	6	47	< 400	
	NA	0.25	334	21	50	17	14	2	1	7	< 400	
8	0	0.4	1,268	79	190	63	54	6	3	25	< 400	
	0	NA										
	0	0.1										
1	NA	0.16	367	23	55	18	16	2	1	7	< 400	
5	NA	0.3	500	31	75	25	21	3	1	10	< 400	
	0	0.8	2,002	125	300	100	85	10	5	40	< 400	
	0	3.8	6,672	200	500	167	284	33	17	133	< 400	
7	0	0.4	1,234	77	185	62	52	6	3	25	< 400	
	0	1.0	2,669	167	400	133	113	13	7	53	< 400	
	66.0	310.0	660,528	23,118	84,216	28,072	23,449	4,293	1,651*	9,908*	< 400	Assumed figures, actual data not available
4	69.1	335.21	729,049	27,183	93,992	31,331	26,361	4,635	1,824	11,277		
	NA	0.2	667	42	100	33	28	3	2	13	< 400	
5	0	0.8	2,502	156	375	125	106	13	6	50	< 400	

Table BA-III-A-1 EXISTING MUNICIPAL WASTEWATER T

Sewage Treatment Plant Name	Location (Receiving Stream, Mile Designation point)	Sewer Type: Sanitary	Sewer Type: Combined	Present Treatment: Primary	Present Treatment: Secondary	Present Treatment: Advanced	Pop. Served (1000's)	Estimated Service Area Square Miles)	Estimated Present Average Wastewater Flow (MGD)	Estimated Industrial Average Wastewater Flow (MGD)	Estimated Design Capacity Average (MGD)	Total Dissolved Solids	Suspended Solids
MSDGC-Lemont	SSC 10.2	X			X		5.0	20.6	0.69	0.2	0.7	2,302	144
Lockport	DR 1.3, SSC 1.9, Des 16.9		X	X			8.5	4.0	0.9	0	1.0	3,002	758
Subtotal Chicago Sanitary & Ship Canal prior to the confluence with Des Plaines River							5693.75	785.7	1399.59	584.5	1956.95	4,669,031	245,145
Derby Meadows U.C.	Lo 11.2	X			X		NA	NA	NA	NA	0.05		
Chickasaw Hill U.C.	Lo 8.9	X			X		NA	NA	NA	NA	0.1		
Lockport Heights S.D.	Lo 6.8, IMC	X			X		1.0	NA	0.1	NA	0.11	334	21
Bonnie Brae - Forest Manor S.D.	Fi 1.4, IMC, Des 15.8	X			X		2.8	NA	0.28	NA	0.25	934	58
Hickory Creek Sub-drainage Basin													
Prestwick U.C.	Hi 20	X			X		NA	NA	NA	NA	0.03		
Citizens-Arbury Hills	Hi 16.3	X			X		0.7	NA	0.07	NA	0.24	233	15
Frankfort	Hi 13.9	X			X		1.7	NA	0.17	NA	0.35	567	35
Mokena	E. Br. Ma 4.4, Hi 10.3	X			X		5.0	1.0	0.5	0.02	0.35	1,668	104
New Lenox	Hi 8.5	X			X		1.8	NA	0.18	NA	0.25	600	38
Oak Highlands-Ingalls Pk. S.D.	Hi 4.0	X			X		1.0	NA	0.1	NA	0.25	334	21
Preston U.C.	Hi 1.0	X		X			1.2	NA	0.12	NA	0.2	400	25
Joliet	Hi 0.1, Des 13.2		X		X		82.0	11.0	18.0	7.22	22.0	60,048	3,753
Subtotal Hickory Creek prior to the confluence with the Des Plaines River							93.40	12.0	19.14	NA	23.67	63,850	3,991
Ranch Oaks Serv. Assn.	Ja 16.2	X			X		0.2	NA	0.02	0	0.03	67	4
Manhattan	Man 5.3, Ja 10.9, Des 6.4	X			X		1.4	0.8	0.14	593.42	0.2	467	29
Subtotal Des Plaines River prior to the confluence with the DuPage River							6043.96	877.5	1447.49	593.42	2017.41	4,828,823	254,715
DuPage River Sub-drainage Basin													
MSDGC-Hanover	W. Br. Du 58.5	X			X	X	21.3	11.2	1.53 0.6	0	NA	5,104 2,002	319 60

Estimated Present Average Wastewater Flow (MGD)	Estimated Industrial Average Wastewater Flow (MGD)	Estimated Design Capacity Average (MGD)	ESTIMATED WASTE LOADINGS (LBS/DAY)									Comments
			Total Dissolved Solids	Suspended Solids	COD	BOD	NH_3-N	Organic N	NO_3-N	P	Fecal Coliform Bacteria (MPN/100 ml)	
0.69	0.2	0.7	2,302	144	345	115	98	12	6	46	< 400	
0.9	0	1.0	3,002	758	2,703	901	169	94	< 1	68	< 400	
1399.59	584.5	1956.95	4,669,031	245,145	553,682	184,562	124,777	31,840	11,491	45,211		
NA	NA	0.05										
NA	NA	0.1										
0.1	NA	0.11	334	21	50	17	14	2	1	7	< 400	
0.28	NA	0.25	934	58	140	47	40	5	2	19	< 400	
NA	NA	0.03										
0.07	NA	0.24	233	15	35	12	10	1	1	5	< 400	
0.17	NA	0.35	567	35	85	28	24	3	1	11	< 400	
0.5	0.02	0.35	1,668	104	250	83	71	8	4	33	< 400	
0.18	NA	0.25	600	38	90	30	26	3	2	12	< 400	
0.1	NA	0.25	334	21	50	17	14	2	1	7	< 400	
0.12	NA	0.2	400	25	60	20	17	2	1	8	< 400	
18.0	7.22	22.0	60,048	3,753	9,007	3,002	2,552	301	150	1,200	< 400	
19.14	NA	23.67	63,850	3,991	9,577	3,192	2,714	320	160	1,276		
0.02	0	0.03	67	4	10	3	3	< 1	< 1	1	< 400	
0.14	593.42	0.2	467	29	70	23	23	2	1	9	< 400	
1447.49	593.42	2017.41	4,828,823	254,715	576,687	192,231	131,568	32,640	11,890	48,406		
1.53	0	NA	5,104	319	766	255	217	26	13	102		
0.6			2,002	60	150	50	85	10	5	40	< 400	

Table BA-III-A-1 EXISTING MUNICIPAL WASTEWATER TR

Sewage Treatment Plant Name	Location (Receiving Stream, Mile Designation point)	Sewer Type: Sanitary	Sewer Type: Combined	Present Treatment: Primary	Present Treatment: Secondary	Present Treatment: Advanced	Pop. Served (1000's)	Estimated Service Area (Square Miles)	Estimated Present Average Wastewater Flow (MGD)	Estimated Industrial Average Wastewater Flow (MGD)	Estimated Design Capacity Average (MGD)	Total Dissolved Solids	Susp Soli
MSDGC-Bartlett	W. Br. Du 53.7	X			X		4.6	8.0	0.46	0	NA	1,535	9
Apple Orchard U.C.	W. Br. Du 52.9	X			X		0.4	NA	0.04	NA	0.26	133	
Maddox	W. Br. Du 49.4	X			X		NA	NA	NA	NA	0.01		
DCDPW-Cascade	W. Br. Du 49.0	X			X		*	0	NA	0	0.01		
Carol Stream	Kl 2.2, W. Br. Du 47	X			X		4.5	5.0	0.45	0.1	0.5	1,501	9
Winfield	W. Br. Du 44	X			X		3.0	1.5	0.3	0	0.5	1,000	6
West Chicago	W. Br. Du 43	X			X		11.0	6.0	1.5	0.1	3.0	5,004	31
Wheaton S.D.	Sp 3.4, W. Br. Du 39.6		X		X		38.0	14.0	6.16	0	5.0*	20.550	1,28
Utilities Inc., Westfield	Fe 4.7	X			X		NA	NA	NA	NA	0.06		
Utilities Inc., Scots Plains	Fe 0.2, W. Br. Du 36.8	X			X		.4	NA	0.04	NA	0.26	133	
Naperville-North	W. Br. Du 35.3	X			X			1.1	1.0	0.6	0.75	3,336	20
-Central	W. Br. Du 32.4		X		X		23.0	3.4	2.0	0.04	2.5	6,672	41
-South	W. Br. Du 30.5, Du 27.7	X			X			1.1	0.6	0	0.6	2,002	12
Subtotal W. Branch DuPage River prior to the confluence with the E. Branch							108.20	51.3	14.68	0.3	13.45	48,972	2,9
Glendale Heights	E. Br. Du 49.2	X			X		6.8	2.5	0.68	0	1.0	2,268	1
DCDPW-Glen Ellyn Hts	E. Br. Du 47.7	X			X		1.0	NA	0.1	NA	0.2	334	
Lombard	E. Br. Du 46.6		X		X		33.0	5.0	3.7	0.03	4.4	12,343	7
Glen Ellyn	E. Br. Du 43.7	X			X		21.0	7.5	2.1	0	2.3	7,006	4
DCDPW-Butterfield	E. Br. Du 43.0	X			X		2.4	NA	0.24	NA	0.72	801	
Citizens-Valley View	E. Br. Du 41.0	X			X		2.4	NA	0.24	NA	0.24	801	
Downers Grove S.D.	St. J. 3.3, E. Br. Du 39.6	X	X	X	X		40.0	5.0	4.5	0.09	8.0* 5.5	15,012	9
DCDPW-Lisle	E. Br. Du 38.5	X			X		7.0	2.5	0.7	0	0.9	2,335	1
Woodridge S&W Co.	E. Br. Du 35.4, Du 27.7	X			X		3.6	1.9	0.36	0	0.4	1,201	
Subtotal E. Branch DuPage River prior to the confluence with the W. Branch							117.20	24.4	12.62	0.12	15.66	42,101	2,6
Plainfield	Du 18.5	X			X		2.2	NA	0.22	NA	0.3	734	
Citizens-W. Suburban	Li 14.5, Du 14.4	X			X		0.7	NA	0.07	NA	0.24	236	
Will County Water Co.	Du 10	X			X		NA	NA	NA	NA	0.1		
Camelot U.C. Inc.	Du 7.2	X			X		0.1	NA	0.01	NA	0.04	33	
Crest Hill-East	Ro 10	X			X		0.3	NA	0.03	NA	0.05	100	
Crest Hill-Paramount	Ro 9.5	X			X		0.5	NA	0.05	NA	0.06	167	

Estimated Present Average astewater Flow (MGD)	Estimated Industrial Average Wastewater Flow (MGD)	Estimated Design Capacity Average (MGD)	ESTIMATED WASTE LOADINGS (LBS/DAY)									Comments
			Total Dissolved Solids	Suspended Solids	COD	BOD	NH_3-N	Organic N	NO_3-N	P	Fecal Coliform Bacteria (MPN/100 ml)	
0.46	0	NA	1,535	96	230	77	65	8	4	31	< 400	
0.04	NA	0.26	133	8	20	7	6	1	< 1	3	< 400	
NA	NA	0.01										
NA	0	0.01										Services drive-in & truck rental Co.
0.45	0.1	0.5	1,501	94	225	75	64	8	4	30	< 400	
0.3	0	0.5	1,000	63	150	50	43	5	3	20	< 400	
1.5	0.1	3.0	5,004	313	751	250	213	25	13	100	< 400	
6.16	0	5.0*	20.550	1,284	3,082	1,027	873	103	51	411	< 400	Expanding to 5.3 including stormwater overflow lagoon
NA	NA	0.06										
0.04	NA	0.26	133	8	20	7	6	1	< 1	3		
1.0	0.6	0.75	3,336	209	500	167	142	17	8	67	< 400	Presently expanding plant
2.0	0.04	2.5	6,672	417	1,001	334	284	33	17	133	< 400	
0.6	0	0.6	2,002	125	300	100	85	10	5	40	< 400	
14.68	0.3	13.45	48,972	2,996	7,195	2,399	2,083	247	123	980		
0.68	0	1.0	2,268	142	340	113	96	11	6	45	< 400	
0.1	NA	0.2	334	21	50	17	14	2	1	7	< 400	
3.7	0.03	4.4	12,343	771	1,851	617	525	62	31	247	< 400	
2.1	0	2.3	7,006	438	1,051	350	298	35	18	140	< 400	
0.24	NA	0.72	801	50	120	40	34	4	2	16	< 400	
0.24	NA	0.24	801	50	120	40	34	4	2	16	< 400	
4.5	0.09	8.0* 5.5	15,012	938	2,252	751	638	75	38	300	< 400	*Plans to upgrade sec. to 6 MGD & also chem. precipitation
0.7	0	0.9	2,335	146	350	117	99	12	6	47	< 400	
0.36	0	0.4	1,201	75	180	60	51	6	3	24	< 400	
12.62	0.12	15.66	42,101	2,631	6,314	2,105	1,789	211	107	842		
0.22	NA	0.3	734	46	110	37	31	4	2	15	< 400	
0.07	NA	0.24	236	15	35	12	10	1	1	5	< 400	
NA	NA	0.1										
0.01	NA	0.04	33	2	5	2	1	< 1	< 1	1	< 400	
0.03	NA	0.05	100	6	15	5	4	1	< 1	2	< 400	
0.05	NA	0.06	167	10	25	8	7	1	< 1	3	< 400	

Table BA-III-A-1 EXISTING MUNICIPAL WASTEWATER TREATM

Sewage Treatment Plant Name	Location (Receiving Stream, Mile Designation point)	Sewer Type		Present Treatment			Pop. Served (1000's)	Estimated Service Area (Square Miles)	Estimated Present Average Wastewater Flow (MGD)	Estimated Industrial Average Wastewater Flow (MGD)	Estimated Design Capacity Average (MGD)		
		Sanitary	Combined	Primary	Secondary	Advanced						Total Dissolved Solids	Susp Sol
Crest Hill-West	Ro 8.5	X			X		0.4	NA	0.04	NA	0.05	133	
Westfield	Ro 6.2, IMC, Du 1.0, Des 3.8	X			X		0.4	NA	0.04	NA	0.12	133	
Subtotal DuPage River prior to the confluence with the Des Plaines River							230.0	75.7	27.76	0.42	30.07	92,609	5
Total Des Plaines River out of Study Area							6273.96	953.2	1475.25	593.84	2047.48	4,921,432	260
Rockdale	IMC		X		X		2.0	NA	0.2	NA	0.3	667	
LAKE MICHIGAN DRAINAGE BASIN													
Camp Logan	Ke 0.3, LM 42°27'50", 87°47'50")				X		NA	NA	NA	NA	0.1		
NSSD-Waukegan	LM(42°22'30", 87°48'45")		X		X		65.0	NA	9.75*	NA	9.05	32,526	2,
NSSD-North Chicago	LM(42°19', 87°49'50")	X			X		20.5	NA	3.0*	NA	3.35	10,008	
Great Lakes Naval Training Center-Lake Front	LM(42° 18', 87° 50')		X		X		17.0	1.7	1.7	0	2.1	5,671	3
NSSD-Lake Bluff	LM(42°16'30", 87°49'45")		X	X			3.5	NA	0.5	NA	0.28*	1,668	4
NSSD-Lake Forest	LM(42°14'30", 87°49')	X		X			10.9	NA	1.1	NA	1.2*	3,670	9
Fort Sheridan	LM(42°13', 87°48'15")		X	X			5.0	NA	0.5	NA	1.25	1,668	4
NSSD-Park Ave.	LM(42°12', 87°47'45")	X		X			5.1	NA	0.51	NA	0.7*	1,701	4
NSSD-Ravine Dr.	LM(42°0'50", 87°46'25")	X		X			4.5	NA	0.7*	NA	0.9	2,335	5
NSSD-Cary Ave.	LM(42°10'10", 87° 47')	X		X			7.1	NA	1.0*	NA	0.9	3,336	8
Grand Calumet River Drainage Basin													
Hammond S.D.	Gr Cal 12.0, Cal 7.6, LM(41° 44', 87°31' 45")		X		X		180.0	47.5	35.9	NA	36.0*	119,762	7,
E. Chicago S.D.	Gr Cal 13.7, IHC 4.0		X		X		57.0	12.3	10.5	NA	20.0	35,028	2,
Gary	Gr Cal 18.5 IHC 4.0, LM(41°40', 87°26'30")		X		X		200.0	42.0	38.2	1.25	60.0	127,435	7,
Total Grand Calumet River discharging into Lake Michigan							437.00	101.8	84.6	1.25	116.0	282,225	17,

Estimated Industrial Average Wastewater Flow (MGD)	Estimated Design Capacity Average (MGD)	ESTIMATED WASTE LOADINGS (LBS/DAY)									Comments
		Total Dissolved Solids	Suspended Solids	COD	BOD	NH_3-N	Organic N	NO_3-N	P	Fecal Coliform Bacteria (MPN/100 ml)	
NA	0.05	133	8	20	7	6	1	< 1	3	< 400	
NA	0.12	133	8	20	7	6	1	< 1	3	< 400	
0.42	30.07	92,609	5,722	13,739	4,582	3,937	467	233	1,854		
593.84	2047.48	4,921,432	260,437	590,426	196,813	135,505	33,107	12,123	50,260		
NA	0.3	667	42	100	33	28	3	2	13	< 400	
NA	0.1										
NA	9.05	32,526	2,033	4,879	1,626	1,383	163	81	650	< 400	*Estimated @ 150 gpcd
NA	3.35	10,008	626	1,500	500	425	50	25	200	< 400	*Estimated @ 150 gpcd
0	2.1	5,671	354	851	284	241	28	14	113	< 400	
NA	0.28*	1,668	421	1,500	500	94	52	< 1	38	< 400	*Plans call for abandoning plant
NA	1.2*	3,670	927	3,300	1,100	206	115	< 1	83	< 400	*Plans call for abandoning plant
NA	1.25	1,668	421	1,500	500	94	52	< 1	38	< 400	
NA	0.7*	1,701	430	1,530	510	96	53	< 1	38	< 400	*Plans call for abandoning plant
NA	0.9	2,335	590	2,100	700	131	73	< 1	53	< 400	*Plans call for abandoning plant
NA	0.9	3,336	842	3,000	1,000	188	104	< 1	75	< 400	*Plans call for abandoning plant
NA	36.0*	119,762	7,485	17,964	5,988	5,091	600	299	2,395	< 400	Under construction 48 MGD Expansion
NA	20.0	35,028	2,189	5,254	1,751	1,489	175	88	88*	< 400	*Phosphorus removal by chemical precipitation
1.25	60.0	127,435	7,965	19,115	6,372	5,417	638	319	2,548	< 400	
1.25	116.0	282,225	17,639	42,333	14,111	11,997	1,413	706	5,031		

Table BA-III-A-1 EXISTING MUNICIPAL WASTEWATER TR

Sewage Treatment Plant Name	Location (Receiving Stream, Mile Designation point)	Sewer Type: Sanitary	Sewer Type: Combined	Present Treatment: Primary	Present Treatment: Secondary	Present Treatment: Advanced	Pop. Served (1000's)	Estimated Service Area (Square Miles)	Estimated Present Average Wastewater Flow (MGD)	Estimated Industrial Average Wastewater Flow (MGD)	Estimated Design Capacity Average (MGD)	Total Dissolved Solids
Little Calumet River Drainage Basin to Lake Michigan												
Chesterton	L. Cal 53.5		X		X		4.7	10.8	0.7	0	1.5	2,335
Valparaiso	Sa 16.2, L. Cal 49.8, Bu 1.3, LM(41°37'50" 87°10'35")		X		X		20.0	7.6	3.1	0.1	3.0	10,342
Crown Point	BD 28.7, Deep 25.4		X		X		11.0*	7.0	1.8	0	1.8	6,005
Hobart	Deep 7.5, L. Cal 41.6, Bu 1.3, LM(41°37'50", 87°10'35")	X			X		17.0*	12.0	1.7	0	2.1	5,671
Total Little Calumet River discharging into Lake Michigan							59.7	37.4	7.3	0.1	8.4	24,353
Michigan City	Tr 1.7, LM (42°13', 86°54'30")				X		63.0	16.0	8.3	0.9	NA	27,689
Total Discharges into Lake Michigan							691.30	210.9*	118.96	4.55*	NA	396,850

Legend

- BOD - Biochemical oxygen demand
- COD - Chemical oxygen demand
- Di - Ditch
- E Br - East Branch
- Fr - Fork
- N - Nitrogen
- NA - Not Available
- N Br - North Branch
- P - Phosphorus
- S Br - South Branch
- S. D. - Sanitary District
- S&W - Sewer & Water
- UC - Utility Company
- W Br - West Branch
- DCDPW - DuPage County Department of Public Works
- LCPWD - Lake County Public Works Department
- MSDGC - Metropolitan Sanitary District of Greater Chicago
- NSSD - North Shore Sanitary District

Stream Legend

Stream Legend

- Ad - Addison Creek
- Ap - Aptakisic Creek
- BD - Beaver Dam Ditch
- Bu - Buffalo Creek
- Bul - Bull Creek
- But - Butterfield Creek
- Cal-S - Calumet-Sag Channel
- Cal-U - Calumet Union Drainage Ditch
- Chi - Chicago River
- DR - Deep Run
- De - Deer Creek
- Deep - Deep River
- Des - Des Plaines River
- Du - DuPage River
- Fe - Ferry Creek
- Fi - Fiddyment Creek
- Fl - Flagg Creek

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r	Estimated Industrial Average Wastewater Flow (MGD)	Estimated Design Capacity Average (MGD)	ESTIMATED WASTE LOADINGS (LBS/DAY)									Comments
			Total Dissolved Solids	Suspended Solids	COD	BOD	NH_3-N	Organic N	NO_3-N	P	Fecal Coliform Bacteria (MPN/100 ml)	
	0	1.5	2,335	146	350	117	99	12	6	47	< 400	Plans for phosphorus removal & detention pond
	0.1	3.0	10,342	646	1,551	517	440	52	26	207	< 400	Installing phosphorus removal equipment & plant expansion to 6 MGD
	0	1.8	6,005	375	901	300	255	30	15	120	< 400	*Population estimated
	0	2.1	5,671	354	851	284	241	28	14	113	< 400	*Population estimated
	0.1	8.4	24,353	1,521	3,653	1,218	1,035	122	61	487		
	0.9	NA	27,689	1,731	4,153	1,384	1,177	139	69	554	< 400	
	4.55*	NA	396,850	27,535	70,299	23,433	17,067	2,364	956	7,360		*Includes the NSSD total service area 54 sq. miles and a total industrial flow = 2.3 MGD

nd

ddison Creek	Gr Cal - Grand Calumet River	NSC - North Shore Channel
ptakisic Creek	Har - Hart Ditch	Pl - Plum Creek
eaver Dam Ditch	Haw - Hawthorn Drainage Ditch	Ro - Rock Run
uffalo Creek	IMC - Illinois & Michigan Canal	SSC - Sanitary & Ship Canal
ull Creek	In - Indian Creek	Sa - Salt Creek
utterfield Creek	Ja - Jackson Creek	Saw - Sawmill Creek
alumet-Sag Channel	Ke - Kellog Ravine Ditch	Sc - Schererville Ditch
alumet Union Drainage Ditch	Kl - Klein Creek	Sk - Skokie River
hicago River	L.Cal - Little Calumet River	Sp - Spring Brook
eep Run	LM - Lake Michigan	St. J - St. Joseph Creek
eer Creek	Li - Lily Cache Creek	Su - Sugar Creek
eep River	Lo - Long Run	Thi - Third Creek
es Plaines River	Ma - Marley Creek	Tho - Thorn Creek
uPage River	Man - Manhattan Creek	Ti - Tinley Creek
erry Creek	McD - McDonald Creek	Tr - Trail Creek
iddyment Creek	McG - McGinnis Slough	
lagg Creek	Mi - Mill Creek	

Table BA-III-A-2 INDUSTRIAL SURFACE WASTEWATER D

Company Name	Location (Recovery stream, mile designating point)	Watershed No.	Wastewater Flow (MGD)	Industrial Process: Cooling	Industrial Process: Process	Industrial Process: Sanitary	Type of Industry	Character of Wastewater	Color (units) I/D	Heat (°F) Winter I/D	Heat (°F) Summer I/D	Fecal Coliform Bacteria MPN/100 ml. I/D	Pollutant Loading: Total Dissolved Solids I/D	Suspended Solids I/D	BOD I/D	COD I/D	NO_3-N I/D	NH_3-N I/D	Organic N I/D	P I/D	Oils & Greases I/D	Phenols I/D
Desplaines River Drainage Basin																						
O'Hare Field	Wi. 2 to Des. 60	5	15.6		X		Airport-deicing chemicals	Chemical	BL	ambient	NA	BL	NA	BL	BL	BL	BL	NA	NA	BL	BL	BL
O'Hare Field	Cry. 2 to Des. 57.5	5	5.2		X		Airport-deicing chemicals	Chemical	BL	ambient	NA	BL	NA	BL	BL	BL	BL	NA	NA	BL	BL	BL
Sanitary & Ship Canal Sub-Drainage Basin																						
Proctor & Gamble	N.Br.Chi 2	4	11.38	X			Soap, food Processing	Solids BOD	25/ 15	NA/ 55	NA/ 55	NA	41.4/ 53.2	.175/ 2.65	.57/ 1.41	4.75/ 6.32	.002/ .012	.885/ .92	.13/ .105	2.85/ 2.7	.855/ 1.15	.013/ .015
Prudential Building	Chi. 0.5	4	5.0	X			Office Bldg.	Thermal	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Equitable Life Bldg.	Chi. 0.5	4	5.4	X			Office Bldg.	Thermal	BL	39/ 82	70 84	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL
Kemper Insurance Bldg.	S.Br.Chi 3.5	4	4.5	X			Office Bldg.	Thermal	NA	NA	65/ 85	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hartford Building	S.Br.Chi 3.5	4	9.07	X			Office Bldg.	Thermal	NA	NA	70/ 87	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
150 South Wacker Drive Building	S.Br.Chi 3.5	4	11.52	X			Office Bldg.	Thermal	NA	NA	70/ 80	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Commonwealth Edison Fisk Station	S.Br.Chi 1.0	4	423.45	X			Power	Thermal	BL	45/ 52	73/ 82	BL	173/ 173	63.5/ 67.5	24.5/ 28.5	106/ 106	60/ 60	12.5/ 12.5	.264/ .23	28/ 28	BL	BL
Commonwealth Edison Crawford St. Station	SSC 27.5	4	475.92	X			Power	Thermal	BL	46/ 57	73/ 87	BL	1,300/ 1,300	43.5/ 43.5	20/ 20	83.5/ 83.5	3.4/ 3.4	20/ 20	2.38/ 1.55	.915/ .915	BL	BL
Commonwealth Edison Ridgeland Station	SSC 24.25	4	783.36	X			Power	Thermal	BL	50/ 60	79/ 87	BL	2,760/ 2,760	104.5/ 104.5	52.5/ 52.5	261.5/ 261.5	1.45/ 1.45	43.2/ 43.2	4.375/ 5.225	5.35/ 5.35	13.5/ 13.5	BL
Cal-Sag Channel Sub-Drainage Basin																						
Interlake, Inc. Chicago	Gr. Cal. 8.25	4	26.5	X			Steel	Solids, BOD	10/ 10	NA	NA	BL	BL	1.645/ 2.215	5.54/ 35.445	17.14/ 3.775	BL	.645/ .420	BL	BL	10.5/ 3.83	.003/ .002
			12.1	X	X		Steel	Solids	10/ 15	NA	NA	BL	BL	.935/ 1.545	7.92/ 2.84	1.765/ 1.515	BL	BL	BL	BL	1.51/ .006	.001/ .002
Interlake, Inc. Riverdale	L.Cal.11.5 to SSC 13.0 via Cal-S	4	15.04	X			Steel	COD, Color	17/ 10	NA	NA	BL	BL	10.465/ 10.515	8.8/ 8.795	33.54/ 54.405	BL	1.645/ 8.375	BL	BL	.985/ .86	.003/ .005
			5.4		X		Steel		20/ 20	NA	NA	BL	BL	3.340/ 2.615	2.415/ 5.4	4.673/ 3.545	BL	.680/ .715	BL	BL	.79/ .06	.009/ .008
Subtotal: Cal-Sag Sub-Drainage Basin			59.8										BL	17/17	19/54	87/93	BL	3/10	BL	BL	13/5	.016/ .017
CECO Corporation Lamont Mfg. Div.	SSC 8.5	10	8.33		X		Steel	Color	0/ 22	12/ 59	73/ 80	BL	169.5/ 176	3.1/ 2	.8/ .64	2.1/ 2.03	.08/ .15	1.8/ .275	BL	.265/ .355	0/ .801	0/ .001
Commonwealth Edison Will County Station	SSC 5.25	10	1116	X			Power	Thermal	BL	50/ 60	73/ 87	BL	4,500/ 4,500	130.3/ 130.3	65.15/ 65.15	307.15/ 307.15	1.5/ 1.5	68/ 68	4.85/ 4.84	9.5/ 9.5	BL	BL
Texaco, Inc. Lockport, Ill.	SSC 3.0 to Des. 15.75	10	5.33		X		Petroleum	Color, TDS	21/ 29	60/ 65	65/ 100	237,000 870	21.5/ 40	1.11/ .665	.355/ .355	1.8/ 2.5	0/ .205	.355/ .310	.165/ .09	.019/ .008	0/ .045	.001/ .001
			15.12	X			Petroleum	Thermal	21/ 20	55/ 78	82/ 102	237,000 73,500	61.15/ 61.15	3.15/ 3.15	1.01/ 1.01	4.54/ 4.54	BL	1.01/ 1.01	.755/ .67	.2/ .2	BL	.003/ .003
Subtotal: Sanitary & Ship Canal Sub-Drainage Basin			2914.22										9,016/ 9,069	367/ 367	184/ 220	809/ 837	64/ 65	151/ 158	13/13	47/47	33/19	.033/ .037
U.S. Steel Joliet	Des. 15.75	12	20.15	X	X		Steel	Color, Solids, BOD	15/ 50	38/ 45	82/ 88	NA	71.42/ 92.2	2.165/ 4.62	1.43/ 1.56	8.22/ 12.6	.135/ .175	.8/ 1.145	NA	.135/ .16	3.025/ 1.30	NA/ .003
Commonwealth Edison Joliet	Des. 13	12	1680.48	X			Power	Thermal	BL	48/ 57	82/ 78	NA	8,650/ 8,650	265.4/ 265.4	86.7/ 86.7	504.5/ 504.5	6.65/ 6.65	21.4/ 31.4	5.04/ 4.19	6.125/ 6.125	BL	BL
Joliet Army Ammunition Plant	Ja. 2.5 to Des. 6.[illegible]	15	19.41	X			Inorganic Chemical Explosives	Solids, NO_3-N	NA	73/ 72	NA	21,400 26,900	65.2/ 94.6	3.135/ 5.89	.6/ .490	2.75/ 4.655	1.78/ 13.2	.009/ .024	.115/ .3	.14/ .05	BL	BL
	Gr. 3 to Des. [illegible]	15	10.8	X	X			Solids, BOD	NA	75/ NA	NA	BL	38.275/ 70.1	1.8/ 6.35	.335/ 1.245	1.035/ 3.51	.71/ 4.27	.005/ .035	BL	.17/ .157	BL	BL
Total: Desplaines River Drainage Basin			4885.86										15,850/ 15,978	639/ 659	275/ 313	1325/ 1363	73/ 85	241/ 246	19/ 17	56/ 54	40/ 21	.033/ .040

Pollutant Loadings (1000 lbs/day)

COD I/D	NO3-N I/D	NH3-N I/D	Organic N I/D	P I/D	Oils & Greases I/D	Phenols I/D	Toxic Substances As I/D	B I/D	Cyanide I/D	Trace Metals Al I/D	Cd I/D	Cr I/D	Cu I/D	Fe I/D	Pb I/D	Mn I/D	Hg I/D	Ni I/D	Zn I/D	Comments
BL	BL	NA	NA	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	Winter discharge only
BL	BL	NA	NA	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	Winter discharge only
.75/ 6.32	.002/ .012	.985/ .97	.13/ .105	2.85/ 2.7	.855/ 1.15	.013/ .015	.040/ .040	.125/ .095	NA	NA	.005/ .005	.009/ .003	.007/ .006	.009/ .009	.045/ .052	.009/ .009	.285/ .135	NA	.015/ .024	
NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	
NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	Summer discharge only
NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	Summer discharge only
NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	Summer discharge only
06/ 106	60/ 60	12.5/ 12.5	.264/ .23	28/ 28	BL	BL	.14/ .105	4.06/ 4.06	BL	.725/ 1.11	.014/ .014	.076/ .076	.24/ .305	1.305/ 1.395	.206/ .189	.132/ .122	BL	.109/ .145	.312/ .184	Radioactivity (pc/l) Counting Error (RMS) Alpha .6/.6 3.3/3.3 Beta .4/19.1 10.3/13.1 Gamma 40.6/97.6 202/202
.5/ 43.5	1.4/ 1.4	20/ 20	2.38/ 1.55	.915/ .915	BL	BL	.18/ .24	8.55/ 4.4	BL	.955/ .875	.012/ .012	.051/ .024	.893/ .054	1.865/ 1.47	.478/ .36	.071/ .064	BL	.238/ .215	1.2/ .425	Alpha .4/.9 2.3/2.4 Beta .4/.4 7.3/7.3 Gamma 1.3/122 142/142
.5/ 41.5	1.45/ 1.45	43.2/ 43.2	4.575/ 5.225	5.35/ 5.35	22.5/ 12.5	BL	BL	9.15/ 8.8	BL	BL	BL	.238/ .195	.379/ .415	6.175/ 6.895	BL	.229/ .252	.001/ .001	.859/ .921	.4/ .37	
14/ 775	BL	.445/ .420	BL	BL	10.5/ 3.83	.003/ .002	BL	BL	.009/ .011	BL	.001/ .001	.110/ .110	.195/ .105	.580/ .740	.092/ .09	BL	BL	.018/ .018	.048/ .038	
765/ 515	BL	BL	BL	BL	1.51/ .006	.001/ .002	BL	BL	.014/ .015	BL	BL	.050/ .050	.005/ .005	.363/ .295	.07/ .07	BL	BL	.008/ .008	.024/ .067	
54/ 405	BL	1.945/ 8.375	BL	BL	.985/ .86	.003/ .005	BL	BL	.004/ .005	BL	BL	.003/ .004	.005/ .007	1.375/ 2.06	.007/ .007	BL	.001/ .001	.007/ .007	.046/ .055	
675/ 545	BL	.680/ .715	BL	BL	.09/ .08	.009/ .008	BL	BL	.001/ .002	BL	.001/ .001	.001/ .001	.002/ .001	.360/ .320	.005/ .005	BL	.001/ .001	.005/ .005	.015/ .016	
63	BL	3/10	BL	BL	15/5	.016/ .017	BL	BL	.028/ .033	BL	.002/ .002	.164/ .165	.107/ .118	2.678/ 3.415	.174/ .172	BL	.002/ .002	.038/ .038	.133/ .176	
9/ 05	.08/ .15	1.8/ .275	BL	.285/ .355	0/ .805	0/ .001	0/ .003	BL	0/ .004	BL	0/ .001	0/ .001	0/ .003	0/ .077	0/ .004	BL	0/ .012	0/ .035	0/ .06	
.15/ .15	1.5/ 1.5	88/ 88	4.93/ 4.84	9.5/ 9.5	BL	BL	.37/ .42	18.6/ 22.3	BL	2.115/ 2.73	.033/ .037	.135/ .172	.730/ .790	6.19/ 6.515	.181/ .228	.233/ .219	.001/ .001	.604/ .507	.76/ .835	Radioactivity (pc/l) Counting Error (RMS) Alpha 0.9/8.6 2.4/4.4 Beta 12.9/38.7 8.7/10.9 Gamma 1.1/45 142/142
5/ 9	0/ .205	.355/ .310	.265/ .09	.019/ .009	0/ .043	.001/ .001	.045/ .045	BL	.002/ .001	.089/ .089	BL	.004/ .013	.002/ .002	.04/ .009	.004/ .004	BL	BL	.004/ .004	.004/ .002	
54/ 54	BL	1.01/ 1.01	.755/ .83	.2/ .2	BL	.003/ .001	.125/ .125	BL	.005/ .003	.252/ .253	0/ .001	.013/ .013	.005/ .004	.113/ .05	.013/ .013	.013/ .013	BL	.013/ .013	.013/ .009	
[illegible]	84/ 85	151/ 158	13/13	47/47	37/19	.033/ .037	.9/ .978	38/41	.035/ .041	4.336/ 5.056	.066/ .072	.710/ .688	2.463/ 1.697	18.375/ 19.835	1.101/ 1.022	.687/ .679	.289/ .151	1.865/ 1.878	2.837/ 2.085	
[illegible]	.135/ .175	8/ 1.185	NA	.125/ .14	1.075/ 1.65	NA/ .003	.028/ .008	BL	BL	BL	BL	BL	.009/ .009	.16/ 1.5	NA/ .505	BL	BL	BL	.042/ .101	97% cooling water
5/ 5	6.65/ 6.65	91.4/ 91.4	5.04/ 4.19	6.125/ 6.125	BL	BL	.56/ .505	10.13/ 9.2	BL	3.645/ 4.285	.019/ .016	.358/ .195	.72/ 1.023	9.314/ 11.2	.707/ .689	1.55/ 1.55	.002/ .002	1.3/ .975	.852/ 1.114	Radioactivity (pc/l) Counting Error (RMS) Alpha .4/.4 2.8/2.8 Beta 38.1/28.7 13.4/12.4 Gamma 38/79 175/175
[illegible]/ 5	1.39/ 11.2	.009/ .024	.21/ .2	.14/ .15	BL	BL	BL	BL	BL	.170/ .125	BL	.007/ .062	BL	.086/ .177	BL	BL	BL	BL	BL	
5/ [illegible]	.37/ 4.27	.205/ .035	BL	.17/ .177	BL	BL	BL	BL	BL	.093/ .087	BL	.002/ .004	BL	.092/ .075	BL	.01/ .008	BL	BL	BL	
[illegible]	.732/ .89	245/ 248	19/ 18	54/ 54	40/ 21	.033/ .040	1.468/ 1.571	49/ 50	.035/ .041	8.284/ 5.557	[illegible]	[illegible]/ .869	3.382/ 2.731	28/ 34	[illegible]/ 2.116	2.197/ 2.237	.291/ .153	3.165/ 2.853	3.731/ 3.300	

Table BA-III-A-2 INDUSTRIAL SURFACE WASTEWAT

Company Name	Location (Recovery stream, mile designating point)	Watershed No.	Wastewater Flow (MGD)	Industrial Process: Cooling	Industrial Process: Process	Industrial Process: Sanitary	Type of Industry	Character of Wastewater	Color (units) I/D	Heat (°F) Winter I/D	Heat (°F) Summer I/D	Fecal Coliform Bacteria MPN/100 ml. I/D	Total Dissolved Solids I/D	Suspended Solids I/D	BOD I/D	COD I/D	NO_3-N I/D	NH_3-N I/D	Organic N I/D	P I/D	Oils & Greases I/D
Lake Michigan <u>Drainage Basin</u>																					
<u>Direct Discharge</u>	(Lat, Long)																				
Commonwealth Edison Zion Station	L.M. 42-26-44 87-47-52	1	2203	X			Power	Thermal	NA	40/ 54	62/ 70	NA	2,960/ 2,980	238.85/ 238.85	36.75/ 36.75	165.35/ 165.35	2.2/ 2.2	1.285/ 1.285	NA	4.08/ 4.08	NA
Commonwealth Edison Waukegan Station	L.M. 42-23-00 87-48-30	1	853.92	X			Power	Thermal	BL	39/ 47	62/ 73	BL	1,380/ 1,380	135.3/ 135.3	28.5/ 28.5	35.5/ 35.6	3.06/ 3.06	.78/ .78	940/ 947.2	.925/ .925	BL
			8.4		X		Power	Solids, T.M.	BL	NA	48/ 60	BL	13.6/ 16.1	1.33/ 1.54	.28/ .28	.35/ .35	.03/ .032	.007/ .023	BL	.009/ .02	BL
U. S. Steel Waukegan	L.M. 42-20-53 87-48-10	1	6.27		X		Steel	Solids, BOD	1/7	34/ 36	68/ 73	BL	8.375/ 14	.26/ 1.47	.115/ .3	.76/ 1.66	0/.04	.024/ .013	BL	0/ .008	.1/ .097
Abbott Laboratories North Chicago	L.M. 42-15-50 87-49-50	1	16	X			Drug	Solids, BOD, Toxic Substance	5/ 20	35/ 64	63/ 85	BL	24/ 60	2/ 3.34	.27/ 2.67	.67/ 6.67	.093/ .133	.053/ .467	BL	.005/ .133	.265/ .040
Winnetka Municipal Electric Generating Station	L.M. 42-06-26 87-44-11	1	52.13	X			Power	Thermal	NA	42/ 52	57/ 68	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Central Water Filtration Plant Chicago	L.M. 41-54-03 87-36-08	4	17		X		Water Filtration	Backwash Solids	NA	32/ NA	75/ NA	BL	NA	NA	NA	NA	NA	NA	NA	NA	BL
U. S. Steel South Works	L.M. 41-44-20 87-31-50	4	113.9		X		Steel	TDS, COD, Nitrogen	5/6	50/ 47	85/ 75	BL	162.4/ 262	93.6/ 24.6	3.565/ 1.97	11.4/ 31.7	.182/ .65	.285/ .785	.478/ 0	.034/ .043	.945/ .95
			110.89*	X			Steel	COD	5/6	50/ 46	85/ 83	BL	158.1/ 164.6	91.15/ 5.55	3.47/ 2.59	11.09/ 14.8	.177/ 0	.277/ 0	.466/ 0	.033/ .028	.92/ 0
Commonwealth Edison State Line Station	L.M. 41-42-28 87-31-07	18	820	X			Power	Thermal, T.M.	NA	42/ 49	69/ 76	NA	1,169/ 1,172	61.55/ 63.13	20.5/ 20.5	47.9/ 47.9	1.5/ 1.5	.41/ .41	.547/ .41	1.37/ 1.37	NA
American Maize Products Co. Hammond, Ind.	L.M. 41-41-50 87-30-18	18	10.02	X	X		Grain Mill	Thermal, BOD	5/5	40/ 78	68/ 109	76/ 0	16.1/ 21.2	1.7/ 1.86	.39/ 2.02	.840/ 4.53	.015/ .020	.002/ .127	BL	.006/ .042	.262/ .259
Union Carbide Corp. Whiting, Ind.	L.M. 41-41-25 87-28-20	18	47.76	X	X		Organic Chemical	BOD	5/5	39/ 63	63/ 84	BL	74.15/ 0	4.36/ .95	1.030/ 2.7	4.76/ 5.335	.16/ 0	.14/ 0	.16/ .16	.029/ .018	.278 .675
American Oil Co. Whiting, Ind.	L.M. 41-40-36 87-28-24	18	29.17	X	X		Petroleum	Solids, Color, Thermal, BOD, Nitrogen, Oils, Phenols	5/ 48	35/ 71	66/ 90	BL	58.15/ 82.7	2.92/ 4.865	.243/ 4.915	1.215/ 24.035	0/ .022	.015/ 1.32	.007/ .657	.002/ .007	.073/ 1.170
			98.80	X			Petroleum	Thermal, BOD, Oils	BL	35/ 74	66/ 96	BL	196.9/ 161.5	9.9/ 9.9	.825/ 3.3	4.12/ 13.2	0/ .033	.05/ .05	BL	.009/ .009	.247/ .742
U. S. Steel Buffington Station	L.M. 41-38-20 87-24-44	18	6.6	X			Cement	Solids, Thermal COD	BL	NA	68/ 86	BL	0/ 13.15	0/ .633	BL	.2/ 1.56	BL	0/ .017	.025/ .215	0/ .004	0/ .098
Northern Indiana Public Service Co. Gary, Indiana	L.M. 41-28-26 87-24-16	18	413	X			Power	Thermal, Solids	BL	38/ 57	68/ 75	BL	63.72/ 647.55	51.7/ 68.9	5.17/ 5.17	BL	.515/ .515	BL	BL	BL	BL
Union Carbide Corp. Linde Division Gary, Indiana	L.M. 41-38-21 87-23-58	18	100	X			Chemical	Thermal	BL	40/ 50	65/ 82	BL	160.1/ 161.8	1.67/ 1.67	1.67/ 1.67	1.67/ 1.67	.292/ .292	.05/ .05	BL	.025/ 0	BL
U. S. Steel Gary	L.M. 41-37-29 87-19-32	18	78.3		X		Steel	Solids, Nitrogen, Oils, T.M.	5/4	NA	67/ 72	BL	106.3/ 131.2	2.35/ 12.85	.55/ .45	8.535/ 14.8	.005/ .594	.047/ .19	.37/ .088	.009/ .007	1.16/ 1.96
			76.8	X			Steel	COD	3/3	NA	72/ 75	BL	100/ 98	1.92/ 1.92	5.12/ .448	2.56/ 12.17	BL	.192/ .192	BL	.006/ .013	1.28/ 1.28
			28.2	X	X		Steel	Solids, BOD	5/3	NA	67/ 84	BL	38.3/ 37.15	.846/ 2.35	.2/ .66	3.075/ 2.59	.002/ 0	.017/ 0	.133/ 0	.003/ .005	.417/ .47
Northern Indiana Public Service Co. Chesterton, Ind.	L.M. 41-38-46 87-07-21	21	456	X			Power	Thermal	BL	45/ 57	68/ 83	BL	585.7/ 585.7	76.1/ 76.1	9.125/ 9.125	BL	.57/ .57	BL	BL	BL	BL
Northern Indiana Public Service Co. Michigan City, Ind.	L.M. 41-43-20 86-54-40	21	278	X			Power	Thermal	BL	37/ 50	70/ 79	BL	526.3/ 526.3	27.8/ 27.8	9.275/ 9.275	BL	BL	BL	BL	BL	BL
Subtotal: Direct Discharge to Lake Michigan			5824.18										8375/ 8515	805/ 684	127/ 133	300/ 384	8.8/ 9.661	3.634/ 5.709	942/ 949	6.545/ 6.712	5.947/ 7.741

Pollutant Loadings (1000 lbs/day)

COD I/D	NO3-N I/D	NH3-N I/D	Organic N I/D	P I/D	Oils & Greases I/D	Phenols I/D	Toxic Substances: As I/D	Toxic Substances: B I/D	Toxic Substances: Cyanide I/D	Trace Metals: Al I/D	Trace Metals: Cd I/D	Trace Metals: Cr I/D	Trace Metals: Cu I/D	Trace Metals: Fe I/D	Trace Metals: Pb I/D	Trace Metals: Mn I/D	Trace Metals: Hg I/D	Trace Metals: Ni I/D	Trace Metals: Zn I/D	Comments
165.35/ 165.35	2.2/ 2.2	1.285/ 1.285	NA	4.08/ 4.08	NA	BL	NA	.900/ 9.2	NA	NA	NA	.350/ .350	NA	13/ 13	NA	1.3/ 1.3	NA	.950/ .950	2.2/ 2.2	Radioactivity (pc/l) Counting Error (RMS) Alpha .55/1.11 ±.288/.42 Beta 3.3/9 ±.35/.5 Gamma<72/<274 ± 50/160 Tr 340/2374 ± 50/50
35.6/ 35.6	3.06/ 3.06	.78/ .78	940/ 947.2	.925/ .925	BL	BL	.64/ .5	8.9/ 8.9	BL	1.21/ 1.71	.018/ .018	.032/ .039	.355/ .555	1.6/ 2.315	.214/ .178	.025/ .032	.002/ .001	.207/ .385	.093/ .157	Alpha 1.3/.4 2.6/2.3 Beta 6.9/23.6 8.1/9.7 Gamma 55.1/1.3 142/142
.35/ .35	.03/ .032	.007/ .023	BL	.009/ .02	BL	BL	.006/ .004	.088/ .151	BL	.012/ .083	BL	BL	.003/ .015	.016/ .057	.002/ .002	0/ .009	BL	.002/ .002	.001/ .003	Summer discharge only, radioactivity present
.76/ 1.66	0/.04	.024/ .013	BL	0/ .008	.1/ .097	0/ .083	BL	BL	BL	BL	BL	BL	BL	.008/ .086	BL	BL	BL	BL	.006/ .002	pH varies with flow process. Intake loadings based on average of two intakes.
.67/ 6.67	.093/ .133	.053/ .467	BL	.005/ .133	.265/ .040	0/ .013	.001/ .053	BL	BL	BL	BL	BL	BL	.032/ .053	BL	BL	BL	BL	BL	
NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
NA	NA	NA	NA	NA	BL	NA	BL	NA	NA	NA	NA	NA	NA	NA	BL	NA	NA	NA	NA	Propose elimination of discharge by Dec., 1972.
11.4/ 31.7	.182/ .65	.285/ .785	.478/ 0	.034/ .043	.945/ .95	.034/ .01	BL	BL	BL	BL	BL	BL	BL	4.66/ 1.776	BL	BL	BL	BL	.002/ .103	Intake loadings based on average of two intakes.
11.09/ 14.8	.177/ 0	.277/ 0	.466/ 0	.033/ .028	.92/ 0	.033/ .018	BL	BL	BL	BL	BL	BL	BL	4.535/ 3.7	BL	BL	BL	BL	.002/ .37	*200 MGD is not recorded, intake loadings based on average of two intakes.
47.9/ 47.9	1.5/ 1.5	.41/ .41	.547/ .41	1.37/ 1.37	NA	BL	.27/ .27	3.76/ 3.76	NA*	.89/ .99	.017/ .017	.02/ .027	.533/ .403	.99/ 2.051	.157/ .130	.034/ .133	1.4/ 1.06	.178/ .201	.215/ .314	
.040/ .53	.015/ .020	.002/ .127	BL	.006/ .042	.262/ .259	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	
4.76/ 5.335	.16/ 0	.14/ 0	.16/ .16	.029/ .018	.278 .675	0/ .002	BL	.04/ .04	BL	.218/ .198	BL	BL	.05/ .05	.079/ .079	BL	0/ .039	BL	BL	BL	
1.215/ 0.035	0/ .022	.015/ 1.32	.007/ .657	.002/ .007	.073/ 1.170	.004/ .606	.002/ 0	BL	BL	.01/ .122	.002/ 0	.002/ 0	.005/ .005	.115/ .087	.002/ 0	BL	BL	0/ .1	.007/ 0	
4.12/ 3.2	0/ .033	.05/ .05	BL	.009/ .009	.247/ .742	.014/ .026	.008/ 0	BL	BL	.033/ .082	.008/ 0	.008/ 0	.016/ .016	.387/ .19	.008/ 0	BL	BL	.33/ 0	.025/ .025	
.2/ 1.56	BL	0/ .017	.025/ .215	0/ .004	0/ .098	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	
BL	.515/ .515	BL	BL	BL	BL	BL	BL	BL	BL	.690/ 1.033	BL	BL	BL	BL	BL	BL	BL	BL	BL	
1.67/ 1.67	.292/ .292	.05/ .05	BL	.025/ 0	BL	BL	.023/ .023	BL	.005/ .009	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	
0.535/ 14.8	.005/ .594	.047/ .19	.37/ .088	.009/ .007	1.16/ 1.96	BL	BL	BL	BL	BL	BL	BL	BL	.15/ 1.134	BL	BL	BL	BL	.018/ .039	Total plant discharge, cooling: 553 MGD process: 238 MGD, sanitary: 9 MGD Intake loadings based on average of five intakes.
2.56/ 12.17	BL	.192/ .192	BL	.006/ .013	1.28/ 1.28	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	.019/ .013	Intake loadings based on actual intake assignment.
3.075/ 2.59	.002/ 0	.017/ 0	.133/ 0	.003/ .005	.417/ .47	BL	BL	BL	BL	BL	BL	BL	BL	.054/ .023	BL	BL	BL	BL	.006/ .005	Intake loadings based on actual intake assignment.
BL	.57/ .57	BL	BL	BL	BL	BL	BL	BL	BL	.76/ 1.14	BL	BL	BL	BL	BL	BL	BL	BL	BL	
BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	
300/ 304	8.8/ 9.661	3.634/ 5.709	942/ 949	6.545/ 6.712	5.947/ 7.741	.085/ .758	.95/ .85	1.4/ 22	.005/ .009	3.823/ 5.358	.058/ .035	132/ 130	.962/ 1.044	26/ 25	.383/ .31	1.359/ 1.513	1.402/ 1.061	1.767/ 1.538	2.594/ 3.231	

Table BA-III-A-2 INDUSTRIAL SURFACE WASTEWA

Company Name	Location (Recovery, stream, mile designating point)	Watershed No.	Wastewater Flow (MGD)	Industrial Process: Cooling	Industrial Process: Process	Industrial Process: Sanitary	Type of Industry	Character of Wastewater	Color (units) I/D	Heat (°F) Winter I/D	Heat (°F) Summer I/D	Fecal Coliform Bacteria MPN/ 100 ml. I/D	Pollut… Total Dissolve Solids I/D	Suspended Solids I/D	BOD I/D	COD I/D	NO_3-N I/D	NH_3-N I/D	Organic N I/D	P I/D
Calumet River Sub-Drainage Basin																				
Allied Chemical Corporation	Cal.5	4	14.4	X			Inorganic Chemical	Solids	20/ 27	55/ 67	74/ 84	BL	33.63/ 42.885	2.4/ 2.84	.6/ .75	1.8/ 2.955	.12/ .113	.120 .105	BL	.007/ .009
Republic Steel Corporation	Cal.4	4	64.8		X		Steel	Oils	5/6	47/ 53	76/ 86	BL	BL	BL	BL	BL	.187/ .241	BL	BL	.054/ .054
			14.4	X			Steel	Thermal	5/6	48/ 73	79/ 106	BL	BL	BL	BL	BL	.041/ .041	BL	BL	.012/ .012
			30.24	X	X		Steel	Thermal, Oils	5/6	48/ 74	79/ 102	BL	BL	BL	BL	BL	.026/ .066	BL	BL	.025/ .025
International Harvester Co. Wisc. Steel Div.	Cal. 2.75	4	42	X			Steel	Thermal, Solids, COD, Oils	15/ 15	43/ 60	82/ 95	BL	92.8/ 108.6	6.3/ 3.1	3.15/ 2.45	3.85/ 6.3	BL	.26/ .322	BL	.07/ .07
			8		X		Steel	Thermal, Solids, COD, Oils	15/ 15	43/ 60	82/ 94	BL	17.7/ 20	1.2/ 1.935	.6/ .467	.735/ 1.2	BL	.049/ .046	BL	.013/ .013
Commonwealth Edison Calumet Station	Cal. 1.75 to L.M. 41 44-00 Lat. 87-31-42 Long	4	93.6	X			Power	Thermal	BL	51/ 61	77/ 90	BL	149.9/ 150	10.15/ 10.15	1.8/ 1.8	2.9/ 2.9	.335/ .335	.6/ .6	.047/ .047	.275/ .275
Subtotal: Calumet River Sub-Drainage Basin			267.44										294/ 321	20/ 24	6.150/ 5.467	9.285/ 13	.709/ .796	1.029/ 1.073	.047/ .047	.393/ .458
Indiana Harbor Ship Canal Sub-Drainage Basin																				
Grand Calumet Sub-Drainage Basin																				
U.S. Steel Gary	Gr.Cal. 22	18	419.47	X	X	X	Steel	Solids, BOD, Oils, Nitrogen, Iron	5/20	NA	67/ 76	BL	569.6/ 1.180	12.6/ 50.8	2.935/ 22.7	45.7/ 81	.03/ .925	.25 .635	1.97/ 5.715	.05/ .66
Cities Service Oil Company East Chicago	Gr.Cal 16.25 to I.H.S.C.	18	66	X	X		Petroleum	Thermal, TDS, BOD, Oils	10/ 15	35/ 60	68/ 90	BL	84.2/ 89.5	7.64/ 7.64	.55/ 6	4.95/ 21.8	.237/ .191	.055/ .382	.22/ .327	.132/ .109
Subtotal: Grand Calumet Sub-Drainage Basin			485.47									BL	654/ 1270	20/ 58	3.485/ 29	51/ 103	.267/ 1.116	.305/ 1.017	2.19/ 6.042	.182/ .769
Atlantic Richfield Company East Chicago	I.H.S.C. 2.5	18	4.75	X			Petroleum	Color, Thermal, Solids, COD, Nitrogen, Oils	5/30	45/ 98	75/ 105	BL	10.7/ 37.65	.2/ .595	.4/ .4	.8/ 4.95	.04/ .06	.04/ .4	.317/ .79	0/ .06
Inland Steel Co. East Chicago, Indiana	I.H.S.C. 1.5	18	330	X			Steel	Thermal, T.M., Solids, COD, Toxic Substance	10/ 14	34/ 47	68/ 81	BL	459.6/ 479.4	22/ 46.3	8.25/ 5.325	16.5/ 23	.413/ .607	.358/ .456	BL	.025/ .065
			564.75		X		Steel	Color, Thermal, Solids, BOD, Oils, Phenols Toxic Substance T.M.	8/ 31	34/ 46	68/ 80	BL	786.6/ 803.9	37.7 83.7	4.13/ 25.17	24.7 63.2	.705/ 1.02	.61/ 3.52	BL	.014/ .06
			115.85	X		X	Steel	Thermal, Solids, Nitrogen, Oils, Phenols, Toxic Substance	8/ 15	34/ 54	68/ 38	BL	161.35/ 219.05	7.73/ 14.7	2.9/ 1.935	5.8/ 5.58	.145/ .403	.126/ 2.457	BL	.004/ .024
Youngstown Sheet & Tube Company East Chicago, Ind.	I.H.S.C. 1 to L.M. 41-40-02 Lat 87-26-31 Long	18	55.44	X			Steel	Solids	BL	50/ 75	70/ 84	BL	95.5/ 109.1	7.67/ 12	1.8/ 1.843	7.1/ 6.55	.82/ .14	1.635/ 1.09	BL	.017/ .028
			79.19	X	X		Steel	Solids, BOD, Oils, Color	15/ 80	50/ 68	70/ 79	BL	115.6/ 172.8	9.245/ 59	2.18/ 2.47	8.585/ 20.89	.99/ .164	1.981/ 1.333	BL	.020/ .023
			121.57		X		Steel	Solids, Oils Toxic Substance T.M.	15/ 22	50/ 56	70/ 79	BL	177.5/ 287	14.2/ 22.3	3.345/ 1.62	13.2/ 8.11	1.52/ .193	BL	3.04/ 3.04	.029/ .028

STRIAL SURFACE WASTEWATER DISCHARGES (Cont.)

Pollutant Loadings (1000 lbs/day)

COD I/D	NO3-N I/D	NH3-N I/D	Organic N I/D	P I/D	Oils & Greases I/D	Phenols I/D	Toxic Substances: As I/D	Toxic Substances: B I/D	Toxic Substances: Cyanide I/D	Trace Metals: Al I/D	Trace Metals: Cd I/D	Trace Metals: Cr I/D	Trace Metals: Cu I/D	Trace Metals: Fe I/D	Trace Metals: Pb I/D	Trace Metals: Mn I/D	Trace Metals: Hg I/D	Trace Metals: Ni I/D	Trace Metals: Zn I/D	Comments
8/ .955	.12/ .113	.120 .105	BL	.007/ .009	BL	.005/ .004	.01/ .008	BL	.003/ .003	.012/ .017	.001/ .001	.001 .001	BL	.092/ .043	.007/ .002	BL	BL	BL	.002/ .013	
L	.187/ .241	BL	BL	.054/ .054	1.26/ 1.8	.017/ .011	.011/ .011	BL	.006/ .006	BL	.004/ .003	.002/ .006	.009/ .008	.775/ 1.3	BL	BL	BL	.005/ .004	.039/ .029	
L	.041/ .041	BL	BL	.012/ .012	.24/ .24	.005/ .002	.002/ .002	BL	.001/ .001	BL	.001/ .001	0/ .004	.002/ .003	.132/ .18	BL	BL	BL	.001/ .001	.009/ .02	
L	.026/ .066	BL	BL	.025/ .025	.5/ .75	.01/ .035	.005/ .005	BL	.003/ .018	BL	.002/ .002	.001/ .003	.004/ .005	.275/ .43	BL	BL	BL	.003/ .002	.019/ .017	
85/ 3	BL	.26/ .322	BL	.07/ .07	.35/ 1.05	.002/ .007	.001/ .001	BL	.004/ .014	BL	BL	.004/ .014	.004/ .018	.175/ .7	.013/ .03	BL	.001/ .001	BL	.007/ .105	
735/ 2	BL	.049/ .046	BL	.013/ .013	.056/ .266	0/ .001	BL	BL	.001/ .002	BL	BL	.001/ .003	.001/ .001	.033/ .133	.003/ .005	BL	BL	BL	.013/ .02	
9/ 9	.335/ .335	.6/ .6	.047/ .047	.275/ .275	BL	BL	BL	BL	BL	BL	BL	.003/ .025	BL	.335/ .328	BL	.022/ .023	BL	.02/ .018	.03/ .027	
285/ 3	.709/ .796	1.029/ 1.073	.047/ .047	.393/ .458	2.416/ 4.106	.039/ .06	.029/ .027	BL	.018/ .044	.012/ .017	.008/ .007	.012/ .056	.02/ .035	1.817/ 3.114	.023/ .037	.022/ .023	.001/ .001	.029/ .025	.182/ .231	
.7/ 1	.03/ .925	.25 .635	1.97/ 5.715	.05/ .66	6.2/ 14.775	0/ .017	BL	BL	0/ .004	BL	BL	BL	BL	.800/ 11.25	BL	BL	BL	BL	.1/ .71	Intake loadings based on average of five intakes.
95/	.237/ .191	.055/ .382	.22/ .327	.132/ .109	1.65/ 2.565	.001/ .019	.003/ .002	BL	BL	.055/ .041	.005/ .005	.005/ .005	.017/ .142	.132/ .207	.005/ .044	BL	BL	.005/ .005	.083/ .049	Cooling 62.04 MGD Process 3.96 MGD
/	.267/ 1.116	.305/ 1.017	2.19/ 6.042	.182/ .769	7.85/ 17	.001/ .036	.003/ .002	BL	0/ .004	.055/ .041	.005/ .005	.005/ .005	.017 .142	.932/ 11	.005/ .044	BL	BL	.005/ .005	.183/ .759	
/	.04/ .06	.04/ .4	.317/ .79	0/ .06	.04/ .2	0/ .003	.004/ .004	BL	.002/ .004	.003/ .011	BL	.004/ .006	.002/ .01	.016/ .022	.002/ .009	BL	BL	.001/ .003	.002/ .006	
5/	.413/ .607	.358/ .456	BL	.025/ .065	4/ 5.685	0/ .017	.005/ .006	BL	0/ .22	BL	BL	.01/ .017	.02/ .034	.514/ 2.682	.022/ .112	BL	BL	.02/ [illegible]	.02/ .356	
7 2	.705/ 1.02	.61/ 3.52	BL	.014/ .08	4.71/ 18.8	0/ .354	.007/ .028	BL	0/ 1.15	BL	BL	.01/ .018	.02/ .064	.612/ 8.522	.022/ .055	BL	BL	.02/ .05	.02/ .196	
/ [illegible]	.145/ .403	.126/ 2.457	BL	.004/ .024	.966/ 3	0/ .071	.002/ .006	BL	0/ .092	BL	BL	.001/ .003	.005/ .008	.191/ .292	.005/ .011	BL	BL	.005/ .01	.005/ .45	
[illegible]	.82/ .14	1.635/ 1.09	BL	.017/ .028	.032/ 0	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	BL	
[illegible]	[illegible]	1.381/ [illegible]	BL	.020/ .023	2.64/ 4.665	BL	BL	BL	.001/ .001	BL	BL	BL	BL	.346/ .711	BL	BL	BL	BL	BL	
[illegible]	[illegible]	BL	3.04/ 3.04	.029/ .028	4.055 10.14	.006/ .011	BL	BL	.010/ .172	BL	BL	.004/ 13.18	BL	2.685/ 8.67	BL	BL	BL	BL	.001/ .013	

Table BA-III-A-2 INDUSTRIAL SURFACE WASTEWATER D

Company Name	Location (Recovery, stream, mile designating point)	Watershed No.	Wastewater Flow (MGD)	Industry Process: Cooling	Industry Process: Process	Industry Process: Sanitary	Type of Industry	Character of Wastewater	Color (units) I/D	Heat (°F) Winter I/D	Heat (°F) Summer I/D	Fecal Coliform Bacteria MPN/100 ml. I/D	Pollutant L… Total Dissolved Solids I/D	Suspended Solids I/D	BOD I/D	COD I/D	NO_3-N I/D	NH_3-N I/D	Organic N I/D	P I/D	Oils & Grease I/D
Subtotal: Indiana Harbor Ship Canal Sub-Drainage Basin			1767.02										2461/ 2235	119/ 297	26/ 67	127/ 235	4.900/ 3.703	5.055/ 10.273	5.547/ 9.872	.291/ 1.077	24/ 60
Little Calumet Sub-Drainage Basin																					
Bethelem Steel Burns Harbor	L.Cal.36.5 to B.Di. 1.5	20	116	X	X		Steel	Solids, BOD, Oils, Phenols	0/8	32/ 41	69/ 74	BL	17.9/ 24.7	15.5/ 30	.965/ 1.935	7.74/ 10.64	1.935/ 3.87	.097/ .290	BL	.145/ .358	2.42/ 4.16
			147	X			Steel	TDS, COD	BL	32/ 40	69/ 74	NA	226.8/ 243	19.7/ 19.7	1.23/ 1.23	9.8/ 16	2.45/ 3.685	.123/ .123	NA	.184/ .258	3.065/ 3.3
National Steel Corp. Portage, Ind.	B.Di. 0.5 to L.M. 47-37-55 Lat. 87-10-37 Long		4.98	X			Steel		5/5	35/ 48	65/ 74	213/ 213	9.75/ 9.75	.43/ .43	.043/ .043	.042/ .042	.057/ .057	1.05/ 1.05	.75/ .75	.005/ .005	.104/ .104
			9.06	X	X		Steel	Thermal, TDS, BOD	5/10	35/ 70	65/ 86	70/ 28	6/ 59.1	.785/ .81	.077/ .235	.075/ 1.548	.103/ .113	1.91/ 1.4	1.36/ .3	.008/ .008	.189/ .151
Subtotal: Little Calumet Sub-Drainage Basin			277.04										260.45/ 336.55	36.415/ 50.94	2.315/ 3.443	17.657/ 28.23	4.545/ 7.725	3.18/ 2.863	2.11/ 1.05	.342/ .629	5.778/ 7.715
Total: Lake Michigan Drainage Basin			8135.66										11390/ 11408	981/ 1056	162/ 210	454/ 661	19/ 22	13/ 20	950/ 960	7.634/ 8.876	38/ 79
Drainage into Wolf Lake Lever Bros. Co. Hammond, Indiana	Wolf Lake 41-41-33 Lat 87-30-47 Long	18	5.15	X	X		Soap & Detergent	BOD, Oils	4/8	35/ 55	70/ 79	BL	7.56/ 7.6	1.29/ .775	.043/ .6	.385 1.59	.007/ .005	BL	.013/ .009	.001/ .002	.21/ .33

LEGEND

Stream Abbreviations

B.Di.	Burns Ditch
Cal.	Calumet River
Cal-S.	Calumet Sag Channel
Chi.	Chicago River
Cry.	Crystal Creek
Des.	Des Plaines River
Gr.	Grant Creek
Gr. Cal.	Grand Calumet River
I.H.S.C.	Indiana Harbor Ship Canal
Ja.	Jackson Creek
L.Cal.	Little Calumet River
L.M.	Lake Michigan
N.Br.Chi.	North Branch Chicago River
S.Br.Chi.	South Branch Chicago River
SSC	Sanitary and Ship Canal
Wi.	Willow Creek

Al	Aluminum
Ar	Arsenic
B	Boron
BL	No change from Background Level
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
Cd	Cadmium
Cr	Chromium
Cu	Copper
Disc	Discharge Only
Fe	Iron
Hg	Mercury
KW HR	Kilowatt Hour
MGD	Million Gallons per Day
Mn	Manganese
MPN	Most Probable Number
MWH	Megawatt Hour
NA	Not Available
Ni	Nickle
NH_3-N	Nitrogen as Ammonia
NO_3-N	Nitrogen as Nitrates
Organic N.	Organic Nitrogen
P	Phosphorus (total)
Pb	Lead
pc/l	Pico Curie per Liter
RMS	Root Mean Square(at 95% confidence level)
S	Summer
SS	Suspended Solids
TDS	Total Dissolved Solids
T.M.	Trace Metal
W	Winter
Zn	Zinc

Pollutant Loadings (1000 lbs/day)

COD I/D	NO3-N I/D	NH3-N I/D	Organic N I/D	P I/D	Oils & Greases I/D	Phenols I/D	Toxic Substances: As I/D	Toxic Substances: B I/D	Toxic Substances: Cyanide I/D	Trace Metals: Al I/D	Trace Metals: Cd I/D	Trace Metals: Cr I/D	Trace Metals: Cu I/D	Trace Metals: Fe I/D	Trace Metals: Pb I/D	Trace Metals: Mn I/D	Trace Metals: Hg I/D	Trace Metals: Ni I/D	Trace Metals: Zn I/D	Comments
127/ 235	4.900/ 3.703	5.055/ 10.273	5.547/ 9.872	.291/ 1.077	24/ 60	.007/ .492	.021/ .046	BL	.013/ 1.643	.058/ .052	.005/ .005	.034/ 13	.064/ .258	5.296/ 32	.056/ .231	BL	BL	.051/ .099	.231/ 1.780	
7.74/ 10.64	1.935/ 3.87	.097/ .290	BL	.145/ .358	2.42/ 4.16	.001/ .014	.484/ .484	BL	0/ .019	BL	.009/ .012	0/ .019	.034/ .034	.794/ .847	.031/ .031	BL	BL	.018/ .018	.043/ .046	
9.8/ 16	2.45/ 3.685	.123/ .123	NA	.184/ .258	3.065/ 3.3	.001/ .001	NA	BL	NA	NA	NA	BL	.043/ .041	.980/ .793	.034/ .024	NA	BL	.023/ .027	.055/ .063	
.042/ .042	.057/ .057	1.05/ 1.05	.75/ .75	.005/ .005	.104/ .104	BL	.001/ .001	BL	.001/ .001	.002/ .002	.001/ .001	.002/ .002	.001/ .001	.005/ .005	.001/ .001	BL	BL	.002/ .002	.002/ .002	
.075/ 1.548	.103/ .113	1.91/ 1.4	1.36/ .3	.008/ .008	.189/ .151	0/ .001	.001/ .001	BL	.001/ .004	.004/ .004	.002/ .009	.004/ .002	.004/ .004	.008/ .038	.001/ .001	BL	BL	.004/ .004	.004/ .004	
17.657/ 28.23	4.545/ 7.725	3.18/ 2.863	2.11/ 1.05	.342/ .629	5.778/ 7.715	.002/ .016	.486/ .486	BL	.002/ .024	.006/ .006	.02/ .022	.006/ .023	.082/ .080	1.787/ 1.683	.072/ .057	BL	BL	.047/ .051	.104/ .115	
454/ 661	19/ 22	13/ 20	950/ 960	7.634/ 8.876	38/ 79	.133/ 1.326	1.486/ 1.409	14/ 22	.038/ 1.720	3.899/ 5.433	.053/ .069	132/ 143	1.128/ 1.417	35/ 62	.534/ .635	1.381/ 1.536	1.403/ 1.062	1.894/ 1.713	3.111/ 5.357	
.385 1.59	.007/ .005	BL	.013/ .009	.001/ .002	.21/ .33	0/ .002	BL	BL	BL	BL	BL	BL	BL	0/ .043	BL	BL	BL	BL	BL	

Table BA-III-A-3

CURRENT WASTE SOLIDS MANAGEMENT

Class of Industry	Process Generating Waste Solid	Character of Waste	Type of Treatment	Present Solids Management
Steel	Blast Furnace	Flue, Dust containing iron oxide, alumina, silica, carbon, lime & magnesia	Physical settling	95% reused in process 5% treated w/lime and lagooned
	Coke	Gas-Tar & ammonia, phenols & BOD, cyanide	Physical settling, recirculation, biological	Recover ammonium sulfate, crudetar, gas, naphthalene, coke dust, benzene, tolvene, xylene
	Pickling	$FeSO_4$ (unused acid iron salts)	Physical-evaporation-stripping	Treatment produces recycled sulfuric acid and the following potential by-product(s): Copperas & $FeSO_4 \cdot H_2O$ Copperas & H_2SO_4 $FeSO_4 \cdot H_2O$ & H_2SO_4 $Fe_2(SO_4)$ & H_2SO_4 Fe^{+++} 7 H_2SO_4 Iron Powder Fe_3O_4 (polishing & pigments) Fe_3O_4 & Al_2 $(SO_4)_3$
	Rolling Mills	Oils	Physical	Burned or reused SS
	Mill Scale		Physical	Reused in process
Petroleum	Pumping, desalting, distilling, fractionation alkylation, and polymerization	SS,DS, oil, wax, sulfides, chlorides, mercaptans phenolic compounds, cresylates & dissolved iron	Scrubbing, evaporation, flotation, mixing, aeration, biological, oxidation, coagulation, centrifugation and incineration	Reprocessed, burned or scavenger service (80-90% of total water used in plants are for cooling only)
Pharmaceutical	Fermentation-antibiotic waste	Organic substances, penicillin	Anaeobic digestion, controlled aeration, evaporation & incineration	Dried and use in food stock
Food Processing	Cannery	Organic	To municipal system, lagoon, spray irrigation, anaerobic digestion	Land Disposal
Explosives	TNT	Volatile solids, strongly acid, color	Filter through black soil	Land Disposal
	Smokeless-powder	Acid, guncotton ether alcohol, aniline	Aeration & biological	Land Disposal
	Small arms ammunition	Oily, copper & zinc grease	Grease flotation, chemical precipitation	Land Disposal
Power	Solid radioactive waste	Radioactive	Burial, incineration, or remelting	Land Disposal
Soap	Soap	Floatable fatty acid	Flotation	Reprocessed

III. FLOW BASIS OF DESIGN

B. FUTURE DOMESTIC-COMMERCIAL AND INDUSTRIAL FLOWS

C-SELM POPULATIONS AND PROJECTIONS (1950-2020)

Presented in Table BA-III-B-1 of this section are population data for the C-SELM area for the period 1950-2020. This data is taken from U. S. Census Bureau statistics and previous material developed by the Corps of Engineers and revised following suggestions by NIPC. Figure BA-III-B-1 indicates the three sub-areas within the City of Chicago.

Table BA-III-B-1

COOK COUNTY, ILLINOIS
(Population 1000's)

Townships	1950	1960	1970	1980	1990	2000	2010	2020
Berwyn-Cicero-Oak Park	182	184	182	185	185	185	185	185
Bloom	41	71	95	117	140	154	161	165
Bremen	25	55	94	134	190	226	237	240
Calumet	12	19	24	26	28	31	33	35
Chicago (City) North	1019	1024	1014	1014	1014	1022	1030	1038
Chicago (City) Central	2251	2131	1921	1835	1835	1843	1851	1859
Chicago (City) South	352	397	431	451	451	460	469	478
Elk Grove	6	28	80	105	112	117	122	127
Evanston	74	79	80	82	84	86	88	90
Lemont	5	7	8	15	28	40	43	46
Leyden-Norwood Park	64	112	131	124 31 155	146 31 177	161 31 192	168 31 199	173 31 204
Lyons	52	82	101	125	135	143	147	149
Maine	39	95	140	178	186	194	199	201
New Trier	42	60	65	66	66	66	66	66
Niles	25	96	111	130	135	135	135	135
Northfield	17	44	66	96	117	120	120	120
Orland	2	7	15	36	72	88	96	99

Table BA-III-B-1 (Cont.)

COOK COUNTY, ILLINOIS (Cont.)
(Population 1000's)

Townships	1950	1960	1970	1980	1990	2000	2010	2020
Palatine	8	31	55	81	109	133	133	133
Palos	6	18	33	49	57	62	64	66
Proviso-River Forest-Riverside	123	191	205	205	205	205	205	205
Rich	9	35	45	68	97	116	116	116
Schaumberg	1	11	51	76	106	124	124	124
Stickney	11	31	42	54	64	72	75	77
Thornton	77	138	188	215	250	250	250	250
Wheeling	17	59	119	147	159	166	173	176
Worth	42	108	156	172	186	196	202	204
C-SELM Total	4502	5113	5452	5817	6183	6426	6523	6588
Barrington	4	5	8	11	17	25	28	30
Hanover	4	11	34	50	76	112	141	150
County Total	4510	5129	5494	5878	6281	6563	6692	6768

Table BA-III-B-1 (Cont.)

DU PAGE COUNTY, ILLINOIS
(Population 1000's)

Townships	1950	1960	1970	1980	1990	2000	2010	2020
Addison	18	42	72	120	158	183	195	200
Bloomingdale	4	15	37	59	86	113	132	140
Downers Grove	36	67	93	122	137	144	150	154
Lisle	11	21	49	75	100	126	142	150
Milton	26	51	76	103	150	181	195	200
Naperville (part)	5	8	10	20	35	60	80	90
Wayne (part)	2	3	4	12	20	40	61	65
Winfield	10	16	23	34	52	72	100	115
York	43	90	125	161	165	165	165	165
C-SELM Total	155	313	489	706	903	1084	1220	1279
Naperville (part)	0	0	3	8	15	29	47	65
Wayne (part)	0	0	1	2	7	12	23	30
County Total	155	313	493	716	925	1125	1290	1374

Table BA-III-B-1 (Cont.)

LAKE COUNTY, ILLINOIS
(Population 1000's)

Townships	1950	1960	1970	1980	1990	2000	2010	2020
Antioch (part)	1	3	4	5	7	10	11	12
Avon (part)	4	7	8	12	15	22	31	40
Benton-Zion	15	22	31	43	53	65	76	88
Deerfield-West Deerfield	29	50	64	93	125	140	150	150
Ela (part)	2	4	6	9	13	19	25	31
Fremont (part)	1	3	4	6	9	13	17	22
Lake Villa (part)	2	4	6	7	8	11	16	22
Libertyville	10	19	26	40	72	102	119	129
Newport	2	2	3	5	9	11	15	20
Shields	29	41	55	68	80	85	85	85
Vernon	3	7	13	22	39	51	57	60
Warren	4	10	16	25	35	44	52	56
Waukegan	51	70	77	99	115	120	125	125
C-SELM Total	153	242	313	434	580	693	779	840
Antioch (part)	4	6	8	9	10	10	12	13
Avon (part)	5	10	12	16	22	29	39	55
Cuba	4	6	9	14	23	33	42	49
Ela (part)	2	4	6	9	13	18	24	30
Fremont (part)	2	5	8	12	17	24	33	42

Table BA-III-B-1 (Cont.)

LAKE COUNTY, ILLINOIS (Cont.)
(Population 1000's)

Townships	1950	1960	1970	1980	1990	2000	2010	2020
Grant	5	9	11	16	21	30	43	60
Lake Villa (part)	1	4	6	7	8	11	15	21
Wauconda	3	7	10	13	15	18	20	22
County Total	179	293	383	530	709	866	1007	1132

Table BA-III-B-1 (Cont.)

WILL COUNTY, ILLINOIS
(Population 1000's)

Townships	1950	1960	1970	1980	1990	2000	2010	2020
Channahon	1	2	3	4	5	6	7	9
Crete (part)	4	10	13	17	22	28	34	40
DuPage	1	5	20	33	48	62	77	92
Frankfort	3	6	9	18	32	46	55	62
Green Garden (part)	0	0	0	0	1	1	2	3
Homer	1	4	7	15	28	46	67	90
Jackson (part)	1	1	2	2	3	4	6	8
Joliet	77	94	96	107	130	157	176	190
Lockport	17	27	33	40	58	74	89	104
Manhattan (part)	0	0	0	1	2	3	3	4
Monee (part)	1	3	4	35	45	60	73	85
New Lenox	3	6	10	16	26	40	55	70
Plainfield	4	7	11	16	24	38	50	60
Troy	1	3	12	19	31	45	62	80
Wheatfield	1	1	2	5	11	17	25	35
C-SELM Total	115	173	227	328	466	627	781	932
Crete (part)	2	2	2	2	2	2	1	1
Florence	1	1	1	2	3	4	5	6
Green Garden (part)	1	1	1	2	4	5	10	12
Jackson (part)	0	0	0	1	1	2	2	2

Table BA-III-B-1 (Cont.)

WILL COUNTY, ILLINOIS (Cont.)
(Population 1000's)

Townships	1950	1960	1970	1980	1990	2000	2010	2020
Manhattan (part)	1	2	2	2	3	4	6	7
Monee	1	2	3	5	7	8	11	15
Peotone	2	2	3	4	6	10	15	20
Reed	2	2	3	4	5	6	7	8
Washington	2	2	3	4	5	6	9	12
Wesley-Custer	1	2	3	4	5	6	7	8
Will	1	1	1	2	3	4	5	6
Willmington	4	5	5	6	7	9	10	12
Wilton	1	1	1	2	3	4	5	6
County Total	134	192	250	368	520	697	874	1047

Table BA-III-B-1 (Cont.)

LAKE COUNTY, INDIANA
(Population 1000's)

Townships	1950	1960	1970	1980	1990	2000	2010	2020
Calumet	150	211	216	220	226	236	245	256
Center (part)	10	15	19	30	35	45	51	60
Hobart	22	39	41	52	64	72	81	90
North	162	204	203	206	209	214	219	226
Ross	7	15	29	41	57	72	87	100
St. John (part)	5	10	15	26	38	50	62	75
Winfield (part)	1	1	1	2	3	4	7	8
C-SELM Total	357	495	524	577	632	693	752	815
Cedar Creek	4	5	6	11	14	18	21	24
Center (part)	1	2	3	4	8	7	9	11
Eagle Creek	1	1	1	2	4	7	10	12
Hanover	3	6	7	12	17	24	29	35
St. John (part)	1	2	2	2	3	3	3	3
West Creek	2	2	3	5	7	9	11	14
Winfield (part)	0	0	0	1	3	4	5	6
County Total	369	513	546	614	688	765	840	920

Table BA-III-B-1 (Cont.)

LA PORTE COUNTY, INDIANA
(Population 1000's)

Townships	1950	1960	1970	1980	1990	2000	2010	2020
Center (part)	11	13	13	15	17	20	22	25
Cool Spring	3	5	11	17	23	28	34	40
Michigan	32	39	40	41	42	43	44	45
New Durham (part)	1	2	1	2	3	3	4	5
Springfield (part)	1	2	2	3	4	5	6	7
C-SELM Total	48	61	67	78	89	99	110	122
Cass	1	1	1	1	1	2	2	2
Center (part)	11	11	11	11	11	11	11	10
Clinton	1	1	1	1	1	2	2	2
Dewey	1	1	1	1	1	2	2	2
Galena	1	1	1	1	2	3	4	5
Hanna	1	1	1	1	1	2	2	2
Hudson	1	2	2	2	3	4	5	6
Johnson	*	*	*	*	*	1	1	1
Kankakee	2	2	3	3	3	4	5	6
Lincoln	1	1	2	2	2	3	3	4
New Durham (part)	1	3	3	4	5	6	7	8
Noble	1	1	1	1	1	2	2	2
Pleasant	1	2	2	2	2	3	3	4
Prairie	*	*	*	*	*	1	1	1

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Table BA-III-B-1 (Cont.)

LA PORTE COUNTY, INDIANA (Cont.)
(Population 1000's)

Townships	1950	1960	1970	1980	1990	2000	2010	2020
Scripo	1	2	2	2	2	3	3	4
Springfield (part)	1	1	2	3	4	5	6	7
Union	2	2	2	2	2	3	3	4
Washington	1	1	1	1	1	2	2	2
Wills	1	1	1	1	1	2	2	2
County	77	95	104	117	132	160	176	196

Table BA-III-B-1 (Cont.)

PORTER COUNTY, INDIANA
(Population 1000's)

Townships	1950	1960	1970	1980	1990	2000	2010	2020
Center	15	19	25	30	37	46	58	77
Jackson (part)	1	1	1	2	4	7	10	15
Liberty (part)	2	2	2	7	12	20	30	40
Pine	2	3	3	8	12	17	25	34
Portage	6	14	28	44	64	90	121	164
Union (part)	1	2	2	3	6	11	17	24
Westchester	7	11	14	22	32	44	59	80
C-SELM Total	34	52	75	116	167	235	320	434
Boone	2	2	3	4	5	7	11	14
Jackson (part)	0	0	1	1	2	2	3	5
Liberty (part)	0	0	1	1	2	1	1	2
Morgan	1	1	1	3	6	9	13	17
Pleasant	2	2	2	3	5	7	11	14
Porter	1	2	2	5	8	12	17	23
Union (part)	0	0	0	0	0	1	1	2
Washington	1	1	1	3	6	10	15	19
County Total	41	60	86	136	201	284	392	530

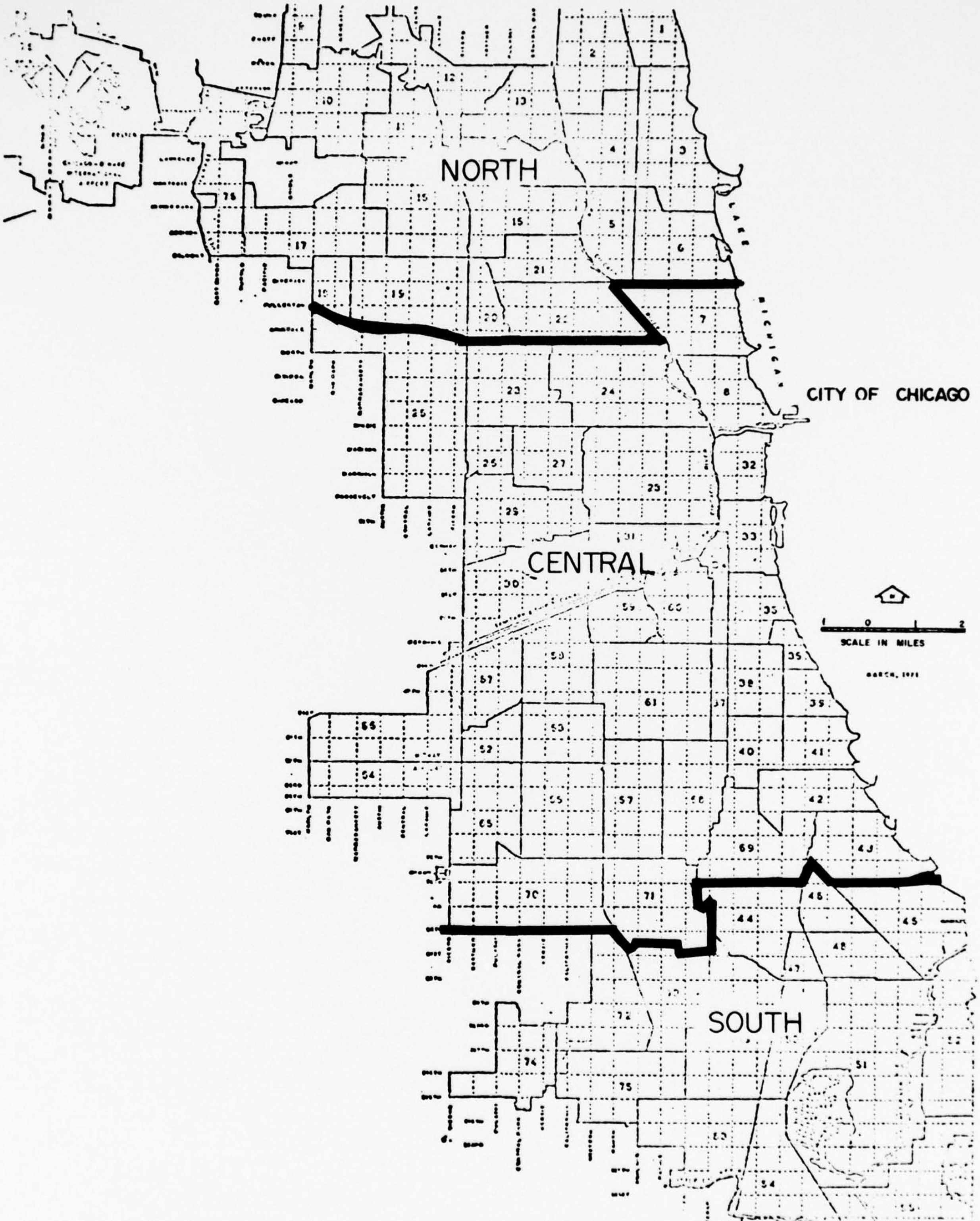


Figure BA-III-B-1

MAJOR SUB-AREAS WITHIN THE CITY OF CHICAGO

DATA ANNEX B

COMPONENT BASIS OF DESIGN

DATA ANNEX B

IV. COMPONENT BASIS OF DESIGN

A. REGIONAL TREATMENT SYSTEMS

1. Soils Information
2. Irrigation Impact on Agriculture
3. Nitrogen and Phosphorus Loading Calculations
4. Irrigation and Drainage System Analysis
5. The Use of Land as a Method of Treating Wastewater

IV. COMPONENT BASIS OF DESIGN

A. REGIONAL TREATMENT SYSTEMS

1. SOILS INFORMATION

Introduction

Among the most important items which must be considered in the selection of a site suitable for wastewater renovation by the "living filter" is the soil. The soil dictates not only the quality considerations of the land treatment system, but also the engineering, design and subsequent operation of the system. The following portion of this annex will discuss soil characteristics which are pertinent to the selection of a land treatment site. The methodology of site selection based upon these key soil characteristics follows the discussion on Soil Selection Considerations. Soil characteristics are also very important in creating an optimum design of irrigation equipment. An analysis of this impact follows the Site Selection. The final portion of this section presents a discussion of the soil process associated with the "living filter" concept.

Soil Selection Considerations

General

What is Soil? A clear distinction should be made at this time in reference to the type and nature of soils information that is required for site selection. A differentiation should be made between what might be called geologic, engineering and soil science terminology. Each of these are important and play a part in the proper selection of suitable irrigation sites. Geologists view the earth's crust as made up of rock and so-called unconsolidated sediments. This unconsolidated material is composed mainly of solid particles derived from physical and chemical weathering of the rock plus varying amounts of moisture, organic material, and air. This same material is what the engineer calls "soil". He is chiefly concerned with its various physical and mechanical properties and how they influence the support of structures, the maintenance of excavations and other considerations. As these sediments, or engineering soils, are exposed to the influences of weather, temperature, biological activity, and other factors, they are further modified. Eventually, the surface layers become capable of sustaining plant growth. These upper layers, usually identified as from five to six feet in depth, are what concern the soil scientist and the agricultural users of the earth's surface.

The following discussion and terminology used in that discussion is kept, to the most part, within the framework of soil science. In only isolated situations are geologic and/or engineering terminologies used. These uses are identified and explained.

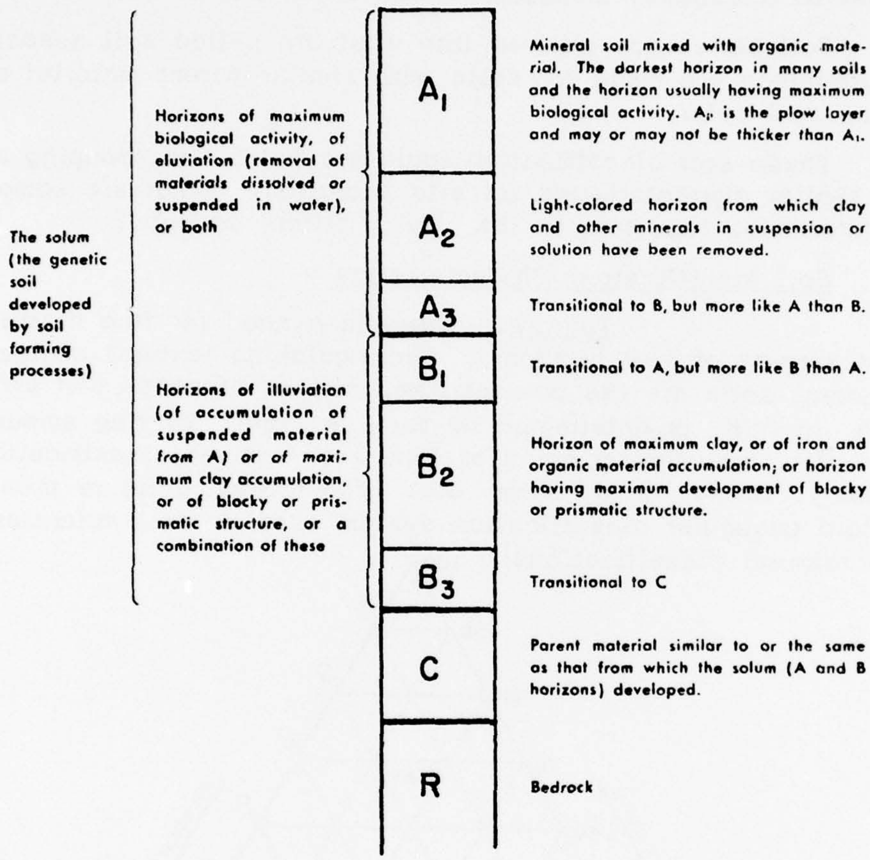
A great deal of information is available on the characteristics of Illinois and Indiana soils. The United States Soil Conservation Service (SCS), in cooperation with agricultural experiment stations at state universities, provide numerous publications dealing with soil characteristics and properties. These include such excellent sources as individual county soil surveys, irrigation and drainage guides, soil interpretation sheets and many, many more.

Before specific soil properties important to site selection are addressed, an introductory discussion is presented which goes into the formation and classification of agricultural soils.

Soil Formation and Classification. The main factors which influence the formation of soils are; parent materials, climate, native vegetation, drainage, time, and, of course, man. The parent material of mineral soils are formed by the disintegration and decomposition of rock. These materials may be moved from place to place by glacial, wind or water action. Organic soils are formed from the remains of plants. The main parent materials for the soils in the area of this study consist of loess, outwash, till, and alluvium.

Climate is an important factor in soil development and is responsible for many soil differences. Climate largely determines the type of weathering which takes place, and influences vegetation types. Temperature and rainfall are the major components of climate. Vegetation refers to the native vegetation under which the soils formed. For the states of Illinois and Indiana, for instance, the native vegetation was prairie grass and forest or trees. Drainage is generally controlled by relief. The amount of moisture in the soil during its development, a direct influence of amount of drainage, affects the rate of weathering and the development of soil colors. Time as a factor in soil formation is highly dependent upon the other forming factors.

The soil formation process creates a characteristic profile which conceptually is the same for most soils. A vertical section through what are called "horizons" and extending into the parent material, is known as a soil profile. An idealized soil profile, with key identifications is shown in the following figure:



Principal horizons of upland soils.

The processes of soil formation take place primarily in the A and B horizon. Maximum biological activity takes place in the A horizon, while the greatest degree of accumulation of leached materials will be in the B horizon. In discussions which follow, reference will be made to surface and subsurface soils. The A horizon is usually called the surface soil. The B and C horizons are considered surface soils, also, within the context of this report, although they are described by other terms in soil science writings.

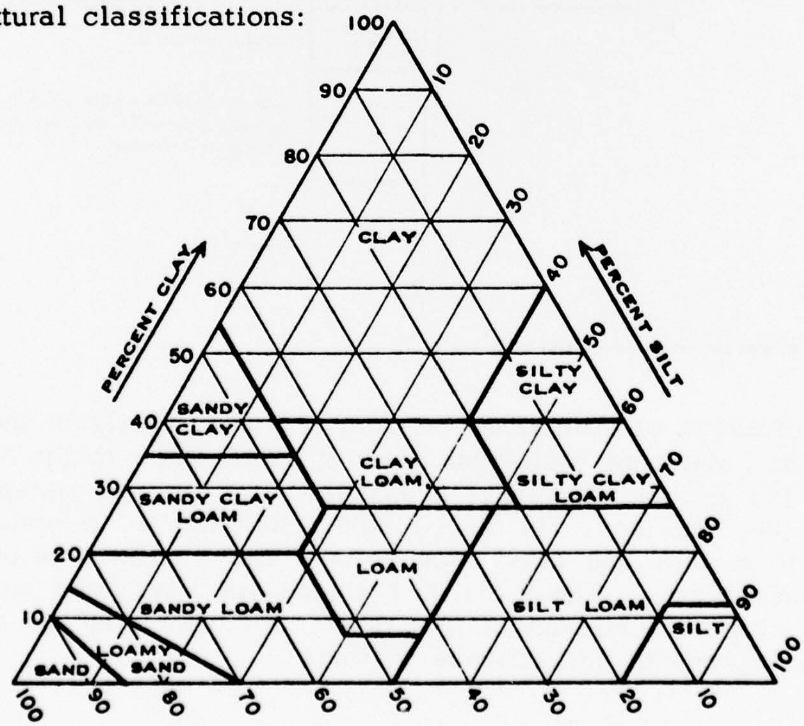
Soils that have very similar profiles are usually placed in the same soil series. Each of these soil series is named for a nearby geographic feature or town. With the exception of the A horizon, all major horizons of all soils within a particular series are similar with respect to thickness, arrangement and other characteristics.

Soil series are grouped into what are called soil associations. The groupings are made for soils with similar parent material and surface soil color.

These soil classification tools are helpful in grouping soils with similar characteristics for site selection, What are some of the characteristics important to the "living filter" concept?

Soil Identification Characteristics

Texture. There is a need for fine distinctions in the texture of soil horizons. Distinguishing textural characteristics of mineral soils are the percent compositions of sand, silt and clay, which, in turn, is determined by particle size. Varying amounts of sand, silt, and clay combine to form soil textural classifications such as sandy, loamy, sandy loam, etc. The following figure presents the standard triangular classification system used by soil scientists to make textural classifications:



Triangular Textural Classification Chart

Structure. Soil particles are usually aggregated or grouped. The size and shape of these groupings is called structure. Structure plays a key role in crop productivity by affecting root penetration, water intake rate, movement of water within the soil and the resistance of the soil to erosion.

Color. Different soil colors result from a number of key factors. Color indicates the amount of organic materials, chemical compounds, and probably most importantly, the drainage of the soil. For instance, light yellow to yellowish-brown soils indicate good drainage, with a fully established aerobic regime in the surface horizon.

There are numerous other identifying characteristics, but for our purposes, it will suffice to just mention those presented above. The next important area in the description of soil selection considerations is the interaction of the soil and the water which moves through the soil.

Soil-Water Considerations

General. The movement of water into and through the soil horizons plays what is probably the most important part in dictating the selection of a particular soil for a spray irrigation application. It should be pointed out here, however, that upper horizons of a soil are not the only part of the soil complex that effects water movement. Parent materials below the developed soil profiles are also important. If an impermeable layer is found three feet below the surface, there would be little chance that one could apply large doses of irrigation water to the surface of the soil and expect a viable, aerobic condition suitable for crop growth to exist very long. The underlying parent material must be capable of removing, or draining away the water which is supplied at the surface and doing so on a sustained basis. If a situation exists where natural conditions do not allow proper drainage, modifications to the soil system can be made to induce this drainage. Such modifications are made on a regular basis in farming situations and present no new technological implications.

The following parts of this discussion will address some of the important parameters involved in the movement of water into and through soils in the soil profile discussed above. In addition, general comments will be addressed to the same considerations for the underlying, parent material.

Infiltration, Percolation and Permeability. Infiltration is described as the passage of water through the soil surface interface into the underlying substratum or horizons of the soil. A distinction is made between infiltration, percolation and permeability. Percolation is the downward movement of water through an unsaturated soil. The soil contains numerous noncapillary channels through which this gravity water will flow. The gravity water will follow the path of least resistance. Permeability permits the movement of water through a saturated soil medium. In addition, permeability can be thought of in connection with either a vertical or horizontal movement of water. The three phenomena are closely related since infiltration cannot continue unimpeded unless percolation and/or permeability move the infiltrated water away from the surface.

The rate at which the water moves through the soil is expressed as either the percolation rate (length/time), or permeability (length/time) according to whether you are considering an unsaturated or saturated soil. Infiltration rate, as used in most literature on the subject, is the rate at which the water moves into the soil surface, when the soil beneath the surface is saturated. Additional information on infiltration, percolation and permeability and its effect on spray irrigation system design will be covered in another portion of this annex.

It is important to have a rate of infiltration, percolation and permeability that will insure the adequate drainage of the soil under irrigation. The rate of percolation is tied to the permeability, with the permeability as a lower bound on its value. In addition, since the rate of infiltration is usually determined with a saturated condition below the surface, one can associate a maximum steady-state infiltration rate with the permeability of the soil. Therefore, any value of permeability will serve as a lower bound, or minimum expected level, for the other two terms.

What are some of the soil characteristics that influence the permeability of a soil? Permeability is influenced by particle size, void space (pores) and soil structure. For an indication of the particle size, and subsequently textural influence, on permeability, reference is made to the table below.

The void or pore space is proportional to the particle size with the smaller the particle size the smaller the void size. Structure is one of the most important soil characteristics influencing permeability, especially in fine grained soils. When the structure is aggregated or grouped, as pointed out earlier, there are larger channels or pores for flow, and subsequently higher permeability. In fine grained soils

	PARTICLE SIZE RANGE				"EFFECTIVE" SIZE		PERMEABILITY COEFFICIENT—k		
	Inches		Millimeters						
	$D_{max.}$	D_{min}	D_{max}	D_{min}	D_{20} in.	D_{10} mm.	Ft./yr.	Ft./mo.	Cm./sec.
Derrick STONE	120	36	—	—	48	—	100×10^6	100×10^5	100
One-man STONE	12	4	—	—	6	—	30×10^6	30×10^5	30
Clean, fine to coarse GRAVEL	3	¼	80	10	½	—	10×10^6	10×10^5	10
Fine, uniform GRAVEL	⅜	1/16	8	1.5	⅛	—	5×10^6	5×10^5	5
Very coarse, clean, uniform SAND	⅛	1/32	3	0.8	1/16	—	3×10^6	3×10^5	3
Uniform, coarse SAND	⅛	1/64	2	0.5	—	0.6	0.4×10^6	0.4×10^5	0.4
Uniform, medium SAND	—	—	0.5	0.25	—	0.3	0.1×10^6	0.1×10^5	0.1
Clean, well-graded SAND & GRAVEL	—	—	10	0.05	—	0.1	0.01×10^6	0.01×10^5	0.01
Uniform, fine SAND	—	—	0.25	0.05	—	0.06	4000	400	40×10^{-4}
Well-graded, silty SAND & GRAVEL	—	—	5	0.01	—	0.02	400	40	4×10^{-4}
Silty SAND	—	—	[illegible]	0.005	—	0.01	100	10	10^{-4}
Uniform SILT	—	—	0.05	0.005	—	0.006	50	5	0.5×10^{-4}
Sandy CLAY	—	—	1.0	0.001	—	0.002	5	0.5	0.05×10^{-4}
Silty CLAY	—	—	0.05	0.001	—	0.0015	1	0.1	0.01×10^{-4}
CLAY (30 to 50% clay sizes)	—	—	0.05	0.0005	—	0.0008	0.1	0.01	0.001×10^{-4}
Colloidal CLAY ($-2\mu \leq 50\%$)	—	—	0.01	10Å	—	40Å	0.001	10^{-4}	10^{-9}

Typical values of permeability coefficients.

which are not aggregated, the permeability will be much less. The aggregated soils are usually naturally occurring, but can become disaggregated through excess tilling operations, lack of vegetal cover, and other outside influences. Also, crop root systems help to develop extensive channels and increase permeability.

Permeability is presented in most soil science publications in descriptive terms. Terminology used in the Illinois Drainage Guide is used as a standard for this analysis with respect to the soil horizons above the parent material. These definitions are as follows:

1. Rapidly permeable (more than 6 inches per hour and moderately rapidly permeable (2 to 6 inches per hour).
2. Moderately permeable (.6 to 2 inches per hour).
3. Moderately slowly permeable (.2 to .6 inches per hour).
4. Slowly permeable (.06 to .2 inches per hour) and very slowly permeable (less than .06 inches per hour).

Based upon drainage requirements mentioned in the Component Basis of Design Section of this report, the "moderately permeable" and the "rapidly permeable and moderately rapidly permeable" classifications present a range of values adequate to provide sufficient drainage. If necessary however, where all other conditions are adequate, a moderately slowly permeable rating will be tolerated. With respect to textural classifications and, subsequently, particle size, this range of permeability is reflected in most cases by a silt loam soil for the moderate permeability to sandy-gravelly soil for the rapidly permeable.

The foregoing discussion on permeability for the upper horizons also holds true, in most cases, for the underlying parent material.

Other Considerations. In addition to the internal drainage considerations reflected through the permeability discussion above, surface drainage and other topographical features of an area are important. The area should be relatively flat to lightly rolling in topography to most readily accept the center-pivot system, and to control surface drainage.

The physical considerations of site selection as discussed above are extremely important. But just as important are the biological and chemical mechanisms within the soil which provide a large portion of the pollutant removal abilities associated with the soil. Biological considerations such as microbes which bring nutrients to the plants and stabilize soil structure are important. Chemical considerations such as cation exchange capacity and iron and aluminum concentration are also important.

Most soils which have been productive in the past have an active biological community; this criteria, however, is of limited importance to site selection since the majority of Illinois and Indiana soils are highly productive. The cation exchange capacity and iron and aluminum concentration is available from actual field sampling and laboratory testing or from agricultural soil publications such as county soil surveys. These properties are most closely associated with soils which have some fine-grained texture within the surface horizons. Most Illinois and Indiana soils also meet this criteria. Information on specific soils will be given in other sections of this annex.

The actual soil process associated with the passage of treated wastewater through the soil, and how all of the factors, physical, chemical, and biological affect it, is covered in Section V of this annex, entitled Soil Process.

The importance of parent material permeability was discussed above. Another concern which must be addressed is the thickness of this parent layer. Adequate thickness is necessary to develop the proper drainage regime as discussed in Appendix B Section IV-A.

Summary. To summarize, one might say that to be ideally suitable for selection as a spray irrigation site, the soils within a particular area should have adequate permeability, healthy biological environment, proper chemical composition, be underlain by a parent material of proper depth and permeability and exist in a flat to gently rolling topographical setting.

Site Selection

General. This section presents a detailed discussion of general areas which were selected for use in the land treatment system. A selection methodology is outlined, followed by a site-by-site tabular description of the various major soil associations (see above) within these areas. These descriptions are given on Tables B-IV-A-1 - 5.

Selection Methodology. Each major soil association for both states was studied in detail within the framework of the Soil Selection Considerations presented above. Particular attention was given to the permeability component. As a first cut-off, all soils which did not fall within the first three permeability criteria, as outlined above, were automatically removed from consideration. This information was available for both Illinois and Indiana from overall soils maps and county soil survey publications.

The next criteria observed was the underlying parent material. Permeability and thickness were determined from all available information, which included geologic and engineering publications, field drilling records, well logs, interviews with knowledgeable persons in state engineering and geologic agencies, and, of course, the soil survey information. Those soils with unsuitable parent materials were deleted. Unsuitable parent materials were identified as those which were basically impermeable.

Following this, information from state publications on the irrigation potential from a strictly agricultural point of view was considered. This helped establish soil infiltration rates and other pertinent features. Those soils which did not have adequate irrigation potential and/or infiltration rates were deleted. An infiltration rate of greater than or equal to 1.5 inches per hour was selected as a lower limit.

The next criteria observed was the overall soil color. This helped establish if the soil had exhibited adequate drainage over its historical development. A light colored soil would indicate, in general, a good aerobic condition.

At this point in the analysis, the geographical location of the remaining soil associations was considered. All associations which were not within a reasonable distance to the actual study area were deleted.

The next step in selecting the general areas was to reduce the scope of observation from the soil association level to the soil series level. Individual series were studied, and where available, key physical-chemical relationship such as cation exchange capacity were observed. This information is incorporated in some county soil surveys.

Soils within the individual soil series were investigated for permeability. At this time, requirements were stiffened to include only the first two categories of permeability. Except for one or two isolated cases, all soil series selected fell within this stipulation. Also, individual series were investigated for their irrigation potential.

The soils which survived this rigorous screening are presented below. Samples were taken in the field at randomly selected sites within the soil area chosen. Laboratory tests were run on these sites to determine the cation exchange capacity and the iron and aluminum content. In addition, trained personnel were sent to the field to observe actual soil conditions.

<u>Selected Soils</u>. The following information on soils within the selected land treatment areas is presented in a tabular form. The irrigation areas are identified by county of location, and, where necessary, location within the county. Major soil associations are identified and broken down into major soil series within the association. Other soil series which may be associated with the particular association are also shown. Surface and subsurface characteristics are shown.

For surface soils, i.e., A-B horizons, the texture, infiltration rate, permeability and thickness are shown. For the subsurface soils, the texture, permeability, and depth to impermeable layer are presented. The depth to the water table is also shown.

The final three columns present the results of the laboratory analysis on cation exchange capacity and iron and aluminum content. These samples for this series of tests were obtained for only the predominate soil series within any single association, so values may not be shown for certain series listed. In addition, no pertinent samples were taken in Kendall County.

TABLE BA-IV-A-1 SELECTED SOILS, MC HENRY COUNTY WEST

Area of Selected Soils	Major Soil Associations	Other Associated Soil Series	SURFACE CHARACTERISTICS: Texture	SURFACE CHARACTERISTICS: Infiltration (in/hr.)	SURFACE CHARACTERISTICS: Permeability (in/hr.)	SURFACE CHARACTERISTICS: Thickness (Ft.,Ave.)	SUBSURFACE SOILS: Texture	SUBSURFACE SOILS: Permeability (in/hr.)	SUBSURFACE SOILS: Ave. Depth to Impermeable Layer (Ft.)	Depth to Water Table (Ft.)	Cation Exchange Capacity (me./100g)	Iron (ppm)	Aluminum (ppm)
McHenry County West	Strawn Miami												
	Strawn		Silt Loam	1.5	0.6 to 2.0	3.0	Till	6.0	20 - 50	0 - 40			
	Miami		Silt Loam	1.5	0.6 to 2.0	4.0	Till						
	Drummer Proctor												
	Proctor		Silt Loam	1.5	0.6 to 2.0	5.0	Loam Silt Loam Outwash				16.9	14.3	28.0
	Drummer		Silty Clay Loam	1.5	0.6 to 2.0	5.0	Outwash				-	-	-
	Brenton		Silt Loam to Silty Clay Loam	1.5	0.6 to 2.0	5.0	Outwash				16.9	14.3	28.0
	Selma		Loam to Clay Loam	1.5	0.6 to 2.0	5.0	Sandy Loam to Sand Outwash				-	-	-
	LaHogue		Loam to Clay Loam	1.5	0.6 to 2.0	4.0	Sand Outwash				-	-	-
	Lomax		Loam to Silty Loam	1.5	2.0 to 6.0	4.0	Sand to Loamy Sand				-	-	-

TABLE BA-IV-A-1 SELECTED SOILS MC HENRY COUNTY WEST (Continued)

Area of Selected Soils	Major Soil Associations	Other Associated Soil Series	SURFACE CHARACTERISTICS				SUBSURFACE SOILS			Depth to Water Table (Ft.)	Cation Exchange Capacity (me./100g)	Iron (ppm)	Aluminum (ppm)
			Texture	Infiltration (in/hr.)	Permeability (in/hr.)	Thickness (Ft.,Ave.)	Texture	Permeability (in/hr.)	Ave. Depth to Impermeable Layer (Ft.)				
McHenry County West	Drummer-Proctor (Cont.)												
	Otter		Silt Loam	1.5	0.6 to 2.0	4.0	Silt Loam to Loam	6.0	20 - 50	0 - 40	-	-	-
	Volinia		Silt Loam to Silty Clay Loam	1.5	0.6 to 2.0 to 2.0 to 6.0	2.0 to 3.0	Sand and Gravel				-	-	-
	Fox - Homer												
	Fox		Silty Loam to Clay Loam	1.5	0.6 to 2.0	4.0	Gravel				16.0	10.6	21.3
	Casco		Silt Loam to Silty Clay Loam	1.5	2.0 to 6.0	3.0	Gravel				14.7	13.0	29.5
	Rodman		Gravelly Loam to Gravel	1.5	6.0	2.0	Gravel				-	-	-

TABLE BA-IV-A-2 SELECTED SOILS, MC HENRY COUNTY CENTRAL

Area of Selected Soils	Major Soil Associations	Other Associated Soil Series	SURFACE CHARACTERISTICS				SUBSURFACE SOILS			Depth to Water Table (Ft.)	Cation Exchange Capacity (me./100g)	Iron (ppm)	Aluminum (ppm)
			Texture	Infiltration (in/hr.)	Permeability (in/hr.)	Thickness (Ft.,Ave.)	Texture	Permeability (in/hr.)	Ave. Depth to Impermeable Layer (Ft.)				
McHenry County Central	Proctor-Drummer												
	Proctor		Silt-Loam	1.5	0.6 to 2.0	5.0	Loam-Silt	6.0	20 - 50	0 - 40	16.9	14.3	28.0
	Harvard		Silt-Loam	1.5	0.6 to 2.0	5.0	Loam to Sandy Loam Outwash				-	-	-
	Drummer		Silty-Clay Loam	1.5	0.6 to 2.0	5.0	Outwash				-	-	-
	Brenton		Silt Loam to Silty Clay Loam	1.5	0.6 to 2.0	5.0	Outwash				16.9	14.3	28.0
		Harpster	Silt Loam	1.5	0.6 to 2.0	5.0	Loam Outwash				-	-	-
		Thorp	Silt Loam	1.5	0.2 to 0.6	4.0	Silt Loam to Loam Outwash				-	-	-
	McHenry LaPeer												
	McHenry		Silt Loam	1.5	0.6 to 2.0	4.0	Silt Loam Till				-	-	-
		Nippersink	Silt Loam	1.5	0.6 to 2.0	4.0	Silt Loam Till				-	-	-
	Ringwood Griswald												
	Ringwood		Silt Loam	1.5	0.6 to 2.0	4.0	Loam Till				-	-	-
	Griswald		Silt Loam	1.5	0.6 to 2.0	4.0	Loam Till				-	-	-

TABLE BA-IV-A-3 SELECTED SOILS, KENDALL COUNTY

Area of Selected Soils	Major Soil Associations	Other Associated Soil Series	SURFACE CHARACTERISTICS				SUBSURFACE SOILS			Depth to Water Table (Ft.)	Cation Exchange Capacity (me./100g)	Iron (ppm)	Aluminum (ppm)
			Texture	Infiltration (in/hr.)	Permeability (in/hr.)	Thickness (Ft.,Ave.)	Texture	Permeability (in/hr.)	Ave. Depth to Impermeable Layer (Ft.)				
Kendall County Site	Saybrook Lisbon												
	Saybrook		Silt Loam	1.5	0.6 to 2.0	3.5	Loam Till	6.0	20'	0 - 35			
	Lisbon		Silt Loam	1.5	0.6 to 2.0	3.5 to 4.0	Loam Till						
	LaRose												
		Catlin	Silt Loam	1.5	0.6 to 2.0	3.5 to 4.0	Loam Till						
		Drummer	Silt Loam	1.5	0.6 to 2.0	4.0	Loam Outwash						
		Flanagan	Silt Loam	1.5	0.6 to 2.0	4.0	Loam Till						
	Brenton Drummer												
	Brenton		Silty Loam to Silty Clay Loam	1.5	0.6 to 2.0	5.0	Outwash						
	Drummer		Silty Clay Loam	1.5	0.6 to 2.0	5.0	Loam Outwash						
		Elliott	Silt Loam	1.5	0.2 to 0.6	4.0	Silt Loam Till						

TABLE BA-IV-A-4 SELECTED SOILS, WILL-GRUNDY-KANKAKEE COUNTIES

Area of Selected Soils	Major Soil Associations	Other Associated Soil Series	SURFACE CHARACTERISTICS				SUBSURFACE SOILS			Depth to Water Table (Ft.)	Cation Exchange Capacity (me./100g)	Iron (ppm)	Aluminum (ppm)
			Texture	Infiltration (in/hr.)	Permeability (in/hr.)	Thickness (Ft.,Ave.)	Texture	Permeability (in/hr.)	Ave. Depth to Impermeable Layer (Ft)				
Will-Grundy Kankakee	Planfield-Hagener-Maumee												
	Planfield		Sand	1.5	6.0	Variable	Sand	27	20 - 100'	0 - 40	2.4-2.7*	2.1*	6.3-7.4*
	Hagener		Loamy Sand	1.5	6.0	"	Sand				1.5-4.7*	2.9-4.5*	5.2-12.3*
	Maumee		Fine Sandy Loam to Loam Sand	1.5	6.0	"	Sand				1.0-7.0*	1.9-6.1*	11.3-20.5*
	Pittwood		Fine Sandy Loam	1.5	2.0 to 6.0	"	Sand				-	-	-
	Ridgeville		Fine Sandy Loam	1.5	2.0 to 6.0	"	Sand				-	-	-
	Watseka		Fine Sandy Loam	1.5	2.0 to 6.0	"	Sand				-	-	-
		Lahogue	Loam to	1.5	0.6 to 2.0	4.0	Outwash				-	-	-
		Harpster	Silt Loam	1.5	0.6 to 2.0	4.0	Silt Loam to Loam Outwash				-	-	-
	Saybrook Lisbon												
	Saybrook		Silt Loam	1.5	0.6 to 2.0	3.5	Loam Till				-	-	-
	Lisbon		Silt Loam	1.5	0.6 to 2.0	3.5 to 4.0	Loam Till				-	-	-
		Drummer	Silt Loam	1.5	0.6 to 2.0	4.0	Loam Outwash				-	-	-

NOTE: * (multiple samples)

TABLE BA-IV-A-5 SELECTED SOILS, NEWTON-JASPER-PULASKI COUNTIES, INDIANA

Area of Selected Soils	Major Soil Associations	Other Associated Soil Series	SURFACE CHARACTERISTICS				SUBSURFACE SOILS			Depth to Water Table (Ft.)	Cation Exchange Capacity (me./100g)	Iron (ppm)	Aluminum (ppm)
			Texture	Infiltration (in/hr.)	Permeability (in/hr.)	Thickness (Ft.,Ave.)	Texture	Permeability (in/hr.)	Ave. Depth to Impermeable Layer (Ft)				
Newton-Jasper-Pulaski	Maumee Newton												
	Maumee		Fine Sandy Loam	1.5	6.0	Variable	Sandy	6.0	20 - 100	0 - 35	3.5	3.2	8.0
	Newton		Fine Sand	1.5	6.0	"	Sand				-	-	-
	Plainfield		Sand	1.5	6.0	"	Sand				3.4	3.4	3.3
	Brems		Sand	1.5	6.0	"	Sand				3.2	3.2	0.8
		Rensselaer	Loam	1.5	0.6 to 2.0	-	Sand				5.50	4.8	4.0
	Parr-Chalmers												
	Parr		Silt Loam	1.5	0.6 to 2.0	-	Sand				-	-	-
	Chalmers		Silt Loam	1.5	0.2 to 0.6	-	Sand				-	-	-
	Odell		Silt Loam	1.5	0.6 to 2.0	-	Sand				-	-	-
	Miami		Loam	1.5	0.6 to 2.0	5.0	Loam				1.2	3.1	1.5
	Ade		Fine Sandy Loam	1.5	6.0	5.0	Sand				-	-	-
		Crosby	Silt Loam	1.5	0.2 to 0.6	5.0	Loam Till				-	-	-
		Corwin	Silt Loam	1.5	0.6 to 2.0	5.0	Loam Till				-	-	-
		Montgomery	Silt Clay	1.5	0.06 to 0.2	5.0	Loam Till				-	-	-
		Chelsea	Fine Sand	1.5	6.0	5.0	Sand				-	-	-
		Brookston	Silt Loam	1.5	0.2 to 0.6	5.0	Till				-	-	-

Implications of Infiltration, Percolation and Permeability on Center-Pivot Design and Operation

The section above on Soil Selection Considerations discussed the differences between infiltration, percolation, and permeability, and their rate considerations. These three parameters of the soil are extremely important when the use of a spray irrigation system is anticipated. As the amount of water to be applied in any one period increases, and the time available in which to apply it remains the same, it becomes a distinct possibility, that, without proper design of application, the soil complex can become overtaxed and surface runoff of applied flows may result. The following discussion addresses this concern.

Infiltration is considered as the movement of water through the interface of soil surface into the pore space of the soil. Implicit in this statement is the assumption that the water which is infiltrating into the soil is applied uniformly over the surface, and that the infiltration rates reflect a uniform application over the surface. However, soil conditions under a farming situation do not allow the water being applied to spread evenly over the entire soil surface. Farming tends to change the uniform surface application by the influence of the canopy effect set up by plants, and the general nature of row cropping operations. A better term for the acceptance of water into the soil might well be "intake", with an analogous term of "intake rate" used for the time rate at which water is accepted into the soil. The terms intake and intake rate are used by most irrigation texts and practitioners.

The intake rate, like the infiltration rate, depends on many factors, such as, soil type, texture, structure, porosity, degree of saturation, amount of organic material, vegetal cover, and time of the year. One of the soil characteristics which probably most influences the intake rate is the noncapillary porosity. Porosity determines the storage capacity of the soil and also effects resistance to flow. Intake rate tends to increase with increasing porosity. An increase in the organic matter may result in increased intake capacity, largely because of an increase in porosity associated with the structure of the organic material.

The exact effect of vegetation on the capacity is somewhat difficult to identify because it also influences interception. Just the same, vegetal cover does increase intake as compared to barren soil, and three main reasons can be advanced: (1) it retards surface flow, giving the water additional time to enter the soil; (2) the root system increases the perviousness of the soil; and (3) the foliage shields the soil from water droplet impact, and therefore, reduces "packing" of the soil surface.

The intake rate of a particular soil greatly influences the selection of a particular area for spray irrigation. This is even more true when the irrigation is to be accomplished by the use of the center-pivot system. With the center-pivot system, the circumferential distance traveled increases as you move radially out along the lateral arm of the rig and subsequently, the speed of the moving lateral increases. With increasing speed, the intensity at which the water is applied to the soil increases. If this application rate exceeds the intake rate of the soil, runoff will occur. The problem then is to properly balance the center-pivot system with the soil conditions to produce a situation of no runoff.

A great deal of work has been done in trying to determine the intake rate of a soil. Some investigators have assumed that the intake rate is equal to the steady state, saturated percolation rate. However, it has been shown that the intake rate of a nonsaturated soil can be defined as a decaying function of time, with higher intake rates being available in the early stages of water application, and decreasing rates available as the time duration extends. This intake rate would reach some steady-state value which would be approximately equal to the soil's permeability.

It might be remembered in the discussion of the difference between percolation and permeability, that percolation was a downward movement of water through the unsaturated soil. Therefore, in the early stages of water application, water moves not only down through the channels, but also has to fill these channels. This implies a greater movement of water into these "pores" in the early time period, and this is reflected in a faster intake rate. In addition, there are capillary pores which, if not already filled, will store water. Capillary forces will continuously divert gravity water into the capillary pores, so that the quantity of gravity water passing successively lower horizons is diminished. This leads to increasing resistance to gravity flow in the surface layer and again implies a decreasing intake rate as the length of irrigation incidence increases in time. The intake rate in the early phases of an irrigation application is less if the capillary pores are filled from a previous irrigation.

Figure BA-IV-A-1 presents a typical intake rate curve for a fine sandy loam soil. It can be seen that in the early time periods the intake rate is quite high, but decays over time, becoming asymptotic

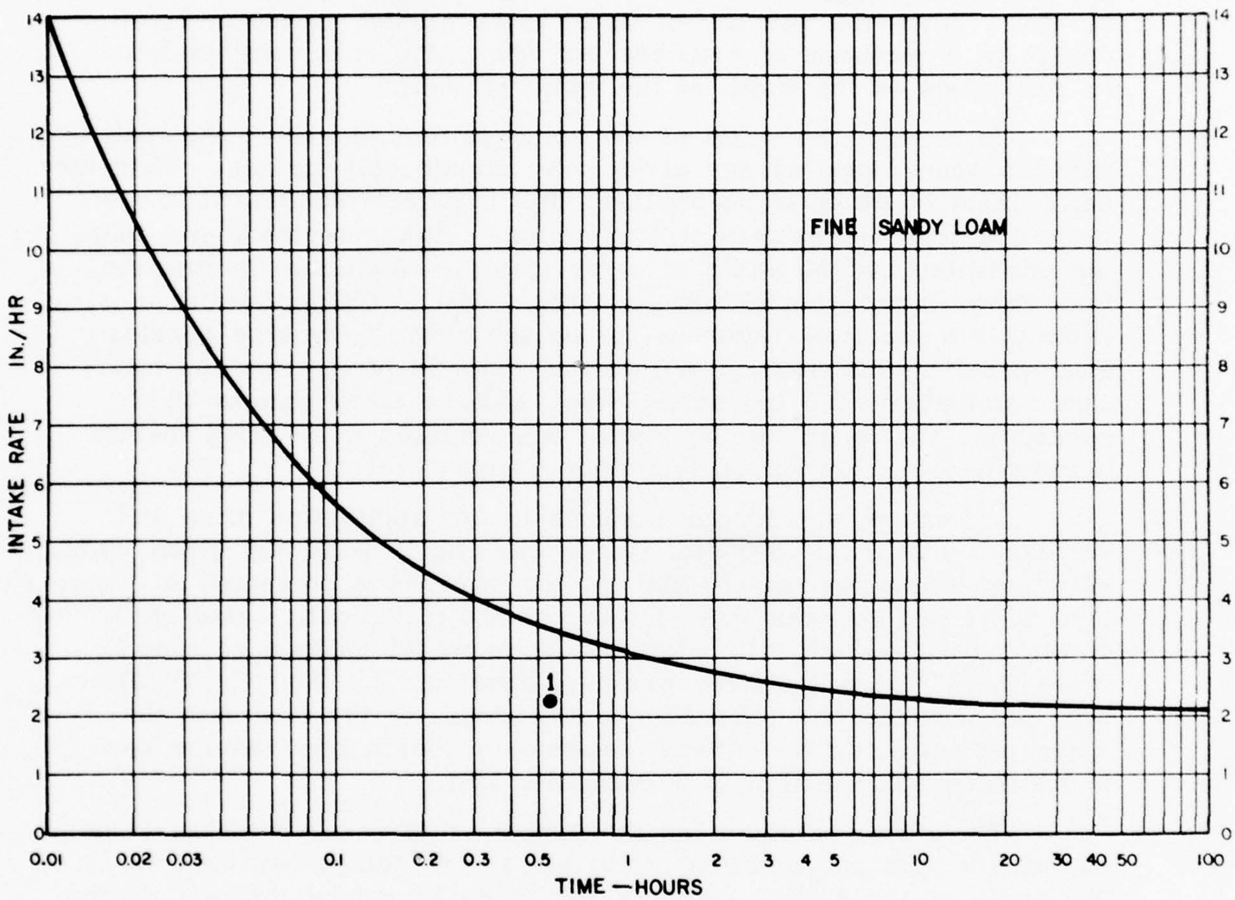


Figure BA-IV-A-1

INTAKE RATE vs TIME

to the steady-state permeability of the soil.

The determining factors for the application rate at any given point on the irrigation lateral of the center-pivot system is the depth of water which must be applied and the width of the spray pattern. The application rate is independent of the rotational speed of the system. Since the quantity of water to be applied in the C-SELM design is a maximum of 6 inches per week, the only variable left to manipulate is the width of the spray pattern.

Increasing the width of the spray pattern increases the time duration spent covering any given point on the soil surface. With the same depth of water to be applied, this in effect reduces what might be called the average rate of application. However, there are limiting conditions on the width of spray pattern. Available information from center-pivot manufacturers indicates that a 100 foot width of spray pattern is a practical maximum, using the down-spray type nozzles anticipated in this study. Within the confines of the required maximum application of 6 inches per week and the spray pattern width constraint, the length of the lateral arm becomes a dictating feature in matching a center-pivot system to a given soil.

Increasing arm length produces higher application rates and decreased durational times for the lateral arm to pass any given point. When examining the intake rate vs. the time curve presented in Figure BA-IV-A-1, it can be seen that plotted points of application rate vs. duration (time) which fall below the curve would produce no runoff, while those that fall above, would produce runoff. Since application rate and duration are a function of the length of the rig, with the spray pattern along the lateral, lateral arm length becomes the key in matching a rig design to a particular soil.

Therefore, to create an optimum (in this case, minimum value) application rate and duration combination, two things can be done. The width of the spray pattern is set so as to reduce the rate of application to the lowest possible value. In addition, the number of revolutions used to supply the total weekly application is increased, thus decreasing the time duration needed to apply any given amount of water (remembering that the application rate is not a function of time). The table below presents an example of application rates for a specific center-pivot system.

Interpretation of the table indicates that the most desirable (minimum value) combination, with respect to intake would be 1.2 inches per application for 5 revolutions per week. This produces a

1000 FT. LATERAL, CENTER-PIVOT SYSTEM 6 IN/WK APPLICATION, 168 HR. TOTAL APPLICATION TIME

Radial Distance from Center-Pivot (feet)	Spray Width [a] (feet)	Duration of Pass (Hours)			Application Rate (Inches / Week)		
		3 Revs. Per Wk. 2"/Rev.	4 Revs. Per Wk. 1.5"/Rev.	5 Revs. Per Wk. 1.2"/Rev.	3 Rev/Wk	4 Rev/Wk	5 Rev/Wk
300	58	1.73	1.29	1.04	1.16	1.16	1.16
600	76	1.13	0.85	0.68	1.77	1.77	1.77
1000	100	0.89	0.67	0.54	2.25	2.25	2.25

[a] Rig design features a spray width which increases linearly with increasing distance from the center pivot.

duration of 0.54 hours at the end of the 1,000 foot rig. By referring to the intake curve in Figure BA-IV-A-1 this would be reflected by point "1", which falls well below the plot of intake-rate vs. time, indicating no runoff. This analysis can be expanded to other soils and rig lengths.

Two distinctive soil textures were chosen as representative of the treatment site soils, i.e., fine sandy loam and silt loam. Using the analysis above, each soil and center-pivot rig system were compared to assure that no runoff would occur.

The intake rate curve shown in Figure BA-IV-A-1 has been characterized by investigators as lineal in a log-log plot. From such a log-log plot an equation was obtained for the intake rate curve associated with a particular soil. This has been done for the two representative soils mentioned above, and their plots are presented in Figure BA-IV-A-2. Figure BA-IV-A-2 also presents a plot of the application rate vs. time for the 1,000 foot irrigation rig defined in the table presented above. It was brought out earlier that when the application rate was below the intake rate, no runoff would occur. Therefore, it can be seen that as long as the application rate vs. time (A-T) plot lies below the intake rate vs. time (I-T) plot, the system will produce no runoff.

As an example, if for a design capacity of 6 inches per week, this 6 inches is applied in 3 rotations, the A-T plot will lie above

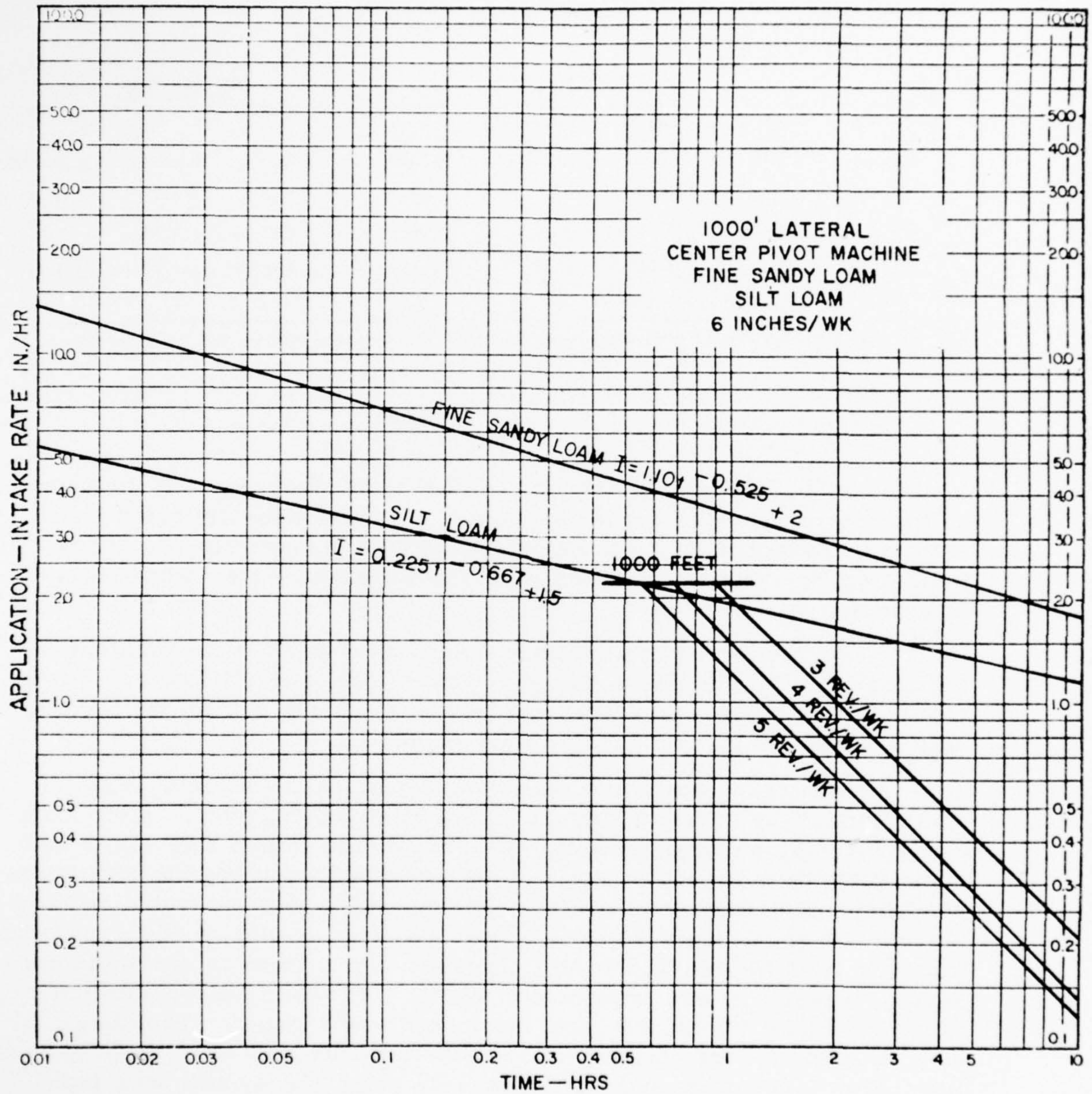


Figure BA-IV-A-2

APPLICATION—INTAKE RATE vs TIME

the silt loam I-T curve and below the fine sandy loam I-T curve. One can assume, therefore, that runoff will be produced with this rig combination on silt loam, but not on fine sandy loam. It can also be seen from these A-T and I-T curves that, if the same six inches is applied in five rotations, no runoff will be produced for either soil. Similar plots are presented in Figures BA-IV-A-3 and BA-IV-A-4 for 1,300-foot and 1,500-foot lateral arm center-pivot systems, respectively.

In Figures BA-IV-A-3 and BA-IV-A-4, it can be seen that the length of the rig influences the application rate and the duration such that runoff would be produced on a silt loam soil. Again, as in the case of the 1,000-foot rig, the 1,300-foot and 1,500-foot rig would not produce runoff on a fine sandy loam. It should be pointed out at this time that the intake curves shown were developed for a bare soil. This is a very conservative condition, as was brought out above in the discussion on the effect of ground cover. Also ignored for the sake of conservatism is the effect of what hydrologists call "depression storage". Normally, depression storage is about 1" in volume on flat to gently rolling farm land. The depression storage temporarily stores excess applied water and gives a greater duration for infiltration than the duration of irrigation water application during one pass of a pivot rig. On a particular site selected for final design, the amount of depression storage can be evaluated for each tract to be irrigated and its magnitude taken into account in determining the permissible length of center-pivot machine. If 1" of depression storage were to be always present, for example, it could be added to the infiltration capacity for the duration of the machine traverse to obtain a longer design length of machine. This in turn would reduce the cost of the irrigation system. The application of the above-mentioned factors to reduce irrigation system cost is reserved to subsequent final design.

This analysis shows that definite limitations on the length of center-pivot systems and its conditions of operation are brought into play by the type of soil being used at a particular site. Design lengths used in this study conservatively reflect these limitations. All rigs placed on silt loam type soils have been designed at 1,000-foot lengths while those on sandy soils have been designed up to 1,500-foot in length. In addition to the design restriction, the actual operation of the center-pivot irrigation rig has been established. In the silt loam soil areas, operation is required on a five rotation per week basis; at full capacity, six inches is applied. If less than the six inches is applied, the speed of rotation must still be maintained. For instance, if during one week only four and one-half inches were to be

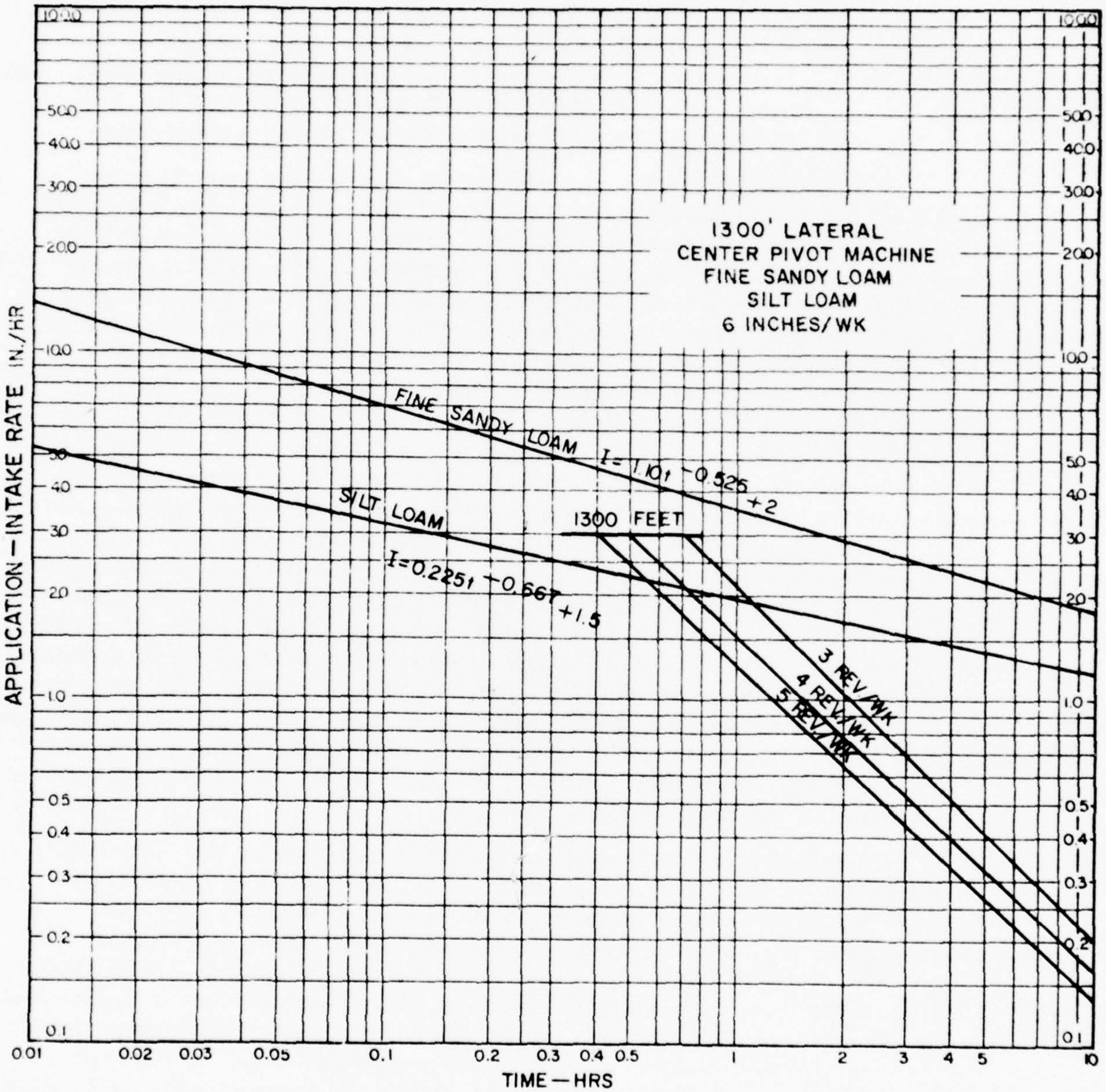


Figure BA-IV-A-3

APPLICATION — INTAKE RATE vs TIME

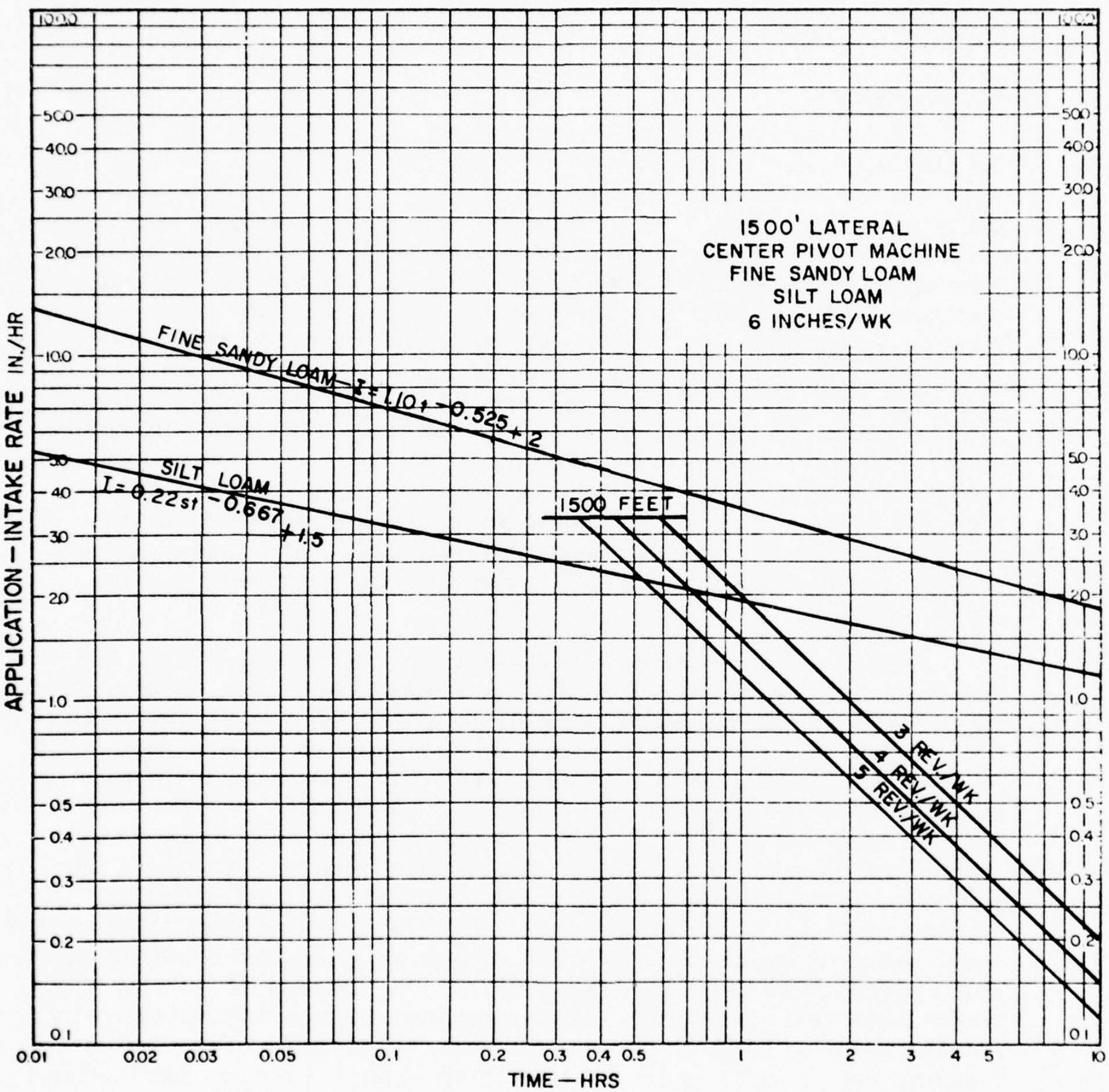


Figure BA-IV-A-4

APPLICATION—INTAKE RATE vs TIME

applied, it would be applied in three and three-quarter revolutions, in order to provide the application rate-duration combination which produces no runoff.

Soil Process

Potential contents of wastewater vs. the soil process. Proposals for the utilization of wastewater for irrigation and the use of soil systems for the reclamation of wastewater have recently received wide acclaim as novel ideas. Yet, Whetstone (1965) has presented, in chronological order, 663 abstracts of papers reporting observations and data from water reuse applications and studies. The annotated bibliography was compiled from the literature dealing with wastewater reuse for irrigation, recreation, and groundwater recharge during a period dating from 1892 through 1965. Another annotated bibliography containing 202 abstracts of papers dealing more specifically with the use of sewage effluent as an agricultural water resource and land disposal of liquid waste was published by Law (1968). Todd (1959) has summarized recharge of ground water up to and including the calendar year 1954. Several of the papers he abstracted presented information about the use of sewage effluent for groundwater recharge, while others reported results regarding the use of soil systems to purify polluted surface water supplies.

From the large body of literature it is obvious that not all researchers had the same objectives. Sometimes the objective was simply to spread contaminated water on soils to avoid the cost of the treatment which would be necessary to permit its discharge to surface waters. In some water-deficient areas, wastewater has been used to irrigate crops at rates and amounts sufficient for good yields because other sources were not available. Often wastewater has been applied to agricultural land far in excess of the needs of plants. The main objective in applying excessive water to crop land was to utilize the growing plant as a scavenger of the nutrients from the percolating wastewater before it eventually recharged ground water aquifers. Many times, soil systems have been used as filters in the absence of growing crops. Where water was returned to surface supplies by pumping strategically located wells or used to prevent the intrusion of saline water by increasing the water level in aquifers, high application rates have often precluded the growing of crops.

Although the distinction has not always been made in the older literature, sewage spreading, sludge disposal on land, and the use of effluent for irrigation and/or ground water recharge are not synonymous terms. Because of its continually changing and widely-varied composition, raw sewage (as a unique entity) has not been studied in sufficient detail, in conjunction with land application practices, to establish standards concerning its effect on the land as regards: possible disease transmission through crops; alteration of physical, chemical and biological characteristics of soil; and chemical pollution of water supplies. For this reason, the spreading of untreated waste (sewage spreading) on land is not an acceptable practice in the United States, although is it successfully practiced in such locations as Paris, France, and Melbourne, Australia. Before waste can be recycled, solids (sludge) and wastewater (effluent) must be appropriately treated to cause it to be compatible with the soil system and the environmental concerns associated with soil systems.

Municipal waste frequently consists of mixtures of domestic or household waste, surface runoff or stormwater, and industrial waste. Some processing industries, particularly the food industry, produce wastes which are amenable to biological treatment even though they are usually much more concentrated than domestic sewage. It may be of interest to compare some of the average BOD (biochemical oxygen demand) values for several kinds of industrial waste as given by Judell (1966), reproduced below, with the BOD value of 300 mg/1 normally used as an average for domestic sewage. While it is often purported that many of the high BOD wastes can be directly spread on land as an economical and effective means of disposal, such wastes improperly managed could cause odor and insect problems.

TYPICAL BOD VALUES OF SOME INDUSTRIAL EFFLUENTS

TYPE OF WASTE	BOD (5 DAYS) (mg/l)
Abattoir	2,500
Brewery	500
Gas Works	6,500
Dairy (whey)	32,000
Maltings	1,200
Petroleum Refinery	800
Starch Process	10,000
Tannery	2,500
Pharmaceutical	4,000
Petrochemical	8,000
Distillery	7,000
Raw Sugar Processing	500

Many toxic and nontoxic organic waste materials arise from industrial processes, such as the chemical production of textiles, plastics, pharmaceuticals, detergents and pesticides. After a period of acclimation, some organic toxic substances, such as phenols and formaldehyde, can be almost completely removed from wastewater by biological treatment, even though at sufficiently high concentrations they are bactericidal (Jackson & Brown, 1970).

Low (1970) provides information regarding concentration levels of various toxicants in the effluents from a range of processes used in the metal finishing and allied industries. Metals commonly present in metal finishing effluents at relative high concentration are copper, nickel, zinc, and chromium. There is some indication that when any one of the above metals exceeds a concentration greater than 10 mg/l in sewage the biological treatment of sewage effluent is seriously impeded (USPHS 1965). Even in the absence of inhibitory concentration levels, biological processes of sewage treatment seldom remove more than 80 percent of the metals. Thus, it is possible even for a secondary effluent to contain metals in concentrations greater than those established as permissible levels in irrigation water. It may be reasoned that even though biological treatment does not guarantee that continued use of a waste will not result in an accumulation of a toxic substance in soils, it does mitigate against the ominous situation always present when untreated municipal wastes or wastes treated by chemical-physical methods are recycled to land. Because toxic substances reduce the rate at which wastes can be treated in a biological system, the increased cost for treatment plant capacity, ancillary equipment, aeration, and personnel will prompt the staff of sanitary districts to enforce the elimination of concentrated toxicants at their source. Pretreatment of toxic waste prior to discharge to sewage works has been thoroughly discussed by Chalmers (1970).

Incidents of accidental contamination of underground water supplies by metal processing waste, open stockpiling of salt, leaching from garbage pits, broken sewers, inadequately designed drainage fields for septic tanks, mine drainage, brine discharge, etc. are reported often enough as to leave little doubt that there is a limit to the capacity of soil system to assimilate waste. Although soils have varying capacities to remove water contaminates by filtering, sorption, exchange and precipitation, to a large extent its effectiveness in water renovation is determined by the ability of the microorganisms that populate the first few feet of soil depth to convert the contaminates to innocuous volatile substances and to some degree incorporate the materials into new protoplasm. Thus, waste materials supplied in concentrations that inhibit the growth of microorganisms, either directly as a toxicant or indirectly by adversely altering favorable physical properties of the soil, reduce the soil's capacity to assimilate waste materials. Once wastewater contaminates have migrated below the biologically active zone in soils, their removal is mainly by sorption and chemical precipitation reactions. The fixed capabilities of these physical and chemical processes can also be exceeded, thus permitting contaminates to travel long distances as a constituent of water moving through biological materials in response to a pressure gradient. Contamination of underground water supplies can often be traced to situations where polluted water was either directly injected or allowed to circumvent the biologically active soil surface.

Davids and Lieber (1951) have reported chromium contamination of ground water at a distance greater than one mile from an aircraft industry's waste disposal pit located in Nassau County, New York. Concentrations up to 40 mg/l were found in some of the water samples collected from test wells. Later, it was discovered that ground water was also being contaminated with cadmium migration from the pits used to dispose of plating and anodizing wastes (Leiber and Welsch, 1954). Water collected from a depth of 33 feet in one of several test wells located a distance of 700 feet from the pit had a cadmium content of 3.2 mg/l. Similar incidents of contaminating ground water with chromium from attempts to dispose of electroplating waste in infiltration pits were discussed by Deutsch (1963). Discharge of plating waste in a pit located in Allegan County, Michigan, resulted in the contamination of a glacial drift aquifer for at least 1,000 feet in one direction from the pit and to a depth of at least 37 feet. He cites other examples of contamination of aquifers with chromium originating from infiltration pits but says the hazard to water supplies from the cyanide contained in such waste is largely eliminated by the method of disposal. Such heavy metal contamination of ground water is principally the result of improper acidity control associated with the metal-bearing wastes. The resulting highly acid condition pervades the soil mantle and destroys the metal-fixing capabilities of the soil.

Deutsch (1963) also reports several examples of pollution of underground water supplies by organic materials, such as gasoline, fuel oil, creosote and picric acids. A glacial drift aquifer below a charcoal waste pit in Antrim County, Michigan was contaminated with phenol in an area 3 miles long, a half mile wide and to a depth of about 200 feet.

The acceptance of a variety of industrial waste and stormwater flows into sewer systems complicates the problem of characterizing untreated waste. Some of the wide variation in composition of effluent from place to place and time to time is removed by biological treatment of sewage. Thus, from the standpoint of designing a safe reclamation and recycling system, one could make a strong argument for accepting only effluent from a biological pre-treatment facility with a composition equivalent to secondary effluent. Some average concentration levels of various constituents of secondary effluent were presented by Weinberger, et al (1966) and is reproduced below as Table BA-IV-A-6.

General capabilities of the soil process. Where soil systems are to be used for renovating wastewater, plans should include management practices to optimize conditions for the maintenance of mixed cultures of organisms to consume the waste by their multiplicity of metabolic processes. Such management practices cannot be specifically stated without an examination and analysis of the climatic, soil, geologic, and hydrologic conditions of the site to be used for wastewater disposal and/or renovation. However, it is possible to state in general terms what might be expected from a properly selected and well managed soil system. For general statements regarding soil systems it seems appropriate to quote from an excellent literature review and interpretation of research findings prepared by McGauhey and Krone (1967).

> "Reconstructed soil systems such as sand filters for water treatment are well known to the engineer and are quite predicable both in rate of infiltration of water and change in quality to be expected. In the case of natural soil systems, however, most of the engineering effort reported in the literature has been concerned with taking advantage of the ability of underground strata to store or to transport water. Essentially no effort has been made to engineer a soil system deliberately to exploit its ability to change the quality of the water; and it is in this area that the greatest gap exists between research and engineering practice. Therefore, it is important to summarize what is known concerning the quality factors which a soil system will and will not remove from a wastewater.

Bacteria and viruses. Research findings from studies of the travel of bacterial and viral pollutants with percolating water and with groundwater in saturated aquifers reveal a number of facts of engineering importance. Among the most pertinent are:

1. Bacteria behave like other particulate matter in soils and are removed by straining, sedimentation, entrapment, and absorption. In addition they are subject to die-away in an unfavorable environment.

Table BA-IV-A-6

AVERAGE COMPOSITION OF MUNICIPAL SECONDARY EFFLUENT

Component	Average concentration in secondary effluent (mg/l)	Average increment added during water use [b] mg/l	Average increment added during water use [b] lb/day/ 1000 pop.
Gross organics	55	52	64
Bio-degradable organics (as BOD)	25	25	31
Methylene blue active substance (MGAS) [a]	6	6	7
Na^+	135	70	86
K^+	15	10	12
NH_4^+	20	20	25
Ca^{++}	60	15	18
Mg^{++}	25	7	9
Cl^-	130	75	92
NO_3^-	15	10	12
NO_2^-	1	1	1
HCO_3^-	300	100	120
$CO_3^=$	0	0	0
$SO_4^=$	100	30	37
$SiO_3^=$	50	15	18
$PO_4^=$	25	25	31
Hardness ($CaCO_3$)	270	70	86
Alkalinity ($COCO_3$)	250	85	100
Total dissolved solids	730	320	390

[a] Apparent alkyl benzene sulphonate
[b] Concentration increase from tap water to secondary effluent

2. The ability of bacteria as living matter with enzyme systems to move more freely than inert particles has not been evaluated, since most research has utilized living particles as the test material.

3. Coliform and other bacteria has been observed to move but a few feet with percolating water in unsaturated flow and a few hundred feet in groundwater in saturated systems.

4. Intestinal pathogens may survive in soil for periods up to about 2 months, depending upon the organic content of the soil, and retain their virulence during the period of survival.

5. Viruses are removed by soil systems, probably principally by adsorption, as effectively as are bacteria.

6. It may be concluded that both biological antagonisms and physical removal of bacterial and viral cells characterize the change in biological quality of water percolating through a soil system; and that the system is a quite efficient device for removing such cells.

Chemicals. The ability of soil systems to remove chemicals from percolating water is quite limited. Biodegradable organic materials are normally attacked in the clogging zone and reduced to intermediate compounds and ultimately to stable compounds which characterize groundwater, e.g., nitrates, phosphates, carbonates, sulfates, etc. Concerning these and other ions which may come from industrial wastewaters, a number of important facts may be noted:

1. A considerable fraction of the 300 mg/l total dissolved solids added to water by domestic use appear as anions and cations normally found in groundwater. Thus an increase in the normal mineralization of groundwater is to be expected if wastewater is percolated through a soil system. Under normal conditions of soil pH, phosphates are effectively removed. Chlorides, sulfates, and nitrates, however, move quite freely with percolating water and situations have already developed where nitrate content has limited the use of sewage effluents for groundwater recharge.

2. Chromate, gasoline, phenols, picric acid, and miscellaneous chemicals have been observed to travel many miles; hence, in general, soil systems must be considered ineffective in treating many industrial wastewaters. However, under appropriate conditions not clearly defined at present, soils may have a capacity for removing chromate, phenols, and other compounds.

3. Synthetic detergents can be effectively destroyed by biochemical degradation in a biologically active aerobic soil system in which there is no escape of partially degraded material from the biosystem.

4. Radioisotopes of various elements are removed to varying degrees in a soil system. The problem, however, is a specialized one beyond the scope of this report.

5. Most of the common pesticide residues move very slowly downward in a soil profile. With increasing water solubility insecticides tend to move more rapidly.

Particulate matter. Inert and organic particulate matter is effectively removed, usually by the top 5 or 6 inches of a soil system. Individual particles may penetrate further, but is to be expected that a soil system will remove particulates from a wastewater. Clogging of the infiltrative surface rather than quality of the percolated water is the principal factor in relation to particles, with the possible exception of bacterial and viral cells which have the potential to multiply in the human body."

To progress from the general statements above to predictions of water quality that can be obtained from a specific soil system, several factors must be considered. The quality of water obtained by way of groundwater recharge with wastewater depends on:

1. Quality of wastewater.

2. The method of application (i.e., crop irrigation or rapid infiltration basins).

3. Rate of application and total annual quantities applied.

4. The depth to the water table, characteristics of the soils above the water table, and the characteristic of the geological material below the water table comprising the aquifer.

5. The elapsed time between application and withdrawal as determined by rate of groundwater flow and distance between point of application and discreet drainage collector.

Le Grand (1964) described a method for conducting a preliminary site evaluation in terms of groundwater contamination potential from areas where wastes are released to loose granular earth at or near ground surface. He presented the method as a means for making a quick initial appraisal of the suitability of a site for the discharge of "contaminates that attenuate or decrease in potency with time, by oxidation, chemical or physical sorption, and dilution through dispersion". The method involves the estimation or measurement of five environmental factors. The factors are the (1) depth to permanent water table, (2) adsorption capacity of the geological materials, (3) permeability of the geological material, (4) water table gradient, and (5) distance to point of use. His figure, reproduced below, depicts the relationship between the five factors:

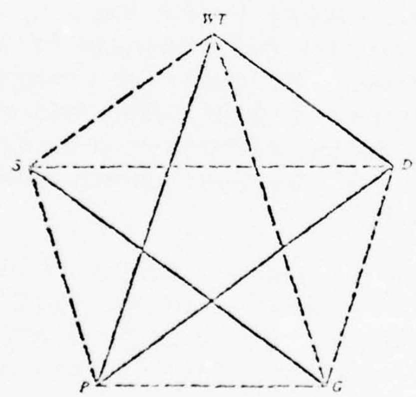


Diagram of Environmental Factors

WT stands for water table; D, distance; G, gradient; P, permeability; and S, sorption. The solid lines connect directly related factors; the dashed lines, inversely related factors. Relationships are not necessarily mutually exclusive and may be lacking or obscured because of overriding factors.

The water table is the distance below the base of the disposal line (soil surface for crop irrigation), as determined by its position 95 percent of the time. Both sorption and permeability is based on particle size or texture of the geological material. The water table gradient is determined from the average elevation values obtained from a water table topographical map for the affected area. The distance used is the straight line distance the fluid travels. From repeated trials and adjustments of values obtained from actual and hypothetical field conditions, Le Grand developed a scale for each of the five factors from which measured values can be converted to weighted values. He refers to the weighted values as "point values". A point value is a numerical expression of the relative importance that a particular factor exerts in the dissipation of the contaminates contained in wastewater. The sum of the "point values" representing each of the five environmental factors is used to predict the suitability of a particular site for renovating wastewater. Prediction of the possibility of water contamination based on total "point values" for a particular waste discharge site are interpreted from another scale. Potential contamination classifications range from imminent to impossible. He also points out that sites may be improved by such things as lowering the water table, reducing gradients by reduced pumping of wells and/or reducing input or loading rates, appropriate pre-treatment of waste, introduction of sorptive material in the path of the waste, etc.

Le Grand's empirical method for evaluating sites for waste disposal and water renovation points the way for the development of better methods for prediction. It succeeds in organizing five interdependent factors in such a way that a deficiency in one factor and its compensation by another is taken into account for easy interpretation.

Nelson and Eliason (1966) described a more sophisticated method for predicting the movement of components through the ground. Their method involves the solving of a Eulerian boundary value problem to obtain the potential energy distribution throughout a particular flow system which is then used to set up Lagrangian equations. Solving the Lagrangian equations provides the paths of flow, the flux or material distribution, and the time of travel along the flow paths. After having obtained the macroscopic or average flow effects, they show how the microscopic aspects of hydrodynamic dispersion and diffusion can be combined with the macroscopic analysis. The combination permits the prediction of the arrival distribution at a particular point in the porous media of a fluid-coincident component (travels with and at the same rate as water) contained in the wastewater.

Along the same line of reasoning Cearlock (1966) illustrated how equations describing biological, chemical, and physical reactions of pollutants with their environments could be interrelated with those for flow analyses. The transport equation, derived from the interrelation of the equations for the two independent phenomena of fluid flow and reactions rate, yields the concentrations distribution of a fluid-non-coincident component (such as ammonium, phosphate ions, etc.) in the groundwater flow region.

Before wastewater disposal or water reclamation projects are initiated, every effort should be made to anticipate the quality of the reclaimed water attainable from the use of a particular site. The calculation of concentration distributions of components provides information that can be used to assure the most efficient and economic use of a site, control of the water after infiltration, efficient location of sampling wells for monitoring and drainage wells for recovery.

Nitrogen and phosphorus. The use of several agronomic crops and native forests have been used in a study still in progress at Pennsylvania State University, to determine the chemical, physical, and economic feasibility of using growing plants and soil systems to renovate secondary waste treatment plant effluents (Kardos, 1967) (Sopper,1968). From the work now in progress at Penn State and other reported experiences, it appears that the amount of nitrogen applied as a constituent of the effluent will limit the amount that can be continuously applied on a particular soil area. Phosphorus sorption and conversion to sparingly soluble compounds should be sufficiently rapid in most agricultural soils that its transport to ground water supplies would be exceedingly small, corresponding to background unpolluted ground water and surface water concentrations.

Furthermore, there is reason to believe from information reported by Ellis and Erickson (1969), that much of the phosphorus adsorption capacity of the soil would be restored during the winter months by conversion of adsorbed phosphorus to sparingly soluble substances. They found that 33 to 100 percent of the phosphorus adsorption capacity was recovered at the end of 3 months in the phosphorus saturated surface horizons of 29 soils found in Michigan. Many of the soils had sandy surface horizons. The B horizon of most of the soils had recovered 100 percent of their phosphorus adsorption capacity at the end of three months. Most of the soils having sandy surface horizons adsorbed three to four times more phosphorus than dune sand. Thus, even the most unproductive type of soil found in the Midwestern States would appear to have sufficient capacity to renovate wastewater containing relatively high concentrations of phosphorus for long periods of time.

Trace elements. Trace elements originating from industrial waste are likely to be present in relatively low concentration in treated effluents as compared to their concentration in the sludge material. About 75 to

85 percent of the trace elements arriving at an activated sludge treatment plant are removed and accumulate in the sludge. Even so, effluent will, for the most part, be applied on land at much higher rates than sludge and probably on sandy lands where high infiltration capacities are assured. Infiltration rates for water from sludges is controlled by the sludge solids and not by soil class; that is, soil texture is relatively unimportant from the standpoint of dewatering sludge on land. But because clay minerals, with their combination of adsorption and ion exchange properties, are important in fixing heavy metals in insoluble forms, heavy textured soils are preferred for utilizing sludge. Since sandy soils, with a reduced capacity for fixing heavy metals, are more likely to be used for renovating wastewater effluents, every effort should be made to keep soluble metal elements at tolerable concentration levels. Tolerable concentrations are those recommended as maximum permissible levels in irrigation water by the National Technical Advisory Committee (1968) and published in Water Quality Criteria. For the major portion of the metals, most municipal effluents would meet the recommended standards for heavy metal concentrations. In the municipalities where heavy metal problems arise, those industries discharging large quantities of the problem metal elements should be persuaded to appropriately pretreat their wastes.

Summary. The performance of the soil process can be most concisely summarized by examining the end-product of each constituent that might come into contact with the soil via wastewater irrigation.

Suspended solids are removed by the array of mechanisms one ascribes to dispersed media filters, i.e., screening, entrapment, gravity forces, coagulation and flocculation and Van Der Waal forces. Organic suspended solids thus captured by the soil mantle slowly breakdown and solubilize and are converted through microorganism metabolism to new organic cell matter and gaseous carbon dioxide. The new organic matter and the inert residues, together with the inert suspended solids that are also captured, accumulate slowly in the soil mantle. The solid, but organic, content of soils, with or without irrigation, solubilizes and is lost to the soil mantle at a net rate of three to four percent per year. The critical design consideration for application rate of suspended solids via irrigation is that the soil system does not become clogged and that the rate of organic deposition does not exceed the eventual assimilation capabilities of the soil microorganisms. The literature is replete with documentation indicating that pre-treated wastewater, such as characterized by municipal secondary effluent, does not begin to strain the soil's assimilative capacity for suspended solids.

Dissolved organics, including organic nitrogen constituents and those constituents characterized as biochemical oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon (TOC), organic-derived color, oils and grease, are removed in the soil mantle by means of an adsorption mechanism. Two widely different components in the soil are capable of this adsorption mechanism. One of the components, microorganisms, must adsorb the dissolved organics into their exterior enzyme system in order to pre-process the dissolved organics for subsequent metabolic uptake in which new cell matter and carbon dioxide are the final products. The latter part of this process requires aerobic soil conditions. The second soil component, clays, are also capable of adsorbing dissolved organics much like activated carbon adsorbents. The organics sorbed on such clays are, in a sense, stockpiled for subsequent processing by microorganisms. In this case, however, the microorganisms must be mobile since the organic molecules remain fixed to the clay adsorbent until completely assimilated by microorganisms. In the case of either adsorbent, the uptake of organics can be quite rapid. A substantial literature testifies to the adequacy of the soil process for easily assimilating dissolved organics in the range of concentrations encountered in municipal secondary effluents.

Nitrogen, in the form of ammonia and nitrates and nitrites, is captured by a variety of mechanisms and is the constituent in wastewater that limits the overall irrigation application rate of a typical municipal secondary effluent wastewater. Ammonia nitrogen is captured by an ion exchange mechanism, commonly referred to as the cation exchange capacity of the soil, which is particularly manifested by organic and clay components of the soil mantle. This mechanism is capable of capturing other cations as well as the ammonium ion but maintains a rechargeable selectivity for the ammonium ion large enough to give the soil mantle a nitrogen banking capacity against the future distributed nitrogen demands of the growing crop. This is the soil property that permits the farmer to apply his fertilizer in discrete amounts and still supply the distributed demand of his crops. The ammonia nitrogen is subsequently attacked by nitrifying microorganisms during the spring to fall period of the year and converted to nitrate nitrogen which is no longer held by the soil mantle but is instead free and mobile and capable of migrating to the crop roots where it is assimilated by the growing crop.

Not all of the nitrate nitrogen is adsorbed by the crop roots, however, and this balance, together with any nitrite nitrogen, is free to migrate down towards the groundwater sump below the soil mantle.

Along the way, the nitrate and nitrite nitrogen will encounter denitrifying bacteria that will, as long as a source of dissolved organic carbon is available, partially reduce the oxidized nitrogen forms to nitrogen gas and manufacture some new organic cell material. The remainder of unreduced nitrate and nitrite nitrogen will eventually migrate to the groundwater table where further change will cease.

Some of the ammonium ion stored in the soil mantle will also be the nitrogen source for the new microbial cells formed by aerobic synthesis in the upper soil mantle. If more dissolved organic carbon substrate were available in the irrigated municipal secondary effluent wastewater, a much more significant portion of the total nitrogen applied in irrigation would report to microbial synthesis. Present well-managed fertilizer strategies, as applied to agricultural crops, regardless of whether the fertilizer source is commercial chemical or irrigated municipal secondary effluent, appears to permit a residual of approximately ten percent of the applied nitrogen to percolate through to the groundwater. While this residual concentration is below any problem-causing concentrations, it nevertheless is a waste of a resource.

It is possible that regional wastewater management, through its bringing together of municipal and industrial waste residues, will produce a combined irrigable wastewater with a higher overall carbon to nitrogen ratio that will materially affect the nitrogen dynamics within the soil mantle and that will likely affect the governing rate of total irrigating water per acre per year. Most industries producing an organic waste have a wastewater that is nitrogen-deficient as contrasted with municipal secondary effluent.

The evidence in the agricultural literature demonstrates that nitrogen applications in practical balance with crop uptakes yield agricultural drainage water with up to 2 mg/l nitrogen representing ten percent of the applied nitrogen. While it is possible to produce much higher nitrogen concentrations in the drainage water consistent with much higher rates of application, this practice does not reflect good management, regardless of whether the source of nitrogen is commercial fertilizer or pre-treated wastewater.

Phosphorus, in the soluble form as orthophosphate, is removed in the soil mantle by adsorption/ion exchange on soil clay constituents. In acid soils, the phosphorus absorbing constituents are primarily aluminum and iron. In basic soils, the calcium and magnesium content of the clays can contribute strong adsorption sites for phosphorus.

There is always an equilibrium amount of soluble phosphorus present in the soil solution from which the crop is able to derive its requirements through the root structure. Phosphorus is applied at a rate which exceeds the crop uptake; thus, the soil is called upon to act as an ultimate sink for phosphorus.

The active adsorbing components in the soil clays at any one time are only an estimated ten percent of the total components within the soil potentially capable of adsorbing and holding phosphorus. Once the immediate phosphorus adsorbing capabilities of the soil have been saturated, a resting period, such as the winter non-irrigation season, is required to permit the chemical equilibria within the soil mantle to readjust and produce new active phosphorus adsorption sites. Complete adsorption activity is recovered within three to six months.

From a short-term equilibrium adsorption consideration, the range of sandy-to-clay soils and their respective depths that have been encountered have exhibited phosphorus removal lives of ten to one hundred years. From the standpoint of the long-term equilibrium adsorption capabilities of this same soil range, allowing for appropriate rest and recovery periods, the phosphorus removal life of these soils is between one hundred and one thousand years. The capabilities of the soil to adsorb and hold phosphorus is evident both from the literature and from the residual concentrations of phosphorus in groundwater in agricultural areas. In well designed irrigation systems, using municipal secondary effluents, it is possible to produce an agricultural drainage of reclaimed water with background phosphorus concentrations of 0.01 mg/l.

Virus and pathogens are removed by the same mechanisms as cited for suspended solids since they are, indeed, microscopic suspended solids. Various investigations have determined that, once these constituents have been captured in the soil mantle, they do not long persist. Apparently, the soil environment is not conducive to their survival, perhaps, because the indigenous soil microorganisms are too acclimated and competitive to permit a less than indigenous species to survive. A properly designed soil process irrigation system is capable of doing a one hundred percent effective job of disinfection.

Heavy metals are ion exchange/adsorbed by the clay constituents of soils and are chelated by the organic constituents of soils. Once captured by the soil, they are held irreversibly in the normal soil experience, requiring varying degrees of acidic leaching to effect their release. Within certain limitations prescribed by agricultural experience, small residual concentrations of most metals are compatible with soils and can be almost completely removed by soils. As the organic concentration of soils decomposes, new solid organic matter is being formed along with the deposition of more clays, so that in a "living filter" type of soil system there appears to exist an unlimited life sink for controlled amounts of heavy metals.

Chlorinated hydrocarbons, pesticides and phenol-like substances are captured in the soil by adsorption mechanisms much like other dissolved organics and subsequently converted to new cell material and gaseous carbon dioxide by aerobic microorganisms. The acceptable concentration of these constituents in the soil and wastewater system must be substantially controlled and regulated by pre-treatment, however, much like the limitation on heavy metals. These organic species are largely inimical to the soil microorganisms, and to abuse the soil system with an overload would eliminate the very microorganisms that accomplish the adsorption, an ultimate disposal. The pre-treatment afforded by the municipal biological system in producing a secondary effluent is sufficient guarantee against excessive concentrations of these species.

Total dissolved solids exclusive of the species heretofore discussed, pass through the soil process unaltered. Typical of constituents in this category are sodium, sulfate, and chloride. Potassium is largely extracted by the crop root system for crop growth.

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2. IRRIGATION IMPACT ON AGRICULTURE

Productivity

There is little doubt that in most years in the North Central States, feed grain and forage crop yields could be increased 20 to 100 percent, depending on the soil type, by the process of wastewater irrigation according to crop nutrient needs. The greater yields, in terms of percentage increase, would be expected on soils with low available water holding capacities, such as sandy loams and sands. Wastewater irrigation has also been carried on with success in less permeable soils without any detrimental effects due to the prevailing moist soil conditions. It is unlikely, however, that crop yields would show marked increases under those latter conditions. There certainly exists some level of minimum soil permeability for a given crop and a given irrigation rate at which detrimental effects would be observed in the crop production.

Recommended Grass Crop

Where sandy soils are to be utilized for renovation of wastewater, the one most ideal crop appears to be Reed canarygrass, *Phalaris arundinacea*. First, it is adapted to the northern half of the United States and Canada. It grows well in poorly drained areas and can withstand several weeks of flooding without excessive injury. Paradoxical as it may seem, Reed canarygrass is also one of the most drought-resistant, cool-season grasses. This is not really a paradoxic characteristic, however, because nearly all grass plants capable of withstanding long periods of flooding are also exceedingly drought tolerant. It is a cool season perennial, one of the earliest grasses to begin growth in the spring, one of the very few grasses that will continue to grow in July, and only a few grasses, such as Kentucky bluegrass, will continue to grow at colder temperatures than will Reed canarygrass. From the standpoint of selecting a plant to serve as a scavenger of plant nutrients from wastewater, it is helpful to have a plant that starts growth very early in the spring with a full-blown root system and which continues to grow during the summer season and well on into late fall.

If not managed by proper grazing or cutting for hay, Reed canarygrass may grow to heights of four to seven feet and become very coarse and unpalatable to livestock. On the other hand if, by either grazing or clipping, the grass is not permitted to make excessive growth, it compares very well in palatability and rate of intake by livestock with a number of other grasses. When properly fertilized and managed, Reed canarygrass is superior to several other grasses in that it often has a higher protein and mineral content and a lower lignin and fiber content. Reed canarygrass yields and protein content can be greatly increased with nitrogen fertilizer as evidenced by the data in Table BA-IV-A-7 compiled from a report by Ramage et al (1958).

The four levels of nitrogen shown in Table BA-IV-A-7 were applied annually for three years in the form of ammonium nitrate on a pure Reed canarygrass stand grown on Duchess shale loam at the Rutgers Dairy Research Farm in northern New Jersey. The 50 and 100 lbs per acre nitrogen applications were made each year after the first cutting, while the two higher levels were split, half of each being applied each year in March and the remaining half after the first cutting. All plots were fertilized each spring with the equivalent of 100 lbs per acre of P_2O_5, and 100 lbs per acre of K_2O. The grass was cut three times each year and the dry matter yields reported in Table BA-IV-A-7 are average total yields for three cuttings for three years. Dry matter yields were determined by drying at 100°C.

In view of the yields as given in Table BA-IV-A-7 it is tempting to speculate that where wastewater is supplied in sufficient amounts at time intervals just adequate to maintain optimum levels of water, nitrogen, and other nutrients in the grass root zone, average dry matter production might exceed by a considerable margin the 4.5 tons per acre obtained with the 400 lbs per acre nitrogen treatment. If the dry matter yield could be increased by optimizing the water and nutrient supply, there is no reason not to also expect even higher protein levels in the forage. Protein contents may approach those normally reported for alfalfa. The potassium supplied by wastewater may be a real advantage in considering the demand for the element with increasing yields, as reflected from the results for potassium removal. Furthermore, it seems reasonable to expect that a considerably greater percent of the nitrogen supplied in wastewater would be recovered than is reported in Table BA-IV-A-7 for application of ammonium nitrate. First, the nitrogen would be evenly distributed throughout the growing season in amounts that meet but do not greatly exceed the nutrient needs of the grass for maximum production. Secondly, the nitrogen supplied in wastewater would be in the ammonium and organic form and thus would be retained within the grass root zone by light, frequent applications.

Daily intermittent spray irrigation may be especially significant in obtaining high yields of forage materials in that the continuous maintenance of high moisture levels will help to insure maximum intensity of cell division and cell enlargement in plant leaves. Intensive cell division and a high degree of cell enlargement provide conditions for a more efficient photosynthetic capacity of leaves, than can be achieved when plants are

Table BA-IV-A-7

EFFECT OF NITROGEN LEVELS ON REED CANARYGRASS YIELDS, COMPOSITION AND RECOVERY OF N AND K

Treatment	Dry Matter	Protein	Potassium	K Removed	Available K Flow layer 1955	Nitrogen Recovered 1954 only	
lbs of N/Acre	lbs/Acre	percent	percent in forage	lbs/A/yr.	lbs/Acre	percent	
						vs. zero level	vs. next lower level
50	4,991	12.94	2.34	126	185	60.5	60.5
100	6,359	13.67	2.26	148	154	75.4	90.2
200	8,086	15.36	2.19	187	130	62.7	50.2
400	9,319	19.62	1.96	191	104	58.7	50.0

allowed to periodically suffer a water stress. Under normal field conditions growing plants often suffer relatively short periods of water stress during the day when the rate of water loss from leaves by transpiration exceed the rate of water intake by roots. The severity of the water stress in terms of yield reductions depend on soil moisture content, soil type, climatic conditions, kind of crop, and stage of plant growth. For vegetative crops the water stress can often be severe enough to affect yields of dry matter without being visually obvious. During summer months in the North Central States, daily spray irrigation is probably the only way periods of water stress can be prevented in plants growing on coarse sandy textured soils. By spray irrigation of water directly on leaf surfaces to maximize evaporation the losses of water by transpiration are lower. Thus, the demand for a high rate of water adsorption by plant roots from the surrounding soil is decreased. The reduced requirement for a rapid intake of water by roots in sandy soils is of special benefit because water conductivities in sands decrease very rapidly as water content decreases. When the flux of water from the soil to the root surface is less than the outflow of water by transpiration, water is depleted in plant leaf tissues as water continues to be lost by transpiration. This water stress and the causing of reduced yields may often be temporary, developing only during periods of maximum radiation loads.

To prevent the development of water stresses that may decrease yields of Reed canarygrass growing on sandy lands, soil moisture contents should be maintained at not less than eighty percent of the available water holding capacity of the soil.

Daily light spray applications of wastewater would provide for a longer retention period near the soil surface and within the plant root zone for efficient adsorption of the plant nutrients. With frequent, light applications, a greater quantity of the plant nutrients contained in wastewater will be exposed to the adsorption surfaces of plant roots, lessening the chance for nutrients to move with percolating water to soil depths below the root zone. Furthermore, daily spray irrigation with wastewater would very likely increase the total and actively adsorbing root surface over that obtainable with infrequent heavy application. Almost any practice that increases top or shoot growth would also increase root development.

Impact of Grass Crop Strategy on Area

Since it is envisioned that for some large metropolitan areas as much as 1,000 square miles may be needed for a wastewater irrigation project, some thought has to be given to the utilization of the grass produced by the operation. Utilization as a hay crop would require a rather large livestock enterprise within or adjacent to the wastewater reclamation site. On the basis of the above estimated yields, about 3.8 million tons of hay would be produced each year. Assuming the consumption of 25 pounds of hay per day per 1,000 pound animal, about

5 tons of hay per year would be required per animal. Thus, to use all the hay would require the presence of about 760,000 cattle in the area. Since each animal would excrete 0.3 to 0.4 pounds of nitrogen each day, about 97.3 million pounds of nitrogen would be generated each year from the livestock operation. Allowing for an ammonia volatilization loss of 40 percent of the nitrogen contained in animal waste, about 58.4 million pounds of nitrogen would need to be recycled to land. A maximum loading rate of 500 pounds of animal waste nitrogen per acre per year, would require 116,800 acres of additional land. The next year additional livestock would be needed to consume the produce from the additional 116,800 acres, increasing the animal waste disposal problem and the requirement for additional acreage each year. Utilization of the grass through a silage system would result in similar nitrogen retentions within the area. Thus, export of some crops from C-SELM for animal feed is required. The amount of nitrogen exported from the area in this manner should just equal the amount of nitrogen imported into the C-SELM area in the form of other food products. Another Alternative is the use of the animal manures on otherwise unfertilized acres; this approach properly applied can accommodate the C-SELM produced nitrogen entirely in the C-SELM area of influence.

One way to avoid compounding an animal waste disposal program with a municipal wastewater renovation program would be to cut Reed canarygrass at a height of about 12-18 inches, dehydrate, pelletize, and market in much the same way as alfalfa is handled. Properly managed the total and digestable protein content of the grass should compare favorably with alfalfa. One great advantage to this method of marketing the grass is that it would present a minimum of inconvenience to the irrigation operation. Reed canarygrass produces a massive root system, capable of supporting harvesting equipment immediately following an application of water by irrigation or rainfall. Therefore, irrigation schedules do not need to be changed for harvesting operations.

Alfalfa is the crop most commonly dehydrated, but grass crops properly managed can be processed for marketing in the same way. Perennial rye, canary, and fescue grasses are grown in British Columbia for dehydration (Chrisman 1956). In Florida, Pensacola Bahia grass is dehydrated and pelleted for cattle and horse feeds (Brown 1966). In the Southeastern United States, coastal burmuda grass is dehydrated on a fairly extensive scale. The U.S.D.A. Agricultural Research Service has accumulated a great deal of information regarding the dehydration and pelleting of coastal burmuda grass at their research laboratory at the Georgia Coastal Plains Experiment Station, Tifton, Georgia.

Freshly harvested grasses generally have higher moisture contents than alfalfa and thus the operating cost of dehydrating grass is higher than for alfalfa. Therefore, to reduce the cost for dehydrating Reed canarygrass it might be desirable to utilize field drying after clipping to reduce moisture contents to not more than about 70 to 75 percent of its dry weight. With field drying, cost of dehydrating to a final moisture content of 8 to 10 percent dry weight should be comparable to the cost for processing alfalfa.

Figure BA-IV-A-5 is a schematic view of the dehydration and pelleting process for Reed canarygrass, which was originally presented as Figure 5 in Guidelines for Cooperative Alfalfa Dehydrating Plants, U.S.D.A., Farmer Cooperative Service, Information Bulletin 68, 1970. The economic considerations of dehydration are discussed in some detail in the same bulletin. It is estimated that the cost for a dehydration plant having an 18,000 pound per hour evaporative capacity would range from 377,515 to 419,165 dollars. The estimate includes cost of land, buildings, and equipment for harvesting and hauling, dehydration, grinding, pelleting, and storage. Such a dehydration plant would have a 3 to 4 dry ton per hour output and a 100 day seasonal output of 10,000 tons. Considering all fixed and variable cost, including marketing, it is estimated that the total cost for producing a ton of dehydrated alfalfa pellets would be 40.55 dollars. However, this estimate includes a purchase cost of 10.50 dollars per ton of fresh alfalfa on a dry weight basis. From these data it appears that a cost of 30 to 35 dollars per dry ton would be a reasonable cost estimate for processing and marketing the Reed canarygrass used as a nutrient scavenger in a water reclamation project.

Dehydration plant sizes generally range from 6,000 to 30,000 pounds per hour of evaporative capacity. Some reduction in processing cost might be realized by the installation of a larger capacity plant than the size for which estimates were presented. Generally, the capacity of dehydration plants have been regulated by the availability of the crop. To keep transporting cost to a reasonable level, the haulage distance from the field to the dehydration plant should not exceed 10 miles.

Where several square miles are dedicated to the continuous growing of Reed canarygrass as part of the scheme for renovating wastewater, the dehydration plant could be centrally located to minimize cost for transporting the raw materials. For example, if the dehydration plant was centrally located in a 10 square mile area the haulage distance would seldom exceed much more than about 5 miles. The 10 square

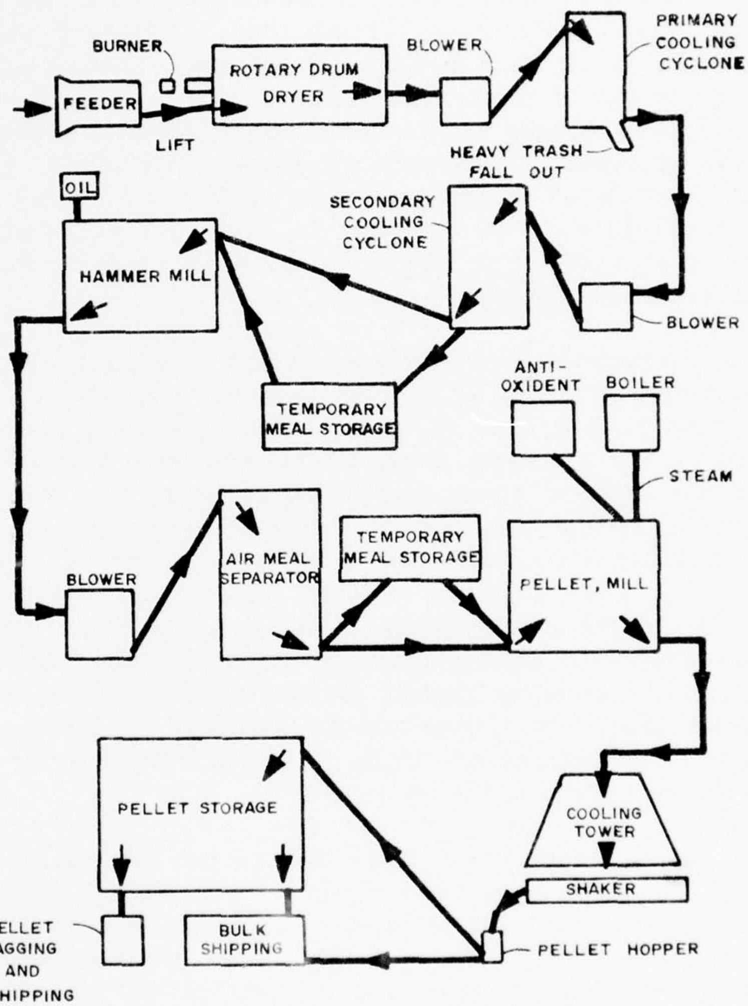

Figure BA-IV-A-5

DEHYDRATED ALFALFA PLANT MATERIAL FLOW

miles could enclose 64,000 acres on which about 320,000 tons of Reed canarygrass could be produced at an annual production of 5 tons per acre. If during the growing season the dehydration plant is operated 120 days, then about 2,666 tons of raw material must be dehydrated during each 24 hour day. On an hourly basis the dehydration plant must have an output of 111 dry tons. Assuming for grass that a dehydration plant must have an evaporative capacity of 6,000 pounds per hour per ton of production, then a plant with an evaporative capacity of 666,000 pounds per hour will be needed to process the Reed canarygrass produced within each 10 square mile area. If some economies can be realized in the construction of a larger dehydration plant, centrally located with respect to fields for efficiency of operation, then processing cost should be no more than 30 dollars per ton and perhaps significantly less.

During the last ten years prices for dehydrated alfalfa meal, containing at least 17 percent protein and 100,000 units of vitamin A, have ranged from 42 to 52 dollars per ton. Dehydrated Reed canarygrass produced under wastewater irrigation conditions will have a nutrient value equivalent in all respects to alfalfa, but what kind of price it will command on the open market is not known. However, considering the quality and quantity of produce, and the convenience to Great Lakes shipping centers, foreign markets may be developed for all of the production by an effective promotional program. The sizeable volume of quality produce would warrant a large-scale promotional program to develop foreign markets which have not been available to alfalfa producers. Overland transport of alfalfa meal is expensive and many large centers of alfalfa production are too far from port facilities to compete in world markets.

If a market price of 45 dollars per ton could be developed then about 75 dollars per acre would be available to offset the wastewater application cost. Once Reed canarygrass has been established, the cost for producing raw materials is essentially that of wastewater applications. All other cost of harvesting are included in the 30 dollars per ton of processing cost.

Recommended Grain Crops

Substantially greater amounts of nitrogen are removed from soils by the harvesting of corn than by any other grain crop. Each bushel of corn grain harvested will contain about one pound of nitrogen. A bushel of wheat will contain about one-third of a pound more nitrogen than corn, but total yields per acre for wheat are considerably lower than corn, at least in the North Central states. With good management practices, a yield of 200 bushels per acre of corn grain should be possible on the corn belt sandy lands irrigated with municipal pretreated wastewater. Special care will be needed to maintain the moisture supply at a level greater than 80 percent of the available moisture holding capacity of sandy soils, especially during the critical period of six weeks before to three weeks after the tasseling stage. On some sandy soils with less than an inch of available water per foot depth, at least 0.35 inches of wastewater per day will be required from May 15 to August 15 of each year.

Precautions Against Hazards to Soil, Crops and Humans

Using soil columns and field plots, Lehman and Wilson (1970) studied the fate of iron, manganese, nickel, copper, zinc, lead, cobalt, hexavalent chromium, cadmium, and strontium during and after their application on soils as a constitutent of sewage effluent. They found significant amounts of iron, manganese and copper in filtrate samples and concluded that these metals may be the first to saturate soils. Cobalt and hexavalent chromium were never present in detectable amounts in the sewage effluent. Strontium moved with water through the soils at a relatively rapid rate. Intermittent irrigation practices that resulted in an aerobic environment provided the most favorable conditions for the filtration of metals by soils. Bermuda grass did assimilate several trace elements but not in sufficient quantities to sustain the metal filtering capacity of the soil. Effluent applications ranged from 427 to 602 inches in 11 weeks.

LeRiche (1968) found increased concentrations of chromium, copper, nickel, lead, and zinc in 0.5N acetic acid extract of soil samples collected from plots treated with 568 tons of sewage sludge per acre, as compared to untreated plots. He also determined trace element concentration in leeks, beets, potatoes, and carrots grown on treated and untreated plots. Plants grown on treated and untreated plots were analyzed for cobalt, chromium, copper, molybdenum, nickel, lead, and zinc contents. Those from treated plots contained larger concentrations of nickel and zinc but not of copper and lead when compared to amounts in plants grown on control plots. Nickel and zinc tended to be more strongly concentrated in tops than roots. There was no evidence that the sludge treatment caused an increased uptake of heavy metals in potato tubers. Crop yields were not affected by sludge treatments.

Hinesly, et al (1971) have analyzed various types of crop plants grown on plots fertilized with anaerobically digested sludge for several trace elements. While nearly all of the trace elements except mercury tend to increase in plants with increased sludge fertilization rates, none approach levels that would present a hazard to animals consuming the produce.

Three important literature reviews reveal the fact that, even with partial treatment of waste and chemical disinfection, some potential disease hazards exist for both human and animal consumption of uncooked crops which have been irrigated with waste treatment plant effluents (Rudolfs, Falk, and Ragotzke, 1951) (Seep, 1963) (Geldreich and Bordner, 1970). In general, it appears that only secondary effluent or equivalently treated wastewater which has been chlorinated should be used for irrigation of vegetables to be eaten raw. Even treated wastewater should not be used for irrigation of vegetables during the last twenty days prior to harvest.

Adams and Spendlove (1970) found aerosolized microorganisms transported downwind during the night a distance of 0.8 miles from a trickling filter used in secondary treatment of sewage effluent. However, it should be pointed out that the potential health hazard from pathogenic microorganism transported in aerosols has not been well documented. Such concerns may lack foundation because no one has ever been able to show that the incidence of disease in sewage treatment workers is greater than chance occurences to be expected in normal populations (Dixon and McCabe, 1964). However, to preclude against any such possibilities, wastewater irrigation systems must be designed to eliminate aerosal development through proper design of dispersion systems and all effluents to be irrigated must be disinfected prior to irrigation to the extent necessary to preclude significant health hazard.

In a discussion of pond systems for wastewater purification Stander, et al (1970) states that "an effluent bacteriological count of 1,000 E. coli Type I per 100 ml should be considered the upper limit of the 97.5% confidence range (exceeded by only 2.5%) of effluent quality. In most instances, such effluents should be acceptable for flood irrigation of crops for human consumption that are not likely to be eaten raw, for flood irrigation of fruit and trellised vines, for irrigation of pastures for grazing, for irrigation of golf courses, parks and sport fields, and for discharge into streams." A National Technical Advisory Committee (1968) suggested as a guideline for the bacterial quality of irrigation water that the fecal coliform should not exceed an arithmetic average of 1,000 per 100 ml. The average count should be based on at least two consecutive samples examined per month during the irrigation season and any one sample examined in any month should not exceed a fecal coliform density of more than 4,000 per 100 ml.

Except perhaps for the protection of workmen employed on the irrigation wastewater renovation site, the above bacteriological quality criteria may be too restrictive. First, the criteria is intended for use on waters for irrigation under conditions in which no provisions exist for controlling tail waters and return flows. Plans for wastewater reclamation sites must always include plans to maintain complete control over all water applied or falling on the area. Secondly, the criteria was established to protect the public, members of which might come into immediate contact with the irrigation water. A wastewater reclamation site would usually be considered a tertiary water treatment facility except for multiple use areas such as parks and green spaces and thus should be no more public than any other similar processing plant. The third point to make is that, where grass is used as a nutrient scavenger to be dehydrated by heat before it is marketed, the chances for disease agents to be transmitted through the crop produce is nil.

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3. NITROGEN BALANCE FOR THE LAND TREATMENT SYSTEM

Introduction

The purpose of this section is to present the detailed design calculations for the nitrogen loading and nitrogen balance of the land treatment system. As previously mentioned in Appendix B, Section IV-A, the mass of nitrogen applied to the land controls the application rate of wastewater. The detailed calculations for estimating C-SELM wastewater nitrogen concentrations for the design year 2020 are presented in this section together with the irrigation application rates and the design land system nitrogen balance.

Nitrogen Concentration for Design Year 2020

Introduction. A detailed analysis is performed to estimate as closely as possible the C-SELM wastewater nitrogen content for the design year 2020. Because of the varying character of the wastewaters, three major wastewater generators are analyzed. The first is typical domestic wastewater generated in the suburbs of Illinois. The second type is the MSD wastewater where flow is characterized by large industrial inputs. The third type is that projected for the State of Indiana. Included in this flow are typical municipal wastewater together with recycled flows from the two critical industries, petroleum and steel.

Illinois suburbs. For the design year 2020, approximately 18% of the total dry weather wastewater flow in the C-SELM study area is contributed by suburban areas in Illinois. The character of this flow is mainly that of a domestic wastewater. After secondary treatment, the total nitrogen content of this waste is assumed to equal 20 mg/l.

MSD. For the design year 2020, approximately 67% of the total C-SELM dry weather flow is contributed by urban areas in Illinois which are presently typified by the MSD wastewater flows. These flows have significant industrial contributions and therefore cannot be considered typical of a domestic waste. Data covering a five-year period for the three largest MSD plants serving the Chicago area indicates that the average nitrogen content of the wastewater is 15.2 mg/l.[1/]

Indiana. The Indiana wastewater flows are comprised of three major types. The municipal sector contributing 57% of the total flow is characterized by a typical total nitrogen content of 20 mg/l. As presented in Appendix B, Section III-B, approximately 10% of the total dry weather flow in Indiana is contributed by the petroleum industry.

This flow represents a 91% recycle of wastewater over the present practices. It is estimated that presently 35 pounds (#) of ammonia nitrogen finds its way into industrial wastewaters per 1000 barrels of crude oil produced.[2] The production of 1000 barrels of oil presently requires 440 gallons of wastewater. Therefore the estimated present nitrogen content of petroleum wastes is

$$\frac{35\#\ N}{1000\ barrels} \times \frac{1\ barrel}{440\ gal.} \times \frac{1\ MG\text{-}mg}{8.34\ \#\text{-}1} \times \frac{10^6\ gal.}{MG} = 9.54\ mg/l$$

Assuming a 91% petroleum wastewater recycle for the year 2020, then .09 (440) or only 40 gallons of wastewater would be generated per 1000 barrels of crude oil produced. This recycling effect increases the 2020 total nitrogen concentration in petroleum wastes to:

$$\frac{440}{40}\ (9.54) = 105\ mg/l$$

The third type of waste generated in Indiana is contributed by the steel industry. As presented in Appendix B, Section III-B some 3640 pounds of ammonia nitrogen are lost to wastewater in the production of 4110 tons of steel. Present steel production practices utilize 40,000 gallons of water per ton of steel. This represents an estimated total nitrogen content of the wastewater equal to:

$$\frac{3640\ \#\ NH_3}{4110\ Tons\ of\ steel} \times \frac{14\#\ NH_3\text{-}N}{17\#\ NH_3} \times \frac{1\ Ton\ steel}{40{,}000\ gal.} \times \frac{1\ MG\text{-}mg}{8.34\ \#\text{-}1} \times \frac{10^6\ gal.}{MG} = 2.2 mg/l$$

Assuming a 92.5% recycle of the present steel wastewater generation, then 0.075 (40,000) or 3,000 gallons of wastewater are generated per ton of steel produced. This recycling effect increases the 2020 total nitrogen concentration in steel wastes to:

$$\frac{40{,}000}{3000}\ (2.2) = 29.3\ mg/l$$

The weighted total nitrogen concentration for Indiana wastewater is as follows:

Municipal	= 57% of flow @ 20 mg/l	= 11.4
Petroleum	= 10% of flow @ 105 mg/l	= 10.5
Steel	= 33% of flow @29.3 mg/l	= 9.8
	Average Total N Content	= 31.7 mg/l

Summary. A summary of the three major wastewater types are presented below:

Illinois Suburbs = 18% of flow @ 20 mg/l = 3.6

MSD = 67% of flow @ 15.2 mg/l = 10.2

Indiana = 15% of flow @ 31.7 mg/l = 4.8

Total Nitrogen Content on a dry weather flow basis = 18.6 mg/l

As presented in Appendix B, Section III-C, the stormwater flow to municipal systems is equal to $\frac{3630 - 2927}{3630}$ or 24% of the average dry weather flow. The total nitrogen content of urban stormwater runoff is cited to range from 2.7 to 3.5 mg/l.[3][4] Assuming a nitrogen content in stormwater runoff of 3.1 mg/l, the following calculation provides an estimated C-SELM wastewater nitrogen concentration on a wet flow basis.

$$\text{Nitrogen Content} = \frac{1(18.6) + .24(3.1)}{1.24} = 15.6 \text{ mg/l}$$

Assuming a 5% contingency factor, the total nitrogen content of the wastewater used in the design of the land treatment system is 16.5 mg/l.

Nitrogen Design Loading for Land System

The wastewater irrigation application rate for the land treatment system is equal to 4.5 inches per week for 30 weeks or some 134 inches of wastewater per year. The following calculation provides the design nitrogen load to the land system.

$$\text{Amount of Nitrogen Applied} = \frac{135 \text{ in.}}{\text{Yr.}} \times \frac{1 \text{ Ft}}{12 \text{ in}} \times \frac{1 \text{ MG}}{3.07 \text{ Ac.-Ft}} \times 16.5 \text{ mg/l} \times 8.34$$

$$= 500 \text{ pounds total Nitrogen/Ac./Yr.}$$

Nitrogen Balance

In order to insure conformance with the NDCP effluent standards, the amount of nitrogen applied must be consistent with the nitrogen crop uptake and the volitalization and denitrification nitrogen removal mechanism. It is assumed that 300 pounds of nitrogen/Ac./Year can be utilized by crops as shown in the agricultural cropping program paper of this section. Also 150 pounds of nitrogen/Ac./Year are lost through volitalization and denitrification processes. The remaining 50 pounds of nitrogen/Ac./year lost to the groundwater system is equivalent to the residual NDCP effluent nitrogen standard of some 2 mg/l.

PHOSPHORUS LOADING CALCULATIONS

Introduction & Assumptions

Assuming that phosphorus is retained in the acid C-SELM soils principally by the soil's concentration of available iron and aluminum, and that the stoichiometry between phosphorus and iron and aluminum can be expressed as follows, P + Fe and Al $\rightarrow$ $FePO_4$ and $AlPO_4$ the stoichiometric ratios between phosphorus and iron and aluminum for the respective C-SELM agricultural areas are as follows:

C-SELM Agricultural Areas
Soil Concentration in mg/kg

	Kendall County	McHenry County	Kankakee River Basin Area
Iron, Fe^{+3}	8	10	5
Aluminum, Al^{+3}	23	21	9
TOTAL	31	31	14

The average atomic weight of iron (atomic weight - 56) and aluminum (atomic weight - 27) in the C-SELM agricultural areas is designated by $\sum$ which equals:

Kendall County Calculation

$$\sum = \frac{8}{31}(56) + \frac{23}{31}(27) = 34.4$$

McHenry County Calculation

$$\sum = \frac{10}{31}(56) + \frac{21}{31}(27) = 36.3$$

Kankakee County Calculation

$$\sum = \frac{5}{14}(56) + \frac{9}{14}(27) = 37.4$$

The stoichiometric ratio of phosphorus to $\sum$ for these areas is:

Stoichiometric Ratio P/ , in #/#	C-SELM Agricultural Area
$\frac{31}{34.4} = 0.90$	Kendall County
$\frac{31}{36.6} = 0.86$	McHenry County
$\frac{31}{37.4} = 0.83$	Kankakee River Area

It is assumed that one-half the depth of the non-consolidated or soil layer is available for saturation for phosphorus adsorption and subsequent fixation without exceeding the design concentration for phosphorus in the drainage water, (a reasonable assumption inasmuch as the phosphorus concentration gradient in soil has been demonstrated to exhibit such a behavior).[5/] The phosphorus adsorption capability of the various C-SELM agricultural areas are as follows:

C-SELM Agricultural Area	1/2 Average Depth to Aquiclude, Feet	Phosphorus Adsorption Capability, #/Ac.
Kendall County	10	1220
McHenry County	10	1160
Kankakee River Area	30	1520

Kendall and McHenry County Calculation

$$4.35(10^4)\ \text{Ft.}^2/\text{Ac.} \times 10\ \text{Ft.} \times (10^2)\ \#/\text{Ft}^3 \times 31(10^{-6})\ \#\ \text{P}/\#\text{Soil} \times 0.86$$

$$= 1220\ \#\text{P}/\text{Ac. Adsorption Capability}$$

Kankakee Area Calculation

$$4.35(10^4)\ \text{Ft}^2/\text{Ac.} \times 30\ \text{Ft.} \times (10^2)\ \#/\text{Ft}^3 \times 14(10^{-6})\ \#\ \text{P}/\#\text{Soil} \times 0.83$$

$$= 1520\ \#\text{P}/\text{Ac. Adsorption Capability}$$

Land System Life for Phosphorus Loadings

The phosphorus concentration of irrigated wastewater applied to agricultural lands is estimated to equal 5 mg/l as soluble orthophosphate phosphorus. This concentration is based on present municipal wastewater data in the C-SELM area (6 mg/l) together with data on soluble phosphorus concentration of stormwater (1mg/l). This stormwater flow is estimated to equal some 20% of the total.

$$\frac{135}{12}\ \frac{\text{Ft of } H_2O}{\text{Yr.}} \times 62.4\ \#/\text{Ft}^3 \times 4.35(10^4)\ \text{Ft}^2/\text{Ac.} \times 5(10^{-6})\ \#\text{P}/\#H_2O$$

$$= 154\ \#\text{P/Year Input}$$

Phosphorus uptake by crop = 50 #P/Year

Net Phosphorus adsorbed in Land = 104 #P/Year

Therefore on the basis of available iron and aluminum concentrations, the short-term phosphorus removal lives of the C-SELM agricultural areas are as follows:

C-SELM Agricultural Areas	Short-Term P Adsorption Life of C-SELM Soils, Year
Kendall County	12
McHenry County	11
Kankakee River Area	14

The work of Ellis and Erickson,[6/] gives clear evidence that the short-term available iron and aluminum adsorption capability of soils is a renewable characteristic if a suitable rest period is provided the soil. During such a rest period the soil undergoes a shift in chemical equilibrium with the adsorbed phosphorus being more firmly fixed to the now adsorbed iron and aluminum sites. Simultaneously, new and previously unavailable iron and aluminum sites within the soil matrix are made available for additional phosphorus adsorption. The equilibrium adsorption sites available in a given soil are a function of the soil type, its short-term adsorption history and the concentration of phosphorus ion that is in the vicinity and thus in near equilibrium with the adsorption sites. Ellis and Erickson's work demonstrates that this renewable equilibrium adsorption capacity can be accomplished during a three month resting period for the soil providing there is an abundance of iron and aluminum ultimately available in the soil. Although the selected C-SELM agricultural soils are relatively low in iron and aluminum concentration, it is estimated that they nevertheless contain 0.5 to 1.0 per cent (5000 to 10000 mg/kg) iron and 1 to 2 percent (10,000 to 20,000 mg/kg) aluminum. These are sufficiently high concentrations to permit continually renewable adsorption capacity for many years even though only a fraction of the ultimately available iron and aluminum concentration would be available at the soil grain surface. It is on the basis of this renewable adsorption capacity that a soil lifetime of 100 to 1000 years is projected for a C-SELM land system with respect to phosphorus removal.

These calculated short-term adsorption capabilities are conservatively low as judged by the comparable phosphorus adsorption characteristics reported for comparable sandy loams and clay loams in the paper by Ellis and Erickson. They routinely report 1000 to 2000 #P/Acre for a 3 foot soil depth. Prorating these characteristics to our comparable C-SELM soils and depths would yield short-term adsorption characteristics of 5000 to 40,000 #P/Acre.

The Kendall and McHenry County soils are underlain by calcerous soils which are capable of chemically adsorbing phosphorus due to their high calcium content. No credit has been taken for this subsequent removal in this analysis.

Finally, no credit has been taken for the iron and aluminum concentrations present in the effluent administered to the land. These concentrations can amount to 1 to 10 mg/l and can represent a further significant in-situ adsorption capacity for phosphorus. Furthermore, if additional extension of phosphorus removal life is desired, it can be induced by appropriate chemical additions of soluble iron and/or aluminum to the secondary effluent, prior to irrigation.

The foregoing analysis was made prior to the availability of data from the MSD showing the influence of the City of Chicago phosphate detergent ban on residual soluble phosphorus in secondary effluent. The average soluble phosphorus concentration now being discharged from the three large MSD plants, which comprise the majority of the C-SELM treated flows, is approximately 1 mg/l. Thus, the phosphate detergent ban has reduced soluble phosphorus concentrations from the MSD treatment plants by a factor of six as contrasted with the earlier projections. Similar phosphate detergent bans have been requested by the Federal EPA on State-wide bases, but there appear to exist some legal questions that first need resolution. Should phosphate detergent bans become universally applied, the inputs to the above analysis would obviously change significantly to further alleviate concern about the phosphorus removal life of the land treatment system.

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4. IRRIGATION AND DRAINAGE SYSTEM ANALYSIS

Introduction

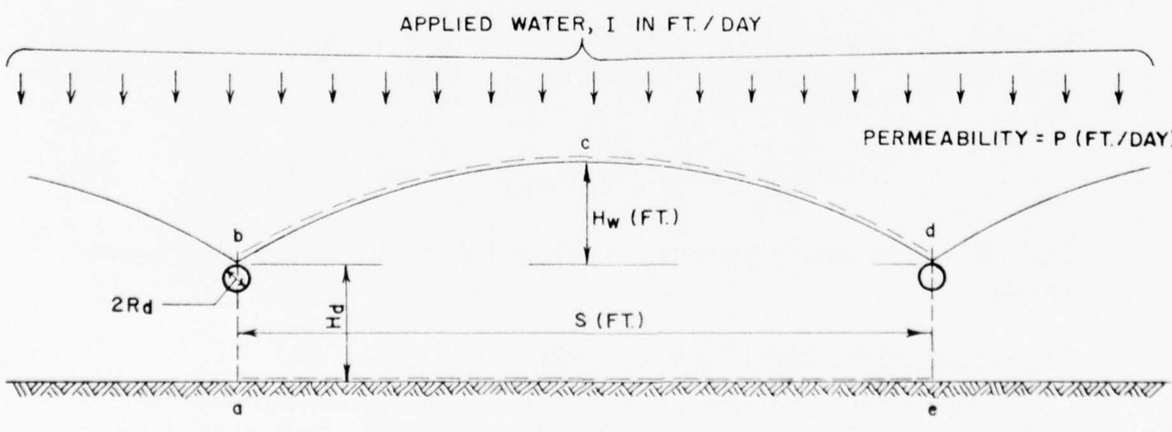
The drainage system to be installed in the proposed irrigation area is designed to avoid the intrusion of groundwater into the aerated zone for periods less than 24 hours and to provide sufficient storage volume for winter reuse flows. In order to clarify the performance of the proposed system a mathematical model simulating the actual operation of the land treatment system is established. This section intends to present the basic equation and the tillage schedule used in the analysis and the results of the analysis.

Basic Equations

The continuity equation for the control volume abcde (refer to the sketch below) can be written as follows:

$$\frac{d\,Hw}{d\,t} + \frac{Hw}{A} = 0 \qquad (1)$$

in which A is defined by A = SCFf/p; S is the space between two drain tiles; C is a factor which accounts for change in shape and varies between 0.8 to 1.0 in typical cases; F is the function of the radius of the drain tile, Rd, the height of the drain tile from the impervious layer, Hd, and the spacing of the drain tiles; f is the drainable pore-space fraction and p is the permeability of the soil.



By imposing a forcing function that represents the application rate of water, the general solution of Equation (1) can be expressed by:

$$(Hw)_N = (\frac{A}{f}) (e^{\frac{1}{A}} - 1) \sum_{n=1}^{N} I_N \; e^{-(N-n+1)/A} \qquad (2)$$

in which I is the application rate of water including rainfall and irrigation water, and N is number of days from the day when irrigation started.

Eq. (2) can be divided into two components, the component due to the current application of water and the component due to the previous application. That is

$$(Hw)_N = (\frac{A}{f}) (e^{\frac{1}{A}} - 1) \left\{ I_N \, e^{-\frac{1}{A}} + \sum_{n=1}^{N-1} \text{In} \; e^{-(N-n+1)/A} \right\} \qquad (3)$$

The component due to previous application, on the other hand, can be obtained by solving Eq. (1) when the force term is zero. The result is

$$(Hw)_n = (Hw)_{n-1} \, e^{-\frac{1}{A} t} \qquad (4)$$

If t is taken as one day then Eq. (4) can be simplified

$$(Hw)_n = (Hw)_{n-1} \, e^{-\frac{1}{A}} \qquad (5)$$

If $(Hw)_n$ is considered as the component due to previous application then $(Hw)_{n-1}$ is equivalent to $(Hw)_{N-1}$, thus Eq. (3) can be rewritten as

$$(Hw)_N = e^{-\frac{1}{A}} \left\{ (Hw)_{N-1} + \frac{A}{f} (e^{\frac{1}{A}} - 1) I_N \right\} \qquad (6)$$

Eq. (6) is the basic equation used in the mathematical simulation model.

<u>Tillage Schedule and Results of Analysis</u>

Two different types of tillage schedules, conventional and no-tillage are considered in association with the rainfall time series described in the main text. Each schedule is determined based on the agricultural discussion presented in Data Annex B, Section IV-A.

determined based on the agricultural discussion presented in Data Annex B, Section IV-A and also presented in the following table.

	No Tillage		Conventional Tillage	
Month	Till.Sched. Day	App.Rate	Till.Sched. Day	App.Rate
April	29 - 30	4	7 - 11	5
May	1 - 11	1	2 - 4	5[h] 1[i] 2[j]
June	--	1[a] 2[b] 6[c]	2 - 4 17 - 18	2[a] 3[k] 6[l]
July	--	6	--	6
Aug.	26 - 31	6	10 - 14 26 - 31	6
Sept.	1 - 17	6	1 - 17	6
Oct.	--	6[d] 5[e]	--	6
Nov.	14 - 19	5[f] 4[g]	14 - 19	5

Note: The application rate changes during a month are shown in superscript a, b, c etc., and the details are as follows:

a: from June 1 to June 1
b: from June 2 to June 12
c: from June 13 to June 30
d: from Oct. 1 to Oct. 30
e: Oct. 31 to Oct. 31
f: Nov. 1 to Nov. 13
g: Nov. 20 to Nov. 30
h: May 1 to May 1
i: May 5 to May 25
j: May 26 to May 30
k: June 5 to June 9
l: June 10 to June 30

The results of the analysis for the no-tillage and for the conventional tillage schedule are presented in the following tables.

Presented in Figure BA-IV-A-6 is a graphical presentation of this drainage analysis.

Table BA-IV-A-8

RESULTS OF SIMULATION ANALYSIS USING CONVENTIONAL TILLAGE SCHEDULE FOR MC HENRY CO. TYPE SOIL

DR 22:23 PC-T.. WEDS. 01/08/73

HYDROLOGIC CONDITION:
FREQUENCY OF RAINFALL = 100. YR

DRAINAGE SYSTEM:
DRAIN TILE SPACING = 100. FT
DEPTH OF AQUIFER = 11.0 FT
(SATURATED)
SIZE OF DRAIN PIPE = 0.50 FT
HEIGHT OF ROOT ZONE = 7.00 FT
(FROM TOP OF DRAIN TILE)
MAX CAP OF DRAIN SYST = 0.8571 IN/DAY

AQUIFER CHARACTERISTICS:
PERMEABILITY = 100.00 GPD/SQ FT
STORAGE COEFFICIENT = 0.10

TILAGE SCHEDULE: CONVENTIONAL TILAGE

DRAINAGE SYSTEM OPERATION:
START DATE FLOW REGUL = 23TH DAY OF 8TH MONTH
REGULATED FLOW = 0.05827 IN/DAY

M	D	RF	EVL	AIR	AW	QDR	SUMRF	SUMEV	SUMIR	SUMDR
4	1	0.19	0.00	0.71	0.71	0.06	0.19	0.00	0.71	0.06
4	2	0.00	0.05	0.71	0.72	0.65	0.19	0.05	1.43	0.71
4	3	0.97	0.05	0.71	1.39	0.83	1.16	0.10	2.14	1.53
4	4	0.00	0.05	0.71	1.23	0.86	1.16	0.14	2.86	2.39
4	5	0.00	0.05	0.71	1.07	0.86	1.16	0.19	3.57	3.25
4	6	0.00	0.05	0.71	0.92	0.86	1.16	0.24	4.29	4.10
4	7	1.07	0.05	0.00	1.06	0.86	2.23	0.29	4.29	4.96
4	8	0.00	0.05	0.00	0.47	0.68	2.23	0.34	4.29	5.64
4	9	0.00	0.05	0.00	0.38	0.06	2.23	0.38	4.29	5.69
4	10	0.00	0.05	0.00	0.29	0.06	2.23	0.43	4.29	5.75
4	11	0.08	0.05	0.00	0.27	0.06	2.31	0.48	4.29	5.81
4	12	0.00	0.05	0.71	0.78	0.06	2.31	0.53	5.00	5.87
4	13	0.00	0.05	0.71	0.75	0.70	2.31	0.58	5.71	6.57
4	14	0.00	0.05	0.71	0.74	0.68	2.31	0.62	6.43	7.25
4	15	0.00	0.05	0.71	0.73	0.67	2.31	0.67	7.14	7.92
4	16	0.00	0.05	0.71	0.73	0.67	2.31	0.72	7.86	8.59
4	17	0.52	0.05	0.71	1.05	0.80	2.83	0.77	8.57	9.39
4	18	0.12	0.05	0.71	0.99	0.86	2.95	0.82	9.29	10.25
4	19	0.11	0.05	0.71	0.92	0.86	3.06	0.86	10.00	11.10
4	20	0.19	0.05	0.71	0.93	0.85	3.25	0.91	10.71	11.95
4	21	0.00	0.05	0.71	0.82	0.80	3.25	0.96	11.43	12.75
4	22	0.62	0.05	0.71	1.19	0.84	3.87	1.01	12.14	13.59
4	23	0.00	0.05	0.71	1.03	0.86	3.87	1.06	12.86	14.45
4	24	0.61	0.05	0.71	1.38	0.86	4.48	1.10	13.57	15.31
4	25	0.00	0.05	0.71	1.22	0.86	4.48	1.15	14.29	16.17
4	26	0.21	0.05	0.71	1.24	0.86	4.69	1.20	15.00	17.02
4	27	0.80	0.05	0.71	1.75	0.86	5.49	1.25	15.71	17.88
4	28	0.61	0.05	0.71	2.10	0.86	6.10	1.30	16.43	18.74
4	29	0.38	0.05	0.71	2.25	0.86	6.48	1.34	17.14	19.59
4	30	0.00	0.05	0.71	2.10	0.86	6.48	1.39	17.86	20.45

Table BA-IV-A-8 (Continued)

M	D	RF	EVL	HIR	HW	QDR	SUMRF	SUMEV	SUMIR	SUMDR
5	1	0.00	0.07	0.71	1.92	0.86	6.48	1.46	18.57	21.31
5	2	0.00	0.07	0.00	1.14	0.86	6.48	1.54	18.57	22.17
5	3	0.00	0.07	0.00	0.50	0.71	6.48	1.61	18.57	22.88
5	4	0.00	0.07	0.00	0.19	0.32	6.48	1.68	18.57	23.19
5	5	0.00	0.00	0.14	0.26	0.06	6.48	1.68	18.71	23.25
5	6	0.00	0.07	0.14	0.27	0.06	6.48	1.75	18.86	23.31
5	7	0.00	0.07	0.14	0.28	0.06	6.48	1.83	19.00	23.37
5	8	0.00	0.07	0.14	0.29	0.06	6.48	1.90	19.14	23.43
5	9	0.03	0.07	0.14	0.33	0.06	6.51	1.97	19.29	23.48
5	10	0.15	0.07	0.14	0.46	0.06	6.66	2.04	19.43	23.54
5	11	0.37	0.07	0.14	0.78	0.06	7.03	2.11	19.57	23.60
5	12	0.00	0.07	0.14	0.41	0.54	7.03	2.19	19.71	24.14
5	13	1.70	0.07	0.14	1.33	0.06	8.73	2.26	19.86	24.20
5	14	0.00	0.07	0.14	1.18	0.86	8.73	2.33	20.00	25.06
5	15	0.00	0.07	0.14	0.61	0.76	8.73	2.40	20.14	25.82
5	16	0.00	0.07	0.14	0.33	0.43	8.73	2.48	20.29	26.25
5	17	0.58	0.07	0.14	0.82	0.06	9.31	2.55	20.43	26.31
5	18	0.06	0.07	0.14	0.46	0.58	9.37	2.62	20.57	26.89
5	19	0.33	0.07	0.14	0.74	0.06	9.70	2.69	20.71	26.95
5	20	0.00	0.07	0.14	0.39	0.52	9.70	2.76	20.86	27.47
5	21	0.00	0.07	0.14	0.40	0.06	9.70	2.84	21.00	27.52
5	22	0.00	0.07	0.14	0.41	0.06	9.70	2.91	21.14	27.58
5	23	0.04	0.07	0.14	0.45	0.06	9.74	2.98	21.29	27.64
5	24	0.00	0.07	0.14	0.46	0.06	9.74	3.05	21.43	27.70
5	25	0.27	0.07	0.14	0.70	0.06	10.01	3.13	21.57	27.76
5	26	0.00	0.07	0.29	0.45	0.52	10.01	3.20	21.86	28.28
5	27	0.00	0.07	0.29	0.58	0.06	10.01	3.27	22.14	28.34
5	28	0.00	0.07	0.29	0.40	0.45	10.01	3.34	22.43	28.79
5	29	0.00	0.07	0.29	0.52	0.06	10.01	3.41	22.71	28.84
5	30	0.00	0.07	0.29	0.37	0.41	10.01	3.49	23.00	29.25
5	31	0.23	0.07	0.29	0.69	0.06	10.24	3.56	23.29	29.31
6	1	0.00	0.10	0.29	0.43	0.51	10.24	3.66	23.57	29.82
6	2	0.00	0.10	0.00	0.29	0.06	10.24	3.77	23.57	29.88
6	3	0.00	0.10	0.00	0.16	0.06	10.24	3.87	23.57	29.94
6	4	0.00	0.00	0.00	0.11	0.06	10.24	3.87	23.57	30.00
6	5	0.04	0.00	0.43	0.45	0.06	10.28	3.87	24.00	30.06
6	6	0.65	0.10	0.43	1.21	0.06	10.93	3.98	24.43	30.11
6	7	0.05	0.10	0.43	0.83	0.84	10.98	4.08	24.86	30.95
6	8	0.23	0.10	0.43	0.71	0.70	11.21	4.18	25.29	31.66
6	9	0.00	0.10	0.43	0.52	0.56	11.21	4.29	25.71	32.22
6	10	0.00	0.10	0.86	0.68	0.55	11.21	4.39	26.57	32.77
6	11	0.70	0.10	0.86	1.22	0.81	11.91	4.50	27.43	33.57
6	12	0.32	0.10	0.86	1.40	0.86	12.23	4.60	28.29	34.43
6	13	1.25	0.10	0.86	2.35	0.86	13.48	4.70	29.14	35.29
6	14	0.00	0.10	0.86	2.27	0.86	13.48	4.81	30.00	36.15
6	15	0.00	0.10	0.86	2.18	0.86	13.48	4.91	30.86	37.00
6	16	0.00	0.10	0.86	2.09	0.86	13.48	5.02	31.71	37.86
6	17	0.08	0.10	0.00	1.36	0.86	13.56	5.12	31.71	38.72
6	18	0.00	0.10	0.00	0.62	0.79	13.56	5.22	31.71	39.51
6	19	0.00	0.10	0.86	0.73	0.62	13.56	5.33	32.57	40.12
6	20	0.00	0.10	0.86	0.78	0.69	13.56	5.43	33.43	40.81
6	21	1.00	0.10	0.86	1.54	0.84	14.56	5.54	34.29	41.65
6	22	0.00	0.10	0.86	1.45	0.86	14.56	5.64	35.14	42.51
6	23	0.00	0.10	0.86	1.36	0.86	14.56	5.74	36.00	43.37
6	24	0.00	0.10	0.86	1.28	0.86	14.56	5.85	36.86	44.23
6	25	0.05	0.10	0.86	1.23	0.86	14.61	5.95	37.71	45.08
6	26	0.17	0.10	0.86	1.29	0.86	14.78	6.06	38.57	45.94
6	27	2.56	0.10	0.86	3.33	0.86	17.34	6.16	39.43	46.80
6	28	0.00	0.10	0.86	3.25	0.86	17.34	6.26	40.29	47.65
6	29	0.00	0.10	0.86	3.16	0.86	17.34	6.37	41.14	48.51
6	30	0.00	0.10	0.86	3.07	0.86	17.34	6.47	42.00	49.37

Table BA-IV-A-8 (Continued)

M	D	RF	EVL	HIR	HW	QDR	SUMRF	SUMEV	SUMIR	SUMDR
7	1	0.00	0.14	0.86	2.96	0.86	17.34	6.61	42.86	50.23
7	2	0.00	0.14	0.86	2.85	0.86	17.34	6.74	43.71	51.08
7	3	0.00	0.14	0.86	2.73	0.86	17.34	6.88	44.57	51.94
7	4	0.12	0.14	0.86	2.72	0.86	17.46	7.02	45.43	52.80
7	5	0.00	0.14	0.86	2.60	0.86	17.46	7.16	46.29	53.65
7	6	0.00	0.14	0.86	2.49	0.86	17.46	7.29	47.14	54.51
7	7	0.00	0.14	0.86	2.38	0.86	17.46	7.43	48.00	55.37
7	8	0.00	0.14	0.86	2.26	0.86	17.46	7.57	48.86	56.23
7	9	0.00	0.14	0.86	2.15	0.86	17.46	7.70	49.71	57.08
7	10	0.00	0.14	0.86	2.03	0.86	17.46	7.84	50.57	57.94
7	11	0.00	0.14	0.86	1.92	0.86	17.46	7.98	51.43	58.80
7	12	5.40	0.14	0.00	5.59	0.86	22.86	8.11	51.43	59.65
7	13	3.55	0.14	0.00	7.72	0.86	26.41	8.25	51.43	60.51
7	14	0.00	0.14	0.00	6.89	0.86	26.41	8.39	51.43	61.37
7	15	0.00	0.14	0.86	6.78	0.86	26.41	8.52	52.29	62.23
7	16	0.00	0.14	0.86	6.67	0.86	26.41	8.66	53.14	63.08
7	17	0.00	0.14	0.86	6.55	0.86	26.41	8.80	54.00	63.94
7	18	0.00	0.14	0.86	6.44	0.86	26.41	8.93	54.86	64.80
7	19	0.00	0.14	0.86	6.32	0.86	26.41	9.07	55.71	65.65
7	20	0.00	0.14	0.86	6.21	0.86	26.41	9.21	56.57	66.51
7	21	1.18	0.14	0.86	7.08	0.86	27.59	9.34	57.43	67.37
7	22	0.01	0.14	0.00	6.26	0.86	27.60	9.48	57.43	68.23
7	23	0.00	0.14	0.86	6.15	0.86	27.60	9.62	58.29	69.08
7	24	0.00	0.14	0.86	6.03	0.86	27.60	9.75	59.14	69.94
7	25	0.00	0.14	0.86	5.92	0.86	27.60	9.89	60.00	70.80
7	26	0.00	0.14	0.86	5.80	0.86	27.60	10.03	60.86	71.65
7	27	0.00	0.14	0.86	5.69	0.86	27.60	10.16	61.71	72.51
7	28	0.00	0.14	0.86	5.58	0.86	27.60	10.30	62.57	73.37
7	29	0.00	0.14	0.86	5.46	0.86	27.60	10.44	63.43	74.23
7	30	0.00	0.14	0.86	5.35	0.86	27.60	10.58	64.29	75.08
7	31	0.00	0.14	0.86	5.23	0.86	27.60	10.71	65.14	75.94
8	1	0.00	0.14	0.86	5.12	0.86	27.60	10.85	66.00	76.80
8	2	0.00	0.14	0.86	5.01	0.86	27.60	10.98	66.86	77.65
8	3	0.46	0.14	0.86	5.28	0.86	28.06	11.12	67.71	78.51
8	4	0.00	0.14	0.86	5.16	0.86	28.06	11.25	68.57	79.37
8	5	0.00	0.14	0.86	5.05	0.86	28.06	11.39	69.43	80.23
8	6	0.00	0.14	0.86	4.94	0.86	28.06	11.53	70.29	81.08
8	7	0.00	0.14	0.86	4.83	0.86	28.06	11.66	71.14	81.94
8	8	0.00	0.14	0.86	4.71	0.86	28.06	11.80	72.00	82.80
8	9	0.00	0.14	0.86	4.60	0.86	28.06	11.93	72.86	83.65
8	10	0.00	0.14	0.00	3.77	0.86	28.06	12.07	72.86	84.51
8	11	0.00	0.14	0.00	2.95	0.86	28.06	12.20	72.86	85.37
8	12	0.00	0.14	0.00	2.12	0.86	28.06	12.34	72.86	86.23
8	13	0.00	0.14	0.00	1.29	0.86	28.06	12.47	72.86	87.08
8	14	0.00	0.14	0.00	0.55	0.76	28.06	12.61	72.86	87.84
8	15	0.00	0.14	0.86	0.68	0.56	28.06	12.74	73.71	88.40
8	16	0.00	0.14	0.86	0.74	0.65	28.06	12.88	74.57	89.05
8	17	0.00	0.14	0.86	0.77	0.69	28.06	13.02	75.43	89.74
8	18	0.00	0.14	0.86	0.78	0.71	28.06	13.15	76.29	90.44
8	19	0.00	0.14	0.86	0.78	0.71	28.06	13.29	77.14	91.16
8	20	0.00	0.14	0.86	0.79	0.72	28.06	13.42	78.00	91.88
8	21	0.00	0.14	0.86	0.79	0.72	28.06	13.56	78.86	92.60
8	22	0.00	0.14	0.86	0.79	0.72	28.06	13.69	79.71	93.32
8	23	0.00	0.14	0.86	1.34	0.06	28.06	13.83	80.57	93.37
8	24	0.00	0.14	0.86	1.89	0.06	28.06	13.96	81.43	93.43
8	25	0.00	0.14	0.86	2.45	0.06	28.06	14.10	82.29	93.49
8	26	0.00	0.14	0.00	2.29	0.06	28.06	14.24	82.29	93.55
8	27	0.00	0.14	0.00	2.12	0.06	28.06	14.37	82.29	93.61
8	28	0.63	0.14	0.00	2.49	0.06	28.69	14.51	82.29	93.67
8	29	0.00	0.14	0.00	2.33	0.06	28.69	14.64	82.29	93.72
8	30	0.00	0.14	0.00	2.17	0.06	28.69	14.78	82.29	93.78
8	31	0.00	0.14	0.00	2.00	0.06	28.69	14.91	82.29	93.84

Table BA-IV-A-8 (Continued)

M	D	RF	EVL	HIR	HW	QDR	SUMRF	SUMEV	SUMIR	SUMDR
9	1	0.00	0.12	0.00	1.86	0.06	28.69	15.03	82.29	93.90
9	2	0.04	0.12	0.00	1.74	0.06	28.73	15.15	82.29	93.96
9	3	0.00	0.12	0.00	1.60	0.06	28.73	15.27	82.29	94.02
9	4	0.00	0.12	0.00	1.45	0.06	28.73	15.38	82.29	94.07
9	5	0.00	0.12	0.00	1.31	0.06	28.73	15.50	82.29	94.13
9	6	0.00	0.12	0.00	1.16	0.06	28.73	15.62	82.29	94.19
9	7	0.00	0.12	0.00	1.01	0.06	28.73	15.73	82.29	94.25
9	8	0.00	0.12	0.00	0.87	0.06	28.73	15.85	82.29	94.31
9	9	0.00	0.12	0.00	0.72	0.06	28.73	15.97	82.29	94.36
9	10	0.00	0.12	0.00	0.57	0.06	28.73	16.09	82.29	94.42
9	11	0.00	0.12	0.00	0.43	0.06	28.73	16.20	82.29	94.48
9	12	0.13	0.12	0.00	0.39	0.06	28.86	16.32	82.29	94.54
9	13	0.00	0.12	0.00	0.24	0.06	28.86	16.44	82.29	94.60
9	14	0.00	0.12	0.00	0.10	0.06	28.86	16.56	82.29	94.66
9	15	0.00	0.00	0.00	0.05	0.06	28.86	16.56	82.29	94.71
9	16	0.00	0.00	0.00	0.02	0.03	28.86	16.56	82.29	94.75
9	17	0.00	0.00	0.00	0.01	0.02	28.86	16.56	82.29	94.76
9	18	0.00	0.00	0.86	0.68	0.06	28.86	16.56	83.14	94.82
9	19	0.00	0.12	0.86	1.25	0.06	28.86	16.67	84.00	94.88
9	20	0.00	0.12	0.86	1.81	0.06	28.86	16.79	84.86	94.93
9	21	0.26	0.12	0.86	2.60	0.06	29.12	16.91	85.71	94.99
9	22	0.00	0.12	0.86	3.17	0.06	29.12	17.03	86.57	95.05
9	23	0.00	0.12	0.86	3.73	0.06	29.12	17.14	87.43	95.11
9	24	0.00	0.12	0.86	4.30	0.06	29.12	17.26	88.29	95.17
9	25	0.00	0.12	0.86	4.87	0.06	29.12	17.38	89.14	95.23
9	26	0.00	0.12	0.86	5.44	0.06	29.12	17.50	90.00	95.28
9	27	0.00	0.12	0.86	6.01	0.06	29.12	17.61	90.86	95.34
9	28	0.00	0.12	0.86	5.91	0.86	29.12	17.73	91.71	96.20
9	29	0.00	0.12	0.86	6.48	0.06	29.12	17.85	92.57	96.26
9	30	0.00	0.12	0.86	6.38	0.86	29.12	17.96	93.43	97.11
10	1	0.00	0.08	0.86	6.31	0.86	29.12	18.04	94.29	97.97
10	2	0.00	0.08	0.86	6.25	0.86	29.12	18.12	95.14	98.83
10	3	0.00	0.08	0.86	6.18	0.86	29.12	18.20	96.00	99.69
10	4	0.00	0.08	0.86	6.11	0.86	29.12	18.28	96.86	100.54
10	5	0.00	0.08	0.86	6.05	0.86	29.12	18.36	97.71	101.40
10	6	0.00	0.08	0.86	5.98	0.86	29.12	18.44	98.57	102.26
10	7	0.00	0.08	0.86	6.58	0.06	29.12	18.52	99.43	102.32
10	8	0.00	0.08	0.86	6.51	0.86	29.12	18.60	100.29	103.17
10	9	0.00	0.08	0.86	6.44	0.86	29.12	18.68	101.14	104.03
10	10	0.00	0.08	0.86	6.38	0.86	29.12	18.76	102.00	104.89
10	11	0.00	0.08	0.86	6.31	0.86	29.12	18.84	102.86	105.74
10	12	0.00	0.08	0.86	6.24	0.86	29.12	18.92	103.71	106.60
10	13	0.00	0.08	0.86	6.18	0.86	29.12	19.00	104.57	107.46
10	14	0.00	0.08	0.86	6.11	0.86	29.12	19.08	105.43	108.32
10	15	0.00	0.08	0.86	6.04	0.86	29.12	19.16	106.29	109.17
10	16	0.80	0.08	0.86	6.64	0.86	29.92	19.24	107.14	110.03
10	17	0.00	0.08	0.86	6.58	0.86	29.92	19.32	108.00	110.89
10	18	0.00	0.08	0.86	6.51	0.86	29.92	19.40	108.86	111.74
10	19	0.00	0.08	0.86	6.44	0.86	29.92	19.48	109.71	112.60
10	20	0.00	0.08	0.86	6.38	0.86	29.92	19.56	110.57	113.46
10	21	0.00	0.08	0.86	6.31	0.86	29.92	19.64	111.43	114.32
10	22	0.00	0.08	0.86	6.24	0.86	29.92	19.72	112.29	115.17
10	23	0.00	0.08	0.86	6.16	0.86	29.92	19.80	113.14	116.03
10	24	3.39	0.08	0.00	8.22	0.86	33.31	19.88	113.14	116.89
10	25	0.00	0.08	0.00	7.44	0.86	33.31	19.96	113.14	117.74
10	26	0.20	0.08	0.00	6.33	0.86	33.51	20.04	113.14	118.60
10	27	0.00	0.08	0.86	6.76	0.86	33.51	20.12	114.00	119.46
10	28	0.00	0.08	0.86	6.69	0.86	33.51	20.20	114.86	120.32
10	29	0.00	0.08	0.86	6.63	0.86	33.51	20.28	115.71	121.17
10	30	0.00	0.08	0.86	6.56	0.86	33.51	20.36	116.57	122.03
10	31	0.00	0.08	0.86	6.49	0.86	33.51	20.44	117.43	122.89

Table BA-IV-A-8 (Continued)

M	D	RF	EVL	HIR	HW	QDR	SUMRF	SUMEV	SUMIR	SUMDR
11	1	0.00	0.04	0.71	6.34	0.86	33.51	20.49	118.14	123.74
11	2	0.01	0.04	0.71	6.19	0.86	33.52	20.53	118.86	124.60
11	3	0.00	0.04	0.71	6.04	0.86	33.52	20.57	119.57	125.46
11	4	0.00	0.04	0.71	5.88	0.86	33.52	20.62	120.29	126.32
11	5	0.00	0.04	0.71	6.39	0.06	33.52	20.66	121.00	126.37
11	6	0.00	0.04	0.71	6.24	0.86	33.52	20.70	121.71	127.23
11	7	0.00	0.04	0.71	6.08	0.86	33.52	20.74	122.43	128.09
11	8	0.35	0.04	0.71	6.22	0.86	33.87	20.79	123.14	128.95
11	9	0.00	0.04	0.71	6.07	0.86	33.87	20.83	123.86	129.80
11	10	0.00	0.04	0.71	5.91	0.86	33.87	20.87	124.57	130.66
11	11	0.00	0.04	0.71	6.42	0.06	33.87	20.91	125.29	130.72
11	12	0.00	0.04	0.71	6.27	0.86	33.87	20.96	126.00	131.58
11	13	0.77	0.04	0.71	6.76	0.86	34.64	21.00	126.71	132.43
11	14	0.66	0.04	0.00	6.56	0.86	35.30	21.04	126.71	133.29
11	15	0.00	0.04	0.00	5.81	0.86	35.30	21.08	126.71	134.15
11	16	0.00	0.04	0.00	5.72	0.06	35.30	21.13	126.71	134.20
11	17	0.00	0.04	0.00	5.64	0.06	35.30	21.17	126.71	134.26
11	18	0.51	0.04	0.00	5.98	0.06	35.81	21.21	126.71	134.32
11	19	0.00	0.04	0.00	5.90	0.06	35.81	21.25	126.71	134.38
11	20	0.00	0.04	0.71	6.41	0.06	35.81	21.30	127.43	134.44
11	21	0.00	0.04	0.71	6.25	0.86	35.81	21.34	128.14	135.30
11	22	0.00	0.04	0.71	6.10	0.86	35.81	21.38	128.86	136.15
11	23	0.00	0.04	0.71	5.94	0.86	35.81	21.43	129.57	137.01
11	24	0.00	0.04	0.71	6.45	0.06	35.81	21.47	130.29	137.07
11	25	0.00	0.04	0.71	6.30	0.86	35.81	21.51	131.00	137.92
11	26	0.00	0.04	0.71	6.14	0.86	35.81	21.55	131.71	138.78
11	27	0.00	0.04	0.71	5.99	0.86	35.81	21.60	132.43	139.64
11	28	0.00	0.04	0.71	6.50	0.06	35.81	21.64	133.14	139.70
11	29	0.00	0.04	0.71	6.35	0.86	35.81	21.68	133.86	140.55
11	30	0.00	0.04	0.71	6.19	0.86	35.81	21.72	134.57	141.41
12	1	0.00	0.02	0.00	5.47	0.86	35.81	21.74	134.57	142.27
12	2	0.00	0.02	0.00	5.40	0.06	35.81	21.75	134.57	142.33
12	3	0.10	0.02	0.00	5.43	0.06	35.91	21.77	134.57	142.39
12	4	0.00	0.02	0.00	5.36	0.06	35.91	21.79	134.57	142.44
12	5	0.00	0.02	0.00	5.30	0.06	35.91	21.80	134.57	142.50
12	6	0.06	0.02	0.00	5.29	0.06	35.97	21.82	134.57	142.56
12	7	0.38	0.02	0.00	5.55	0.06	36.35	21.83	134.57	142.62
12	8	0.00	0.02	0.00	5.48	0.06	36.35	21.85	134.57	142.68
12	9	0.00	0.02	0.00	5.42	0.06	36.35	21.86	134.57	142.73
12	10	0.00	0.02	0.00	5.36	0.06	36.35	21.88	134.57	142.79
12	11	0.00	0.02	0.00	5.30	0.06	36.35	21.89	134.57	142.85
12	12	0.00	0.02	0.00	5.24	0.06	36.35	21.91	134.57	142.91
12	13	0.00	0.02	0.00	5.18	0.06	36.35	21.93	134.57	142.97
12	14	0.00	0.02	0.00	5.12	0.06	36.35	21.94	134.57	143.03
12	15	0.00	0.02	0.00	5.05	0.06	36.35	21.96	134.57	143.08
12	16	0.00	0.02	0.00	4.99	0.06	36.35	21.97	134.57	143.14
12	17	0.00	0.02	0.00	4.93	0.06	36.35	21.99	134.57	143.20
12	18	0.46	0.02	0.00	5.25	0.06	36.81	22.00	134.57	143.26
12	19	0.70	0.02	0.00	5.77	0.06	37.51	22.02	134.57	143.32
12	20	0.07	0.02	0.00	5.77	0.06	37.58	22.03	134.57	143.38
12	21	0.00	0.02	0.00	5.71	0.06	37.58	22.05	134.57	143.43
12	22	0.00	0.02	0.00	5.65	0.06	37.58	22.07	134.57	143.49
12	23	0.00	0.02	0.00	5.59	0.06	37.58	22.08	134.57	143.55
12	24	0.00	0.02	0.00	5.53	0.06	37.58	22.10	134.57	143.61
12	25	0.30	0.02	0.00	5.71	0.06	37.88	22.11	134.57	143.67
12	26	0.00	0.02	0.00	5.65	0.06	37.88	22.13	134.57	143.73
12	27	0.15	0.02	0.00	5.72	0.06	38.03	22.14	134.57	143.78
12	28	0.02	0.02	0.00	5.67	0.06	38.05	22.16	134.57	143.84
12	29	0.00	0.02	0.00	5.61	0.06	38.05	22.17	134.57	143.90
12	30	0.00	0.02	0.00	5.55	0.06	38.05	22.19	134.57	143.96
12	31	0.35	0.02	0.00	5.78	0.06	38.40	22.20	134.57	144.02

Table BA-IV-A-8 (Continued)

M	D	RF	EVL	HIR	HW	QDR	SUMRF	SUMEV	SUMIR	SUMDR
1	1	0.00	0.02	0.00	5.72	0.06	38.40	22.22	134.57	144.08
1	2	0.00	0.02	0.00	5.66	0.06	38.40	22.24	134.57	144.13
1	3	0.00	0.02	0.00	5.59	0.06	38.40	22.25	134.57	144.19
1	4	0.00	0.02	0.00	5.53	0.06	38.40	22.27	134.57	144.25
1	5	0.00	0.02	0.00	5.47	0.06	38.40	22.28	134.57	144.31
1	6	0.00	0.02	0.00	5.41	0.06	38.40	22.30	134.57	144.37
1	7	0.00	0.02	0.00	5.35	0.06	38.40	22.31	134.57	144.42
1	8	0.00	0.02	0.00	5.29	0.06	38.40	22.33	134.57	144.48
1	9	0.00	0.02	0.00	5.23	0.06	38.40	22.34	134.57	144.54
1	10	0.00	0.02	0.00	5.16	0.06	38.40	22.36	134.57	144.60
1	11	0.00	0.02	0.00	5.10	0.06	38.40	22.38	134.57	144.66
1	12	0.00	0.02	0.00	5.04	0.06	38.40	22.39	134.57	144.72
1	13	0.00	0.02	0.00	4.98	0.06	38.40	22.41	134.57	144.77
1	14	0.00	0.02	0.00	4.92	0.06	38.40	22.42	134.57	144.83
1	15	0.00	0.02	0.00	4.86	0.06	38.40	22.44	134.57	144.89
1	16	0.00	0.02	0.00	4.79	0.06	38.40	22.45	134.57	144.95
1	17	0.00	0.02	0.00	4.73	0.06	38.40	22.47	134.57	145.01
1	18	0.00	0.02	0.00	4.67	0.06	38.40	22.48	134.57	145.07
1	19	0.00	0.02	0.00	4.61	0.06	38.40	22.50	134.57	145.12
1	20	0.00	0.02	0.00	4.55	0.06	38.40	22.52	134.57	145.18
1	21	0.00	0.02	0.00	4.49	0.06	38.40	22.53	134.57	145.24
1	22	0.88	0.02	0.00	5.16	0.06	39.28	22.55	134.57	145.30
1	23	0.00	0.02	0.00	5.10	0.06	39.28	22.56	134.57	145.36
1	24	0.00	0.02	0.00	5.04	0.06	39.28	22.58	134.57	145.42
1	25	0.01	0.02	0.00	4.98	0.06	39.29	22.59	134.57	145.47
1	26	0.06	0.02	0.00	4.97	0.06	39.35	22.61	134.57	145.53
1	27	0.00	0.02	0.00	4.91	0.06	39.35	22.62	134.57	145.59
1	28	0.00	0.02	0.00	4.85	0.06	39.35	22.64	134.57	145.65
1	29	0.00	0.02	0.00	4.79	0.06	39.35	22.65	134.57	145.71
1	30	0.00	0.02	0.00	4.73	0.06	39.35	22.67	134.57	145.76
1	31	0.00	0.02	0.00	4.66	0.06	39.35	22.69	134.57	145.82
2	1	0.00	0.02	0.00	4.60	0.06	39.35	22.71	134.57	145.88
2	2	0.00	0.02	0.00	4.53	0.06	39.35	22.73	134.57	145.94
2	3	0.00	0.02	0.00	4.46	0.06	39.35	22.75	134.57	146.00
2	4	0.00	0.02	0.00	4.40	0.06	39.35	22.77	134.57	146.06
2	5	0.00	0.02	0.00	4.33	0.06	39.35	22.79	134.57	146.11
2	6	0.00	0.02	0.00	4.27	0.06	39.35	22.81	134.57	146.17
2	7	0.00	0.02	0.00	4.20	0.06	39.35	22.84	134.57	146.23
2	8	0.00	0.02	0.00	4.13	0.06	39.35	22.86	134.57	146.29
2	9	0.00	0.02	0.00	4.07	0.06	39.35	22.88	134.57	146.35
2	10	0.00	0.02	0.00	4.00	0.06	39.35	22.90	134.57	146.41
2	11	0.00	0.02	0.00	3.93	0.06	39.35	22.92	134.57	146.46
2	12	0.00	0.02	0.00	3.87	0.06	39.35	22.94	134.57	146.52
2	13	0.00	0.02	0.00	3.80	0.06	39.35	22.96	134.57	146.58
2	14	0.00	0.02	0.00	3.73	0.06	39.35	22.99	134.57	146.64
2	15	0.09	0.02	0.00	3.74	0.06	39.44	23.01	134.57	146.70
2	16	0.00	0.02	0.00	3.68	0.06	39.44	23.03	134.57	146.76
2	17	0.00	0.02	0.00	3.61	0.06	39.44	23.05	134.57	146.81
2	18	0.00	0.02	0.00	3.54	0.06	39.44	23.07	134.57	146.87
2	19	0.00	0.02	0.00	3.48	0.06	39.44	23.09	134.57	146.93
2	20	0.00	0.02	0.00	3.41	0.06	39.44	23.11	134.57	146.99
2	21	0.00	0.02	0.00	3.34	0.06	39.44	23.14	134.57	147.05
2	22	0.00	0.02	0.00	3.28	0.06	39.44	23.16	134.57	147.11
2	23	0.00	0.02	0.00	3.21	0.06	39.44	23.18	134.57	147.16
2	24	0.00	0.02	0.00	3.14	0.06	39.44	23.20	134.57	147.22
2	25	0.00	0.02	0.00	3.08	0.06	39.44	23.22	134.57	147.28
2	26	0.00	0.02	0.00	3.01	0.06	39.44	23.24	134.57	147.34
2	27	0.77	0.02	0.00	3.59	0.06	40.21	23.26	134.57	147.40
2	28	0.03	0.02	0.00	3.55	0.06	40.24	23.29	134.57	147.45

Table BA-IV-A-8 (Continued)

M	D	RF	EVL	HIR	HW	QDR	SUMRF	SUMEV	SUMIR	SUMDR
3	1	0.00	0.03	0.00	3.48	0.06	40.24	23.31	134.57	147.51
3	2	0.04	0.03	0.00	3.44	0.06	40.28	23.34	134.57	147.57
3	3	0.00	0.03	0.00	3.37	0.06	40.28	23.36	134.57	147.63
3	4	0.00	0.03	0.00	3.30	0.06	40.28	23.39	134.57	147.69
3	5	0.15	0.03	0.00	3.35	0.06	40.43	23.42	134.57	147.75
3	6	0.00	0.03	0.00	3.28	0.06	40.43	23.44	134.57	147.80
3	7	0.00	0.03	0.00	3.21	0.06	40.43	23.47	134.57	147.86
3	8	0.00	0.03	0.00	3.14	0.06	40.43	23.49	134.57	147.92
3	9	0.00	0.03	0.00	3.07	0.06	40.43	23.52	134.57	147.98
3	10	0.00	0.03	0.00	3.00	0.06	40.43	23.54	134.57	148.04
3	11	0.00	0.03	0.00	2.93	0.06	40.43	23.57	134.57	148.10
3	12	0.00	0.03	0.00	2.86	0.06	40.43	23.60	134.57	148.15
3	13	0.00	0.03	0.00	2.79	0.06	40.43	23.62	134.57	148.21
3	14	0.00	0.03	0.00	2.72	0.06	40.43	23.65	134.57	148.27
3	15	0.00	0.03	0.00	2.65	0.06	40.43	23.67	134.57	148.33
3	16	0.00	0.03	0.00	2.58	0.06	40.43	23.70	134.57	148.39
3	17	0.00	0.03	0.00	2.51	0.06	40.43	23.73	134.57	148.45
3	18	0.00	0.03	0.00	2.44	0.06	40.43	23.75	134.57	148.50
3	19	0.00	0.03	0.00	2.37	0.06	40.43	23.78	134.57	148.56
3	20	0.02	0.03	0.00	2.32	0.06	40.45	23.80	134.57	148.62
3	21	0.00	0.03	0.00	2.25	0.06	40.45	23.83	134.57	148.68
3	22	0.00	0.03	0.00	2.18	0.06	40.45	23.85	134.57	148.74
3	23	0.00	0.03	0.00	2.11	0.06	40.45	23.88	134.57	148.79
3	24	0.24	0.03	0.00	2.24	0.06	40.69	23.91	134.57	148.85
3	25	0.00	0.03	0.00	2.17	0.06	40.69	23.93	134.57	148.91
3	26	0.00	0.03	0.00	2.10	0.06	40.69	23.96	134.57	148.97
3	27	0.00	0.03	0.00	2.03	0.06	40.69	23.98	134.57	149.03
3	28	0.00	0.03	0.00	1.96	0.06	40.69	24.01	134.57	149.09
3	29	0.00	0.03	0.00	1.89	0.06	40.69	24.04	134.57	149.14
3	30	0.00	0.03	0.00	1.82	0.06	40.69	24.06	134.57	149.20
3	31	0.00	0.03	0.00	1.75	0.06	40.69	24.09	134.57	149.26

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Table BA-IV-A-9

RESULTS OF SIMULATION ANALYSIS USING CONVENTIONAL TILLAGE SCHEDULE FOR KANKAKEE TYPE SOIL

DR 20:09 PC-TØR WEDS. 01/08/73

HYDRØLØGIC CØNDITIØN:
FREQUENCY ØF RAINFALL = 100. YR

DRAINAGE SYSTEM:
DRAIN TILE SPACING = 400. FT
DEPTH ØF AQUIFER = 40.0 FT
(SATURATED)
SIZE ØF DRAIN PIPE = 0.50 FT
HEIGHT ØF RØØT ZØNE = 7.00 FT
(FRØM TØP ØF DRAIN TILE)
MAX CAP ØF DRAIN SYST = 0.8571 IN/DAY

AQUIFER CHARACTERISTICS:
PERMEABILITY = 400.00 GPD/SQ FT
STØRAGE CØEFFICIENT = 0.20

TILAGE SCHEDULE: CØNVENTIØNAL TILAGE

DRAINAGE SYSTEM ØPERATIØN:
START DATE FLØW REGUL = 25TH DAY ØF 8TH MØNTH
REGULATED FLØW = 0.11654 IN/DAY

M	D	RF	EVL	HIR	HW	QDR	SUMRF	SUMEV	SUMIR	SUMDR
4	1	0.19	0.00	0.71	0.34	0.09	0.19	0.00	0.71	0.09
4	5	0.00	0.05	0.71	0.98	0.70	1.16	0.19	3.57	2.17
4	10	0.00	0.05	0.00	0.42	0.35	2.23	0.43	4.29	5.09
4	15	0.00	0.05	0.71	0.81	0.55	2.31	0.67	7.14	6.84
4	20	0.19	0.05	0.71	1.12	0.77	3.25	0.91	10.71	10.37
4	25	0.00	0.05	0.71	1.28	0.86	4.48	1.15	14.29	14.52
4	30	0.00	0.05	0.71	1.72	0.86	6.48	1.39	17.86	18.81
5	5	0.00	0.07	0.14	0.51	0.41	6.48	1.75	18.71	22.23
5	10	0.15	0.07	0.14	0.40	0.12	6.66	2.11	19.43	23.01
5	15	0.00	0.07	0.14	0.67	0.54	8.73	2.48	20.14	24.82
5	20	0.00	0.07	0.14	0.42	0.33	9.70	2.84	20.86	26.74
5	25	0.27	0.07	0.14	0.45	0.12	10.01	3.20	21.57	27.32
5	30	0.00	0.07	0.29	0.46	0.34	10.01	3.56	23.00	28.37
6	5	0.04	0.00	0.43	0.31	0.12	10.28	4.05	24.00	29.52
6	10	0.00	0.10	0.86	0.73	0.47	11.21	4.57	26.57	31.48
6	15	0.00	0.10	0.86	1.58	0.86	13.48	5.09	30.86	35.48
6	20	0.00	0.10	0.86	0.94	0.64	13.56	5.61	33.43	39.15
6	25	0.05	0.10	0.86	1.19	0.84	14.61	6.13	37.71	43.35
6	30	0.00	0.10	0.86	2.12	0.86	17.34	6.65	42.00	47.63
7	5	0.00	0.14	0.86	1.88	0.86	17.46	7.33	46.29	51.92
7	10	0.00	0.14	0.86	1.60	0.86	17.46	8.02	50.57	56.20
7	15	0.00	0.14	0.86	4.33	0.86	26.41	8.70	53.14	60.49
7	20	0.00	0.14	0.86	4.04	0.86	26.41	9.38	57.43	64.78
7	25	0.00	0.14	0.86	4.25	0.86	27.60	10.07	61.71	69.06
7	30	0.00	0.14	0.86	3.97	0.86	27.60	10.75	66.00	73.35

Table BA-IV-A-9 (Continued)

M	D	RF	EVL	HIR	HW	QDR	SUMRF	SUMEV	SUMIR	SUMDR
8	5	0.00	0.14	0.86	3.82	0.86	28.06	11.57	71.14	78.49
8	10	0.00	0.14	0.00	3.16	0.86	28.06	12.24	74.57	32.78
8	15	0.00	0.14	0.86	1.47	0.86	28.06	12.92	75.43	87.06
8	20	0.00	0.14	0.86	1.19	0.85	28.06	13.60	79.71	91.34
8	25	0.00	0.14	0.86	1.33	0.12	28.06	14.28	84.00	94.62
8	30	0.00	0.14	0.00	1.07	0.12	28.69	14.95	84.00	95.20
9	5	0.00	0.12	0.00	0.49	0.12	28.73	15.68	84.00	95.90
9	10	0.00	0.00	0.00	0.11	0.09	28.73	16.03	84.00	96.45
9	15	0.00	0.00	0.00	0.05	0.04	28.86	16.03	34.00	96.75
9	20	0.00	0.12	0.36	0.86	0.12	28.86	16.26	86.57	97.12
9	25	0.00	0.12	0.86	2.27	0.12	29.12	16.85	90.86	97.71
9	30	0.00	0.12	0.86	3.57	0.12	29.12	17.44	95.14	98.29
10	5	0.00	0.08	0.36	4.94	0.12	29.12	17.84	99.43	98.87
10	10	0.00	0.08	0.86	6.01	0.86	29.12	18.24	103.71	100.19
10	15	0.00	0.08	0.86	6.15	0.86	29.12	18.64	108.00	103.74
10	20	0.00	0.08	0.86	6.32	0.36	29.92	19.04	112.29	108.03
10	25	0.00	0.08	0.00	6.85	0.86	33.31	19.44	114.86	112.31
10	30	0.00	0.08	0.86	6.77	0.86	33.51	19.84	119.14	116.60
11	5	0.00	0.04	0.71	6.35	0.86	33.52	20.13	123.57	121.74
11	10	0.00	0.04	0.71	6.11	0.36	33.87	20.[illegible]	127.14	126.03
11	15	0.00	0.04	0.00	6.03	0.86	35.30	20.56	129.29	129.57
11	20	0.00	0.04	0.71	5.90	0.12	35.81	20.77	130.00	130.89
11	25	0.00	0.04	0.71	6.13	0.86	35.81	20.98	133.57	133.70
11	30	0.00	0.04	0.00	5.48	0.12	35.81	21.20	134.29	135.76
12	5	0.00	0.02	0.00	5.25	0.12	35.91	21.27	134.29	136.34
12	10	0.00	0.02	0.00	5.16	0.12	36.35	21.35	134.29	136.93
12	15	0.00	0.02	0.00	4.88	0.12	36.35	21.43	134.29	137.51
12	20	0.07	0.02	0.00	5.12	0.12	37.58	21.51	134.29	138.09
12	25	0.30	0.02	0.00	4.97	0.12	37.38	21.58	134.29	138.68
12	30	0.00	0.02	0.00	4.77	0.12	38.05	21.66	134.29	139.26
1	5	0.00	0.02	0.00	4.58	0.12	38.40	21.75	134.29	139.96
1	10	0.00	0.02	0.00	4.31	0.12	38.40	21.83	134.29	140.54
1	15	0.00	0.02	0.00	4.03	0.12	38.40	21.91	134.29	141.12
1	20	0.00	0.02	0.00	3.76	0.12	38.40	21.99	134.29	141.71
1	25	0.01	0.02	0.00	3.85	0.12	39.29	22.06	134.29	142.29
1	30	0.00	0.02	0.00	3.60	0.12	39.35	22.14	134.29	142.37
2	5	0.00	0.02	0.00	3.26	0.12	39.35	22.27	134.29	143.57
2	10	0.00	0.02	0.00	2.97	0.12	39.35	22.37	134.29	144.15
2	15	0.09	0.02	0.00	2.72	0.12	39.44	22.48	134.29	144.74
2	20	0.00	0.02	0.00	2.43	0.12	39.44	22.59	134.29	145.32
2	25	0.00	0.02	0.00	2.15	0.12	39.44	22.69	134.29	145.90
3	5	0.15	0.03	0.00	2.09	0.12	40.43	22.89	134.29	146.83
3	10	0.00	0.03	0.00	1.79	0.12	40.43	23.02	134.29	147.42
3	15	0.00	0.03	0.00	1.50	0.12	40.43	23.15	134.29	148.00
3	20	0.02	0.03	0.00	1.21	0.12	40.45	23.28	134.29	148.58
3	25	0.00	0.03	0.00	1.01	0.12	40.69	23.40	134.29	149.16
3	30	0.00	0.03	0.00	0.72	0.12	40.69	23.53	134.29	149.75

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Table BA-IV-A-10

RESULTS OF SIMULATION ANALYSIS
USING NO TILLAGE SCHEDULE

DR1 14:49 CTI TUES. 02/20/73

HYDRØLØGIC CØNDITIØN:
FREQUENCY F RAINFALL = 100. YR

DRAINAGE SYSTEM:
DRAIN TILE SPACING = 100. FT
DEPTH ØF AQUIFER = 11.0 FT
(SATURATED)
SIZE ØF DRAIN PIPE = 0.50 FT
HEIGHT ØF RØØT ZØNE = 7.00 FT
(FRØM TØP ØF DRAIN TILE)
MAX CAP ØF DRAIN SYST = 0.8571 IN/DAY

AQUIFER CHARACTERISTICS:
PERMEABILITY = 100.00 GPD/SQ FT
STØRAGE CØEFFICIENT = 0.10

TILAGE SCHEDULE: NØ TILAGE

DRAINAGE SYSTEM ØPERATIØN:
START DATE FLØW REGUL = 25TH DAY ØF Ø8TH MØNTH
REGULATED FLØW = 0.05827 IN/DAY

M	D	RF	EVL	HIR	HW	QDR	SUMRF	SUMEV	SUMIR	SUMDR
4	1	0.19	0.00	0.57	0.59	0.06	0.19	0.00	0.57	0.06
4	2	0.00	0.06	0.57	0.57	0.53	0.19	0.06	1.14	0.59
4	3	0.97	0.06	0.57	1.17	0.76	1.16	0.12	1.71	1.35
4	4	0.00	0.06	0.57	0.88	0.85	1.16	0.18	2.29	2.20
4	5	0.00	0.06	0.57	0.71	0.73	1.16	0.24	2.86	2.93
4	6	0.00	0.05	0.57	0.63	0.61	1.16	0.30	3.43	3.54
4	7	1.07	0.06	0.57	1.28	0.80	2.23	0.36	4.00	4.34
4	8	0.00	0.06	0.57	0.99	0.86	2.23	0.42	4.57	5.19
4	9	0.00	0.06	0.57	0.76	0.79	2.23	0.48	5.14	5.99
4	10	0.00	0.06	0.57	0.66	0.65	2.23	0.54	5.71	6.64
4	11	0.08	0.06	0.57	0.65	0.60	2.31	0.60	6.29	7.23
4	12	0.00	0.06	0.57	0.60	0.57	2.31	0.66	6.86	7.81
4	13	0.00	0.06	0.57	0.58	0.54	2.31	0.72	7.43	8.35
4	14	0.00	0.06	0.57	0.57	0.52	2.31	0.78	8.00	8.87
4	15	0.00	0.06	0.57	0.56	0.52	2.31	0.84	8.57	9.39
4	16	0.00	0.06	0.57	0.56	0.51	2.31	0.90	9.14	9.90
4	17	0.52	0.06	0.57	0.86	0.65	2.83	0.96	9.71	10.55
4	18	0.12	0.06	0.57	0.77	0.75	2.95	1.02	10.29	11.30
4	19	0.11	0.06	0.57	0.72	0.68	3.06	1.08	10.86	11.98
4	20	0.19	0.06	0.57	0.75	0.67	3.25	1.14	11.43	12.66
4	21	0.00	0.06	0.57	0.65	0.64	3.25	1.20	12.00	13.29
4	22	0.62	0.06	0.57	0.96	0.74	3.87	1.26	12.57	14.03
4	23	0.00	0.06	0.57	0.75	0.78	3.87	1.32	13.14	14.81
4	24	0.61	0.06	0.57	1.01	0.80	4.48	1.38	13.71	15.61
4	25	0.00	0.06	0.57	0.77	0.80	4.48	1.44	14.29	16.41
4	26	0.21	0.06	0.57	0.78	0.71	4.69	1.50	14.86	17.12
4	27	0.80	0.06	0.57	1.18	0.83	5.49	1.56	15.43	17.95
4	28	0.61	0.06	0.57	1.40	0.86	6.10	1.62	16.00	18.81
4	29	0.38	0.06	0.00	0.95	0.86	6.48	1.68	16.00	19.67
4	30	0.00	0.06	0.00	0.41	0.62	6.48	1.74	16.00	20.29

Table BA-IV-A-10 (Continued)

5	1	0.00	0.09	0.00	0.29	0.06	6.48	1.83	16.00	20.35
5	2	0.00	0.09	0.00	0.16	0.06	6.48	1.92	16.00	20.41
5	3	0.00	0.00	0.00	0.11	0.06	6.48	1.92	16.00	20.46
5	4	0.00	0.00	0.00	0.07	0.06	6.48	1.92	16.00	20.52
5	5	0.00	0.00	0.00	0.03	0.04	6.48	1.92	16.00	20.57
5	6	0.00	0.00	0.00	0.01	0.02	6.48	1.92	16.00	20.59
5	7	0.00	0.00	0.00	0.01	0.01	6.48	1.92	16.00	20.60
5	8	0.00	0.00	0.00	0.00	0.00	6.48	1.92	16.00	20.60
5	9	0.03	0.00	0.00	0.02	0.01	6.51	1.92	16.00	20.61
5	10	0.15	0.00	0.00	0.10	0.05	6.66	1.92	16.00	20.66
5	11	0.37	0.00	0.00	0.36	0.06	7.03	1.92	16.00	20.72
5	12	0.00	0.09	0.14	0.36	0.06	7.03	2.01	16.14	20.78
5	13	1.70	0.09	0.00	1.65	0.06	8.73	2.10	16.14	20.83
5	14	0.00	0.09	0.14	0.98	0.86	8.73	2.19	16.29	21.69
5	15	0.00	0.09	0.14	0.49	0.66	8.73	2.28	16.43	22.36
5	16	0.00	0.09	0.14	0.48	0.06	8.73	2.37	16.57	22.41
5	17	0.58	0.09	0.14	0.96	0.06	9.31	2.46	16.71	22.47
5	18	0.06	0.09	0.14	0.52	0.67	9.37	2.55	16.86	23.14
5	19	0.33	0.09	0.14	0.46	0.45	9.70	2.64	17.00	23.59
5	20	0.00	0.09	0.14	0.46	0.06	9.70	2.73	17.14	23.65
5	21	0.00	0.09	0.14	0.45	0.06	9.70	2.82	17.29	23.71
5	22	0.00	0.09	0.14	0.45	0.06	9.70	2.91	17.43	23.77
5	23	0.04	0.09	0.14	0.48	0.06	9.74	3.00	17.57	23.83
5	24	0.00	0.09	0.14	0.47	0.06	9.74	3.09	17.71	23.88
5	25	0.27	0.09	0.14	0.69	0.06	10.01	3.18	17.86	23.94
5	26	0.00	0.09	0.14	0.35	0.48	10.01	3.28	18.00	24.42
5	27	0.00	0.09	0.14	0.35	0.06	10.01	3.37	18.14	24.48
5	28	0.00	0.09	0.14	0.35	0.06	10.01	3.46	18.29	24.54
5	29	0.00	0.09	0.14	0.34	0.06	10.01	3.55	18.43	24.60
5	30	0.00	0.09	0.14	0.34	0.06	10.01	3.64	18.57	24.65
5	31	0.23	0.09	0.14	0.52	0.06	10.24	3.73	18.71	24.71
6	1	0.00	0.13	0.14	0.25	0.35	10.24	3.86	18.86	25.07
6	2	0.00	0.13	0.29	0.33	0.06	10.24	3.99	19.14	25.12
6	3	0.00	0.13	0.29	0.41	0.06	10.24	4.12	19.43	25.18
6	4	0.00	0.13	0.29	0.50	0.06	10.24	4.25	19.71	25.24
6	5	0.04	0.13	0.29	0.61	0.06	10.28	4.38	20.00	25.30
6	6	0.65	0.13	0.29	0.75	0.62	10.93	4.51	20.29	25.92
6	7	0.05	0.13	0.29	0.47	0.56	10.98	4.64	20.57	26.48
6	8	0.23	0.13	0.29	0.75	0.06	11.21	4.77	20.86	26.54
6	9	0.00	0.13	0.29	0.44	0.54	11.21	4.90	21.14	27.08
6	10	0.00	0.13	0.29	0.52	0.06	11.21	5.03	21.43	27.14
6	11	0.70	0.13	0.29	0.74	0.58	11.91	5.16	21.71	27.72
6	12	0.32	0.13	0.29	0.62	0.62	12.23	5.29	22.00	28.34
6	13	1.25	0.13	0.86	1.59	0.81	13.48	5.42	22.86	29.16
6	14	0.00	0.13	0.86	1.48	0.86	13.48	5.55	23.71	30.01
6	15	0.00	0.13	0.86	1.38	0.86	13.48	5.68	24.57	30.87
6	16	0.00	0.13	0.86	1.27	0.86	13.48	5.81	25.43	31.73
6	17	0.08	0.13	0.86	1.23	0.86	13.56	5.94	26.29	32.58
6	18	0.00	0.13	0.86	1.12	0.86	13.56	6.07	27.14	33.44
6	19	0.00	0.13	0.86	1.01	0.86	13.56	6.20	28.00	34.30
6	20	0.00	0.13	0.86	0.90	0.85	13.56	6.33	28.86	35.15
6	21	1.00	0.13	0.86	1.63	0.86	14.56	6.46	29.71	36.01
6	22	0.00	0.13	0.86	1.52	0.86	14.56	6.59	30.57	36.86
6	23	0.00	0.13	0.86	1.41	0.86	14.56	6.72	31.43	37.72
6	24	0.00	0.13	0.86	1.31	0.86	14.56	6.85	32.29	38.58
6	25	0.05	0.13	0.86	1.24	0.86	14.61	6.98	33.14	39.43
6	26	0.17	0.13	0.86	1.27	0.86	14.78	7.11	34.00	40.29
6	27	2.56	0.13	0.00	2.58	0.86	17.34	7.24	34.00	41.15
6	28	0.00	0.13	0.86	2.47	0.86	17.34	7.37	34.86	42.01
6	29	0.00	0.13	0.86	2.37	0.86	17.34	7.50	35.71	42.86
6	30	0.00	0.13	0.86	2.26	0.86	17.34	7.63	36.57	43.72

Table BA-IV-A-10 (Continued)

7	1	0.00	0.17	0.86	2.12	0.86	17.34	7.80	37.43	44.58
7	2	0.00	0.17	0.86	1.97	0.86	17.34	7.97	38.29	45.43
7	3	0.00	0.17	0.86	1.83	0.86	17.34	8.14	39.14	46.29
7	4	0.12	0.17	0.86	1.79	0.86	17.46	8.31	40.00	47.15
7	5	0.00	0.17	0.86	1.65	0.86	17.46	8.48	40.86	48.01
7	6	0.00	0.17	0.86	1.50	0.86	17.46	8.65	41.71	48.86
7	7	0.00	0.17	0.86	1.36	0.86	17.46	8.82	42.57	49.72
7	8	0.00	0.17	0.86	1.22	0.86	17.46	8.99	43.43	50.58
7	9	0.00	0.17	0.86	1.08	0.86	17.46	9.17	44.29	51.43
7	10	0.00	0.17	0.86	0.93	0.86	17.46	9.34	45.14	52.29
7	11	0.00	0.17	0.86	0.84	0.81	17.46	9.51	46.00	53.10
7	12	5.40	0.17	0.00	4.48	0.86	22.86	9.68	46.00	53.96
7	13	3.55	0.17	0.00	6.58	0.86	26.41	9.85	46.00	54.81
7	14	0.00	0.17	0.86	6.44	0.86	26.41	10.02	46.86	55.67
7	15	0.00	0.17	0.86	6.30	0.86	26.41	10.19	47.71	56.53
7	16	0.00	0.17	0.86	6.15	0.86	26.41	10.36	48.57	57.38
7	17	0.00	0.17	0.86	6.01	0.86	26.41	10.53	49.43	58.24
7	18	0.00	0.17	0.86	5.87	0.86	26.41	10.70	50.29	59.10
7	19	0.00	0.17	0.86	5.73	0.86	26.41	10.88	51.14	59.96
7	20	0.00	0.17	0.86	5.58	0.86	26.41	11.05	52.00	60.81
7	21	1.18	0.17	0.86	6.43	0.86	27.59	11.22	52.86	61.67
7	22	0.01	0.17	0.86	6.29	0.86	27.60	11.39	53.71	62.53
7	23	0.00	0.17	0.86	6.15	0.86	27.60	11.56	54.57	63.38
7	24	0.00	0.17	0.86	6.01	0.86	27.60	11.73	55.43	64.24
7	25	0.00	0.17	0.86	5.86	0.86	27.60	11.90	56.29	65.10
7	26	0.00	0.17	0.86	5.72	0.86	27.60	12.07	57.14	65.96
7	27	0.00	0.17	0.86	5.58	0.86	27.60	12.24	58.00	66.81
7	28	0.00	0.17	0.86	5.44	0.86	27.60	12.41	58.86	67.67
7	29	0.00	0.17	0.86	5.29	0.86	27.60	12.59	59.71	68.53
7	30	0.00	0.17	0.86	5.15	0.86	27.60	12.76	60.57	69.38
7	31	0.00	0.17	0.86	5.01	0.86	27.60	12.93	61.43	70.24
8	1	0.00	0.17	0.86	4.87	0.86	27.60	13.10	62.29	71.10
8	2	0.00	0.17	0.86	4.73	0.86	27.60	13.27	63.14	71.96
8	3	0.46	0.17	0.86	4.97	0.86	28.06	13.44	64.00	72.81
8	4	0.00	0.17	0.86	4.83	0.86	28.06	13.61	64.86	73.67
8	5	0.00	0.17	0.86	4.69	0.86	28.06	13.77	65.71	74.53
8	6	0.00	0.17	0.86	4.54	0.86	28.06	13.94	66.57	75.38
8	7	0.00	0.17	0.86	4.40	0.86	28.06	14.11	67.43	76.24
8	8	0.00	0.17	0.86	4.26	0.86	28.06	14.28	68.29	77.10
8	9	0.00	0.17	0.86	4.12	0.86	28.06	14.45	69.14	77.96
8	10	0.00	0.17	0.86	3.98	0.86	28.06	14.62	70.00	78.81
8	11	0.00	0.17	0.86	3.84	0.86	28.06	14.79	70.86	79.67
8	12	0.00	0.17	0.86	3.70	0.86	28.06	14.96	71.71	80.53
8	13	0.00	0.17	0.86	3.56	0.86	28.06	15.13	72.57	81.38
8	14	0.00	0.17	0.86	3.42	0.86	28.06	15.30	73.43	82.24
8	15	0.00	0.17	0.86	3.27	0.86	28.06	15.47	74.29	83.10
8	16	0.00	0.17	0.86	3.13	0.86	28.06	15.64	75.14	83.96
8	17	0.00	0.17	0.86	2.99	0.86	28.06	15.81	76.00	84.81
8	18	0.00	0.17	0.86	2.85	0.86	28.06	15.98	76.86	85.67
8	19	0.00	0.17	0.86	2.71	0.86	28.06	16.15	77.71	86.53
8	20	0.00	0.17	0.86	2.57	0.86	28.06	16.32	78.57	87.38
8	21	0.00	0.17	0.86	2.43	0.86	28.06	16.48	79.43	88.24
8	22	0.00	0.17	0.86	2.29	0.86	28.06	16.65	80.29	89.10
8	23	0.00	0.17	0.86	2.15	0.86	28.06	16.82	81.14	89.96
8	24	0.00	0.17	0.86	2.00	0.86	28.06	16.99	82.00	90.81
8	25	0.00	0.17	0.86	2.53	0.06	28.06	17.16	82.86	90.87
8	26	0.00	0.17	0.00	2.34	0.06	28.06	17.33	82.86	90.93
8	27	0.00	0.17	0.00	2.15	0.06	28.06	17.50	82.86	90.99
8	28	0.63	0.17	0.00	2.48	0.06	28.69	17.67	82.86	91.05
8	29	0.00	0.17	0.00	2.29	0.06	28.69	17.84	82.86	91.10
8	30	0.00	0.17	0.00	2.10	0.06	28.69	18.01	82.86	91.16
8	31	0.00	0.17	0.00	1.92	0.06	28.69	18.18	82.86	91.22

Table BA-IV-A-10 (Continued)

9	1	0.00	0.15	0.00	1.74	0.06	28.69	18.33	82.86	91.28
9	2	0.04	0.15	0.00	1.61	0.06	28.73	18.47	82.86	91.34
9	3	0.00	0.15	0.00	1.44	0.06	28.73	18.62	82.86	91.40
9	4	0.00	0.15	0.00	1.27	0.06	28.73	18.77	82.86	91.45
9	5	0.00	0.15	0.00	1.09	0.06	28.73	18.91	82.86	91.51
9	6	0.00	0.15	0.00	0.92	0.06	28.73	19.06	82.86	91.57
9	7	0.00	0.15	0.00	0.75	0.06	28.73	19.21	82.86	91.63
9	8	0.00	0.15	0.00	0.58	0.06	28.73	19.35	82.86	91.69
9	9	0.00	0.15	0.00	0.41	0.06	28.73	19.50	82.86	91.75
9	10	0.00	0.15	0.00	0.24	0.06	28.73	19.65	82.86	91.80
9	11	0.00	0.15	0.00	0.07	0.06	28.73	19.79	82.86	91.86
9	12	0.13	0.00	0.00	0.13	0.06	28.86	19.79	82.86	91.92
9	13	0.00	0.00	0.00	0.08	0.06	28.86	19.79	82.86	91.98
9	14	0.00	0.00	0.00	0.04	0.05	28.86	19.79	82.86	92.03
9	15	0.00	0.00	0.00	0.02	0.03	28.86	19.79	82.86	92.06
9	16	0.00	0.00	0.00	0.01	0.01	28.86	19.79	82.86	92.07
9	17	0.00	0.00	0.00	0.00	0.01	28.86	19.79	82.86	92.07
9	18	0.00	0.00	0.86	0.67	0.06	28.86	19.79	83.71	92.13
9	19	0.00	0.15	0.86	1.22	0.06	28.86	19.94	84.57	92.19
9	20	0.00	0.15	0.86	1.76	0.06	28.86	20.09	85.43	92.25
9	21	0.26	0.15	0.86	2.52	0.06	29.12	20.23	86.29	92.30
9	22	0.00	0.15	0.86	3.06	0.06	29.12	20.38	87.14	92.36
9	23	0.00	0.15	0.86	3.61	0.06	29.12	20.53	88.00	92.42
9	24	0.00	0.15	0.86	4.15	0.06	29.12	20.67	88.86	92.48
9	25	0.00	0.15	0.86	4.03	0.86	29.12	20.82	89.71	93.34
9	26	0.00	0.15	0.86	3.90	0.86	29.12	20.97	90.57	94.19
9	27	0.00	0.15	0.86	4.45	0.06	29.12	21.11	91.43	94.25
9	28	0.00	0.15	0.86	4.33	0.86	29.12	21.26	92.29	95.11
9	29	0.00	0.15	0.86	4.20	0.86	29.12	21.41	93.14	95.97
9	30	0.00	0.15	0.86	4.08	0.86	29.12	21.55	94.00	96.82
10	1	0.00	0.10	0.86	4.00	0.86	29.12	21.65	94.86	97.68
10	2	0.00	0.10	0.86	4.58	0.06	29.12	21.75	95.71	97.74
10	3	0.00	0.10	0.86	4.50	0.86	29.12	21.85	96.57	98.60
10	4	0.00	0.10	0.86	4.41	0.86	29.12	21.95	97.43	99.45
10	5	0.00	0.10	0.86	4.33	0.86	29.12	22.05	98.29	100.31
10	6	0.00	0.10	0.86	4.25	0.86	29.12	22.15	99.14	101.17
10	7	0.00	0.10	0.86	4.16	0.86	29.12	22.25	100.00	102.02
10	8	0.00	0.10	0.86	4.08	0.86	29.12	22.35	100.86	102.88
10	9	0.00	0.10	0.86	4.00	0.86	29.12	22.45	101.71	103.74
10	10	0.00	0.10	0.86	4.58	0.06	29.12	22.55	102.57	103.80
10	11	0.00	0.10	0.86	4.50	0.86	29.12	22.65	103.43	104.65
10	12	0.00	0.10	0.86	4.41	0.86	29.12	22.75	104.29	105.51
10	13	0.00	0.10	0.86	4.33	0.86	29.12	22.85	105.14	106.37
10	14	0.00	0.10	0.86	4.25	0.86	29.12	22.95	106.00	107.23
10	15	0.00	0.10	0.86	4.16	0.86	29.12	23.05	106.86	108.08
10	16	0.80	0.10	0.86	4.75	0.86	29.92	23.15	107.71	108.94
10	17	0.00	0.10	0.86	4.66	0.86	29.92	23.25	108.57	109.80
10	18	0.00	0.10	0.86	4.58	0.86	29.92	23.35	109.43	110.65
10	19	0.00	0.10	0.86	4.50	0.86	29.92	23.45	110.29	111.51
10	20	0.00	0.10	0.86	4.41	0.86	29.92	23.55	111.14	112.37
10	21	0.00	0.10	0.86	4.33	0.86	29.92	23.65	112.00	113.23
10	22	0.00	0.10	0.86	4.25	0.86	29.92	23.75	112.86	114.08
10	23	0.00	0.10	0.86	4.16	0.86	29.92	23.85	113.71	114.94
10	24	3.39	0.10	0.00	6.19	0.86	33.31	23.95	113.71	115.80
10	25	0.00	0.10	0.86	6.11	0.86	33.31	24.05	114.57	116.65
10	26	0.20	0.10	0.86	6.19	0.86	33.51	24.15	115.43	117.51
10	27	0.00	0.10	0.86	6.11	0.86	33.51	24.25	116.29	118.37
10	28	0.00	0.10	0.86	6.02	0.86	33.51	24.35	117.14	119.23
10	29	0.00	0.10	0.86	5.94	0.86	33.51	24.45	118.00	120.08
10	30	0.00	0.10	0.86	5.86	0.86	33.51	24.55	118.86	120.94
10	31	0.00	0.10	0.71	5.65	0.86	33.51	24.65	119.57	121.80

Table BA-IV-A-10 (Continued)

11	1	0.00	0.05	0.71	6.16	0.06	33.51	24.71	120.29	121.85
11	2	0.01	0.05	0.71	6.00	0.86	33.52	24.76	121.00	122.71
11	3	0.00	0.05	0.71	5.84	0.86	33.52	24.81	121.71	123.57
11	4	0.00	0.05	0.71	6.34	0.06	33.52	24.87	122.43	123.63
11	5	0.00	0.05	0.71	6.18	0.86	33.52	24.92	123.14	124.48
11	6	0.00	0.05	0.71	6.01	0.86	33.52	24.97	123.86	125.34
11	7	0.00	0.05	0.71	5.85	0.86	33.52	25.03	124.57	126.20
11	8	0.35	0.05	0.71	6.64	0.06	33.87	25.08	125.29	126.26
11	9	0.00	0.05	0.71	6.48	0.86	33.87	25.13	126.00	127.11
11	10	0.00	0.05	0.71	6.32	0.86	33.87	25.19	126.71	127.97
11	11	0.00	0.05	0.71	6.15	0.86	33.87	25.24	127.43	128.83
11	12	0.00	0.05	0.71	5.99	0.86	33.87	25.29	128.14	129.69
11	13	0.77	0.05	0.71	7.13	0.06	34.64	25.35	128.86	129.74
11	14	0.66	0.05	0.00	6.93	0.86	35.30	25.40	128.86	130.60
11	15	0.00	0.05	0.00	6.17	0.86	35.30	25.45	128.86	131.46
11	16	0.00	0.05	0.00	5.41	0.86	35.30	25.51	128.86	132.32
11	17	0.00	0.05	0.00	5.31	0.06	35.30	25.56	128.86	132.37
11	18	0.51	0.05	0.00	5.65	0.06	35.81	25.61	128.86	132.43
11	19	0.00	0.05	0.00	5.55	0.06	35.81	25.67	128.86	132.49
11	20	0.00	0.05	0.57	5.94	0.06	35.81	25.72	129.43	132.55
11	21	0.00	0.05	0.57	6.32	0.06	35.81	25.77	130.00	132.61
11	22	0.00	0.05	0.57	6.04	0.86	35.81	25.83	130.57	133.46
11	23	0.00	0.05	0.57	5.76	0.86	35.81	25.88	131.14	134.32
11	24	0.00	0.05	0.57	6.14	0.06	35.81	25.93	131.71	134.38
11	25	0.00	0.05	0.57	5.86	0.86	35.81	25.99	132.29	135.24
11	26	0.00	0.05	0.57	6.24	0.06	35.81	26.04	132.86	135.29
11	27	0.00	0.05	0.57	5.96	0.86	35.81	26.09	133.43	136.15
11	28	0.00	0.05	0.57	6.34	0.06	35.81	26.15	134.00	136.21
11	29	0.00	0.05	0.57	6.06	0.86	35.81	26.20	134.57	137.07
11	30	0.00	0.05	0.00	5.30	0.86	35.81	26.25	134.57	137.92
12	1	0.00	0.02	0.00	5.23	0.06	35.81	26.27	134.57	137.98
12	2	0.00	0.02	0.00	5.17	0.06	35.81	26.29	134.57	138.04
12	3	0.10	0.02	0.00	5.19	0.06	35.91	26.31	134.57	138.10
12	4	0.00	0.02	0.00	5.12	0.06	35.91	26.33	134.57	138.16
12	5	0.00	0.02	0.00	5.06	0.06	35.91	26.35	134.57	138.22
12	6	0.06	0.02	0.00	5.04	0.06	35.97	26.37	134.57	138.27
12	7	0.38	0.02	0.00	5.30	0.06	36.35	26.39	134.57	138.33
12	8	0.00	0.02	0.00	5.23	0.06	36.35	26.41	134.57	138.39
12	9	0.00	0.02	0.00	5.17	0.06	36.35	26.43	134.57	138.45
12	10	0.00	0.02	0.00	5.10	0.06	36.35	26.45	134.57	138.51
12	11	0.00	0.02	0.00	5.04	0.06	36.35	26.47	134.57	138.57
12	12	0.00	0.02	0.00	4.97	0.06	36.35	26.48	134.57	138.62
12	13	0.00	0.02	0.00	4.91	0.06	36.35	26.50	134.57	138.68
12	14	0.00	0.02	0.00	4.84	0.06	36.35	26.52	134.57	138.74
12	15	0.00	0.02	0.00	4.78	0.06	36.35	26.54	134.57	138.80
12	16	0.00	0.02	0.00	4.71	0.06	36.35	26.56	134.57	138.86
12	17	0.00	0.02	0.00	4.65	0.06	36.35	26.58	134.57	138.91
12	18	0.46	0.02	0.00	4.97	0.06	36.81	26.60	134.57	138.97
12	19	0.70	0.02	0.00	5.49	0.06	37.51	26.62	134.57	139.03
12	20	0.07	0.02	0.00	5.48	0.06	37.58	26.64	134.57	139.09
12	21	0.00	0.02	0.00	5.41	0.06	37.58	26.66	134.57	139.15
12	22	0.00	0.02	0.00	5.35	0.06	37.58	26.68	134.57	139.21
12	23	0.00	0.02	0.00	5.29	0.06	37.58	26.70	134.57	139.26
12	24	0.00	0.02	0.00	5.22	0.06	37.58	26.72	134.57	139.32
12	25	0.30	0.02	0.00	5.41	0.06	37.88	26.74	134.57	139.38
12	26	0.00	0.02	0.00	5.34	0.06	37.88	26.76	134.57	139.44
12	27	0.15	0.02	0.00	5.40	0.06	38.03	26.78	134.57	139.50
12	28	0.02	0.02	0.00	5.35	0.06	38.05	26.80	134.57	139.56
12	29	0.00	0.02	0.00	5.29	0.06	38.05	26.81	134.57	139.61
12	30	0.00	0.02	0.00	5.22	0.06	38.05	26.83	134.57	139.67
12	31	0.35	0.02	0.00	5.45	0.06	38.40	26.85	134.57	139.73

Table BA-IV-A-10 (Continued)

The following notations are used:

M:	month
D:	day
RF:	rainfall in inches
EVL:	evaporation loss in inches
HIR:	irrigation rate in inches/day
HW:	height of groundwater table from the top of drain tile
QDR:	drainage system flow rate in inches/day
SUMRF:	cummulative rainfall from the beginning of irrigation season in inches
SUMEV:	cummulative evaporation loss from the beginning of irrigation season in inches
SUMIR:	cummulative amount of irrigation from the beginning of irrigation season in inches
SUMDR:	cummulative amount of outflow from the drainage system from the beginning of irrigation season in inches of renovated water drained from the soil

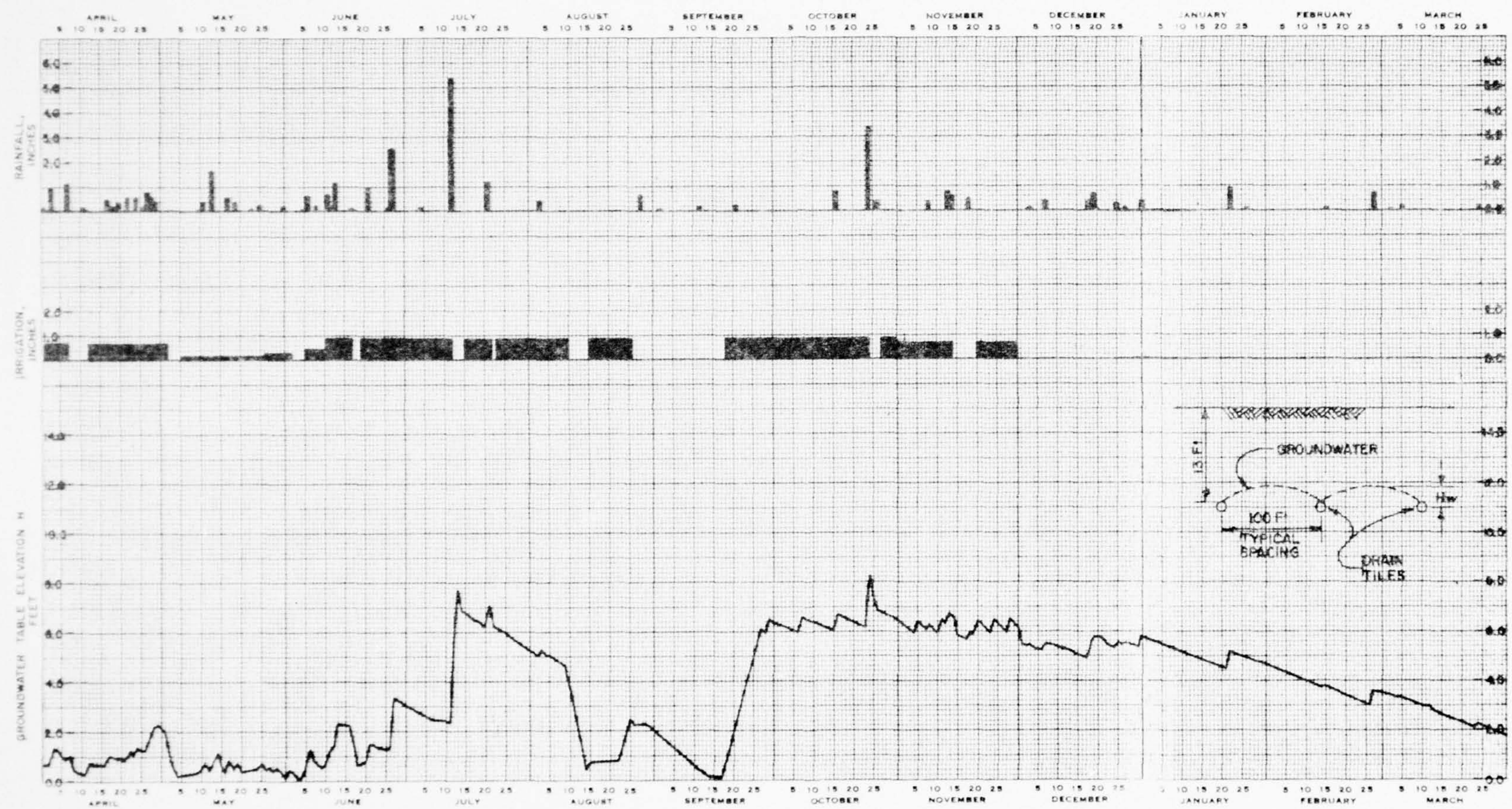

Figure BA-IV-A-6
DRAINAGE ANALYSIS RESULTS
(CONVENTIONAL TILLAGE SCHEDULE)

BIBLIOGRAPHY BA-IV-A-4

REGIONAL TREATMENT SYSTEMS

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5. THE USE OF LAND AS A METHOD OF TREATING WASTEWATER

The following paper discusses land treatment and its meaning to the agricultural community.

THE USE OF LAND AS A METHOD OF TREATING WASTEWATER

(Its Meaning to the Agricultural Community)

Chicago-South End of Lake Michigan Area

Wastewater Management Study

Department of the Army
Chicago District, Corps of Engineers
219 South Dearborn Street
Chicago, Illinois 60604

BA-IV-A-86

PREFACE

Intent

The intent of this paper is to explain how the same biosystem of soil and organic residue that is used to grow crops can be managed as well to purify treated wastewater. The manner in which the system can be incorporated into the area's land use and implemented by normal farming practices and selective cropping patterns also are presented to illustrate the implications to the individual farmer and the agricultural community. In this way those people residing in the rural areas have a basis from which they can objectively evaluate this particular treatment process, one of three processes being investigated.

Moreover the information contained in this paper should prove helpful to the local planners when considering alternate methods for eliminating pollution from sewage in their own areas.

Study Framework

The U. S. Army Corps of Engineers, Chicago District has undertaken a study concerned with the management of wastewater within an area adjacent to Lake Michigan in Illinois and Indiana. The objective was to identify and evaluate alternative wastewater treatment processes that can be incorporated into regional plans. Therefore, while this paper intentionally concentrates on the Land treatment system, the study fully evaluates three advanced treatment technologies and presents a comparative and balanced assessment of each. The alternatives are responsive to the National goal of eliminating the discharge of pollutants into navigable waters by 1985 which was established by the Federal Water Pollution Control Act Amendments of 1972.

The results of the study will be furnished by States of Illinois and Indiana and local governmental entities and planning units for their consideration. Such technical assistance should help the designated agencies substantiate their request for Federal grants beginning after June 30, 1974 that: (1) "alternative waste management techniques have been studied and evaluated"; and (2) "that the works proposed for grant assistance will provide for the application of the best practicable waste treatment technology over the life of the works---", requirements established by Section 201(g)(2)(A) of the Federal Water Pollution Control Act Amendments of 1972.

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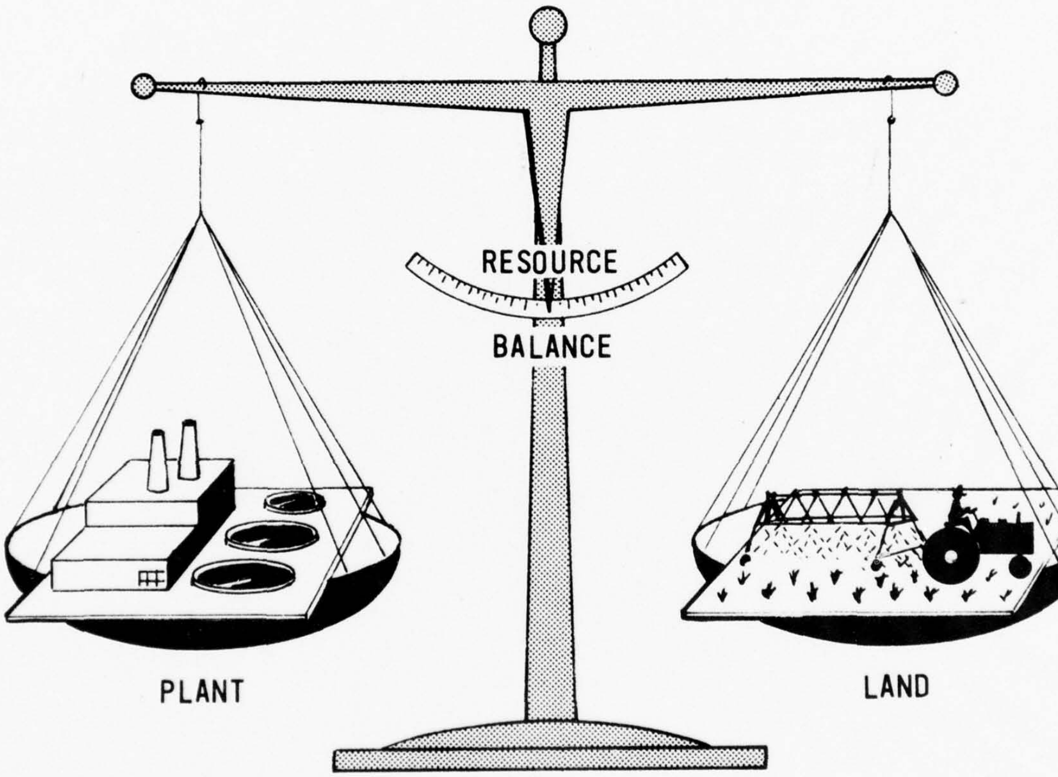
SECTION I

INTRODUCTION



BASIS FOR STUDY

STUDY OBJECTIVE - EVALUATE 3 TECHNOLOGICAL APPROACHES

CONTENT OF PAPER

Basis For Study

National concern for restoring the quality of our streams has focused attention on the wastewater treatment standards currently in effect at the State and local levels. The United States Congress recently has enacted legislation which establishes National water quality goals. One of these goals is the elimination of discharge of pollutants into navigable waters by 1985. If this goal is to be met, new and increased levels of treatment will be required, resulting in far purer water being available for use and for discharge into our streams.

The U. S. Army Corps of Engineers, under a pilot program initiated in 1971 is preparing regional wastewater management studies for: The Chicago Metropolitan area, the Cleveland-Akron area, the Detroit area, the San Francisco Bay area and the Merrimack River Basin-Great Boston area. The results of these five pilot studies will provide a range of alternatives from which the decision-makers in each area can select a system consistent with the water quality goals of the Act, including the 1985 goal mentioned above. The findings in these studies do not mean that any of the alternatives investigated would be constructed. Final decisions as to which alternative, if any, is best suited to a particular region and most acceptable to the people would still be left to the State and local governments which now have that responsibility.

Study Objective

Among the alternatives which the Chicago District formulated and designed were alternative technical systems to achieve the higher water quality objective set forth as a National goal in the Federal Water Pollution Control Act Amendments of 1972. The Chicago District also evaluated the social, environmental, institutional, and economic impacts of each system, as well as determined the relative effectiveness of incrementally meeting other requirements of the Chicago-South End of Lake Michigan (C-SELM) study area.

The scope of investigation is preliminary in nature and is not meant to reflect final concepts in terms of design, cost, or impact evaluations. It is a survey study, one which will identify a range of feasible systems for consideration by residents of the region in eventually complying with the water quality goals.

There are three basic technological approaches which can be used to achieve the proposed water quality goals. These are: (1) an Advanced Biological treatment plant system, (2) a Physical-Chemical treatment plant system, and (3) a Land treatment system. None of the three are new or unique. Components of each system can be found in various parts of the Nation and the world. What is comparatively new is the use of these systems to achieve the high level of treatment and the scale to which these systems would be applied. All three treatment processes have their

AD-A036 644 CORPS OF ENGINEERS CHICAGO ILL CHICAGO DISTRICT F/G 13/2
WASTEWATER MANAGEMENT STUDY FOR CHICAGO-SOUTH END OF LAKE MICHI--ETC(U)
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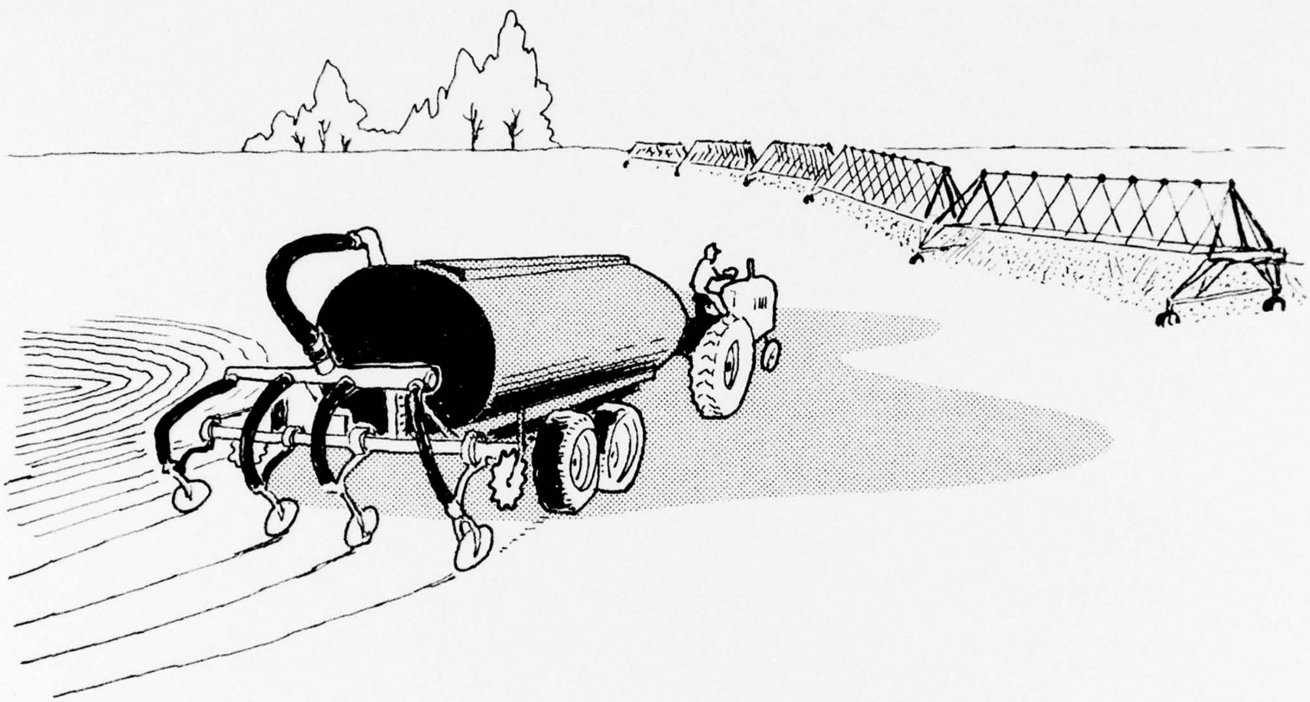
good and bad points. Variations in cost, resource use, and socio-environmental impacts are considerable. These factors have been evaluated as part of the study effort with the final selection or rejection of the alternatives remaining the perogative of the people in the area and their governmental representatives.

Contents Of This Paper

Of the three technological processes, the Land system is the one which is least well known by the general public and so it has been the subject of most questions. As previously indicated Land treatment is not a new concept. Over five hundred municipalities in the United States apply part or all of their pre-treated wastewater on land. What follows is a non-technical discussion of the Land treatment process including its design and operational concepts; illustrative examples of the type of agricultural practices, crop production and management considerations best suited for enhancing the farmer's net income; and an assessment of what the Land treatment system can mean to the individual farmer and the agricultural community as a whole.

SECTION II

LAND TREATMENT CONCEPT



THE COMPONENTS
- PRE-TREATMENT
- PLANTING
- IRRIGATION
- HARVESTING

TREATED WASTEWATER CHARACTERISTICS

THE CONCEPT (BIO-SYSTEM) SOIL AND CROP

THE NITROGEN CYCLE

WATER QUALITY ATTAINED

Functional Components Of The Land Treatment System

The Land treatment system can be described in terms of the operational functions of its physical parts. See Figure 1. Aside from the pipeline network transporting the wastewater from the metropolitan area to the site, the first part consists of two types of lagoons connected in series. In the first (aeration) lagoon, oxygen is added by mechanical aerators and mixers which constantly aerate, mix, and churn the wastewater. The added oxygen provides the necessary environment for microbial organisms living in the water to decompose municipal and industrial wastes, thereby transforming the organic and soluble wastes into suspended solids. The treated wastewater is then transferred to a storage lagoon where the suspended solids settle on the bottom. There the solids or sludge continue to be broken down by further bacterial action until the decomposition process is stabilized. The sludge, which is high in nutrient and organic value, then is removed for subsequent reuse. This sludge can be used either on the adjacent farm lands as a source of fertilization for agricultural production or transported outside the land site area where it may be used as a source of organic material for improving soils and disturbed areas (e.g. strip mined areas) having low productivity capacities.

At this point in the process the wastewater has received the equivalent of primary and secondary treatment. This is the same level of water quality currently being achieved by most of the major sewage treatment plants in the study area. At present this treated wastewater is discharged into nearby streams. The wastewater, however, is still rich in the plant nutrients: nitrogen, phosphorus and potassium. If discharged directly into a stream, nitrogen and phosphorus could stimulate growth of aquatic plants in the stream. Thus, during cycle of growth and decomposition, of these aquatic plants dissolved oxygen in the water can be periodically depleted sometimes to the point of causing a fish kill. This phenomenon of abundant aquatic plants coupled with oxygen depletion is commonly called "eutrophication".

The land system design seeks to take advantage of the nutrient value in the treated wastewater by spraying it on the soil and letting the soluble nutrients be taken up by the crop cover. Before being applied to the land though, the water is chlorinated to kill disease-causing organisms. The chlorine residual concentration will be at a level which is not harmful to the crops.

The treated wastewater is next transported from the storage lagoon to the croplands where the water is applied by the use of a center-pivot or other adapted irrigation system. Applying the treated wastewater to the land is the final or polishing stage in the treatment process. The water is renovated by the entire biosystem of both the soil and cover crop. Involved are the complex physical and chemical reactions, the biological processes of the soil's bacteria and fungi, and the natural crop uptake - all of which form the basis for determining the farmer's present fertility program and cropping practices. By the time the wastewater **percolates** through the soil column and reaches the underdrain system the wastewater has been renovated.

The renovated water, which is of potable quality, is then collected by a system of drain tiles and/or drainage wells and returned to C-SELM area for reuse. The drainage system is designed to maintain an aerated, unsaturated (water) condition in the upper soil layer, thereby protecting the root zone and insuring control of surface and subsurface water flows. Such a drainage system would have eliminated the saturated soil conditions that reduced crop yields and caused harvesting and planting problems for midwest agriculture in the unusually wet period during the fall of 1972 and the spring of 1973.

Treated Wastewater Characteristics

To design the cropping, irrigation and drainage components of the agricultural program, the characteristics of the treated wastewater that would be applied to the land first had to be identified. As previously indicated, the wastewater in the Land system's storage lagoon has received the equivalent of conventional secondary treatment before it is chlorinated. Consequently, a composite listing, typical of the liquid effluent (discharge) from a conventional secondary wastewater treatment plant was prepared, modified to reflect data specific to the study area and used. The chemical characteristics shown in Figure 2 have been defined in terms of the elemental forms even though some may initially be found in the form of compounds.

Concept Of The Land Treatment Process

The pollutants to be removed are actually the consumptive wastes from municipal and industrial usage of our natural and agriculture-related resources and the man-made and natural contaminants picked up by storm water runoff. The method of recapture and potential reuse of the nutrients in the wastewater varies with each of the three treatment processes. In the case of the Advance Biological and Physical-Chemical processes the nutrients along with the other elements are at least partially, extracted from the wastewater and recovered in the sludge. The sludge from the Physical-Chemical system, due to the nature of the process, can only be used as a soil conditioner. While this sludge is rich in lime, the nitrogen and organic matter have been lost by incineration. On the other hand, the sludge from an Advanced Biological plant can be used as a fertilizer since it contains much of the organic matter and nitrogen removed from the wastewater.

In the Land system, however, the liquid portion of the wastewater still contains suspended matter and dissolved nutrients, over and above the amounts extracted with the sludge. Consequently, the Land system is designed to achieve a recycling of the waterborne natural resources in a different way. The cycle starts with the farmer planting, harvesting and marketing his crop. It continues with the consumption and subsequent discharge of food wastes which are combined with other forms of resource by-products that make-up the municipal and industrial wasteload. The wasteload then is subject to primary and secondary treatment including the separation and disposal of the sludge material. The cycle finally ends with the return to the soil of the

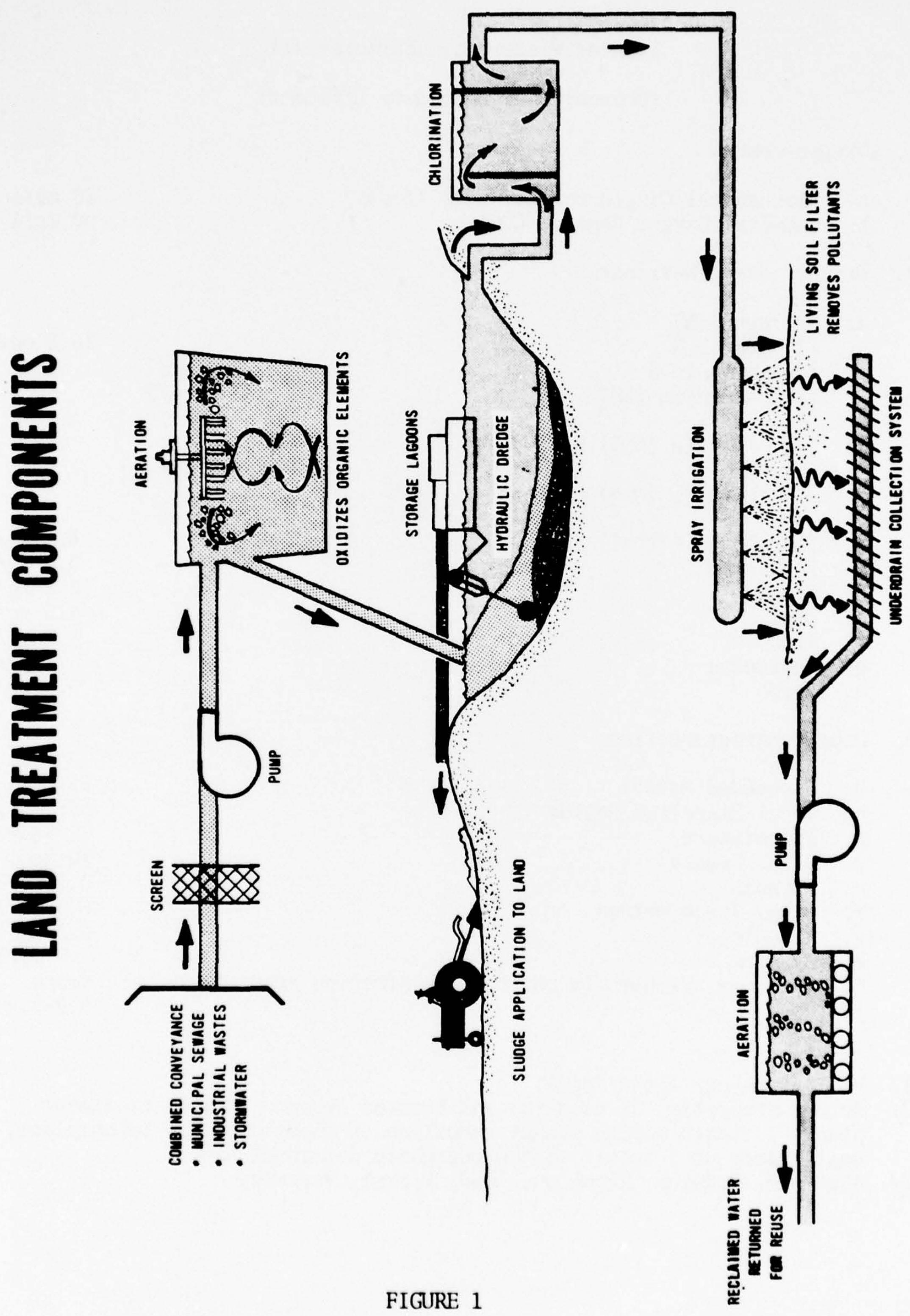

LAND TREATMENT COMPONENTS
COMBINED CONVEYANCE
• MUNICIPAL SEWAGE
• INDUSTRIAL WASTES
• STORMWATER
SCREEN
PUMP
AERATION
OXIDIZES ORGANIC ELEMENTS
STORAGE LAGOONS
HYDRAULIC DREDGE
SLUDGE APPLICATION TO LAND
CHLORINATION
SPRAY IRRIGATION
LIVING SOIL FILTER
REMOVES POLLUTANTS
UNDERDRAIN COLLECTION SYSTEM
PUMP
AERATION
RECLAIMED WATER
RETURNED
FOR REUSE

FIGURE 1

Treated Wastewater Characteristics

(Conventional Secondary Effluent)

1.	Oxygen-demand		
	a. Biochemical Oxygen Demand (BOD) (5-day)		20 mg/1 1/
	b. Chemical Oxygen Demand (COD)		60 mg/1
2.	Primary Plant Nutrients		
	a. Nitrogen (N)		
	(1) Total N		16.5 mg/1
	(2) Organic N	2.0 mg/1	
	(3) Ammonium (NH_4^+)	13.4 mg/1	
	(4) Nitrite (NO_2^-) N / Nitrate (NO_3^-) N	1.1 mg/1	
	b. Phosphorus (Total) (P)		4.1 mg/1 2/
	c. Potassium		8.0 mg/1
	d. Copper		0.1 mg/1
	e. Zinc		0.3 mg/1
	f. Iron		2.0 mg/1
	g. Manganese		0.2 mg/1
	h. Boron		0.7 mg/1
3.	Other characteristics		
	a. Suspended Solids		25 mg/1
	b. Total Dissolved Solids		635 mg/1
	c. Temperature		53-78 °F
	d. Oils, Greases		10 mg/1
	e. Phenols		0.2 mg/1
	f. Other Trace Metals		0.4 mg/1 3/
	g. Arsenic		0.3 mg/1
	h. Cyanide		0 mg/1
	i. Bacteria, Viruses (w/current disinfection practices)		trace
	j. pH		6.9-7.4

1/ Milligrams per liter (mg/1)
2/ Recent monoriting of both raw and treated sewage at MSDGC treatment plants indicate a significant reduction of phosphorus has taken place, most likely as a result of the phosphate detergent ban.
3/ Aluminum, Cadmium, Chromium, Lead, Nickel, Mercury.

treated wastes now in the form of waterborne plant nutrients and other organic and mineral components. These nutrients, applied by field irrigation equipment, stimulate the production of another series of crops thereby completing the cycle.

The Land treatment process utilizes the entire biosystem, including the soil and vegetative or crop cover to purify the wastewater. The wastewater is renovated primarily by four basic internal mechanisms operating within the soil, namely filtration, plant uptake, cation exchange and fixation, and volatilization. These mechanisms are active to some degree in all types of soil and control the effectiveness of the land to sustain optimum crop production. How this is done is illustrated in Figure 3, and discussed in more detail in the following subparagraphs. Many of these mechanisms, in fact, have served as models for the design of our current sewage treatment plants.

Filtration is the physical retention by soil, acting as a screening media, of the suspended solids in the wastewater flows. The effectiveness of the soil as a filter depends upon the soil particle size and distribution. Most of the suspended solids are organic in nature and are primarily decomposed by the microorganisms in the soil. It is this residue which is retained in the soil column.

The plant uptake mechanism relies on the root system to adsorb (held on the particle or root hair surface) portions of the available nutrient elements from the wastewater. In order for the plants to utilize these nutrients, however, they have to be in forms that make them readily available for uptake. As with commercial fertilizer, nutrients such as nitrogen and phosphorus in the wastewater are transformed by complex biological and chemical processes from the applied form to a usable soil form. Nitrogen in ammonium form is mostly converted by the soil micro-organism to nitrate form before being ultimately adsorbed. Nitrogen also may be lost by evaporation of ammonia or reduction of nitrate to inert nitrogen gas.

The conversion to the gaseous form, called volatilization, is an integral part of the normal nitrogen cycle and, under certain circumstances, is an important factor in the ultimate loss of a significant amount of the applied nitrogen. Under aerobic (aerated) conditions, soil organisms degrade organic matter, releasing carbon dioxide gas and water in the process.

Cation Exchange is a key part of the uptake mechanism. Through ion exchange, soils have the capability to temporarily hold certain dissolved chemicals in the wastewater. These positively charged (cations) chemicals are adsorbed by the negatively charged clay minerals and organic matter in the soil. The quantity of positively charged ions that a soil is able to hold is dependent upon its "Cation Exchange Capacity" which in turn is primarily determined by the type and quantity of the clay minerals, the amount of organic matter, and soil pH. Because of differences in ion charge, those dissolved chemicals which have a greater ion strength will usually be preferentially adsorbed, thereby replacing those of lesser strength. This mode of holding is responsible for the retention of calcium, magnesium and potassium against leaching until such time as they are adsorbed by plant roots. Ammonium nitrogen is similarly held in the soil until converted by nitrifying microorganism to nitrate nitrogen which can either be adsorbed by the plant or lost to drainage.

Soils also have the capacity to retain certain other dissolved chemicals very tightly through adsorption. This mechanism called "Fixation" results from either very strong physical or chemical adsorption processes and/or chemical precipitation. The amount of fixation varies with the pH of the soil. Compounds of iron, aluminum, and/or calcium contained in the soil are primarily responsible for the fixation of such elements as phosphorus and trace metals in the soil. The fixed phosphorus and trace metals being in an insoluble form are thus held and not leached from the soil.

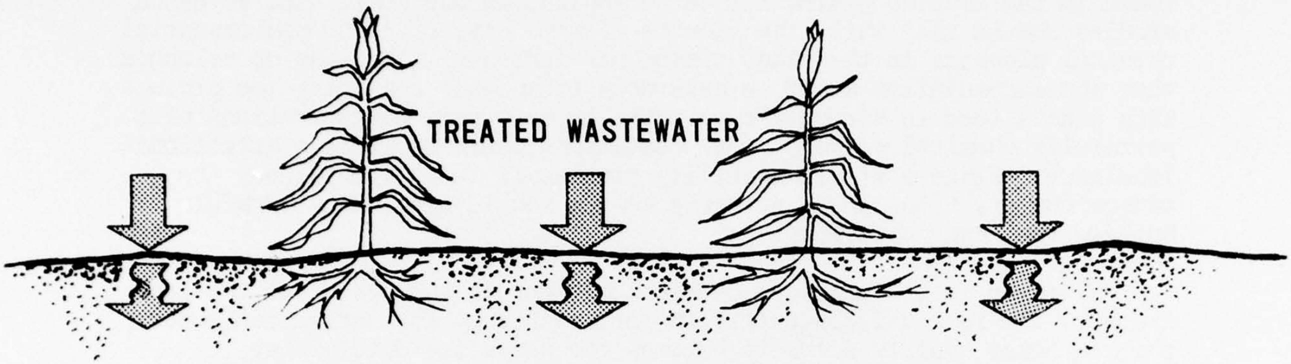
Conversely, the dissolved solids which primarily include soluble sulfate, chloride and bicarbonate salts of sodium, potassium, magnesium and calcium will pass, for all practical purposes through the soil column to be collected and removed by the drainage system. The ion composition of the soluble salts in the drainage water, however, will be different than that originally applied, primarily due to the soil's cation exchange capacity. Thus, the Land treatment process, like the treatment plant technologies, is not designed to reduce the level of the soluble salt concentrations.

The extremely small percent of the pathogens and viruses that remain after chlorination are filtered out by the soil and then degraded by the soil microorganisms. Similarly, the oils and grease which have not been removed during primary and secondary treatment will form films (filtration) on the soil particles and then be degraded by microbial action.

The constituent buildup in the soil, both short and long term, is important in maintaining the integrity of the treatment system and a balanced fertility program for the farmer. Estimates have indicated that phosphorus buildup is the only long range problem of concern and that a loam or clay soil will provide sufficient adsorptive capacity for over 100 years. Where the soil is coarse textured, the adsorptive capacity is maintained over a short-time frame by the aluminum and iron content in the soil and the interaction and formation of sparingly soluble compounds. The adsorptive capacity is extended by the iron and aluminum in the wastewater and to a lesser extent by the organic matter built-up from the crop residue. For the species of plants which are considered feasible for use, because of their nitrogen uptake characteristics, phosphorus build-up in the soils are not likely to adversely affect crop productivity.

Heavy metals are a concern but are not assumed to be a problem, even though they will be held in the soil with the application of the treated wastewater. While the metal ions are held in the soil and can be consodered susceptible for uptake by the plants, this should occur only to the extent normally experienced with the individual crop specie. In well-drained soils with a pH value above 6.0, it is unlikely that a phytotoxic

LAND TREATMENT PROCESS



ROOT SYSTEMS - TAKE UP SOLUBLE NUTRIENTS

SOIL PARTICLES - MECHANICALLY STRAIN SUSPENDED SOLIDS
- ADSORB BACTERIA, VIRUSES, PHOSPHORUS, AND HEAVY METALS

SOIL MICROORGANISMS - CONSUME DISSOLVED ORGANIC, NITROGENOUS AND PHOSPHORUS MATERIALS

FIGURE 3

condition will ever develop from irrigating crops with wastewater which has received the equivalent of secondary treatment. Research by the University of Illinois has demonstrated this in using sludge from conventional secondary wastewater treatment plants as crop fertilizer. This sludge had at least 100 times greater concentrations of heavy metals than that found in the treated wastewater to be applied to the soil. The research studies showed that while the amounts of some essential and non-essential chemical elements in the plant tissue may increase, there was no evidence that the accumulation would be hazardous to animals consuming the produce. Crop plants tend to accumulate potentially hazardous concentrations of a particular chemical element under conditions where there is a nutritional imbalance. Since a viable fertility program is to be maintained, the management practices and monitoring system should preclude a harmful buildup from ever occurring.

Nitrogen is the critical chemical element in the design of the Land system. The residual concentration permissible at the underdrain under the new water quality actually becomes the basis for determining the volume and rate of application for the irrigation system. The concentration in the return flow and the degree of removal is controlled by plant uptake and several conversion processes within the soil. Nitrogen in the wastewater occurs primarily in the form of ammonium which is converted by the soil's microorganisms into the nitrate form for uptake by the cover crop. The rate at which the soil bacteria convert the ammonium nitrogen to nitrate form depends upon a range of physical factors, especially the soil's temperature and pH. In the presence of a large supply of energy materials, such as carbon or crop residue, much of the nitrogen may be temporarily incorporated into new microbial cells. As the crop residue is decomposed, many of the microorganisms die and the nitrogen in their bodies is recycled for crop use.

The Nitrogen Cycle

Nitrogen exists in the treated wastewater in four forms: organic, ammonium (NH_4^+), nitrite (NO_2^-) and nitrate (NO_3^-). Essentially, all the ammonium, nitrite and nitrate nitrogen are in solution. Soil microorganisms at the soil surface convert the organic forms of nitrogen to the inorganic ammonium (NH_4^+) ion form by a process called nitrogen mineralization. The soluble ammonium nitrogen is converted into the nitrite and then the nitrate form by two specific groups of nitrifying organisms. The conversion called nitrification occurs as a result of the microorganisms oxidizing the ammonium to nitrate nitrogen for energy. This energy is essential to the growth and reproduction of the microorganisms. For this process to occur, the soil profile must provide an aerobic (free oxygen) and unsaturated (by water) environment. This in turn has design implications as to soil types and drainage requirements.

The nitrites in the wastewater and those which are formed during the nitrification process are quickly converted to nitrates. The soluble nitrate ions, which have not been removed by plant uptake, continue through the soil until a low, or no, oxygen (anaerobic) environment is reached. There, another specialized group of bacteria, called denitrifying organisms, convert (volatilize) the nitrates into nitrogen gas which escapes from the soil to the air. In this process oxygen from the nitrates is used to oxidize the carbon contained in the soil's decomposable organic matter as a source of energy for the microorganisms. The nitrates not volatilized eventually reach the water table where they will be collected by the drainge system. It is interesting to note that even in soils that are considered aerobic (aerated), comparatively large amounts of nitrates are lost by denitrification (volatilization). This is thought to occur in localized anaerobic zones or pockets in the soil, or even inside the soil granules themselves.

Understanding the nitrogen cycle is critical to the design of the Land system; otherwise the residual level of the nitrate in the renovated water collected by the drainage system can exceed the new water quality goal. Thus, the application rate and irrigation schedule must be framed to coincide with the crop's nitrate uptake requirements, taking advantage of the soil's microbial capability to immobilize the nitrogen until needed. This should provide top yields and facilitate maintaining a continuously balanced fertility program for either a single or double cropping program, assuming the climatic conditions permit.

Water Quality Attained

The wastewater irrigation equipment, application schedule and drainage system have been designed to effectively utilize the biosystem of both the soil and cover crop(s) as the final stage of treatment. The incremental steps of first providing the equivalent of primary and secondary treatment by the aeration and storage lagoons are supplemented by the Land process in achieving the advanced level of treatment. This integrated system will produce renovated water suitable for almost all uses. Shown in Figure 4 is the anticipated quality of the treated water, expressed in terms of concentration levels for critical constituents. A monitoring program, for periodic sampling of the renovated water would be maintained to insure successful control of the system. In addition, the cover crops will be analyzed for selected heavy metal concentrations and nitrogen balance. To assist the farmer in his farm management program, soil samples also will be taken periodically and analyzed relative to pH and the availability of both phosphorous and potassium.

FIGURE 4

Treated Wastewater Characteristics

(Land Treatment Effluent) 1/

1.	Oxygen-Demand		
	a. Biochemical Oxygen Demand (BOD) (5-day)		2 mg/1 2/
	b. Chemical Oxygen Demand (COD)		6 mg/1
2.	Primary Plant Nutrients		
	a. Nitrogen (N)		2 mg/1
	(1) Total N		2 mg/1
	(2) Organic N	0 mg/1	
	(3) Ammonium (NH_4^+)	0 mg/1	
	(4) Nitrite (NO_2^-) N; Nitrate (NO_3^-) N	2 mg/1	
	b. Phosphorus (Total) (P)		0.01 mg/1
	c. Potassium		~0 mg/1
	d. Copper		~0 mg/1
	e. Zinc		~0 mg/1
	f. Iron		~0 mg/1
	g. Manganese		~0 mg/1
	h. Boron		0.7 mg/1
3.	Other characteristics		
	a. Suspended Solids		0 mg/1
	b. Total Dissolved Solids		500 mg/1
	c. Temperature		53-78 °F
	d. Oils, Greases		~0 mg/1
	e. Phenols		0 mg/1
	f. Other Trace Metals 3/		~0 mg/1
	g. Arsenic		~0 mg/1
	h. Cyanide		0 mg/1
	i. Bacteria, Viruses		None
	j. pH		7.0-8.0

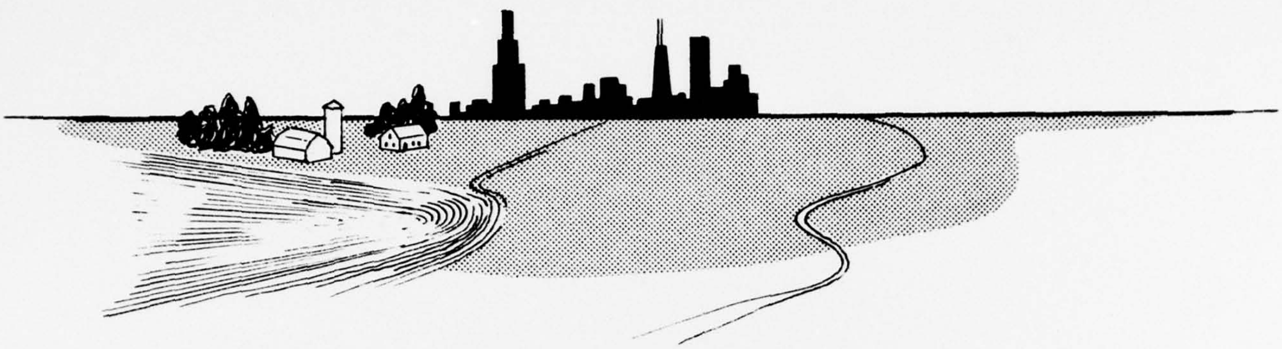
1/ Absent (~0) means not detectable by standard testing methods and current technology.

2/ Milligrams per liter (mg/1)

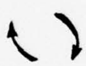
3/ Aluminum, Cadmium, Chromium, Lead, Nickel, Mercury.

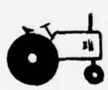
SECTION III

OPERATIONAL AND MANAGEMENT CONSIDERATIONS



 DESIGN OBJECTIVES

 FIELD MANAGEMENT & CROPPING PATTERNS

 NO-TILLAGE FARMING

 CROPPING CONSIDERATIONS

PLANTING CONSIDERATIONS

 SYSTEM SCHEDULES

- NO-TILLAGE
- CONVENTIONAL TILLAGE

N NITROGEN BALANCE

System Design Objectives

Based on the preceding section, it is apparent that the successful operation of a Land treatment system is directly dependent upon the types of vegetative cover and cropping practices employed. A range of vegetative cover is possible. From strictly a treatment standpoint, a cover crop like Reed Canary Grass would be ideal. The grass has very high nitrogen and phosphorus uptake capability, is responsive to an intensive irrigation program, and is capable of sustaining multiple cuttings during the growing season. All these considerations are factors which could minimize the number of acres required for irrigation. However, there is a limited market, at best, for this type of crop today. Before the grass could be considered a cash crop, extensive plant investment for dehydrating and pelletizing the grass would be required, and a market (local, National and/or export), as livestock feed, would have to be developed. Since the plant and resource committments are economically questionable, the use of this type of cover as a primary crop was dropped from further consideration at this time. Instead, selection was limited to field crops which the participating farmer would most likely plant under normal market conditions. For all intents and purposes, this means that the best farming procedures must be adopted and system operations must be responsive to pertinent agricultural requirements. There is, however, an equal and concurrent objective of also treating a specific volume of water. Therefore, the overall goal must be to optimize the yields of the selected crops and minimize the acreage required for non-productive use.

As indicated, crop selection is critical to the system design and operation. This assumes that the soil of the site has been selected relative to its capability for achieving the necessary bacteriological decomposition, adsorption and holding requirements, and that its infiltration and percolation rates and the drainage system are capable of maintaining an effective aerobic condition in the upper 5 feet of the soil profile. Therefore, the final factors governing the system design are:

(1) The types of crops grown should be adaptable not only to the area's climate but to irrigation. Furthermore, the crops selected also should have a relative worth as an income or cash crop to provide a practical basis for the individual farmer to participate.

(2) The volume of wastewater applied must be based on the cover crop's uptake capability of the critical nutrient, nitrogen.

(3) The amount of land required must be determined by comparing the average annual volume of wastewater to be treated with the amount of nitrogen (in the wastewater) which can be applied for the selected crops. Appropriate adjustments also must be made for annual on-site rainfall and acreage required for the physical facilities.

Field Management and Cropping Patterns

There is a continuous and growing trend in row-crop practices towards less tillage. Over time the move to larger, heavier tractors and associated equipment has created a concern about increasing soil compaction with accompanying lower yields. Furthermore, research and actual field observations have demonstrated that minimum tillage reduces soil erosion both from water and wind. This is a matter of practical concern since some states now have regulations dealing with soil erosion as part of their pollutant control program.

Discussed below are the seven most common forms of reduced tillage farm management options. Soil preparation ahead of the planter is minimal and in some is not employed. None of the options use the traditional moldboard plow. The seven options are:

(1) Zero or No-Tillage. This option basically involves the use of a planter with a rolling coulter to cut a slice in the soil for a narrow planter runner. A heavily weighted packer wheel runs back of the runner to push the soil back into contact with the seed.

(2) Strip Till-Plant. This option employs a strip tiller that plants as it passes through the ridge left at the row of last year's crop. Corn roots, stalks and loose soil are moved into the row middles by trash guard rods extending back from the sides of a big duckfoot shovel. The seed is firmed down with a packer wheel. Covering disks follow which help incorporate insecticide placed on top of the row.

(3) Combined Tillage. This option combines tillage with the planting operation. It can include, as example, a front-mounted cultivator used on a tractor pulling the planter or a direct-attached toolbar field cultivator with unit planter added.

(4) Chisel-Plow. In this option chisel plowing to a depth of 15 inches, or so, is employed as a primary tillage operation. Chisel planters combining the chisel plow with a planter unit can work well, but not in all soils. More often, full chiseled ground is worked again at a shallow depth just before planting.

(5) Heavy-duty Disk. In this option extra-heavy offset disks are used for primary tillage. This does a good job of incorporating crop residue into the soil and minimizes the subsequent follow-up (chisel) plowing before planting.

(6) Field Cultivator. This option employs a field cultivator with sweep shovels as a replacement of tandem disks and is used in conjunction with the chisel plow. Field cultivators are often used with planter units to make a once-over pass of final tilling and planting.

(7) Fluted Coulter. In this option a fluted coulter works a narrow strip of soil for the seedbed. The "waved" edge tills a narrow strip of soil as the coulter is pulled through the soil in front of the planter runner. Usually it is used on fields that have been chisel-plowed. Recently, it has been used successfully with no-tillage operations in lieu of the rolling coulter. On unplowed ground extra weight is added to cause sufficient penetration of the ground to provide a good seedbed.

The no-tillage method has been selected as one of the illustrative farm management programs discussed later for use with the Land treatment system. Only in recent years has no-tillage become a practical reality. Functional well-designed equipment for planting in an untilled seedbed and effective contact herbicides that quickly kill existing vegetation yet leave no soil residue to harm the germinating crop, are now available. Both factors help reduce production costs and the time and labor required from planting to harvesting. Generally speaking, no-tillage works well on sandy soil, which is the primary soil textural class selected in locating the spray irragation treatment sites. It also works well on loams and silt loams, provided the soil has good tilth, but the feasibility of using the no-tillage system on clay loams and clays is questionable.

No-tillage has the added advantage of facilitating the adoption of a more intensive two-crop program by minimizing the farmer's field operation and, thus, the down time for the irrigation system. Double cropping also will increase the effectiveness of the system's nitrogen uptake and, consequently, limit the number of acres required for irrigation. A high fertility program, mainly supplied by the nutrients in the wastewater, should permit the participating farmer to increase his profit margin primarily by increasing the crop yields rather than expanding the amount of land under production.

There are, however, some drawbacks to this optimistic picture. The crops that can be planted within the system should be those that have high nitrogen requirements, can respond to irrigation, and can be grown on a continuous and calendarized basis for maximum production control. Corn as a continuous row crop and rye as a combined cover and second (forage) crop are ideally suitable for the northern part of the central midwest and have been selected for illustrative purposes. Other crops such as soybeans or those raised by specialized truck farming operations have not been demonstrated as being adaptable to the system. Their use will probably have to be deferred until additional research has been undertaken.

No-Tillage Farming

Maintaining tilth is of prime importance on fields other than sands that have a cultivated crop every year. The more the seedbed is worked and the crop is cultivated, the more the soil crumb structure is destroyed. This tends to break down the natural aggregation of particles and makes the soil less porous, harder to work and more susceptible to forming clods. High yields of corn with stalks left on the field actually returns a large amount of organic matter to the soil. But the way to produce more organic matter is to use more fertilizer, not less. When the optimum amounts of fertilizer and water are applied, both the corn yields and the amount of residues returned to the soil are high. This increases the number of earthworms, bacteria or micro-organisms and fungi which all depend on organic matter for food. Consequently, after several years of no-till cropping, a gradual but continuous improvement in the soil structure will be attained. Thus, a no-till system and chemical weed control make it possible to grow continuous row crops without destroying tilth.

No-till farming was originally aimed at attaining the advantages of erosion control, time-savings and reduced production costs. Results of actual field tests by many universities and individual farm production records indicate that:

(1) With no-till practices, yields from continuous corn planting are equal to those from conventional tillage where adequate drainage exists.

(2) Double cropping of corn and rye or corn and wheat are feasible and minimizes erosion losses.

(3) It is practical to grow high-value row crops on land previously limited to pasture or forage because of the severe threat from wind or water erosion.

The decayed crop residue retained in the surface layer, absorbs the impact from the rainfall and irrigation spray on the soil. This reduces surface sealing or soil packing which normally speeds runoff. No-tillage and the rye cover crop both help reduce the amount of sediment carried in the rain and snow-melt runoff water by reducing the amount of soil detachment and velocity of the run-off water. As a result, infiltration, or the rate at which water enters the soil, is maximized.

Normally, the increased transpiration losses of the soil's water by the second crop, establishment of an adequate surface mulch, and a suitable drainage system will allow the farmer to get into the field earlier. These factors however, are not too significant where sandy soils are involved. He can plant more acres earlier especially in wet years, and also schedule or calendarize his planting dates to: (1) maximize high yields; (2) achieve an easier, more efficient and profitable harvesting with less losses to bad weather including heat, rain or frost; and (3) get a more effective, early fall stand of the rye cover crop.

The claimed economic advantage of no-tillage farming is that the total production costs are reduced. The time and equipment costs for plowing, disking and cultivating to prepare the seedbed under conventional farming practices are completely eliminated. Thus, if the depreciation and the applicable overhead costs, and the fuel, labor and repairs for the unneeded equipment are dropped from the fixed costs of the production budget, the savings can be substantiated. If, however, just the out-of-pocket field costs are considered, no-tillage is comparable or even slightly higher in costs than expended for conventional tillage. There will be increases in the cost of chemicals. These include insecticides and additional herbicides, since weed control and the elimination of rye as a competitive crop is critical to the double-crop program. The cost of seed will also increase because specific genetic characteristic in terms of yield, field durability and other factors will be desired. The net effect is still one of comparable field production costs and just as significant, less time in the field and more time to better manage the overall farm operation.

Cropping Considerations

The treated wastewater that is applied to the crops contains sufficient nutrients to provide the equivalent effect of a starter fertilizer. It is a relatively clear liquid with comparatively low, but balanced, concentrations of nitrogen, phosphorus and potassium. The use of the wastewater with its natural nutrient composition has the advantage of essentially eliminating the amounts of inorganic fertilizer supplements required to maintain a balanced fertility program. For illustrative purposes, the system's design uses corn as the main cash crop, not only for its natural ability for adsorbing nitrogen (and other nutrients), but also because it makes efficient use of the applied water. Unlike the savings in production costs attained from no-tillage, the economic gains attributable to the irrigation system will be reflected in the savings in fertilizer costs and the higher yields that will be obtained on a continuous yearly basis. As with any irrigation system, the participating farmer will be protected against crop losses he might have suffered during drought years. Conversely, the drainage system will safeguard against wet year losses, since the root zone must be maintained in an unsaturated, aerated condition for the treatment system to work effectively. Furthermore, the wastewater application will be scheduled to help meet the nutrient requirements of the cover crop. Key to this is the rate of nitrogen uptake and utilization which varies over the growth cycle of the corn and rye. This scheduling will help increase the yields of the early maturing hybrids which normally yield less than those of a longer-season variety.

As previously discussed, maintenance of a good mulch cover is critical to no-tillage farming. There are two basic types of mulch--those from cover crops established specifically for that purpose and those which are residues of the existing crop. When one selects a cover crop for building a mulch there are at least three key points to consider:

(1) One must be able to completely kill the cover to keep it from competing with the main cash crop for water and nutrients.

(2) One must be able to plant in it.

(3) The cover crop must provide adequate ground cover.

To further develop mulch, the corn stover would be retained in the field and left as residue.

Winter rye was selected as the cover crop because of its vigor and winter hardiness. It is easy to establish because it can be interseeded before the corn is harvested. In system design, winter rye is utilized both for its nitrogen uptake value during fall irrigation and as a winter cover crop. Furthermore, when wet springs are encountered, rye will remove large amounts of water from the soil profile before the corn is planted, thereby facilitating field operations. Early planting together with comparatively high application of nutrients following the harvesting of corn will result in the rye being heavily tillered (stooled) in the fall. This rye will have a high protein content, approximately 18 to 20 percent crude protein, and have a good market value for forage. Consequently, the rye will be harvested in the fall. By 15 November, it is anticipated that approximately one and a half (1-1/2) tons of dry forage can be harvested per acre. The market value of this rye probably will not be as high as could normally be expected, primarily because of the no-tillage operations. While the corn stover should be pretty well knocked down by the corn combine, some of the corn stubble will be picked up when harvesting the rye. If the rye is dried and pelletized for commercial beef feed, a chemical analysis will be needed to determine the protein, crude fiber, and total digestable nutrient value for marketing purposes. If green chopped for local feedlot or on-farm beef production, its value should not be affected.

The rye should be about 10 to 12 inches high when fall harvested. If the stubble after harvesting is at least 4 inches high, the rye should recover in early spring. The rye then will continue to serve as a cover crop both for erosion contol prior to corn planting and later for use as a mulch. The rye will have developed sufficient hardiness to survive the winter and the normal snow cover will help insure its survival. Thus, early spring irrigation will have three advantages:

(1) It will stimulate the rye to grow, thereby increasing its value as mulch.

(2) By adding more nitrogen, it will hasten the decomposition of the previous corn residue.

(3) It will supply available nitrogen to the corn during the period when the soil organisms are tying up the nitrates. This will avoid a temporary deficiency of available nitrates and serve as a starter or "pop-up" fertilizer.

Winter wheat also was considered for use as a cover crop. It could not, however, be successfully calendarized with the corn's early start date. A later planting date for corn would be required to insure that the wheat had not only jointed but the head was in the boot stage and sufficiently high to be cut by the mower. This would have an adverse impact on the corn yield, and change the agri-chemical program that would have to be adopted.

Planting Considerations

In designing the highly intensified agricultural program planned for the Land treatment system, consideration was given not only to field preparation but also seed selection, planting and equipment.

Irrigation certainly will eliminate the concern over future drought conditions. Blight, root rot and the like are not anticipated to be a problem since the rate of application will be phased to the corn's nitrogen requirements; and the drainage system will maintain an unsaturated and aerated condition in the root zone. To insure the reliability of the system's operation, however, the use of seeds resistant to blight and other diseases must be encouraged. The losses attributable to corn blight in the past have generally occurred when most of the seed sold on the market was of the susceptible varieties.

A high yield planting program has been adopted in establishing the irrigation program. The calendarization calls for the use of a corn hybrid which will regularly reach, or be near, "physiological maturity" by the middle or end of August. This will expedite field dry-down, enabling an optimum moisture level for combining. This in turn will minimize the down-time before irrigation is resumed for the rye. There are no corn varieties which have been developed specifically for no-tillage planting, but the seeding rates should be higher than for conventional practices. Disease resistant hybrids of the 100 to 110 day maturity varieties for No. 2 corn with a planting population of from 26,000 to 28,000 plants per acre is recommended. The high population includes "over-plant" allowances for the following reasons: (1) to offset the reduced germination in the cooler (mulch covered) no-tillage seedbeds and (2) to compensate for harvest losses including those caused by the birds and field mice which commonly hide in a heavy sod cover. Because the goal is to achieve high yields through planting high population, the hybrids selected must be of the population-tolerant type and have proven standability.

Drilled corn gives the most uniform distribution of plants in the field and should, therefore, make the most efficient use of available sunlight, the soluble fertilizers, and moisture. The lodging problem, usually present under high moisture content, should be overcome by the system's drainage system and the present development of better standing hybrids. With the trend to higher plant population, the use of narrower rows, preferrably 30" or less, also will be encouraged to achieve even more uniform planting and maximum yields. Narrow rows make more efficient use of available light and shade the surface soil more completely, thereby also helping combat weed growth. As long as the surface soil is moist, as will be the case, the narrow row planting changes the proportion of water that is evaporated from the soil as opposed to that amount transpired from the leaves. Since more leaf per acre is exposed to the sun, the transpiration loss is greater than that evaporated from the soil. This maximizes photosynthesis and, thus, the proportion of water (and nutrient uptake) that is used in the growth process.

yield increases reported from narrow-row experimental plantings show that it is economically sound to tool up for narrow row operations when you need to replace obsolete or old equipment. Similarly, the time, labor and production savings inherent in the no-tillage operations, the equipment changes should be quickly paid off.

Actually, less equipment is needed for no-tillage farming than for conventional tillage. No soil working implements other than a planter, a tractor and a sprayer are needed, so less tractor horsepower and capital investment should be required. On the other hand, turning over the built-up humus every forth or fifth year may be warranted. By using some form of plow-plant the organic matter will be worked deeper into the root zone, thereby improving the soil's treatment capability. This turnover also would prevent a disease susceptable environment from developing in the soil due to continuous corn cropping. Even so, the no-tillage planter must be capable of:

(1) Cleanly cutting or breaking through the sod or crop residue and loosening the soil enough to prepare a miniature seedbed. A tilled area roughly 2-3 inches wide and 3-4 inches deep should be adequate.

(2) Being able to apply any fertilizer supplements, other than nitrogen, phosphorus and potassium if required.

(3) Deposit the seed at the proper depth. Since the soil temperature is lower for no-tillage than in conventionally worked seedbeds, the ability to plant shallow (approximately 1/2 to 1 inch) is critical if maximum germination is to be attained.

(4) Cover the seed with a uniform layer of soil.

No-tillage equipment now is being marketed by both "short line" and major farm equipment manufacturers. Some manufacturers are producing complete no-tillage planters. Others are providing the basic frame with the choice of the various components optional, thereby permitting the operator to custom-build his planter to his own needs. The ability to apply herbicide using a pressure spraying system on the planter is not particularly recommended. Foliar application is recommended which can be either custom applied or applied by attaching a spray bar and using the irrigation rig for direct application.

System Schedules

In the illustrative example, a planned schedule was prepared for each of the two extremes in field operations. One involved no-tillage and the other, conventional tillage practices. Both were prepared to phase the required field and irrigation operations, to identify the weekly rates of application, and to highlight those phases of farming practices which will require special cost or operational considerations. Calendarization, as such, emphasizes planting dates according to crop maturity, making it possible to field dry and complete harvesting at an opportune time. The range in time shown for emergence, crop maturity, and harvesting reflect the variations in the "Growing Degree Days" required for today's hybrids with sufficient maturity spread to reduce the peak workload during harvesting. As previously discussed, the 100 to 110-day maturity corn hybrids will be used, and, with irrigation, the harvestable yield should approximate those of the longer-growing varieties. An early maturing date will enable the farmer to field dry his corn during the hotter, drier time frame of 15 August to 15 September. This in turn should make it possible to begin harvesting earlier and come of the field with corn at lower moisture content, thereby reducing out-of-pocket drying costs prior to storage.

The rye will be aerially broadcasted about one to two weeks before corn maturity. This type of inter-seeding is gaining widespread acceptance. It offers the advantage of an earlier start with the second crop and provides good soil cover for the irrigation planned after harvesting the corn crop and during early spring. Early spring irrigation should provide good growth for the rye that eventually is recycled into the soil mulch.

Two ranges of acreages were used in the calendarization to better assess the problems that various-sized farming operations might face when working with the proposed irrigation schedule. Selection was confined to the minimum and maximum acreages which could be cultivated by a farm family with essentially no additional labor hire. The 250 (cultivable) acreage was considered the minimum point at which the landowner could farm and be able to obtain a sufficient return in terms of net income to warrant the necessary labor and capital investment. Conversely, the 900 acre farm was considered the maximum a farm family, including relations, could jointly manage without extensive reliance on a permanent source of hired labor. This helped define not only the available manpower but also the type and size of equipment that normally would be available for on-farm operations. The labor and equipment in turn were used to determine the time required for planting and harvesting as well as production budget cost.

No-Tillage Schedule

The operational schedule involving the use of no-tillage practices is shown in Figure 5. Using the no-till concept, the herbicide program replaces the plowing, disking, and harrowing operations in conventional tillage operations. Two types of herbicides are used with the no-tillage program. A contact herbicide will be used to kill the spring growth of the rye. Application should follow immediately after corn planting so that the rye will start to decay before the corn emerges. This also should help the soil warm-up and overcome the cooling effect of the cover mulch. A residual herbicide, not harmful to the corn, will also be needed to kill the weeds that will sprout during the growing season. Under the no-tillage system, a shift from annual to perennial weed species will be noted, in contrast to conventional tillage methods, with emergence frequently occurring at planting time.

Foliar application assures that the contact herbicide is quickly adsorbed by the spring rye and becomes waterproofed in a matter of hours. Once it is adsorbed, rain and subsequent irrigation will not spoil its effectiveness. The dead vegetation is then decomposed along with the applied chemicals by the soil microorganism and becomes part of surface mulch. The nitrogen remaining in this residue is ultimately recycled as part of the total nitrogen balance.

A mineral oil base, water soluble residual herbicide can be applied at a lesser level under the no-tillage system than for the conventional method. Since the soil surface is rough (no crusting), the residual herbicide will remain in the surface layer because of maximum adsorption by the soil particles of clay and organic matter. This should provide an early growing environment for the crop which is free of competition until the weed control. Furthermore, the irrigation operations will be resumed shortly after application in order to carry the residual herbicide down into the top two inches of soil where the majority of weeds usually germinate. This will assure its effectiveness, since the farmer will not have to rely on rain to activate the residual herbicide within two weeks of application.

Insect control also becomes more important with no-tillage farming. The mulch cover will provide a good place for such insects as wireworms, seed corn maggots, grape colapis and seed corn beatles to live and work. Therefore, it is imperative that the biodegradeable insecticides are put down into the soil with the no-tillage corn planter.

Conventional Tillage Schedule

While it was recognized that reduced tillage in any form has certain cost and labor saving advantages, each seemed to have its own inherent problem so far as seedbed preparation was concerned. Though chemicals and equipment modifications have gone far in correcting the problems, primarily weed control, the majority of farmers in the area are presently committed to conventional tillage. Therefore, a schedule for this type of field operation is shown in Figure 6.

The planting, maturity and harvesting dates for corn are the same as used in the no-tillage system since the crop yields would be adversely affected if lagged more than 5-7 days. The main comparative differences attributable to conventional tillage are:

(1) The extensive increment of field time and labor required under conventional tillage.

FIGURE 5

AGRICULTURAL - IRRIGATION OPERATIONS SCHEDULE
(NO TILLAGE SYSTEM)

SCHEDULE FOR FARMED ACREAGE

OPERATIONS	250 ACRES	WEIGHTED	900 ACRES
Plant Corn w/insecticide (start)	30 Apr-1 May	3 May	1-3 May
Plant rate	40 ac/day		180 ac/day
Apply Herbicides (start)	4-5 May	4 May	2-4 May
Start Irrigation, Phase I	7 May	7 May	7 May
Complete Planting & Herbicide Application	10 May	10 May	10 May
Corn Emergence	10-14 May	12 May	9-13 May
Inter-seed Rye		10-24 Aug	
Corn Physiological Maturity and End of 1st Irrigation Phase	23 Aug-10 Sept	25 Aug	21 Aug-5 Sept
Moisture Content @ maturity		35%	
Estimated Field Drying Rates	15 Aug-15 Sept after 15 Sept	@ 1/2% moisture content/day @ 1/4% moisture content/day	
Start Harvesting Corn (28% moisture content)	6-28 Sept	12 Sept	4 Sept-23 Sept
Harvesting Rate	15 ac/day		55 ac/day
Resume Irrigation, Phase 2	12 Sept-4 Oct	18 Sept	10-29 Sept
Complete Harvesting Corn	23 Sept-15 Oct	29 Sept	21 Sept-10 Oct
End of 2nd Irrigation Phase	13 Nov	13 Nov	13 Nov

FIGURE 5 (Cont'd)

AGRICULTURAL - IRRIGATION OPERATIONS SCHEDULE
(NO TILLAGE SYSTEM)

SCHEDULE FOR FARMED ACREAGE

OPERATIONS	250 ACRES	WEIGHTED	900 ACRES
Start Harvesting, Rye	15 Nov	15 Nov	15 Nov
Harvesting Rate	25 ac/day		80 ac/day
Resume Irrigation, Phase 3	20 Nov	20 Nov	19 Nov
Complete Harvesting, Rye	25 Nov	26 Nov	27 Nov
End of 3rd Irrigation Phase	30 Nov	30 Nov	30 Nov
Resume Irrigation, Phase 4	1 Apr	1 Apr	1 Apr
End of 4th Irrigation Phase	27 Apr	27 Apr	27 Apr

FIGURE 6

AGRICULTURAL - IRRIGATION OPERATIONS SCHEDULE
(CONVENTIONAL TILLAGE SYSTEM)

SCHEDULE FOR FARMED ACREAGE

OPERATIONS	250 ACRES	WEIGHTED	900 ACRES
Plant Corn w/insecticide	30 Apr-1 May	2 May	1-3 May
Plant Rate	40 ac/day		180 ac/day
Start Irrigation, Phase I	4 May	5 May	5 May
Complete Planting	10 May	10 May	10 May
Corn Emergence	10-14 May	12 May	8-13 May
End of 1st Irrigation Phase		1 June	
Cultivate-Start	31 May-4 June	2 June	29 May-3 June
Cultivate-Complete	6-10 June	8 June	6-11 June
Resume Irrigation Phase 2	3-7 June	5 June	2-7 June
End of 2nd Irrigation Phase	14-18 June	16 June	14-19 June
Apply Herbicide: Start	15-19 June	17 June	15-20 June
Apply Herbicide: Complete	18-22 June	20 June	19-24 June
Resume Irrigation Phase 3		19 June	
Inter-seed Rye		10-24 Aug	
Corn Physiological Maturity and End of 3rd Irrigation Phase	23 Aug-10 Sept	25 Aug	21 Aug-5 Sept
Moisture Content & Maturity		35%	
Estimated Field Drying Rates	15 Aug-15 Sept	@ 1/2% moisture content/day	
	after 15 Sept	@ 1/4% moisture content/day	

FIGURE 6 (Cont'd)

AGRICULTURAL - IRRIGATION OPERATIONS SCHEDULE
(CONVENTIONAL TILLAGE SYSTEM)

SCHEDULE FOR FARMED ACREAGE

OPERATIONS	250 ACRES	WEIGHTED	900 ACRES
Starting Harvesting Corn (28% moisture content)	6-28 Sept	12 Sept	4 Sept-23 Sept
Harvesting Rate	15 ac/day		55 ac/day
Resume Irrigation Phase 4	12 Sept-4 Oct	18 Sept	10-29 Sept
Complete Harvesting Corn	23 Sept-15 Oct	29 Sept	21 Sept-10 Oct
End of 4th Irrigation Phase	13 Nov	13 Nov	13 Nov
Start Harvesting Rye	15 Nov	15 Nov	15 Nov
Harvesting Rate	25 ac/day		80 ac/day
Resume Irrigation Phase 5	20 Nov	20 Nov	19 Nov
Complete Harvesting Rye	25 Nov	26 Nov	27 Nov
End of 5th Irrigation Phase	30 Nov	30 Nov	30 Nov
Resume Irrigation Phase 6	1 Apr	1 Apr	1 Apr
End of 6th Irrigation Phase	7 Apr	6 Apr	6 Apr
Plow (moldboard)			
Start	8 Apr	7 Apr	7 Apr
Plow Rate	30 ac/day		95 ac/day
Complete Plowing	20 Apr	20 Apr	20 Apr
Disk and Drag, Start	20 Apr	20 Apr	20 Apr
Disk Rate	40 ac/day		120 ac/day
Complete Disking	30 Apr	30 Apr	30 Apr

(2) The loss in growth of the spring rye and the resultant decrease in the build-up of organic matter for surface mulch.

(3) The necessity for having to get into the field in early spring to prepare the field for planting. Unfortunately, fall plowing would destroy the winter rye cover and subject the field to erosion by wind and surface runoff. If, however, plowing were done, there would be no adverse effect on the nitrogen balance and application quantities.

Nitrogen Balance

The system design is predicated on applying the wastewater in amounts consistent with the nitrogen requirements of the crops. Since the requirements of the two crops differ in magnitude and weekly rates, the nitrogen sources must be controlled. Nitrogen for crop uptake comes from two sources - the time-phased application of the treated wastewater and the crop residue. In net effect, the treated wastewater provides only that amount of nitrogen that is actually removed from the system by: (1) harvesting of the corn grain and rye forage; (2) losses due to volitization; and (3) the residual concentration permitted under the standard contained in the renovated water and leaves the system via the underdrains. It is the nitrogen in the crop residue which is recycled over time that is critical to the system design, particularly its availability for crop uptake.

The nitrogen budget applicable to the illustrative cropping pattern and currently being used for this study is shown in Figure 7. This could change, subject to design evaluation and refinement in the final study stage. A planting budget for 200 bushels per acre corn, or some 295 pounds of nitrogen per acre, has been used with an additional 120 pounds per acre applied for the rye. The nitrogen allocation for the rye is programmed to assure obtaining high protein-value forage in the fall for harvesting and an optimum amount of organic matter for incorporation as soil mulch in the spring.

When the corn grain is harvested, large supplies of nitrogen are returned to the soil in the form of the crop residue. The residue contains about 40 percent carbon and 1 to 1.5 percent nitrogen which represents a carbon-to-nitrogen ratio ranging from 26:1 to 40:1. Both the carbon and nitrogen are food for the soil's micro-organisms and are held in the soil, once having been consumed. Plant residues having carbon to nitrogen ratios ranging from 15 to 33:1 generally provide enough nitrogen for their own decomposition without drawing on an outside source. The actual carbon to nitrogen ratios of the decomposing residues, however, at which nitrogen is immobilized (fixed in the soil) or mineralized (released to the soil) depends on the lignin content of the material. In all probability, the lignin content of the corn residues will be sufficiently high to immobilize some portion of the nitrogen applied by irrigation after harvest. Actual mineralization of the nitrogen though, will not likely occur until the carbon-to-nitrogen ratio of the decomposing residues has fallen to at least 20:1. Since microbial action is temperature dependent, this critical level of carbon to nitrogen ratio will not be reached until sometime during the following spring.

To assure that the nitrogen will be held in the soil surface, the rye will be inter-seeded to take up most of the nitrogen applied by irrigation both in the late summer, fall and early spring. Like all small grains, the rye which is killed in the spring by herbicides or by plowing under has an even greater carbon-to-nitrogen ratio than does the corn residue. Thus, the decomposition of the dead rye grass will result in further immobilization of some nitrogen.

It is anticipated that the decomposition rate of the corn and rye residues will be comparatively slow due to low temperatures. About the middle of June, however, the carbon-to-nitrogen ratios of the residues will be sufficiently low to start release or mineralization of some nitrogen. Shown in Figure 8 is the nitrogen requirement for corn during the 30 days following emergence is comparatively low. During this time much of the nitrogen released by mineralization and that added by application will be lost by evaporation and/or denitrification. It is only after this interval that the greatest period of nitrogen demand occurs. At that time, the nitrogen released by mineralization increases significantly and is quickly converted and absorbed by the plant. After the corn has matured, the concentration level of nitrogen in the soil will be minimal. Much of the soil's capacity to hold ammonium nitrogen in exchange forms is available. The ammonium nitrogen held by the soil's exchange complex will be rapidly oxidized to nitrate nitrogen, but in view of the temperature conditions at that time, denitrification and volatilization of the nitrogen will likely be at a maximum.

The nitrogen concentration of the pre-treated wastewater to be irrigated is estimated at 3.74 pounds per acre-inch. This was computed using projected area loadings and the dilution effects of the storm water volume with its lesser concentration.

To provide the required 500 pounds per acre of nitrogen (Figure 7), 134 inches of wastewater must be applied per year. Of the total wastewater applied, the nitrogen in some 58 inches would be required for the corn, 23 inches for the rye, 40 inches would be lost by volatization and 13 inches either returned in the renovated water or held (immobilized) in the soil's organic matter (decomposed residue).

FIGURE 7

NITROGEN ANALYSIS
(LBS. PER ACRE)

NITROGEN BUDGET

1. SYSTEMS ALLOCATIONS			
CORN	@295		
RYE	@120	415	
OTHER SYSTEM MECHANISMS		200*	
TOTAL		615	
2. NET RECYCLED			
CORN ROOT	@15		
CORN STOVER	@65		
RYE	@35	-115	
BALANCE REQUIRED		500	

NITROGEN APPLIED

1. NET HARVESTED		
CORN GRAIN	@ 195	
RYE FORAGE	@ 85	
CORN STOVER	@ 20 **	
NET CROP UPTAKE		300
2. VOLATILIZATION LOSS		150
NET REMOVED BY SOIL BIOSYSTEM		450
3. EQUIVALENT RESIDUAL (NDCP STANDARD)***		50
TOTAL TO BE APPLIED		500

* Volatization and residual in water removed by drainage system.

** Equivalent of corn stubble pickup up when rye is harvested.

*** NDCP - No Discharge of Critical Pollutants

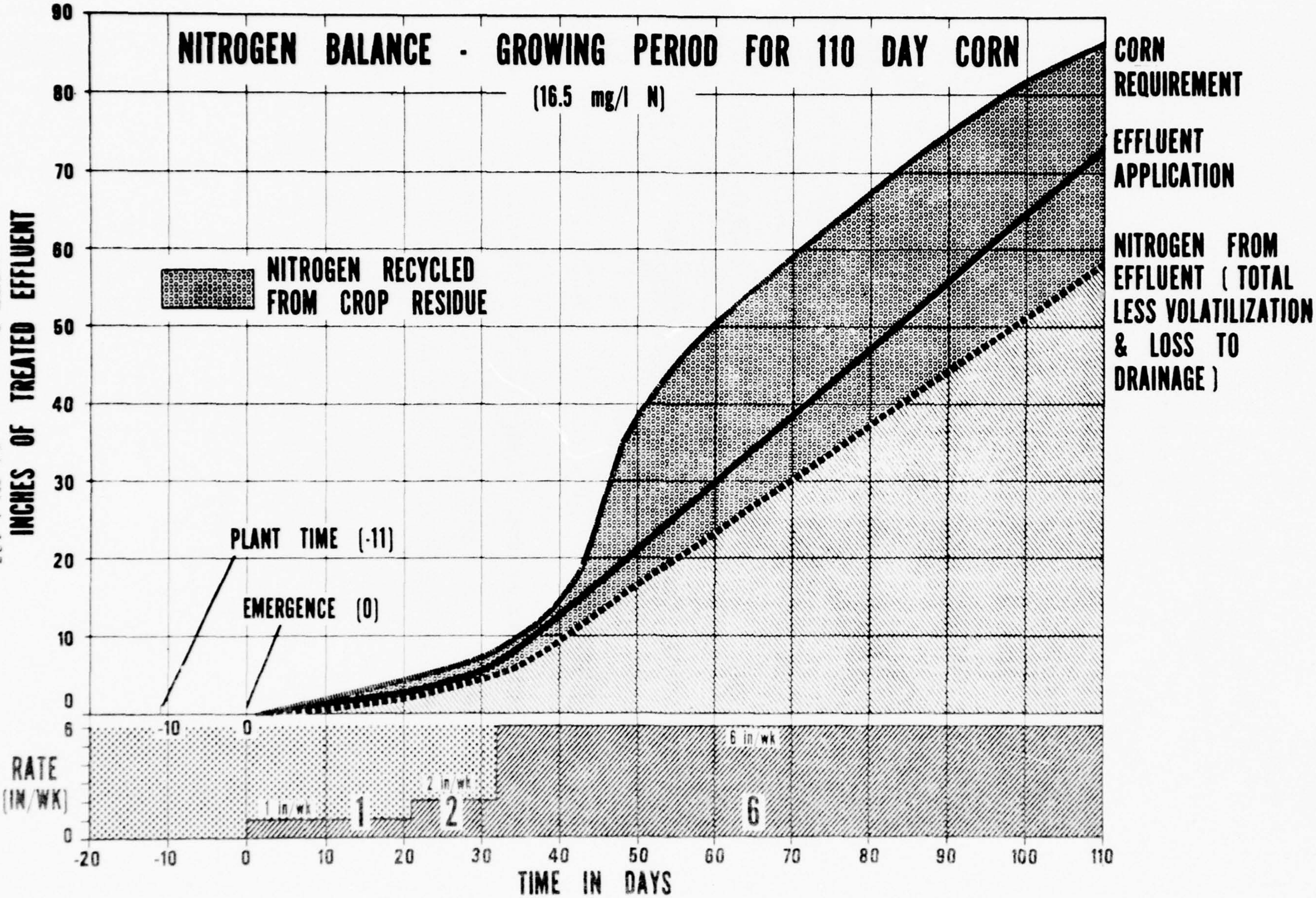


FIGURE 8

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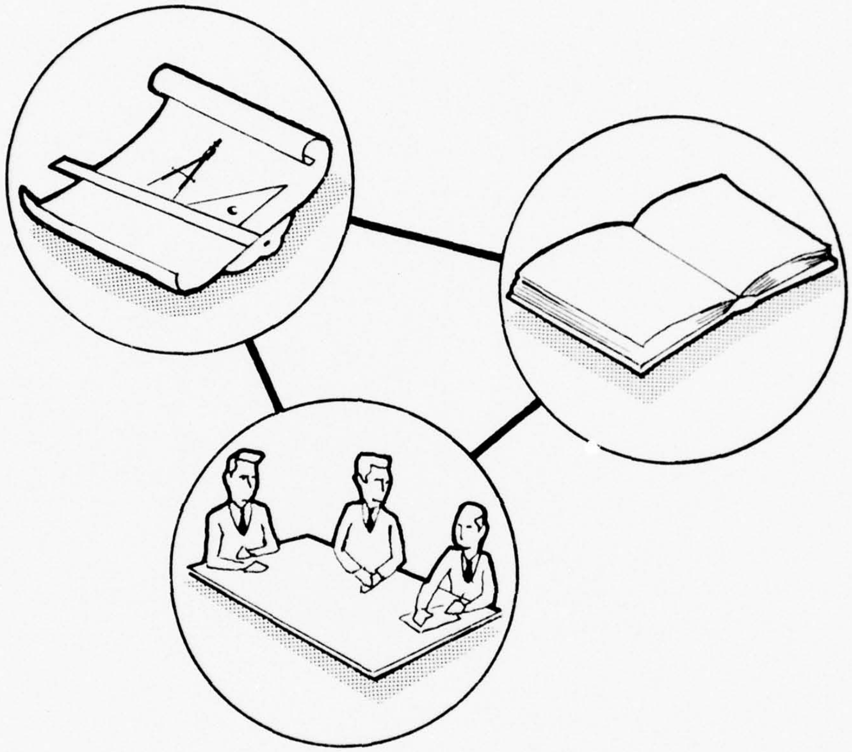
SECTION IV

LAND TREATMENT EVALUATION



Site Considerations

Preliminary Screening

Prototype Model
- Site Layout
- Lagoons
- Center-pivot Irrigation System
- Drainage System

Impact on the Farmer

Impact on the Community

Site Considerations

The double cropping pattern and high application rates utilized in the system's design were adopted to restrict the number of acres needed for irrigation. This attempt to minimize the impact on the life style of the agricultural areas, however, did necessitate selection of specific soil types. Topsoils with high infiltration rates such as sandy loams or silty loams overlying sand or coarse-textured glacial outwash were required. The permeability or percolation rates of these soil columns ranged from moderate (0.6 to 2.0 inches per hour) to moderately rapid (2.0 to 6.0 inches per hour). Using U. S. Department of Agriculture maps, deep, permeable sand soils classified by the Soil Conservation Service as having the desired physical properties were located.

The economics of transporting the wastewater to and from the treatment site was then used to further screen the range of locations. Those sites with minimum population concentrations and having sufficient acreage to justify the investment in the irrigation and drainage system were retained for consideration in the first series of comparative screenings. Suitable acreages of either silty loams and/or sandy loams were found in counties located in both Illinois and Indiana. Included were portions of McHenry, Kendall, Grundy, Will, Kankakee and Iroquois Counties in Illinois and mainly Newton and Jasper Counties in Indiana. A major portion of the total acreage is within the drainage boundary of the Kankakee River basin, located south of the study area.

Preliminary Screening

A range of alternatives employing Land treatment system were all evaluated on a comparative basis. These included an alternative with a single site, and alternatives with dispersed sites, inside and outside the study area, and in combination with the other plant technological processes and with synergistic uses. Institutional constraints were recognized, but design was predicated on regional objectives in compliance with Congressional directives and intent. These alternatives were then screened and analyzed with respect to social, environmental, economic and resource considerations, as were other alternatives utilizing the Advanced Biological and Physical-Chemical plant processes. Of the 19 alternatives originally studied, five have been retained for final study. Two of the five alternatives involve Land treatment to some degree. One is a pure Land treatment system while the other employs land as a supplement to five major Advanced Biological treatment plants located in the metropolitan area. In both cases, the land sites are dispersed around the study area, not concentrated in one particular geographic location.

Prototype Model

In designing the physical layout of the Land treatment system, it was recognized that each site must fit into the general land-use patterns of the surrounding area. Public concern required that every effort must be made to minimize any possible adverse effects on the area's social well being, economic structure and environmental attributes. To determine how this could best be accomplished and to evaluate the full range of design implications, several prototype models, site specific, were developed. What follows is a general description of one model and the land considerations which were used to develop the site plans.

Certain planning objectives were adopted as a result of the preliminary studies and used as the basis for the prototype design:

(1) All lands which are environmentally or ecologically unique in value would not be encroached upon.

(2) All communities, public institutions, and commercial developments would be avoided.

(3) The integrity of the transportation system within the area would be maintained, at least down to the level of the township road. Road relocation and alterations are to be avoided whenever possible.

(4) The physical facilities would be so located as to cause minimum disruption to the farmer - his home, plant and land use.

The size of the prototype model was based on its storage and treatment rate capacity. Selection of the base size was predicated on the potential for synergistic (multiple-purpose) uses, economics of irrigation system design, and capability to shape the treatment system's components within the site's physical features. The illustrative module selected for study encompassed 79,400 acres of which only 32,400 acres would be associated with the wastewater management system. An additional 7,100 acres would be required if the sludge is applied as fertilizer on either cultivated or pasture lands within the module rather than used to reclaim low productive land outside of the module. Figure 9 presents the amount of acreage for each land-use within the prototype model.

In this case study, the irrigation and drainage systems and the lagoons were shaped within the existing road network and around existing developments including home sites in the area. The high percentage of land retained as woodland reflects such constraints as topographic relief (grade) and basic conservation practices where such cover is desirable - as on land in and adjacent to the floodplains. Those lands presently in crop, pasture, or other uses, but not incorporated into the system, were parcels that could not be realistically irrigated because of existing physical features such as roads and unacceptable soils or other design constraints. This acreage could be reduced during subsequent study efforts, but only if acceptable to the residents of the area and the local and State planning agencies. A conceptual presentation of the model is shown in Figure 10.

FIGURE 9

LAND USE (ACRES)
PROTOTYPE LAND TREATMENT MODEL

A.	Land Treatment System	
	1. Irrigated Crop Land	26,600
	2. Aeration Lagoon	200
	3. Storage Lagoon	5,600*
	Subtotal	32,400
	4. Crop Land (Sludge Farming)	7,100**
	Total	39,500
B.	Unaffected Land	
	1. Woodlands, Farm ponds, green space	8,100
	2. Urban Development	3,900
	3. Roads, Railroads and streams	1,000
	4. Crops, pasture or other lands	26,900
	Total	39,900
C.	Grand Total, Prototype Model	79,400

* Includes 200 acre allowance for buffer zone

** Optional for use with sludge, subject to local acceptance.

ARTIST'S CONCEPT PROTOTYPE MODEL

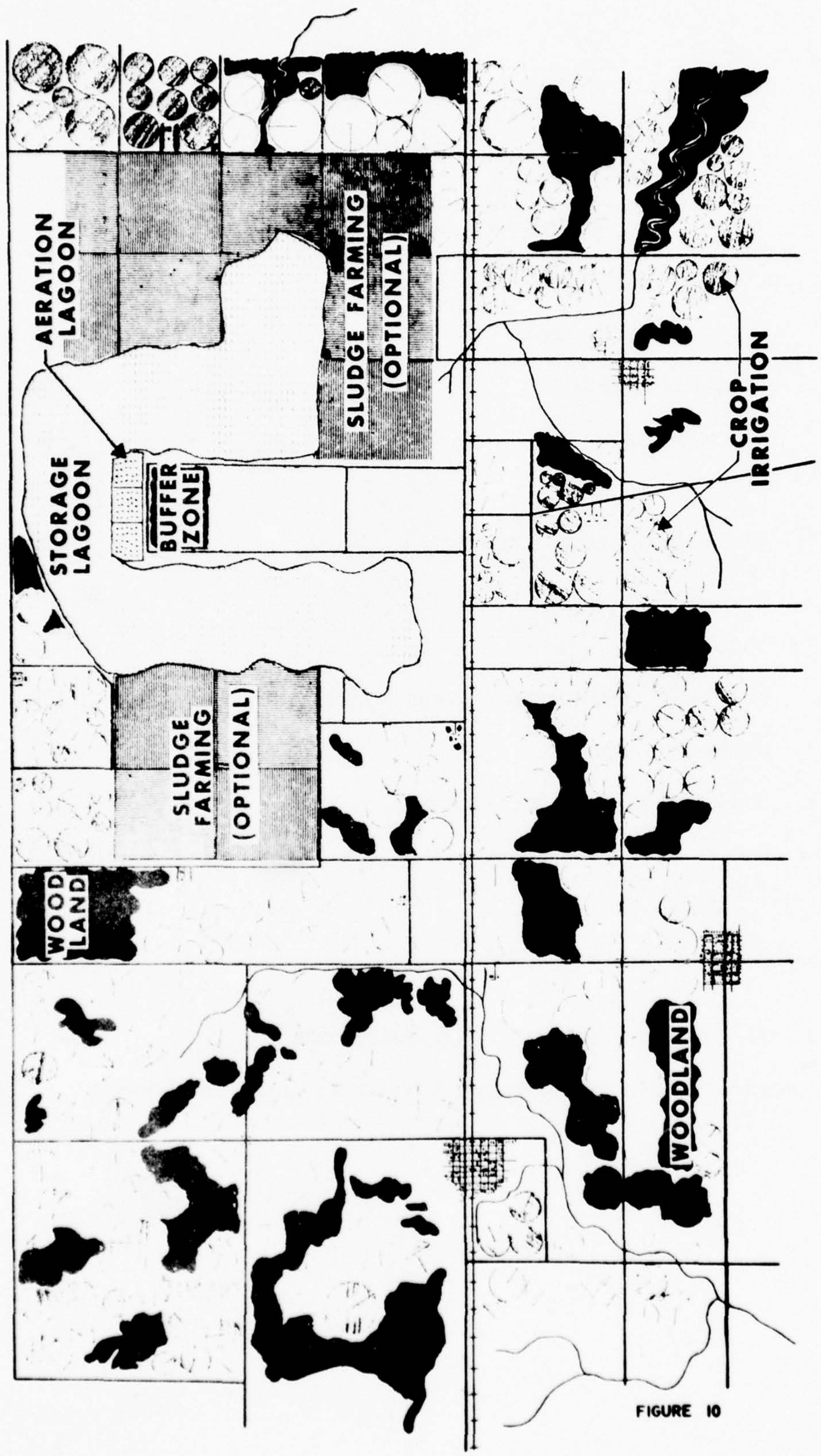


FIGURE 10

The aeration and storage lagoons are designed to provide the double functions of pretreatment and equalization storage. The aeration lagoons are basically interim holding lagoons where the major portion of pre-treatment functions are achieved. These lagoons are sized with an average normal depth of 15 feet to hold the wastewater 3-5 days, during which time air is added and the primary treatment process completed by aerobic microorganisms. The air is added to the wastewater by mechanical surface aerators to satisfy the oxygen demand of the bacteria and other microorganisms living in the wastewater. It is these microorganisms which decompose the solid organic matter and convert soluble organics to sediments (sludge), thereby achieving the equivalent water quality level of conventional secondary treatment plants. The aeration time is set to minimize the daily BOD rate in the storage lagoon and, consequently, reduce the potential for an anaerobic condition to occur.

The primary function of the storage lagoon aside from acting as a settling tank for the sludge is to provide a working storage volume equal to at least 5 months of the average daily incoming wastewater flow. The 5 month duration reflects the system's downtime when the treatment process (irrigation) cannot adequately function because of the low air and soil temperature. The lagoon design also includes provision of an operational freeboard for surface wave action and storage where the sludge will be accumulated prior to being removed. These lagoons because of their minor BOD loadings (20-30 lbs/acre/day) and 25-foot normal water depth should not become surface anaerobic or have associated odors, except possibly during spring thaw when a turnover of the water layers may occur. Even then, the problem can be overcome by aerating the storage lagoon with the portable mechanical aerators for some 30 days after the air and water temperatures begin to rise reflecting the transition from winter to spring.

For the purpose of this illustration, a Center-Pivot Irrigation System is used to apply the treated wastewater to the crop fields. The system consists of self-propelled units which irrigate a circular area. The size of the radial irrigator rig will vary between 1,000 and approximately 2,000 feet in length depending upon the field configuration. The pipe which delivers the effluent to the field is supported between wheeled towers by a braced, under-trussed structure. Depending on the radial length, the irrigator will rotate around a center pivot post and spray approximately 72 to 290 acres during one complete revolution.

The center-pivot machines presently contemplated for use in the wastewater treatment system differ from those generally used for agricultural irrigation in two ways. The standard impact sprinklers are not used nor are they located on top of the spray arm. Instead of using sprinkler nozzles which have high pressure trajectories for maximum coverage, a non-rotating, orifice type, industrial spray nozzle is used to obtain large diameter droplets. The low nozzle pressure and comparatively large orifice size increase the size of droplets, thereby lowering the distance of drift. Furthermore, the spray units are hung on the bottom of the support truss below the wheel towers' alignment and control mechanisms. This also reduces the potential for any aerosol-related problems and insures direct application to the row crops. The spray can be adjusted as close to the top of crop canopy as efficiency allows.

The nozzle size and spacing will be varied to achieve a uniformity of coverage, thereby avoiding high quantities of water being applied near the pivot point and lesser volumes at the outer area. This adjustability can also be used advantageously where differences in soil types or conditions are experienced. There should be little impact and splash from the drops and the field tilth should not be disturbed.

The drainage system will be designed in relation to four governing parameters: (1) the maximum rates of application as determined by the nutrient uptake requirements and local rainfall characteristics; (2) the rate of infiltration at the soil's surface; (3) percolation coefficients within the soil column; and (4) the natural movement of water through the underlying saturation zone. The planned average and peak application will vary from .65 to .86 inches per day or 4.5 and 6 inches per week, respectively. The peak quantity rates are provided to accommodate application rates relative to crop uptake and the down time that will be experienced in the irrigation schedule because of the anticipated rainstorms, including antecedent (lag) conditions. The design of the application and drainage system includes consideration of the frequency, intensity, and duration of storms together with the evapotranspiration losses that can be expected in the Land system areas. Because the design rate of percolation is only a fraction of the percolation capacity of the soil, the vertical movement of water through the aerated, non-saturated soil zone occurs as a system of thin films moving over the surfaces of the soil particles. The vertical movement of water as applied would be slow enough to permit the nutrients to be consumed by plants, and the soil micro-organisms.

Once the percolating water has moved through the upper soil zone, it enters the saturated soil zone. The drain pipes are placed at the top of the saturation zone and thus are able to maintain a controlled water table and capture the renovated water applied by the irrigation system. The horizontal spacing of drain pipes and depth at which the pipes are placed will also control the gradient (flow profile) of the water table and insure that the subsurface flows are inwards towards the center of the irrigation system. Consequently, no leaching or percolation of the high quality renovated wastewater into the adjacent soil profile should occur. Such controls are imposed to safeguard the integrity of the surrounding ground water and its usage by the individual and community. Wells can be used instead of pipes for managing the movement of water through the soils with flow patterns becoming radially symmetrical about the well. Generally, wells are used when the distance from ground surface to ground water is greater than 10 feet. Actually, the higher the ground water table, the easier and more positive is the control of the natural water movements.

Impact On The Farmer

The implications of adapting the Land treatment system to the farmer's needs and life style are the concerns of the designer and certainly the farmer himself. Similar to any irrigation system, there are specific operational controls which have to be maintained if the treatment process is to function properly. Consequently, an interest in the farmer's land would have to be acquired for an extended period of time. This limited interest would require the farmer to agree to the following: (1) to accept a certain amount of treated wastewater within a specific time framework; and (2) to grow and manage those crops suitable to the system's needs. In all cases, the major objectives are to insure proper utilization of the nutrients, particularly nitrogen, and to insure that maximum crop yields are attainable.

In return for participating in this system the farmer can expect to obtain a yearly gain in net income. Presently the average harvested yield, for corn on well managed farms in the counties where the land sites are located is 135 bushels per acre. With the installation of the proposed system and application of the equivalent nitrogen, phosphorus, and potassium budgets for 200 bushels per acre corn; and assuming a 15 to 20% field loss, it is anticipated that an average yearly yield of 165 bushels should be harvested from each acre. Based on an average market value of $1.06 per bushel, the farmer's net income should increase by $31.80 per acre. Furthermore, there should be a net savings in out-of-pocket field operational costs. This is only part of the total savings in production costs and does not include equipment depreciation and other allied operational and overhead factors. The anticipated savings in field production cost is estimated to range from $11.05 to $11.55 per acre, depending upon the type of tillage method employed. The basis and derivation of these net saving is shown in Figure 11. Not included is the net labor saving of 1 day or at least 10 hours per 10 acres that can be achieved using the no-tillage system. This labor saving estimate obtained from a local farmer actually utilizing both tillage methods on his 700 acre farm, correlates very well with other time saving estimates prepared by various Universities and Extensive Service studies.

Based on the foregoing it is estimated that the farmer should be able to increase his net income anywhere from $42.85 to $43.35 per acre. No income allowance gained from the marketing of the rye forage has been included; the value is assumed at this point in time to offset the cost of harvesting. The cost of aerial inter-seeding and installation, operation and maintenance of both the irrigation and drainage systems is expected to be borne by the legally-designated operating entity, not the farmer.

The option of using the spray rigs for applying herbicides to the irrigated areas can be made available to the farmer at no cost other than material cost themselves. This may prove to be the most efficient application technique both from a cost and use standpoint. This latter factor can have significant meaning in light of the current concern over the use of insecticides and herbicides.

Impact To The Community

There are many ramifications that should be considered by the total agricultural community. If the Land treatment system is to be implemented, the commitment for the proposed multiple land-use of treatment and farming could be supplemented by some form of actual zoning ordinances. Many of these lands are in counties that are increasingly being subjected to urban pressures and where land-use patterns are changing. By zoning these lands as open-space, the agro-business could be protected and green belts provided. Furthermore, these lands could serve as the design base for a viable land-use control with various forms of development (commercial, recreational and residential) planned as satellite to the site. Provisions can be made to incorporate the treatment of the wastewater from these developments and the return flow made available for reuse. Consideration also should be given to equating the tax base of these lands relative to their agricultural value and not their potential worth if redeveloped for a higher-assessed use. This is a common concern of many farmers and may be required over time if this use is to be safe-guarded.

The cropping pattern of corn grain and rye forage has the additional potential of fostering beef production on a large scale. The prospect of providing a guaranteed source of feed can attract commercial feedlot operations or encourage the local farmers to expand into either feeder stock and/or finishing beef operations. Either way this can materially improve the economic structure of the area and the marketability of the system's crop production. Furthermore, the potential pollution problem associated with animal wastes can be resolved with minor modification of the Land system design. Assuming the feedlot(s) was located near the treatment site, the decomposed wastes could be used as fertilizer and spread on those lands in between the irrigation areas and/or on the non-irrigated crop or pasture lands. This would be another gain for the participating farmer.

The increased crop production should definitely provide a multiplying effect to the total economic structure of the area. Such factors as expansion in the storage and drying facilities, increase seed and equipment sales and the accompanying increase demand for custom services will all help to stimulate the local economy. Such synergistic potentials as: (1) locating power generating plants at the storage lagoons where the wastewater can be used as cooling water; and (2) developing the fields for use as revenue-producing hunting areas during the winter season also can be investigated as other possibilities for bringing outside investment capital into the area.

FIGURE 11

PRODUCTION COST COMPARISON 1/
($ per acre)
Field Corn Only

Field Operation	No Irrigation: Conventional Tillage	With Irrigation: No Tillage	With Irrigation: Conventional Tillage
Fertilize (excludes material cost)	1.10	1.10	1.10
Plow (moldboard)	4.85	--	4.85
Disk and Drag	2.50	--	2.50
Plant	2.60	5.00	2.60
Spray herbicide	1.50	1.50	1.50
Cultivate	1.70	--	1.70
Harvest	8.10	8.10	8.10
Materials: Fertilizer & Insecticide 2/	28.00	12.00 3/	12.00 3/
Materials: Herbicide	4.00 (band)	12.00 (broadcast)	5.00 (broadcast)
Seed	10.80	13.20	12.55
Hauling, Storage & Drying	5.40	6.60	6.60
Total	70.55	59.50	59.00

1/ Based on average custom rates for the North Central Region as published in Doane's Agricultural Report dated 3/17/72 and/or actual costs incurred on farms within the land site(s) areas.

2/ A cost of $4/ac included as a constant for insecticides.

3/ Includes soil amendments such as dolomitic limestone to maintain soil pH and balanced plant nutrition.

Based on the findings to date, the Land system should not prove disruptive to the social and economic structure of the area. Site design can, and should, avoid adversely affecting any area of environmental value, though there undoubedtly will be some woodlands converted as the individual farmer maximizes his total farm production. Finally, there should be no health hazard to the residents in the area. Field experience in operating actual sludge farms, or even the standard ssewage treatment plant, have shown no evidence of a health problem. Since the liquid which will be applied to the field is already pretreated and also disinfected, no particular health hazard should exist.

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IV. COMPONENT BASIS OF DESIGN

B. INDUSTRIAL TREATMENT SYSTEMS

PLUME ANALYSIS

Introduction

When a turbulent water jet is discharged into a receiving water body, diffusion and mixing of the water takes place. The existing water quality standard applies only in the region outside the mixing zone, which is defined as the area within a 1,000-foot radius from the source of the water jet.

The analysis of the discharge plume may be accomplished by solving a mass balance and the momentum equation. However, the analytical solution of these equations cannot be obtained because the partial differential equation is non-linear. A simplified method using a non-dimensionalized result from a numerical analysis with similar boundary conditions is used for this report.

Method Of Analysis

The basic equations governing the diffusion of the heated waste-water are:

$$\rho(\underset{\sim}{v}\ \text{grad})\underset{\sim}{v} = -\ \text{grad}\ (P + \rho\phi) + \mu\nabla^2\underset{\sim}{v} \qquad (1)$$

and

$$\underset{\sim}{v}\cdot\ \text{grad}\ T = \text{div}\ (K/\rho\ \text{grad}\ T) + \frac{Q_o}{\rho C_w H_w} \qquad (2)$$

in which,

ρ = mass density

$\underset{\sim}{v}$ = velocity vector

P = pressure

ϕ = force potential

μ = viscosity

T = temperature

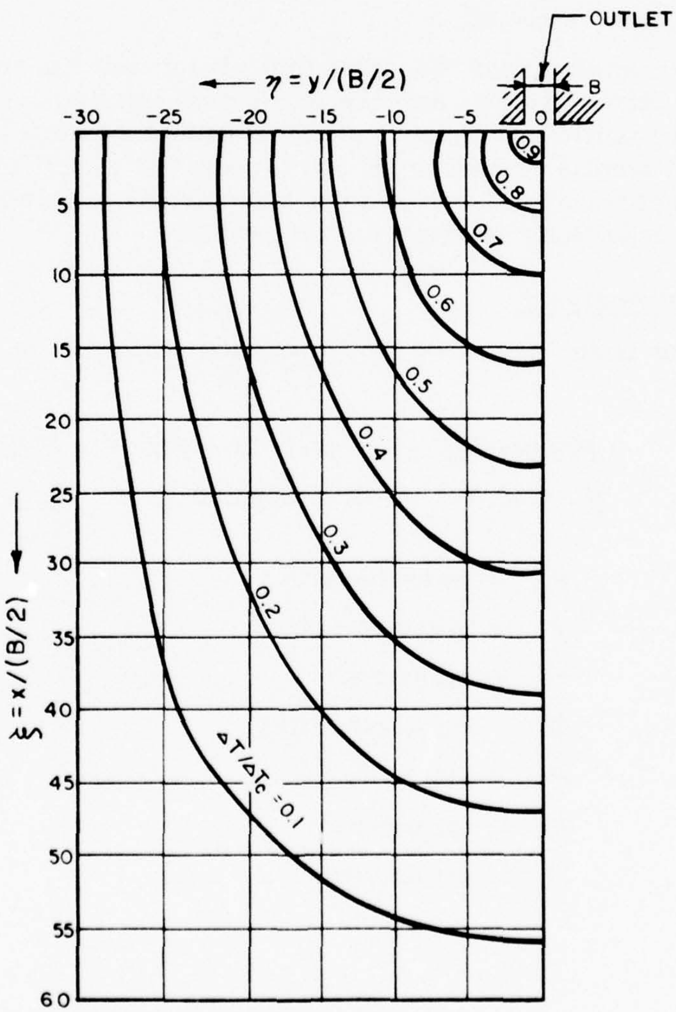
K = diffusivity

Q_o = rate of heat transported through the boundary of the control volume

C_w = specific heat of the water

H_w = effective thickness of the water body which is affected by the heat transfer

Athough the distribution of the temperature may be obtained by solving Equations 1 and 2, the analytical general solution can not be obtained with current available techniques. The numerical solution was obtained by Wada [1/], who assumed that the diffusion is dominated by the turbulent field and that the heat ejected into the atmosphere is negligibly small. The results were expressed in a non-dimensional form as shown in the following graph.



The following notations are used in this graph.

- x; y: the coordination of the point of interest using the centerline of the jet at the outlet point as a reference
- B: width of the outlet channel
- Δ T: increment in temperature from the receiving water body at the point of interest
- Δ To: increment in temperature from the receiving water body at the outlet point

In a two-dimensional flow the temperature change can be expressed in the following form:

$$\Delta T = f\,(\Delta To,\ x,\ y,\ B,\ \rho_o,\ \Delta\rho,\ Vo,\ \mu) \qquad (3)$$

where ρ_o and $\Delta\rho$ are the density of the receiving water and the increment of density, respectively; Vo is the velocity at the outlet and μ is the viscosity of the receiving water. The non-dimensional form of Equation 3 can be obtained through dimensional analysis as follows:

$$\frac{\Delta T}{\Delta To} = f\left(\frac{x}{B},\ \frac{y}{B},\ \frac{\Delta\rho}{\rho_o},\ \frac{Vo}{\sqrt{gB}},\ \frac{VoB\rho o}{\mu}\right) \qquad (4)$$

The term $Vo/\sqrt{gB}$ is the Froude number and $VoB\rho o/\mu$ is the Reynolds number. Since the Froude number of the gravity force dominates the diffusion process in this case, the terms $\Delta\rho/\rho o$ and $VoBPo/\mu$ may be neglected. Then Equation 4 can be rewritten as:

$$\frac{\Delta T}{\Delta To} = f\left(\frac{x}{B},\ \frac{y}{B},\ \frac{Vo}{\sqrt{gB}}\right) \qquad (5)$$

Thus, Wada's non-dimensionalized result can be used for a hydraulically similar system if the Froude number is similar. The experimental work of Jen[2/] indicated that the distribution pattern of the non-dimensionalized temperature change $\Delta T/\Delta To$ does not have any significant change in the region of high Froude number flow. Thus, in this region of Froude number flow, Equation 5 can be simplified as:

$$\frac{T}{To} = f\left(\frac{x}{B},\ \frac{y}{B}\right) \qquad (6)$$

The results imply that Wada's results can be used for the analysis of the discharge plume.

Using the Indiana Harbor Canal discharge into Lake Michigan as an example (B = 400 feet) and assuming that ΔT_o is 5°F, then the temperature change at 1,000 feet ($x/ B/2 = 5$) will be

$$\Delta T = 0.82 \times \Delta T_o = 0.82 \times 5 = 4.1°F$$

The same technique also applies to other intensive parameter pollutants such as BOD, suspended solids or dissolved solids.

BIBLIOGRAPHY BA-IV-B

INDUSTRIAL TREATMENT SYSTEMS

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2. Jen, Y., Wiegel, R. L. and Mobarek, I., "Surface Discharge of Horizontal Warm-Water Jet", Proceed. ASCE, Power Div., Vol. 92 No. PO2, Apr., 1966.

IV. COMPONENT BASIS OF DESIGN

C. SLUDGE MANAGEMENT SYSTEMS

SLUDGE TYPES

Sludge Yield

The yield of each type of sludge is computed as follows:

Conventional biological & land treatment sludges.

1. Influent sewage @200 mg/l SS = .834 T/MG.

2. For every pound of BOD utilized in the secondary contactor assume 1/2 of O_2 goes to CO_2 respiration and the remaining 1/2 O_2 goes to new cell growth ($C_5H_7NO_2$). Assume reduction of soluble BOD in secondary contactor = 60 - 20 = 40 BOD units $\therefore$ 20 mg/l O_2 is utilized for new cell growth. Cell growth $= \frac{C_5H_7NO_2\ (113)}{O_2\ \ (32)}\ 20 \approx 71$ mg/l new solids $\approx$ 600# or .3T/MG.

3. Total solids to secondary clarifier = .834 + .3 = 1.134 T/MG. Assume 25 mg/l SS passes over clarifiers' weir $\approx$ .104 T/MG $\therefore$ Total solids to sludge digestor = 1.03 T/MG.

4. Assume 75% of the solids are volatile 0.77 T/MG. Assume that 60% of the volatiles are destroyed in digestion with 20% being converted into fixed solids. $\therefore$ Net solids destroyed by digestion = .77(.4) $\approx$ .308 T/MG $\therefore$ Yield of digested solids = (1.03-.308) = 0.722 T/MG.

5. Grit yield based on 1970 MSDGC data = 56 T/day @1,369 MGD average daily flow. Yield = 0.041 T/MG.

6. Total sludge - grit yield = 0.722 + 0.041 = 0.763 T/MG say 0.77 T/MG.

Physical-chemical sludge yield.

1. Influent sewage @200 mg/l SS @75% volatile solids
   Ash after incineration $\approx \frac{.25\ (200\ mg/l)(8.34)}{2{,}000\#/T} = .208\ T/MG$

2. Influent phosphorus concentration = 10 mg/l. Assume all of the P (at.wt = 31) is converted to calcium hydroxyapetite $Ca_5(OH)(PO_4)_3$ (A.W. = 502). ∴ $Ca_5OH(PO_4)_3$ yield - $\frac{502}{3(31)}(10)\frac{(8.34)}{2{,}000} = 0.225\ T/MG.$

3. Massive lime addition (CaO) = 400 mg/l; of this amount, 110 mg/l ($\approx$30%) is lost and made up while the remainder is recycled for reuse through the system. Calcium lost or wasted = $\left(\frac{40}{56}\right)$ 110 where 40=A.W. of Ca and 56 = A.W. of CaO. Ca lost = 79 mg/l = .329 T/MG.

   Of this amount, $\left(\frac{200}{502}\right)$ .225 T/MG of Ca is lost in the hydroxyapetite = .090 T/MG. Assume that the remaining Ca is lost as $CaCO_3 = [.329 - .09]\ \frac{100}{40} = 0.597\ T/MG$

4. Based on report from Lake Tahoe, projected $CaCO_3$ requirement for the clinoptilolite ion exchange process = 0.2 T/MG as $CaCO_3$. Assume 30% lime makeup, the $CaCO_3$ lost from the ion exchange process = 0.3(.2) = 0.06 T/MG.

5. Sludge yield from the physical-chemical processes is:

   0.208 T/MG as Ash
   0.225 T/MG as Calcium Hydroxyapetite
   0.657 T/MG as Calcium Carbonate

   $\Sigma =$ 1.090 T. MG

6. Grit yield = 0.04 T/MG $\approx$ same as biological sludges

7. Total sludge - grit yield = 1.09 + .04 = 1.13 T/MG

Advanced biological sludge yield.

1. Biological sludge and grit yields from the conventional treatment units of the advanced biological process has the same design basis as shown on page 1 = 0.77 T/MG.

2. Research has reported a biological sludge yield from the denitrification process = 20% of methanol feed by wt. $\therefore$ Denitrification sludge yield = .2(40 mg/l) = 0.033 T/MG. Assume 75% of these solids are volatile .025 T/MG. Assume that 60% of the volatiles are destroyed in digestion with 20% being converted into fixed solids. $\therefore$ net solids destroyed by digestion = .4(.025) .01 T/MG $\therefore$ yield of denitrification digested solids = .025-.01 = .015 T/MG.

3. Assume secondary effluent SS = 25 mg/l @75% volatile solids. Ash from lime recalcination = $.25 \dfrac{(25\ mg/l)(8.34)}{2,000}$

= 0.026 T/MG

4. Assume effluent phosphorus concentration from secondary clarifier 8 mg/l. Assume all is converted to $Ca_5(OH)(PO_4)_3$ $\therefore$ $Ca_5(OH)(PO_4)_3$ yield $= \dfrac{502}{3(31)} (8) \left(\dfrac{8.34}{2,000}\right) = 0.18$ T/MG

5. Massive lime (CaO) addition = 400 mg/l; of this amount, 110 mg/l ($\approx$30%) is lost and made up while the remainder is recycled for reuse through the system. Calcium lost or wasted as Ca $= \dfrac{40}{56} (110) \dfrac{8.34}{2000} = .329$ T/MG as Ca. Of this amount, $\dfrac{200}{502}$ (.18) T/MG of Ca is lost in the hydroxapetite = .071 T/MG. Assume that the remaining Ca is lost as $CaCO_3 = (.329-.071) \dfrac{100}{40} = 0.645$ T/MG.

6. Total sludge - grit yield is:

0.770 T/MG Grit & Biological Digested Sludge
0.015 T/MG Denitrification Disgested Sludge
0.026 T/MG Ash from Recalcination
0.180 T/MG Calcium Hydroxyapetite
0.645 T/MG Calcium Carbonate

Σ = 1.636 T/MG say 1.64 T/MG

TYPE OF SLUDGE UTILIZATION

Land Reclamation

Lime dosage for ammonia stripping. In order to determine the optimum dosage of lime for ammonia stripping, a laboratory test was conducted at the chemical and engineering laboratory of Tenco Hydro/ Aeroscience, Inc, Countryside, Illinois. The pH and the residual ammonia concentration were measured for each different dosage of $Ca(OH)_2$. The results of the test are presented in the following table.

Results of Ammonia Stripping Test

$Ca(OH)_2$ Dosage (g/kg)	Residual Ammonia (mg/kg)	pH
0	1,355	7.1
0.3	-	7.5
0.7	-	8.0
1.1	-	8.5
3.0	1,150	9.0
3.60	975	9.5
6.25	810	10.0
7.2	600	10.8
8.65	207	11.5
20.5	220	12.0

SLUDGE APPLICATION RATE

The sludge application rates are computed based on the nitrogen balance in the soil for the biological sludge and based on the optimum lime application rate for the physical chemical sludge. The assumptions used in the sludge application rate are described in the text of Appendix B. The application rate of the biological sludge for land reclamation utilization are computed based on the available nitrate balance during the first year of the sludge application, while the application rates of the biological sludge for agricultural utilization are computed based on the available nitrate under a steady state after a number of years of sludge application.

Nitrogen Requirement

It is assumed that the rate of nitrogen uptake of the plants is 360 pounds per acre per year and that 30% of the nitrate nitrogen will be lost through denitrification. Hence, the total nitrate nitrogen required by the plants would be 515 pounds per acre per year (=360/0.7)

Agricultural utilization

Conventional and land treatment sludge

1. Conc. of N in sludge = 0.04 T-N/T-sludge
2. Net Req. Appl. Rate = 515/0.04 x 2000
3. Appl. rate after the volatization loss is added = 6.44/0.5 = 12.88 T/AC/year
4. Appl. rate after the inert grits is added = 12.88/0.95 = 13.5 T/AC/year.

Advanced biological sludge

1. The yield of convent. sludge = 0.77 T/MG.
2. The yield of advanced bio. sludge = 1.64 T/MG.
3. The application rate = $13.5 \times \frac{1.64}{0.77} = 28.8$ T/AC/yr.

Physical chemical sludge

1. Appl. rate of lime as $CaCO_3$ = 1.0 T/AC/yr.
2. Lime content of P-C sludge = 60%
3. Appl. rate = 1/0.6 = 1.67T/Ac/yr.
4. Appl. rate after inert grits is added = 1.67/.965 = 1.73 T/AC/yr.

Land reclamation

Land treatment sludge

1. Amm. nitrog. in sludge = 0.04 x 1/3 = 0.0133 T/T
2. Amm. nitrog. after amm. stripping = 0.0133 x 0.25 = 0.00333 T-N/T-sludge.

3. Amm. nitrog. after volitiz. loss = 0.00333 x 0.5 = 0.00167 T-N/T-sludge.

4. Organic nitrog. at first year = 0.04 x 2/3 = 0.0267 T-N/T-sludge.

5. Amm. nitrog. due to minerization = 0.0267 x 0.04 = 0.001068 T-N/T-sludge.

6. Total available amm. nitrog. = 0.001068 + 0.00167 = 0.00273 T-N/T-sludge = 5.46 lbs-N/T-sludge.

7. Allowable appl. rate = 515/5.46 = 94.6 T-sludge/Ac.

8. Appl. rate after inert grits is added = 94.6/0.95 = 100 T-sludge/Ac.

Advanced biological sludge

1. The yield of convent. sludge = 0.77 T/MG.

2. The yield of advanced bio. sludge = 1.64 T/MG.

3. The application rate = $100 \times \frac{1.64}{0.77} = 213$ T/Ac.

Design Basis Calculations for Sludge Management

Reclamation application. Fresh sludge, anaerobically digested, is available at 4% nitrogen on a dry solids basis. One-third of 1.33% is available as NH_3-N and two-thirds or 2.67% is available as organic N.

$$1.33\%\ NH_3\text{-N @ 6\% TS basis sludge} = 0.08\%\ NH_3\text{-N} = 800\ \text{mg. } NH_3\text{-N}$$

By ammonia stripping @ 8.65 GM/KGM of $Ca(OH)_2$ it is possible to remove NH_3-N down to 200 mg/l or realize 75% reduction of NH_3-N.

With ammonia stripping, there is 0.33% NH_3-N equivalent left on dry basis + 2.67% Org. N for a total of 3.00% Total N. The nitrogen available for each dry ton of sludge would be $(2000)(2.67)(10^{-2})(4)(10^{-2})$ or 2.15 #N/Dry Ton on a yearly basis. This assumes a 4%/year rate of mineralization or organic N plus $(2000)(0.33)(10^{-2})$ or 6.6 #N/Dry Ton. Agricultural experience at the University of Illinois and SEMCO indicates a reduction of 50% in NH_3-N due to volatilization on drying. Thus, the net input of ammonia nitrogen is 3.3 #N/Dry Ton. Thus, the total loading is 3.3 + 2.15 = 5.45 #N/Dry Ton. At 360 #N/Acre-yr.

to Reed canary grass and at 70% yield to crop get 360/0.7 = 515 #N/Acre-yr. 515 #N/Acre-yr. @ 5.45 #N/Dry Ton = 94.6 Dry Tons/Acre-yr. 0.30(515) = 155 #N/Yr. will be lost to denitrification processes. A 30% denitrification loss is projected as reasonable by agricultural experts. The second year after reclamation, the nitrogen yield will be decidedly less per acre, depending entirely upon the mineralization yield of 4% of org. N/Yr. or 196 #N/Ac-Yr, the second year, 188 #N/Ac-Yr the third year and so on. Reclamation total sludge yield (including grit at 0.04 Ton/mg) for standard biological and land treatment sludges = $\frac{0.77}{0.73}(94.6)$ = 100 dry tons/acre, adv. biol. sludges = $\frac{1.64}{0.77}(100)$ = 213 dry tons/ac.

Agricultural application. For an agricultural yield of 360#N/Acre-yr. from reed canary grass requires 515 #N/acre-yr.

At 2.15 #N/dry ton from Org. N plus $2000(1.33)(10^{-2})(0.5)$ or 13.3 #N/dry ton from NH_3-N get a total of 15.45 #N/dry ton.

Over 25 years you get 25(0.5)(2.15) #N/yr. or 26.9 plus 13.3 = 40.2 #N/yr. or 515/40.2 = 12.8 dry tons/acre-yr.

Agricultural use. For standard biological and land system sludges use 12.8 dry tons/acre year $\frac{.77}{.73}$ = 13.5 dry tons/ac-yr.

For advanced biological sludges use = $\frac{1.64}{0.77}(12.8)$ = 27.3 dry tons/ac-yr.

For PC sludges use $\frac{1.13}{1.09}(1.67)$ = 1.73 dry tons/ac-yr.

IV. COMPONENT BASIS OF DESIGN

D. STORMWATER MANAGEMENT SYSTEMS

EVALUATION OF STREAM WATER QUALITY DURING STORMWATER SPILLS

Basis of Design For Sample Calculation

1. Effluent quality to be met by all effluents:
   BOD_5 = 2 mg/l = 0.0167#/1,000 gals. = 16.7#/MG
   Suspended Solids = ~0 mg/l
   Phosphorus = 0.01 mg/l = 0.0000834#/1,000 gals. = .0834#/MG

2. Municipal and industrial flows in C-SELM area = 2,475 MGD

3. Area of C-SELM region = 2,600 mi^2 = 1,664,000 Acres

4. Total yearly C-SELM flow = 2,475 x 365 = 903,339 MG

5. Land use in C-SELM area for 1990:
   Urban = 476.5 mi^2 Rural = 1,323.75 mi^2
   Suburban = 783.8 mi^2
   1,260.3 mi^2 = 806,560 Acres

6. For Urban-Suburban area, total pollutants spilled by M&I flows/acre/year:

   $$BOD_5 = \frac{16.7 \times 903,339}{806,560} = 18.7\#BOD_5/\text{Acre}/\text{Year}$$

   $$\text{Phosphorus} = \frac{0.0834 \times 903,339}{806,560} = 0.0934\#P/\text{Acre}/\text{Year}$$

   Suspended Solids = ~0

Sample Calculation

For an urban C-SELM area -- Area = 304,960 Acres

1. Using the stormwater storage versus number of events in which overflow occurs curve (Figure B-IV-D-3): For 2.5" of storage, overflows will occur during 4.4 events.

2. Total inches of overflow: Area under curve = 10.78"

3. Overflow per event = 10.78/4.4 = 2.45"
or on yearly basis = 10.78/21 = 0.51" per year of record

4. Amounts of pollutants spilled:

a. Pollutants / Acre / Event

Number of acre-feet spilled = $\frac{2.45"}{12"/ft.}$ x 304,960 acres
= 62,267.7 acre/feet

Number of gallons spilled = 62,262.7 acre-feet
x 325,851 MG/acre-feet = 20,288 MG
BOD spilled = $\frac{83.4 \text{ \#BOD/MG} \times 20{,}288 \text{ MG}}{304{,}960 \text{ Acres}}$
= 5.55 #BOD/Acre/Event

Suspended solids spilled = $\frac{1084 \text{ \#SS/MG} \times 20{,}288 \text{ MG}}{304{,}960 \text{ Acres}}$
= 72.12 #SS/Acre/Event

Phosphorus spilled = $\frac{8.34 \text{ \#P/MG} \times 20{,}288 \text{ MG}}{304{,}960 \text{ Acres}}$
= 0.55 #P/Acre/Event

b. Pollutants / Acre / Year of Record

Number of acre-feet spilled = $\frac{0.51"}{12"/ft.}$ x 304,960 acres
= 12,960.8 acre-feet

Number gallons spilled = 12,960.8 acre-feet
x 325,851 = 4,223 MG
BOD spilled = $\frac{83.4 \text{ \#BOD/MG} \times 4{,}223 \text{ MG}}{304{,}960 \text{ acres}}$
= 1.155 #BOD/Acre/Year

Suspended solids spilled = $\frac{1084 \text{ \#SS/MG} \times 4{,}223 \text{ MG}}{304{,}960 \text{ acres}}$
= 15.01 #SS/Acre/Year

Phosphorus spilled = $\frac{8.34 \text{ \#P/MG} \times 4{,}223 \text{ MG}}{304{,}960 \text{ acres}}$
= 0.115 #P/Acre/Year

5. Assume that a spill will occur at the same rate as normal M & I flow -- Therefore: Days of spill flows

$$\frac{20{,}288 \text{ MG}}{2{,}474.9 \text{ MG/Day}} = 8.2 \text{ days} == \text{use 8 days}$$

6. The allowable pollutant loads per event are:

$$\text{BOD} = \frac{18.7 \text{ \#BOD/Acre/Year} \times 8 \text{ days}}{365 \text{ days/year}} = 0.409 \text{ \#BOD/Acre/Event}$$

0.409 #BOD/Acre/Event is less than 5.55 #BOD/Acre/Event Actual Suspended Solids = 0 #SS/Acre/Event is less than 72.12 #SS/Acre/Event

$$\text{Phosphorus} = \frac{0.0934 \text{ \#P/Acre/Year} \times 8 \text{ days}}{365 \text{ days/year}} = 0.002 \text{ \#P/Acre/Event}$$

0.002 #P/Acre/Event is less than 0.555 #P/Acre/Event Actual

The following lists and compares the above results:

Table BA-IV-D-1

POLLUTANT CONTENT OF WATER

	Pollutants/Acre/Event		Pollutant/Acre/Year	
	Allowable	Actual	Allowable	Actual
#BOD Spilled	0.409	5.55	18.7	1.16
#Suspended Solids Spilled	0	72.12	0	15.01
#Phosphorus Spilled	0.002	0.555	0.0934	0.1150

	Per Event	Per Year of Record
No. of Acre-Feet Spilled	62,267.7	12,960.8
No. of Gallons Spilled	20,288	4,223

RURAL DEEP AQUIFER STORAGE

Introduction

Reclaimed water from the rural stormwater management system will be used to recharge nearby streams for eventual downstream potable reuse as outlined in Option 1, Potable Reuse system described in Appendix B, Section IV-G. The design flow reuse is based on an average yearly runoff from the rural area. Because of this, a drought year might create a deficit in available flows. In order to supply sufficient stream recharge for potable reuse during a drought period, a deep well storage system has been considered. This section presents the basis of design and cost information for the deep well storage system.

DESIGN BASIS

A mass-curve analysis using 130 years of annual rainfall records from Midway Airport indicates that the maximum deficit from an average year is approximately 13" over a three-year period. During this three-year period, the maximum deficit for any single year was 7.8 inches. This condition is equivalent to an event expected to occur every 100 years.

If a typical module with a drainage area of 3,000 acres is used, the required pumping rate should be designed to equal the average year flow to the stream from the rural management system. This flow is equal to 3.4 MGD. The recharge rate for deep well recharge is designed to accept all excess flow during the average year. With an irrigation rate of 3.5 inches per week, the maximum available supply for recharge is:

$$Q = \frac{3.5}{12 \times 7} \times \frac{360}{3.07} - 3.4 = 1.5 \text{ MGD}$$

The design recharge and the pumping capacity of the well system are judged to be sufficient to supply, or make up, the water deficit during the drought period.

Two wells, each with a pumping capacity of 1.7 MGD and a recharging capacity of 0.7 MGD, are provided. The wells are separated by a distance of approximately one mile. The capacity of the well system is sufficient since the thickness of the deep sandstone aquifer is estimated to be greater than 200 feet. The depth of the deep aquifer in the study area is approximately 1,300 feet on the average.

The system is designed to borrow the water from the deep aquifer during a drought year and to recharge the system to recover the saturated condition during the wet year. Although the deep aquifer is in an artesian condition during a normal year, the piezometric head near the well is expected to be drawn down to the level below the upper boundary of the deep aquifer. Hence, an air injection pipe is necessary to provide the atmospheric pressure on the free surface when it reaches the free surface condition. During the wet year, the excess flow from the drainage system is diverted to a wet well of the pumping facility, from which part of the water is injected into the recharging well and part of the water is transported to the far-end recharging well. The booster pump installed in the recharge well injects the water into the recharging well. Both recharge wells act as production wells during the dry year. The pumped water is discharged directly into the stream through the discharge line or channel.

Two observation wells are provided about one thousand feet from the recharging well. The operation of recharging groundwater is terminated if the piezometric head observed from the observation well reaches the design value. All of the reclaimed water will be discharged into the stream under this condition.

Cost

Based on the prescribed design, the cost of the system is estimated as follows:

Items	Unit Cost	Quantity	Cost
Well	$204,000	2	$408,000
Pump house	$ 20,000	2	$ 40,000
Transmission line	$ 8/ft.	5,000	$ 40,000
TOTAL			$488,000

IV. COMPONENT BASIS OF DESIGN

G. REUSE SYSTEMS

WATER SUPPLY DEMANDS AND DEFICIENCIES

1. Introduction

The purpose of this report is to present projections of future water supply demand, availability and, where the demand exceeds availavility, deficits. This information has been developed on a township basis for the C-SELM study area.

2. Procedure of Analysis

The procedure used in the analysis of the C-SELM water supply demands and deficiencies for the years 1990 and 2020 is as follows:

a. From Table BA-IV-G-1 obtain 2020 demand, for a particular Township.

b. From Figure BA-IV-G-1 obtain water demand in excess of of groundwater available from natural recharge.

c. Subtract b. from a. to obtain yield of groundwater for year 2020.

d. From Table BA-IV-G-2 obtain projected demands for 1990 and 2020 for a particular Township.

e. Subtract c. from d. to obtain deficiency of potable water for 1990 and 2020.

Example: Schaumburg township will be used.

a. 2020 demand = 18.0 mgd

b. 2020 demand = 14.5 mgd

c. Yield = 18.0 - 14.5 = 3.5 mgd

d. 1990 demand = 16.5 mgd, 2020 demand = 24.8 mgd

e. Subtract c. from d.
1990 deficiency = 16.5 - 3.5 = 13.0 mgd
2020 deficiency = 24.8 - 3.5 = 21.3 mgd

Note: Results of above calculation for all Townships within the C-SELM area are shown in Table B-IV-G-1 in the Annex B, Section IV-G.

TABLE BA-IV-G-1

'LEAST COSTS' OF RAW AND TREATED GROUNDWATER, 1980-2020[a]

Township	B_1 (mgd)	B_2 (mgd)	1980 D (mgd)	1980 Costs Raw	1980 Costs Treated	1990 D (mgd)	1990 Costs Raw	1990 Costs Treated	2000 D (mgd)	2000 Costs Raw	2000 Costs Treated	2010 D (mgd)	2010 Costs Raw	2010 Costs Treated	2020 D (mgd)	2020 Costs Raw	2020 Costs Treated
McHenry County																	
1	2	4	1	3	40	1	3	44	2	3	38	3	3	32	3	3	32
2	0	6	0			0			0			1	3	36	1	3	36
3	1	6	0			0			0			1	3	40	2	3	36
4	2	7	0			1	2	43	2	2	39	3	3	32	4	3	29
5	3	0	0			1	3	40	1	4	44	2	4	39	3	4	32
6	0	0	0			0			1	5	45	2	5	40	3	6	34
7	1	6	1	3	35	1	3	40	1	3	43	2	3	38	3	3	32
8	2	8	1	2	35	1	2	35	1	2	39	1	2	39	2	2	35
9	4	0	2	2	39	3	2	33	4	2	30	5	3	27	6	3	25
10	2	3	0			0			1	2	39	1	2	39	2	2	35
11	1	5	3	3	35	4	3	33	6	3	29	9	4	24	12	5	23
12	2	8	2	2	39	3	3	35	4	3	30	5	3	27	6	3	25
13	2	0	0			0			0			0			0		
14	1	5	0			0			0			1	3	36	1	3	36
15	1	6	1	2	39	1	3	39	2	2	37	2	2	37	3	3	31
16	2	6	5	2	29	7	3	26	9	3	24	12	4	23	15	5	22
Kane County																	
17	1	0	1	4	37	1	4	37	1	4	41	1	4	41	2	5	38
18	1	0	0			1	4	45	1	4	53	3	6	38	6	7	30
19	2	0	6	4	29	8	5	27	10	7	27	12	8	26	15	9	25
20	1	0	0			0			0			0			1	4	37
21	1	0	0			0			1	4	47	2	5	42	4	7	33
22	2	0	10	6	26	13	7	25	15	9	25	18	10	24	23	9	26
23	2	0	0			0			0			1	4	37	1	4	37
24	1	0	0			0			1	4	47	2	5	42	4	7	32
25	2	2	4	3	31	5	4	29	6	5	29	7	5	27	9	6	26
26	2	0	0			0			0			1	4	37	1	4	37
27	1	0	0			1	4	44	2	5	43	3	5	36	5	6	30
28	1	5	5	3	29	7	3	26	9	4	25	10	5	25	14	6	23
29	2	0	0			0			0			1	4	37	1	4	37
30	1	0	1	4	44	1	4	47	3	6	37	4	5	33	6	6	28
31	0	4	15	5	23	18	7	23	22	8	22	26	9	24	29	9	25
Lake County																	
32	0	6	0			1	2	35	1	2	35	1	2	35	1	2	35
33	0	3	1	3	35	1	3	39	1	2	43	2	2	37	3	2	31
34	0	4	0			1	2	39	1	2	43	2	2	37	3	2	31
35	1	1	5	3	29	6	4	28	8	5	27	10	6	26	13	7	25
36	1	3	2	3	38	2	3	38	3	3	32	3	3	32	4	3	29
37	0	3	4	3	30	4	3	31	6	4	28	7	5	27	9	6	26
38	0	4	2	2	39	3	2	33	4	2	30	5	3	28	6	4	27
39	0	0	0			0			0			0			0		
40	0	4	1	2	35	1	2	35	1	2	35	1	2	35	1	2	35
41	0	5	2	3	40	3	3	34	4	3	31	5	3	28	7	4	25
42	1	4	6	3	38	8	3	27	13	5	25	20	7	23	31	9	22
43	0	0	0			0			0			0			0		
44	0	3	1	3	43	2	3	40	3	3	36	4	4	32	7	6	27
45	0	4	2	3	40	3	3	35	4	3	32	6	5	29	9	6	26
46	0	4	2	2	41	3	2	36	5	3	32	8	5	28	15	7	24
47	0	0	0			0			0			0			0		
Cook County																	
48	1	3	2	4	39	2	4	41	3	4	35	4	4	31	5	5	29
49	0	5	8	5	28	13	7	25	17	8	24	21	9	24	26	8	25
50	1	4	14	5	22	16	7	24	17	8	24	18	9	24	19	8	25
51	0	2	0			0			0			0			0		
52	0	0	0			0			0			0			0		
53	2	1	4	4	35	7	6	30	10	8	27	14	9	25	19	10	27
54	0	3	6	5	30	8	7	29	11	8	26	14	9	25	18	9	27
55	0	4	13	5	23	15	8	24	17	9	24	18	8	25	21	8	26
56	1	4	0			0			0			0			0		
57	0	3	2	3	36	2	3	36	2	3	36	2	3	36	2	3	36
58	0	1	0			0			0			0			0		
59	1	4	0			0			0			0			0		
60	0	5	0			0			0			0			0		
61	0	5	0			0			0			0			0		
62	0	7	7	3	24	7	3	25	8	3	24	9	4	24	9	4	24
63	0	5	3	3	31	3	3	31	3	3	31	3	3	31	3	3	31
64	0	4	2	3	42	4	3	31	5	4	31	7	6	28	10	7	26
65	0	5	1	3	40	2	3	38	2	3	40	3	3	32	4	3	28
66	0	5	3	2	32	4	2	29	4	2	30	5	2	26	6	3	26
67	0	1	1	4	36	1	4	36	1	[illegible]	36	1	4	36	1	3	36
68	0	0	4	6	38	8	9	32	12	1[illegible]	30	16	12	29	22	14	28
69	0	5	5	2	30	8	4	26	10	6	26	13	7	25	16	8	24
70	0	4	1	3	35	1	3	35	1	3	35	1	3	35	1	3	35
71	0	5	7	3	27	11	5	26	15	8	26	21	10	25	29	12	25
72	0	7	17	5	21	21	7	22	25	9	23	29	11	23	35	11	24

TABLE BA-IV-G-1 (Continued)

Township	B_1 (mgd)	B_2 (mgd)	1980 D (mgd)	1980 Costs Raw	1980 Costs Treated	1990 D (mgd)	1990 Costs Raw	1990 Costs Treated	2000 D (mgd)	2000 Costs Raw	2000 Costs Treated	2010 D (mgd)	2010 Costs Raw	2010 Costs Treated	2020 D (mgd)	2020 Costs Raw	2020 Costs Treated
Du Page County																	
73	2	2	1	2	48	3	2	35	5	3	30	7	5	28	10	7	26
74	1	3	5	3	31	9	6	28	13	7	24	18	9	24	24	8	25
75	0	4	15	5	22	20	9	23	24	9	24	26	8	25	29	8	25
76	0	3	4	3	32	6	4	29	8	6	28	11	7	26	14	9	25
77	0	5	11	4	25	17	7	23	24	9	22	30	9	24	38	8	25
78	0	5	20	7	21	23	9	23	24	9	24	25	9	24	25	8	24
79	0	5	3	2	36	6	3	28	8	4	27	12	6	24	15	7	24
80	0	5	6	3	29	10	5	26	15	7	24	20	8	23	26	9	24
81	0	7	14	4	21	16	6	22	16	7	23	17	7	23	18	8	23
Will County																	
82	0	5	1	5	36	1	4	41	1	4	41	2	4	37	2	5	37
83	0	6	2	3	40	3	3	34	4	3	31	5	3	28	7	4	25
84	0	6	2	3	39	3	3	36	4	3	34	7	3	26	11	4	22
85	0	5	5	3	29	6	3	28	9	4	26	12	6	24	15	7	24
86	0	5	1	2	51	3	2	40	6	3	33	12	7	26	24	9	23
87	0	8	1	5	45	2	5	44	3	6	41	5	6	32	9	6	26
88	0	7	17	5	21	19	6	22	23	8	22	27	9	22	32	9	23
89	0	5	1	2	46	3	2	35	4	2	33	7	4	27	11	6	25
90	0	5	2	2	41	3	2	37	5	2	32	9	6	27	16	8	24
91	0	7	7	5	27	7	6	28	8	6	27	9	8	27	10	8	27
92	0	6	0			1	3	43	2	3	41	3	3	34	5	3	27
93	0	5	0			0			1	2	39	1	2	39	2	2	35
94	0	5	0			0			1	2	43	1	2	43	3	2	31
95	0	5	2	2	43	3	2	40	6	3	32	12	7	26	22	9	24
96	0	6	2	2	37	2	2	39	3	2	33	4	2	29	5	2	26
97	4	1	1	5	37	1	5	38	1	5	38	1	6	38	1	6	38
98	1	3	0			0			0			1	4	36	1	4	36
99	0	5	0			0			0			1	2	35	1	2	35
100	0	5	0			0			1	2	42	2	2	37	3	2	31
101	0	5	0			0			1	2	42	1	2	42	3	2	31
102	0	6	0			0			0			1	2	35	1	2	35
103	4	2	0			0			0			0			0		
104	1	6	0			0			0			1	5	38	1	6	39

[a] *Costs are in cents per 1000 gallons; township numbers are those shown in figure 4;*
B_1 = potential yield of sand and gravel aquifers; B_2 = potential yield of Silurian dolomite; D = demand

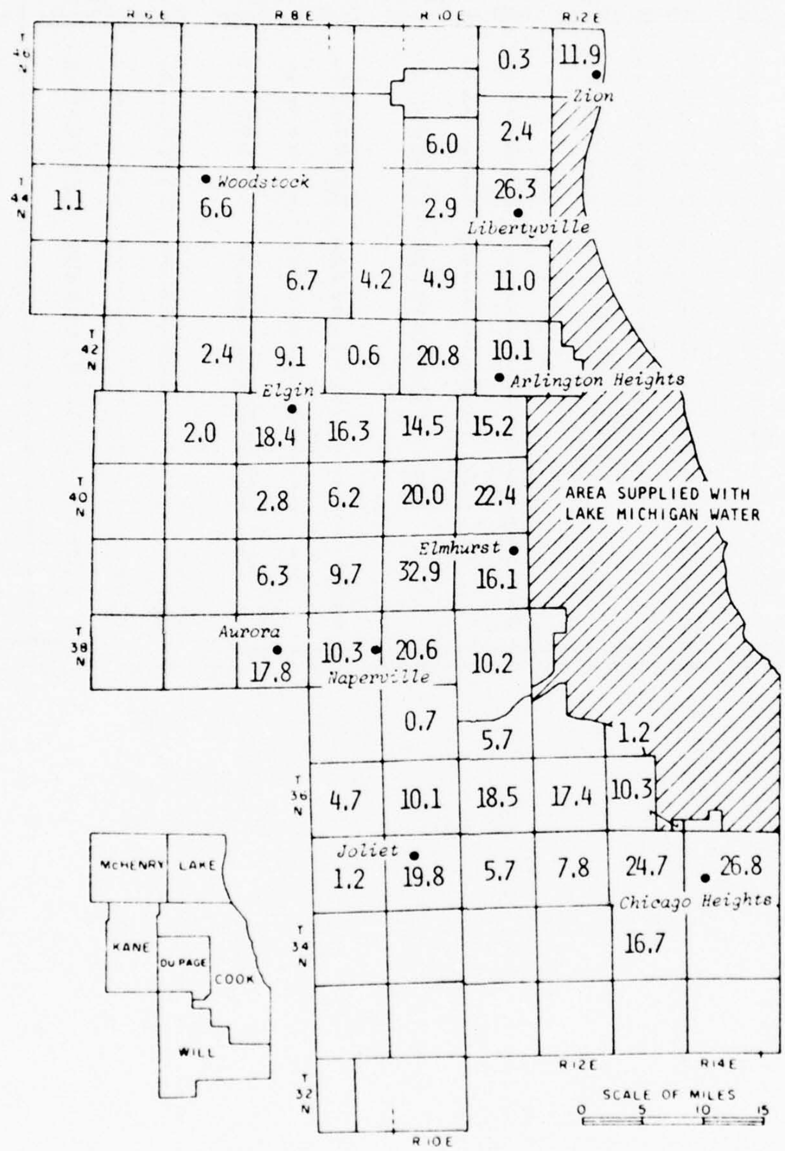

Figure BA-IV-G-1

WATER DEMANDS (MGD) IN 2020 IN EXCESS OF GROUNDWATER AVAILABLE FROM NATURAL RECHARGE

TABLE BA-IV-G-2

C-SELM WATER DEMANDS 1980 - 2020 BY TOWNSHIPS
(UNIT IN MGD)

	DOMESTIC & COMMERCIAL WATER DEMAND				INDUSTRIAL WATER DEMAND				AGRICULTURAL WATER DEMAND				TOTAL WATER DEMAND			
Township	1930	1990	2000	2020	1980	1990	2000	2020	1980	1990	2000	2020	1980	1990	2000	2020
COOK, ILL.																
Chicago	495.0	511.5	532.0	573.8	641.9	587.4	584.0	594.0	0	0	0	0	1136.9	1098.9	1116.0	1167.8
Berwyn[1]	27.8	28.7	29.6	31.5	27.7	29.6	30.8	31.7	0	0	0	0	55.5	58.3	60.4	63.2
Bloom	17.6	21.7	24.6	28.1	23.4	22.2	23.5	24.6	0.2	0.2	0.3	0.4	41.2	44.1	48.4	53.1
Bremen	15.8	23.9	30.3	36.0	2.9	3.3	3.3	3.3	0.2	0.2	0.3	0.4	18.9	27.4	33.9	39.7
Calumet	3.1	3.5	4.2	5.3	3.7	4.1	4.2	4.4	0.1	0.1	0.2	0.2	6.9	7.7	8.6	9.9
Elk Grove	12.4	14.1	15.7	19.1	10.6	12.3	13.5	13.9	0.2	0.2	0.3	0.4	23.2	26.6	29.5	33.4
Evanston	12.3	13.0	13.8	15.3	3.6	3.9	4.1	4.2	0	0	0	0	15.9	16.9	17.9	19.5
Lemont	1.8	3.5	5.4	6.9	12.2	12.5	12.0	11.9	0.2	0.2	0.3	0.4	14.2	16.2	17.7	19.2
Leydon[2]	18.3	22.3	25.7	30.6	43.0	45.3	46.9	48.5	0	0	0	0	61.3	67.6	72.6	79.1
Lyons	14.8	17.0	19.2	22.4	16.3	17.6	18.3	18.9	0	0	0	0	31.1	34.6	37.5	41.3
Maine	21.0	23.4	26.0	30.2	10.8	11.5	11.5	12.3	0	0	0	0	31.8	34.9	37.5	42.5
New Trier	7.8	8.3	8.8	9.9	1.2	1.3	1.4	1.4	0	0	0	0	9.0	9.6	10.2	11.3
Niles	15.3	17.0	18.1	20.3	42.5	44.6	46.6	48.1	0	0	0	0	57.8	61.6	64.7	68.4
Northfield	11.3	14.7	16.1	18.0	5.3	5.9	6.2	6.3	0.1	0.1	0.1	0.1	16.7	20.7	22.4	24.4
Orland	3.9	9.1	11.8	14.9	1.2	1.4	1.5	1.5	0.2	0.2	0.3	0.4	5.3	10.7	13.6	16.8
Palatine	9.6	13.7	17.8	20.0	1.7	2.2	2.3	2.4	0.2	0.2	0.3	0.4	11.5	16.1	20.4	22.8
Palos	5.8	7.2	8.3	9.9	1.2	1.5	1.6	1.6	0.2	0.2	0.3	0.4	7.2	8.9	10.2	11.9
Proviso[3]	24.2	25.8	27.5	30.8	19.4	20.6	21.4	22.0	0	0	0	0	43.6	46.4	49.9	52.8
Rich	7.9	12.2	15.5	17.4	2.2	2.7	2.8	3.0	0.2	0.2	0.3	0.4	10.3	15.1	18.6	20.8
Shaumburg	9.0	13.4	16.6	18.6	2.5	2.9	4.1	6.0	0.2	0.2	0.2	0.2	11.7	16.5	20.9	24.8
Stickney	6.4	8.1	9.6	11.6	10.3	11.0	11.4	11.8	0	0	0	0	16.7	19.1	21.0	23.4
Thornton	25.4	31.5	33.5	37.5	15.3	15.7	16.1	16.7	0.2	0.2	0.3	0.4	40.9	47.4	49.9	54.6
Wheeling	17.4	20.0	22.2	26.4	4.9	5.8	7.1	9.0	0.2	0.2	0.3	0.4	22.5	26.0	29.6	35.8
Worth	20.3	23.4	26.3	30.6	5.7	6.0	7.0	7.2	0	0	0	0	26.0	29.4	33.3	37.8
SUB TOTAL	804.2	887.0	958.6	1065.1	909.5	871.3	881.6	904.7	2.4	2.4	3.5	4.5	1716.1	1760.7	1843.7	1974.3
DU PAGE, ILL.																
Addison	14.2	19.9	24.5	30.0	3.5	4.5	5.1	6.0	0.2	0.2	0.3	0.4	17.9	24.6	29.9	36.4
Blomingdale	6.4	10.8	15.1	21.0	0.3	0.5	0.7	0.8	0.2	0.2	0.3	0.4	6.9	11.5	16.1	22.2
Downers Grove	14.4	17.3	19.3	23.1	1.0	1.4	1.7	2.0	0.2	0.2	0.3	0.4	15.6	18.9	21.3	25.5
Lisle	8.9	12.6	16.9	22.5	0.9	1.2	1.5	1.7	0.2	0.2	0.3	0.4	10.0	4.0	18.7	24.6
Milton	12.2	18.9	24.3	30.0	1.4	1.9	2.3	2.8	0.2	0.2	0.3	0.4	13.8	21.0	26.9	33.2
Naperville (part)	2.2	4.4	8.0	13.5	0.3	0.4	0.6	0.7	0.2	0.2	0.3	0.3	2.7	5.0	8.9	14.5
Wayne (part)	1.4	2.5	5.4	9.8	0.5	0.6	0.8	1.0	0.2	0.2	0.3	0.3	2.1	3.3	6.5	11.1
Winfield	3.7	6.2	9.6	17.3	0.6	0.8	1.1	1.3	0.2	0.2	0.3	0.4	4.5	7.2	11.0	19.0
York	19.0	20.8	22.1	24.8	2.1	2.7	3.2	3.8	0.2	0.2	0.3	0.4	21.3	23.7	25.6	29.0
SUB TOTAL	82.4	113.4	145.2	192.0	10.6	14.0	17.0	20.1	1.8	1.8	2.7	3.4	94.8	129.2	164.9	215.5

[1] Includes Cicero and Oak Park

[2] Includes Norwood Park

[3] Includes River Forest and Riverside

TABLE BA-IV-G-2 (Continued)

	DOMESTIC & COMMERCIAL WATER DEMAND				INDUSTRIAL WATER DEMAND				AGRICULTURAL WATER DEMAND				TOTAL WATER DEMAND			
Township	1980	1990	2000	2020	1980	1990	2000	2020	1980	1990	2000	2020	1980	1990	2000	2020
LAKE, ILL.																
Antioch (part)	0.4	0.6	0.8	1.1	0	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.5	0.8	1.1	1.4
Avon (part)	1.4	1.9	2.9	6.0	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	1.6	2.1	3.2	6.3
Benton-Zion	4.7	6.6	8.7	13.2	0.4	0.6	0.9	1.2	0.2	0.2	0.3	0.3	5.3	7.4	9.9	14.7
Deerfield-W. Deerfield	11.0	15.8	18.8	22.5	1.0	1.3	1.5	1.9	0.2	0.2	0.2	0.2	12.2	17.3	20.5	24.6
Ela (part)	0.9	1.2	2.2	4.3	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3	1.2	1.5	2.7	4.8
Fremont (part)	0.6	1.0	1.7	3.3	0	0	0	0.1	0.1	0.2	0.3	0.3	0.7	1.2	2.0	3.7
Lake Villa (part)	0.8	1.0	1.4	3.3	0	0	0	0	0.1	0.1	0.2	0.3	0.9	1.1	1.6	3.6
Libertyville	4.6	9.1	13.7	19.4	0.7	1.0	1.2	1.5	0.2	0.2	0.3	0.4	5.5	10.3	15.2	21.3
Newport	0.4	0.7	1.0	2.0	0	0	0	0	0.2	0.2	0.3	0.4	0.6	0.9	1.3	2.4
Shields	8.0	10.1	11.4	12.8	0.7	1.0	1.2	1.5	0.2	0.2	0.2	0.2	8.9	11.3	12.8	14.5
Vernon	2.4	4.7	6.6	8.8	0.1	0.2	0.3	0.4	0.2	0.2	0.3	0.4	2.7	5.1	7.2	9.6
Warren	2.8	4.2	5.7	8.4	0.1	0.2	0.4	0.6	0.2	0.2	0.3	0.4	3.1	4.6	6.4	9.4
Waukegan	14.9	17.8	19.2	21.3	11.2	9.7	9.2	9.0	0.2	0.2	0.2	0.3	26.3	27.7	28.6	30.6
SUB TOTAL	52.9	74.7	94.1	126.4	14.4	14.3	15.1	16.6	2.2	2.3	3.3	3.9	69.5	91.3	112.5	146.9
WILL, ILL.																
Channahon	0.3	0.4	0.5	0.7	13.0	9.9	8.4	7.0	0.2	0.2	0.3	0.4	13.5	10.5	9.2	8.1
Crete (part)	1.8	2.5	3.5	5.8	0	0	0.1	0.1	0.2	0.2	0.3	0.4	2.0	2.7	3.9	6.3
DuPage	3.5	5.4	7.9	13.8	0.1	0.2	0.3	0.5	0.2	0.2	0.3	0.4	3.8	5.8	8.5	14.7
Frankfort	1.9	3.5	5.9	9.2	0.3	0.5	0.8	1.4	0.2	0.2	0.3	0.4	2.4	4.2	7.0	11.0
Green Garden (part)	0	0.1	0.1	0.2	0	0	0	0	0	0	0	0	0	0.1	0.1	0.2
Homer	1.6	3.3	5.9	13.5	0	0.1	0.2	0.3	0.2	0.2	0.3	0.4	1.8	3.6	6.4	14.2
Jackson (part)	0.1	0.2	0.3	0.7	0.1	0.2	0.3	0.5	0.2	0.2	0.3	0.4	0.4	0.6	0.9	1.6
Joliet	16.1	20.2	25.1	32.3	13.0	8.1	9.1	11.0	0.2	0.2	0.3	0.4	29.3	28.5	34.5	43.7
Lockport	4.5	7.1	9.9	15.6	15.6	9.9	7.0	4.8	0.2	0.2	0.3	0.4	20.3	17.2	17.2	20.8
Manhattan (part)	0.1	0.2	0.2	0.3	0	0	0	0	0.1	0.1	0.2	0.2	0.2	0.3	0.4	0.5
Monee (part)	4.1	5.7	8.0	12.8	0	0.1	0.2	0.5	0.1	0.1	0.2	0.2	4.2	5.9	8.4	13.5
New Lenox	1.7	3.1	5.2	10.5	0	0.1	0.1	0.3	0.2	0.2	0.3	0.4	1.9	3.4	5.6	11.2
Plainfield	1.7	2.8	4.9	9.0	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.4	2.0	3.1	5.3	9.6
Troy	1.9	3.6	5.7	12.0	0.1	0.1	0.2	0.4	0.2	0.2	0.3	0.4	2.2	3.9	6.2	12.8
Wheatland	0.4	0.9	1.6	4.8	0.1	0.1	0.3	0.5	0.2	0.2	0.3	0.4	0.7	1.2	2.2	5.7
SUB TOTAL	39.7	59.0	84.7	141.2	42.4	29.4	27.1	27.5	2.6	2.6	4.0	5.2	84.7	91.0	115.8	173.9
ILLINOIS TOTALS	979.2	1,134.1	1282.6	1524.7	976.9	929.0	940.8	968.9	9.0	9.1	11.5	17.0	1965.1	2072.2	2236.9	2510.6

TABLE BA-IV-G-2 (Continued)

	DOMESTIC & COMMERCIAL WATER DEMAND				INDUSTRIAL WATER DEMAND				AGRICULTURAL WATER DEMAND				TOTAL WATER DEMAND			
Township	1980	1990	2000	2020	1980	1990	2000	2020	1980	1990	2000	2020	1980	1990	2000	2020
LAKE, IND.																
Calumet	33.0	35.0	37.8	43.5	124.6	79.8	70.4	71.8	0	0	0	0	157.6	114.8	108.2	115.3
Center (part)	3.4	4.2	6.0	9.0	0	0.1	0.1	0.1	0.1	0.1	0.2	0.2	3.5	4.4	6.3	9.3
Hobart	6.1	8.1	9.6	13.5	0	0.1	0.1	0.2	0	0	0	0	6.1	8.2	9.7	13.7
North	30.9	32.4	34.2	38.4	314.6	191.7	137.1	103.6	0	0	0	0	345.5	224.1	171.3	142.0
Ross	4.1	6.4	9.0	15.0	0	0	0.1	0.1	0.2	0.2	0.3	0.3	4.3	6.6	9.4	15.4
St. John (part)	2.9	4.6	6.4	11.3	0	0.1	0.1	0.3	0.2	0.2	0.3	0.3	3.1	4.9	6.8	11.9
Winfield (part)	0.1	0.2	0.3	0.6	0	0	0	0	0.1	0.1	0.1	0.1	0.2	0.3	0.4	0.7
SUB TOTAL	80.5	90.9	103.3	131.3	439.2	271.8	207.9	176.1	0.6	0.6	0.9	0.9	520.3	363.3	312.1	308.3
LA PORTE, IND.																
Center (part)	1.2	1.4	1.8	2.7	0	0	0	0	0.2	0.2	0.2	0.3	1.4	1.6	2.0	3.0
Cool Spring	1.6	2.6	3.3	5.7	0.1	0.1	0.1	0.2	0.5	0.7	0.8	1.0	2.2	3.4	4.2	6.9
Michigan	6.2	6.5	6.9	7.7	1.5	1.6	1.9	2.9	0.2	0.2	0.2	0.3	7.9	8.3	9.0	10.9
New Durham (part)	0.2	0.2	0.2	0.4	0	0	0	0	0.2	0.2	0.2	0.3	0.4	0.4	0.4	0.7
Springfield (part)	0.2	0.3	0.4	0.6	0	0	0	0.1	0.2	0.3	0.3	0.4	0.4	0.6	0.7	1.1
SUB TOTAL	9.4	11.0	12.6	17.1	1.6	1.7	2.0	3.2	1.3	1.6	1.7	2.3	12.3	14.3	16.3	22.6
PORTER, IND.																
Center	3.4	4.5	5.9	11.6	0.1	0.2	0.4	0.7	0	0	0	0	3.5	4.7	6.3	12.3
Jackson (part)	0.2	0.3	0.5	1.2	0	0	0	0	0	0	0	0	0.2	0.3	0.5	1.2
Liberty (part)	0.6	1.1	2.1	5.3	0	0	0	0	0	0	0	0	0.6	1.1	2.1	5.3
Pine	0.6	1.1	1.7	4.1	0	0	0	0.1	0	0	0	0	0.6	1.1	1.7	4.2
Portage	4.5	7.4	12.1	24.6	12.9	11.5	14.1	24.7	0	0	0	0	17.4	18.9	26.2	49.3
Union (part)	0.2	0.5	0.9	2.5	0	0	0	0	0	0	0	0	0.2	0.5	0.9	2.5
Westchester	2.2	3.5	5.4	12.0	38.9	25.1	24.8	31.7	0	0	0	0	41.1	28.6	30.2	43.7
SUB TOTAL	11.7	18.4	28.6	61.3	51.9	36.8	39.3	57.2	0	0	0	0	63.6	55.2	67.9	118.5
INDIANA TOTALS	101.6	120.3	144.5	209.7	492.7	310.3	249.2	236.5	1.9	2.2	2.6	3.2	596.2	432.8	396.3	449.4
GRAND TOTALS	1080.8	1244.4	1427.1	1734.4	1469.6	1239.3	1190.0	1205.4	10.9	11.3	16.1	20.2	2561.3	2505.0	2633.2	2960.0

RECREATIONAL-NAVIGATIONAL REUSE

Channel Capacity In C-SELM Area

General. The channels in the C-SELM area may be divided into two categories; the natural channels and the navigation channels. The natural channels are developed through the natural process, initially, and are improved artificially to meet the requirement to relieve the flood flow thereafter. If the same degree of protection against flood damage is assumed, there will be a certain relationship between the rate of discharge, the velocity and the drainage area. However, the navigation channels are designed for purposes other than flood control so there is no general rule to evaluate the capacity of the channel except by using the characteristic of the specific channel. The following material outlines the method used to determine the maximum allowable streamflow used in the flow routing for recreational-navigational flows presented in Appendix B, Section IV-G.

The capacity of the natural channel.

Characteristics of natural channels in C-SELM area.

A thorough study on the characteristics of Illinois streams has been performed by the Illinois State Water Survey.[1/] The study of channel capacity in the C-SELM area has selected the Des Plaines River as a typical basin and concluded the following statistical results:

$$\ln Q = 1.78 - 4.98F + 0.90 \ln Ad \quad (1)$$

$$\ln V = 0.26 - 1.31F + 0.08 \ln Ad \quad (2)$$

Where Q = the rate of discharge in cfs

F = frequency of occurrence in fraction of time

Ad = drainage area in square mile

V = the velocity in ft/sec

Since erosion control is the major factor which governs the capacity of the channel for this study, we combine

Equations (1) and (2) to eliminate the frequency variable. The result is:

$$\ln Q = 3.801526 \ln V + 0.791603 + 0.595077 \ln Ad$$

Or,

$$Q = 2.207\ V^{3.802}\ Ad^{0.596} \qquad (3)$$

Permissible velocity.

The velocity equation may be plotted as shown in Figure BA-IV-G-2. For a drainage area of 150 square miles, which is not uncommon in the C-SELM area, the mean velocity is read as 1.8 ft/sec for the frequency of 5%. This frequency is reasonable for use in selecting a permissible velocity.

The maximum channel capacity without additional erosion control.

Since the permissible velocity selected is 1.8 ft/sec., the permissible channel capacity can be computed from Equation (3) as:

$$Q = 2.207 \times 1.8^{3.802}\ Ad^{0.596}$$

$$= 20.6\ Ad^{0.596} \text{ cfs}$$

Or,

$$Q = 13.3\ Ad^{0.596} \text{ MGD}$$

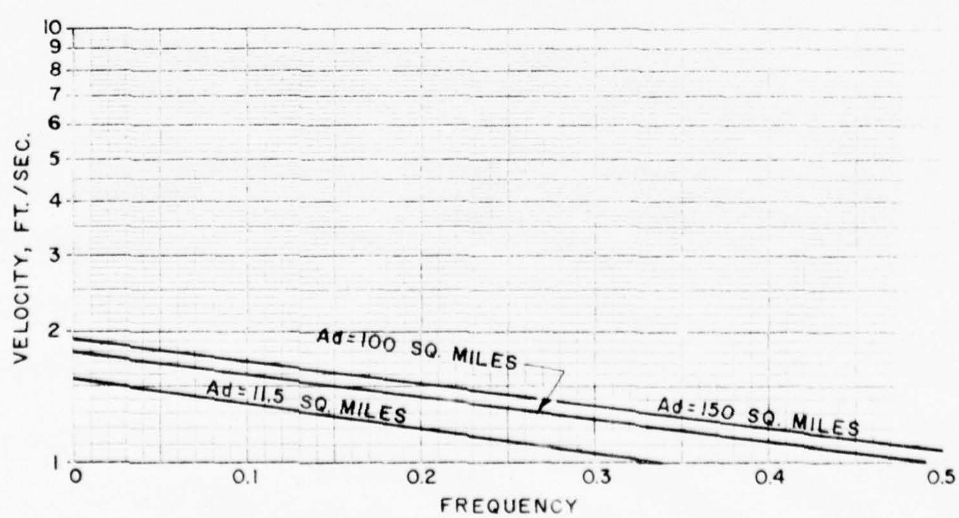

Figure BA-IV-G-2
FREQUENCY VS. VELOCITY

STREAM DEPTHS

The attached table, BA-IV-G-3, summarizes, for key points on C-SELM area streams, the minimum and maximum depths which could be expected in these streams under the 2nd reuse option (no limitation on Lake Michigan diversion in Illinois). Minimum depths were interpreted from flows described as that flow which would be observed in the stream at least 60 percent of the time. Maximum depths were interpreted from flows which were associated with allowable stream capacity at a velocity of 1.8 feet per second. The velocity of 1.8 feet per second establishes stream flow for minimum bank erosion.

BIBLIOGRAPHY BA-IV-G

COMPONENT BASIS OF DESIGN

1. Hydraulic Geometry of Illinois Streams, Stall, J. B., and Fok, Yu-Si, Final Report WRC Research Report No. 15, University of Illinois, July, 1968.

Table BA-IV-G-3

SELECTED STREAM DEPTHS

Note: Stream flows Q shown in cfs, stream heights H shown in feet. Maximum flow and height at limiting flow velocity of 1.8 fps.

			1990 Flows				2020 Flows				Max. flow	
			Summer		Winter		Summer		Winter		@ 1.8 fps	
Ref. No.	Gage No.	Stream Name	Q	H	Q	H	Q	H	Q	H	Q	H
1	5-5278	Des Plaines	193.5	1.34	55.2	.8	193.5	1.34	55.2	.8	365	2.54
5	--	Des Plaines	516.0	1.90	179.0	1.25	591.0	2.18	292.0	1.35	775	2.85
7	5-5350	E.Fork N.Br. Chicago River	15.2	1.16	7.7	.95	13.3	1.0	7.7	.95	23	1.61
9	5-5355	W.Fork N.Br. Chicago River	31.6	1.54	18.3	1.05	26.4	1.28	18.3	1.05	36	1.75
12	5-5315	Lower Salt Cr.	106.5	1.50	64.4	.89	122.9	1.65	92.8	1.01	346	2.51
13	5-5320	Upper Addison Cr.	9.8	.75	9.8	.75	9.8	.75	9.8	.75	64	1.92
16	--	Low E.Br. DuPage	66.1	.80	55.4	.75	106.9	1.10	105.0	1.05	256	2.40
18	5-5399	Mid.W.Br. DuPage	46.1	1.20	11.9	.80	26.1	1.10	11.9	.80	169	2.24
24	4-0890	Lower Thorn Cr.	40.8	1.15	14.4	.95	49.0	1.25	45.7	1.20	140	2.18
27	5-5365	Upper Tinley Cr.	11.8	1.20	6.4	.80	6.4	.80	6.4	.80	42	1.80
31	--	Upper Salt Cr.Ind.	11.3	1.0	7.9	.75	11.3	1.0	7.9	.75	53	1.86
32	4-0932	Low.Salt Cr.Ind.	-	-	-	-	-	-	-	-	620	-
36	5-5285	Buffalo Creek	12.4	1.20	7.4	.95	12.4	1.20	7.4	.95	50	1.84
38	5-5396.5	Jackson Creek	17.5	1.15	9.8	.90	17.5	1.15	9.8	.90	65	1.92
40	4-0880	Upper Thorn Cr.	11.5	1.15	9.3	.95	9.3	.95	9.3	.95	62	1.92

IV. COMPONENT BASIS OF DESIGN

I. NON-STRUCTURAL SYSTEMS

PROVISIONS FOR MODEL CODE FOR SEPTIC SYSTEMS

The accepted guide for septic systems is the U. S. Public Health Service "Manual of Septic Tank Practice," which lists technical standards and procedures and a suggested ordinance that would be applicable for a wide range of conditions over the country. Local standards and requirements cover many of the same considerations, and probably reflect local conditions. The following comments cover (1) General Provisions, (2) Septic Tanks, and (3) Septic Absorption Fields and are intended to select desirable practices from the variety of possibilities covered. This should not, however, indicate that other acceptable procedures do not exist.

For example, absorption fields laid in series that use deep trenches show certain advantages over parallel fields using the traditional shallow, long trenches. Tile in series allow more effective use of the individual segments by inundating one section completely before entering another section. Also sidewalls do not tend to clog as readily as trench bottoms and offer more efficient surfaces for percolation. This does not mean that this approach is always preferable or that other methods are unacceptable.

General Provisions

The use of septic disposal should depend on the availability of central sewers, the amount of wastewater to be treated per day, the size and slope of the area available for an absorption field, and the suitability of the soil and geology of the site.

The lot size should be at least one acre, larger if the slope restricts its use. For example, it has been recommended that a lot be a minimum of 1.5 acres if the drainfield area slopes from 10% to 20%; two acres if the slope is over 20%. This should provide sufficient space for two identical absorption fields, one to be developed at a later time if needed.

Soil suitability should be determined from soil maps and confirmed by on-site inspection and, if necessary, soil percolation tests. The soil mantle should be a minimum of five feet in depth and the investigation should determine the depth, extent, and character of the soil and the location of bedrock and other impervious strata. Acceptable soil should extend at least three feet below the bottom of the trench. Groundwater elevations should be ascertained as well, and inspecting and testing should be performed when groundwater elevations are the highest. The seasonal high groundwater table should be a least three feet below the bottom of the proposed drainfield trench.

Technical standards should be based on the most limiting situation, with the possibility of varying them depending on conditions. For example, coarse-grained materials could allow a design of under 600 square feet of trench sidewall per bedroom, and soil and water conditions could allow increasing or decreasing the depth of the bottom of the trench.

A site plan of the proposed septic installation should be prepared showing finished elevations, soil types, wells, water lines, large trees, water bodies, cuts or embankments, and all proposed surface improvements in relation to the tank and drainfield.

Each property owner should be supplied with information on the proper use of and maintenance necessary for the septic installation so that he can better understand the process and the importance of these factors.

Septic Tanks

The septic tank should be large enough to provide satisfactory detention time and treatment for larger wastewater flows than might be initially anticipated. This is necessary due to the unpredictability of use by a particular family and the radically different use that is possible with a different family. Per capita water use has historically increased and new household devices demand greater amounts of water. Garbage disposal units for example, are relatively inexpensive and easy to install and even though not contemplated when the home is built, may be added at a later time.

A recent study recommended a minimum size of 1200 gallons, with an increase of 250 gallons per bedroom for over four bedrooms. This is based on five persons at 150 gallons per person per day, a 24-hour theoretical detention time, and an accumulated 300 gallons of sludge and 150 gallons of scum. All domestic, laundry, and sanitary wastes should be treated, but stormwater runoff and groundwater should be excluded.

Tanks should be made of durable material, at least as suitable as concrete. They should consist of two chambers with baffles at inlet and outlet, and should have an easily-accessible hatch for inspection and cleaning. A tank having a first compartment twice the capacity of the second has proved to be the most efficient design.

Recommended setbacks are as follows: buildings, property lines, walks and drives, 5 feet; pools, water lines and large trees, 10 feet; creeks or streams and cuts or embankments, 25 feet (unless in water supply watershed, then 200 feet); and wells, 100 feet.

Septic Absorption Fields

A conservative approach is warranted in the design and installation of the drain field due to the many factors that could present problems to its satisfactory operation.

Design should be based on at least 60 gallons per day per person using the system, and the acceptance rate of the receiving soil. This is usually expressed in square feet of percolative surface (or lineal feet of field of a given surface) per bedroom for residential use.

A tile field in series is reported to be more satisfactory than a field with a distribution box and parallel lines. Lines are laid flat, with overflow lines connecting them, and full use is made of any trench cross-section selected. This allows use of deep trenches and the better infiltrative surfaces provided by the sidewalls. One recommended standard is 600 square feet of sidewall per bedroom for any percolation rate.

Trenches should be 12 to 18 inches wide, and may be 24 to 36 inches deep below the drain tile. The trench should ideally be filled so that coarse material surrounds the tile and the material size decreases radially to match the particle size of the infiltrative surface. The filter should be 3/4 to 1-1/2 inch material, at least two inches over the top of the tile. This material should be covered with untreated building paper and then native soil level with the ground surface. Parallel trenches should be a minimum of six feet apart.

Care should be taken in trenching to retain the natural soil texture as much as possible for optimum infiltrative capacity. Compaction of the soil, smearing the soil surface, and filling voids with displaced fines tends to reduce the percolation of effluent. Ideally, there should be several inspections of the installation in process to assure that this and other considerations are taken into account.

Standards for the construction of a replacement field would be the same as for a new field, but there would be an advantage in knowing the life of the first system and the reason for its failure. The design of the replacement field could therefore be modified to operate more effectively in those conditions. There is also an opportunity to resume using the first field after it has "rested" for several years and achieve a longer life for the two fields than would be possible for the sum of the life of the individual fields.

Recommended setbacks for drain fields are as follows: property lines, walks and drives, 5 feet; buildings, water lines, and large trees, 10 feet; pools, 25 feet; creeks or streams and cuts or embankments, 100 feet (unless in water supply watershed, then 200 feet); and wells, 100 feet.

Percolation tests should take into account the type of soil and geology of the area. Too fast a percolation rate could result in groundwater pollution. Presoaking is necessary, especially for clays that swell when wet, to indicate the infiltration rate that can be expected under normal service conditions. Several holes in the area of the proposed drain field should be dug to the design depth. Sides should be supported if necessary to prevent sloughing of the soil, and gravel should be placed on the bottom to prevent clogging. The percolation rate should be at least 1 inch in 60 minutes.

DATA ANNEX B

COST ESTIMATION

V. COST ESTIMATION

A. METHODOLOGY

COMPARATIVE OPERATION AND MAINTENANCE COSTS

Several methods of computing the Operation and Maintenance Costs of pressure force mains, pumping stations, and gravity lines, were investigated and tested to check on the reliability of values obtained. Comparative costs are based on dollars per million gallons per day of wastewater pumped ($/MGD). The methods investigated are:

1. One-half of one percent of total capital cost plus 20 percent for contingencies is considered as cost of labor and material required for yearly operation and maintenance of a facility. Cost of power is added to cost of labor and material for the total cost of O & M.

   Total O & M = (Capital Cost + 20%) x .005 Labor & Material, Power Cost @ $0.01/KWH

2. Labor and Material costs are computed separately for pumping stations (P.S.) and conveyance lines and added to the cost of power. Following equations are used:

   Labor Costs:

   Pumping Stations = (P.S. Capital Cost + 20%) x 0.01

   Lines = (Line Capital Cost + 20%) x 0.002

   Material Costs:

   Pumping Stations = (P.S. Capital Cost + 20%) x 0.005

   Lines = (Line Capital Cost + 20%) x 0.001

   Power Costs:

   Power = $0.01/KWH

   Total O & M = Labor Costs + Material Costs + Power Costs

3. A manual published by the U. S. Environmental Protection Agency was used:

Estimating Costs and Manpower
Requirements for Conventional Wastewater
Treatment Facilities
Water Pollution Research Services 170090
DAN 10/71

Costs of O & M of conveyance lines not available in this report. For comparison, costs of pumping station O & M were used.

Curves for Operation and Maintenance Labor on page 83, Figure 26 were used.

Curves of Materials & Power, page 84, Figure 27 were used.

Example: For comparative calculations, cost of pumping stations for potable water reuse, option 2 was used.

Total Pumpage = 741 MGD	
Capital Cost of Pumping Stations:	\$ 13,468,000
+ 20%	269,360
Capital & Contingencies	\$ 13,737,360

1. O & M = 0.005 (13,737,360) = \$ 68,687
   = 3,092,000
   \$3,160,687

   Based on \$/MGD = \$3,160,687/741 = \$4,265/MGD

2.

P.S. Labor Costs	= 0.01 (13,737,360) =	137,373
Materials	= 0.005 (13,737,360) =	68,687
Power	=	3,092,000
Total	=	3,298,060

   Based on \$/MGD = 3,298,060/741 = \$4,451/MGD

3. Labor Cost of \$4.10 per hour is used.

   From curves: All values per MGD

Maintenance Labor	= 360 hrs.		
Operation Labor	= 450 hrs.		
Total Labor	= 810 hrs. @ 4.10 =		$ 3,240
Materials & Supplies			350
Power			900
Total			$ 4,490/MGD

Cost Comparison:

Method 1)	=	$4,265/MGD
Method 2)	=	4,451/MGD
Method 3)	=	4,490/MGD

Conclusion:

All three methods are comparable and costs obtained by use of the three are reasonably close for comparative calculations.

DATA ANNEX B

IMPACTS OF MANAGEMENT SYSTEMS

VII. IMPACTS OF MANAGEMENT SYSTEMS

B. IMPACTS ON RESOURCES

LAND COSTS

Land and Displacements

In order to derive a per-acre basis of cost for the land treatment sites, several typical areas in representative counties were identified, field surveyed and researched for the following items:

1. Land value
2. Dwelling unit value
3. Average farm size
4. Average household size
5. Residential density (total number of housing units)
6. Nonresidential units (number)

The following factors were assumed to contribute to the overall cost evaluation:

1. A grid consisting of townships and sections in all Illinois Counties and of one-square mile units in all Indiana Counties was employed to estimate the percentage by area of each township or county to be acquired or leased. This was done by overlaying the township-section or square-mile grid on the acquisition area.

2. All urban areas listed as "Places" in the Northeastern Illinois Planning Commission (NIPC) Suburban Factbook 1/, or as separate entities in the 1970 Census of Population: Final Population Counts 2/ 3/ were excluded from acquisition. These are generally places of 100 or more persons.

3. Estimates of owner-occupied and rented dwelling units were made in two ways:

   a. For Illinois where NIPC data was available: "Place" dwellings were subtracted from total township dwellings (from Factbook[1] figures). This resultant figure was then multiplied by the calculated percentage of the township area to be acquired or leased.

b. For other areas: separate entities (total population) were subtracted from township or county totals. This resultant figure was then divided by the average household size for the county (from 1970 Census of Housing: General Housing Characteristics[4] [5]). This number was then multiplied by the calculated percentage of the township or county area to be acquired or leased.

4. Average dwelling cost was obtained in two ways:

a. For NIPC areas: Average dwelling cost (for each township) was extrapolated from Factbook[1] figures. An annual increase in values of 10 per cent was calculated for the two years subsequent to the Census figures.

b. For remaining areas: Average dwelling cost (for each county) was taken from 1970 Census of Housing.[4] [5] An annual increase in value of 10 percent was calculated for the two years subsequent to the Census figures.

5. The number of nonresidential (commercial) units were calculated as follows:

a. For NIPC areas: Commercial units in "Places" were subtracted from totals and proportional areas calculated. It was assumed that there were no industrial establishments outside "Place" areas. An average value of $50,000 per unit was assumed.

6. Land values (for each county) were taken from the 1969 Census of Agriculture for Illinois[6] and Indiana[7]. Land values were assumed to increase at 10 percent per year.

7. The average farm size and number of farms in each county were taken from the 1969 Agricultural Census.4/ 5/

8. After total dwelling units were calculated for each county, the number of farms was calculated by dividing the area to be utilized (minus one to two hundred acres for commercial and special uses) by the average farm size in that county. This figure was subtracted from the total. The remainder was considered to be suburban dwellings.

9. A land area of 1/2 acre per suburban dwelling was assumed as being contained in the average dwelling cost figure. This area was subtracted from the total acquisition or lease area.

10. Average costs for dwelling units pertains to both suburban and farm dwellings. Consequently, all dwelling units are calculated. Farm unit value is not assumed to be part of the land value.

11. Average relocation costs of $1,200 per suburban dwelling; $10,000 per farm; and $20,000 per commercial unit were assumed.

Note: No attempt was made to calculate areas for roads or other special uses. The average land value pertains to all land uses.

Presented below is a summary of the land values and relocation costs for the various rural counties investigated as possible land disposal sites for C-SELM land disposal sites for C-SELM wastewaters.

McHenry County

Land plus relocation cost = $2,445/acre
Land value = $1,040/acre

Kendall County

Land plus relocation cost = $1,400/acre
Land value = $ 898/acre

Kankakee County

Land plus relocation cost = $1,550/acre
Land value = $ 870/acre

Newton & Jasper Counties

Land plus relocation cost = $820/acre
Land value = $600/acre

It should be noted that the land cost methodology resulted in land costs of $597/acre for Newton County and $508/acre for Jasper County. However, the Corps felt these costs were low. Therefore, Indiana land values were assumed at $600/acre.

HUMIDITY ANALYSIS

Introduction

The irrigation system associated with land treatment technology has the potential for increasing the ambient humidity in the irrigated rural areas. The additional vapor generated from the irrigation area is dispersed horizontally and vertically into the atmosphere through the turbulent flow caused by the movement of air.

The transformation of water from liquid to gas takes place in three forms, evaporation from soils, transpiration from living plants and the direct evaporation of irrigated or sprayed water. The rate of transformation depends upon the relative humidity, the turbulent diffusivity of the ambient atmosphere and the wind velocity.

This section presents the basic equations of the mathematical model used in this humidity analysis.

Mathematical Model

Two factors control the rate of vapor generation, the available solar energy and turbulent diffusion. The maximum rate of vapor generation is limited by the total amount of solar energy available at the point of interest. The rate of transfer of the vaporized moisture to the air is determined by the water vapor concentration gradient and the strength of the turbulent diffusion field. The basic equations governing the flow are:

$$\frac{\partial C}{\partial t} + \underline{v} \cdot \text{grad } C = D\nabla^2 \underline{v} \qquad (1)$$

$$\rho\left[\frac{\partial \underline{v}}{\partial t} + (\underline{v} \cdot \text{grad})\underline{v}\right] = -\text{grad}\,(P + \rho\phi) + \mu\nabla^2 \underline{v} + \left(\lambda + \frac{1}{3}\mu\right) \text{grad}\,(\text{div}\,\underline{v}) \qquad (2)$$

in which, C = concentration of vapor

$\mathcal{V}$ = velocity vector

p = pressure

Φ = force potential

D = diffusivity

ρ = mass density

λ = second viscosity coefficient

μ = absolute viscosity coefficient

Although the above equation can be solved for certain boundary conditions, an approximate solution using certain assumptions has been obtained for some simplified boundary conditions. Sutton assumed that the plume spreads pollutants according to a Gaussian distribution in the vertical direction and that the standard deviation in the vertical direction is σ_z [8]. The following solution was obtained:

$$C(x,y,z) = \frac{q}{\sqrt{2\pi}\,\sigma_z U}\left\{\exp\left[-\frac{1}{2}\left(\frac{z-H}{\sigma_z}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{z+H}{\sigma_z}\right)^2\right]\right\} \quad (3)$$

in which q = source strength per unit distance

U = wind velocity

H = assumed plume height

The humidity analysis may be greatly simplified if Sutton's result is used. Assuming the irrigation area has an infinite width, that is, the flow is two dimensional, then the distribution of moisture may be evaluated from

$$C(x,z) = \int_0^x q(\xi)\,\eta(\xi, z)\,d\xi \quad (4)$$

in which, η is defined by

$$\eta = \frac{1}{\sqrt{2\pi}\,\sigma_z U}\left\{\exp\left[-\frac{1}{2}\left(\frac{z-H}{\sigma_z}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{z+H}{\sigma_z}\right)^2\right]\right\} \quad (5)$$

and ξ is a dummy variable.

In order to simplify the analysis, the rate of vapor generation is assumed to be constant over the whole irrigation area and can be computed from Rohwer's formula[9].

$$E = \gamma \, 0.771 \, (1.465 - 0.0186B) \, (0.44 + 0.188U) \, (Pw - Pa)$$

in which γ = ratio of the evapotranspiration to lake evaporation

B = barometric pressure in inches of mercury at 32° F

U = mean velocity of the wind in mile per hour

Pw = pressure of saturated vapor at mean temperature of the water surface in inches of mercury

Pa = average vapor pressure in the air in inches of mercury.

Equations 4, 5 and 6 are the basic equations used in the mathematical model.

Analysis Results

The results of the computer analysis are presented in Table BA-VII-B-1. The notations used in the computer output are as follows:

x. Distance from the edge of irrigation area in 1000 ft. units
q. Rate of evapotranspiration in pounds per square foot
y. Elevation of the point of interest from ground level.

Table BA-VII-B1

RESULTS OF HUMIDITY ANALYSIS

MØISI 11:24 CTI THURS. 03/08/73

RELATIVE HUM. = 0.75
WIND VELØCITY = 10.0
TEMPERATURE = 75.00
EVAP. FACTØR = 1.00

X	Θ	Y= 0	Y= 60	Y= 120	Y= 180	Y= 240	Y= 300	Y= 360	Y= 420	Y= 480	Y= 540
0.0	1.29	0.750	0.740	0.733	0.728	0.724	0.720	0.717	0.714	0.712	0.710
2.0	0.52	0.760	0.747	0.735	0.728	0.724	0.720	0.717	0.714	0.712	0.710
4.0	1.24	0.753	0.743	0.735	0.729	0.724	0.720	0.717	0.714	0.712	0.710
6.0	0.51	0.765	0.751	0.739	0.731	0.725	0.721	0.717	0.714	0.712	0.710
8.0	1.21	0.757	0.746	0.738	0.731	0.726	0.721	0.718	0.714	0.712	0.710
10.0	0.50	0.767	0.754	0.741	0.733	0.727	0.722	0.718	0.715	0.712	0.710
12.0	1.20	0.759	0.749	0.740	0.733	0.728	0.722	0.718	0.715	0.713	0.710
14.0	0.50	0.769	0.756	0.743	0.735	0.728	0.723	0.719	0.715	0.713	0.710
16.0	1.19	0.761	0.751	0.742	0.735	0.729	0.724	0.720	0.716	0.713	0.711
18.0	0.49	0.771	0.758	0.745	0.736	0.730	0.724	0.720	0.716	0.713	0.711
20.0	1.18	0.763	0.752	0.744	0.737	0.731	0.725	0.721	0.717	0.714	0.711
22.0	0.49	0.773	0.759	0.747	0.738	0.731	0.726	0.721	0.717	0.714	0.712
24.0	1.17	0.764	0.754	0.745	0.738	0.732	0.726	0.722	0.717	0.715	0.712
26.0	0.49	0.774	0.761	0.748	0.739	0.733	0.727	0.722	0.718	0.715	0.712
28.0	1.16	0.766	0.755	0.746	0.739	0.733	0.727	0.723	0.718	0.715	0.712
30.0	0.48	0.775	0.762	0.749	0.740	0.734	0.728	0.723	0.719	0.716	0.713
32.0	1.16	0.767	0.756	0.748	0.740	0.734	0.728	0.724	0.719	0.716	0.713
34.0	0.48	0.776	0.763	0.750	0.741	0.735	0.729	0.724	0.720	0.716	0.714
36.0	1.15	0.768	0.757	0.749	0.742	0.735	0.729	0.725	0.720	0.717	0.714
38.0	0.48	0.777	0.764	0.751	0.742	0.736	0.730	0.725	0.720	0.717	0.714
40.0	1.15	0.769	0.758	0.750	0.743	0.736	0.730	0.725	0.721	0.718	0.715
42.0	0.48	0.778	0.765	0.752	0.743	0.737	0.731	0.726	0.721	0.718	0.715
44.0	1.14	0.770	0.759	0.751	0.743	0.737	0.731	0.726	0.722	0.718	0.715
46.0	0.47	0.779	0.766	0.753	0.744	0.738	0.732	0.727	0.722	0.719	0.716
48.0	1.14	0.771	0.760	0.752	0.744	0.738	0.732	0.727	0.722	0.719	0.716
50.0	0.47	0.780	0.767	0.754	0.745	0.739	0.732	0.727	0.723	0.719	0.716
52.0	1.13	0.772	0.761	0.752	0.745	0.739	0.733	0.728	0.723	0.720	0.716
54.0	0.47	0.781	0.767	0.755	0.746	0.739	0.733	0.728	0.724	0.720	0.717
56.0	1.13	0.772	0.762	0.753	0.746	0.740	0.734	0.729	0.724	0.720	0.717
58.0	0.47	0.781	0.768	0.756	0.747	0.740	0.734	0.729	0.724	0.721	0.717
60.0	1.13	0.773	0.763	0.754	0.747	0.740	0.734	0.729	0.725	0.721	0.718
62.0	0.47	0.782	0.769	0.756	0.748	0.741	0.735	0.730	0.725	0.721	0.718
64.0	1.12	0.774	0.763	0.755	0.748	0.741	0.735	0.730	0.725	0.722	0.718
66.0	0.47	0.783	0.770	0.757	0.748	0.742	0.735	0.730	0.726	0.722	0.719
68.0	1.12	0.774	0.764	0.755	0.748	0.742	0.736	0.731	0.726	0.722	0.719
70.0	0.46	0.783	0.770	0.758	0.749	0.742	0.736	0.731	0.726	0.723	0.719
72.0	1.12	0.775	0.765	0.756	0.749	0.743	0.736	0.731	0.727	0.723	0.719
74.0	0.46	0.784	0.771	0.759	0.750	0.743	0.737	0.732	0.727	0.723	0.720
76.0	1.11	0.776	0.765	0.757	0.750	0.743	0.737	0.732	0.727	0.724	0.720
78.0	0.46	0.784	0.771	0.759	0.750	0.744	0.737	0.732	0.727	0.724	0.720
80.0	1.11	0.776	0.766	0.757	0.750	0.744	0.738	0.733	0.728	0.724	0.721

Table BA-VII-B-1 (Continued)

RESULTS OF HUMIDITY ANALYSIS

82.0	0.46	0.785	0.772	0.760	0.751	0.744	0.738	0.733	0.728	0.724	0.721
84.0	1.11	0.777	0.766	0.758	0.751	0.744	0.738	0.733	0.728	0.725	0.721
86.0	0.46	0.786	0.773	0.760	0.751	0.745	0.739	0.734	0.729	0.725	0.721
88.0	1.10	0.777	0.767	0.759	0.751	0.745	0.739	0.734	0.729	0.725	0.722
90.0	0.46	0.786	0.773	0.761	0.752	0.745	0.739	0.734	0.729	0.726	0.722
92.0	1.10	0.778	0.768	0.759	0.752	0.746	0.739	0.734	0.729	0.726	0.722
94.0	0.46	0.787	0.774	0.761	0.753	0.746	0.740	0.735	0.730	0.726	0.722
96.0	1.10	0.779	0.768	0.760	0.753	0.746	0.740	0.735	0.730	0.726	0.723
98.0	0.46	0.787	0.774	0.762	0.753	0.747	0.740	0.735	0.730	0.727	0.723
100.0	1.10	0.779	0.769	0.760	0.753	0.747	0.741	0.735	0.731	0.727	0.723
102.0	0.46	0.788	0.775	0.763	0.754	0.747	0.741	0.736	0.731	0.727	0.723
104.0	1.09	0.780	0.769	0.761	0.754	0.747	0.741	0.736	0.731	0.727	0.724
106.0	0.45	0.788	0.775	0.763	0.754	0.748	0.741	0.736	0.731	0.728	0.724
108.0	1.09	0.780	0.770	0.761	0.754	0.748	0.742	0.737	0.732	0.728	0.724
110.0	0.45	0.789	0.776	0.764	0.755	0.748	0.742	0.737	0.732	0.728	0.724
112.0	1.09	0.780	0.770	0.762	0.755	0.748	0.742	0.737	0.732	0.728	0.725
114.0	0.45	0.789	0.776	0.764	0.755	0.749	0.742	0.737	0.732	0.729	0.725
116.0	1.09	0.781	0.771	0.762	0.755	0.749	0.743	0.738	0.733	0.729	0.725
118.0	0.45	0.789	0.777	0.764	0.756	0.749	0.743	0.738	0.733	0.729	0.725
120.0	1.08	0.781	0.771	0.763	0.756	0.749	0.743	0.738	0.733	0.729	0.726
122.0	0.45	0.790	0.777	0.765	0.756	0.750	0.743	0.738	0.733	0.729	0.726
124.0	1.08	0.782	0.771	0.763	0.756	0.750	0.744	0.738	0.734	0.730	0.726
126.0	0.45	0.790	0.777	0.765	0.757	0.750	0.744	0.739	0.734	0.730	0.726
128.0	1.08	0.782	0.772	0.764	0.757	0.750	0.744	0.739	0.734	0.730	0.726
130.0	0.45	0.791	0.778	0.766	0.757	0.750	0.744	0.739	0.734	0.730	0.727
132.0	1.08	0.783	0.772	0.764	0.757	0.751	0.744	0.739	0.734	0.731	0.727
134.0	0.45	0.791	0.778	0.766	0.758	0.751	0.745	0.740	0.735	0.731	0.727
136.0	1.08	0.783	0.773	0.764	0.757	0.751	0.745	0.740	0.735	0.731	0.727
138.0	0.45	0.791	0.779	0.767	0.758	0.751	0.745	0.740	0.735	0.731	0.728
140.0	1.07	0.784	0.773	0.765	0.758	0.752	0.745	0.740	0.735	0.731	0.728
142.0	0.45	0.792	0.779	0.767	0.758	0.752	0.746	0.740	0.736	0.732	0.728
144.0	1.07	0.784	0.774	0.765	0.758	0.752	0.746	0.741	0.736	0.732	0.728
146.0	0.45	0.792	0.779	0.767	0.759	0.752	0.746	0.741	0.736	0.732	0.728
148.0	1.07	0.784	0.774	0.766	0.759	0.752	0.746	0.741	0.736	0.732	0.729
150.0	0.44	0.793	0.780	0.768	0.759	0.753	0.746	0.741	0.736	0.733	0.729
152.0	1.07	0.785	0.774	0.766	0.759	0.753	0.747	0.742	0.737	0.733	0.729
154.0	0.44	0.793	0.780	0.768	0.760	0.753	0.747	0.742	0.737	0.733	0.729
156.0	1.07	0.785	0.775	0.766	0.759	0.753	0.747	0.742	0.737	0.733	0.729
158.0	0.44	0.793	0.781	0.769	0.760	0.753	0.747	0.742	0.737	0.733	0.730
160.0	1.06	0.785	0.775	0.767	0.760	0.754	0.747	0.742	0.737	0.734	0.730
162.0	0.44	0.794	0.781	0.769	0.760	0.754	0.748	0.743	0.738	0.734	0.730
164.0	1.06	0.786	0.775	0.767	0.760	0.754	0.748	0.743	0.738	0.734	0.730
166.0	0.44	0.794	0.781	0.769	0.761	0.754	0.748	0.743	0.738	0.734	0.730
168.0	1.06	0.786	0.776	0.768	0.761	0.754	0.748	0.743	0.738	0.734	0.731
170.0	0.44	0.794	0.782	0.770	0.761	0.755	0.748	0.743	0.738	0.734	0.731
172.0	1.06	0.786	0.776	0.768	0.761	0.755	0.749	0.743	0.739	0.735	0.731
174.0	0.44	0.795	0.782	0.770	0.761	0.755	0.749	0.744	0.739	0.735	0.731
176.0	1.06	0.787	0.776	0.768	0.761	0.755	0.749	0.744	0.739	0.735	0.731
178.0	0.44	0.795	0.782	0.770	0.762	0.755	0.749	0.744	0.739	0.735	0.731
180.0	1.06	0.787	0.777	0.769	0.762	0.755	0.749	0.744	0.739	0.735	0.732
182.0	0.44	0.795	0.783	0.771	0.762	0.756	0.749	0.744	0.739	0.736	0.732
184.0	1.05	0.787	0.777	0.769	0.762	0.756	0.750	0.745	0.740	0.736	0.732
186.0	0.44	0.796	0.783	0.771	0.763	0.756	0.750	0.745	0.740	0.736	0.732
188.0	1.05	0.788	0.777	0.769	0.762	0.756	0.750	0.745	0.740	0.736	0.732
190.0	0.44	0.796	0.783	0.771	0.763	0.756	0.750	0.745	0.740	0.736	0.733
192.0	1.05	0.788	0.778	0.770	0.763	0.757	0.750	0.745	0.740	0.736	0.733
194.0	0.44	0.796	0.784	0.772	0.763	0.757	0.751	0.745	0.741	0.737	0.733
196.0	1.05	0.788	0.778	0.770	0.763	0.757	0.751	0.746	0.741	0.737	0.733
198.0	0.44	0.797	0.784	0.772	0.764	0.757	0.751	0.746	0.741	0.737	0.733

Table BA-VII-B-1 (Continued)

RESULTS OF HUMIDITY ANALYSIS

200.0	1.05	0.789	0.778	0.770	0.763	0.757	0.751	0.746	0.741	0.737	0.733
202.0	0.44	0.797	0.784	0.772	0.764	0.757	0.751	0.746	0.741	0.737	0.734
204.0	1.05	0.789	0.779	0.771	0.764	0.758	0.751	0.746	0.741	0.738	0.734
206.0	0.43	0.797	0.784	0.773	0.764	0.758	0.752	0.747	0.742	0.738	0.734
208.0	1.05	0.789	0.779	0.771	0.764	0.758	0.752	0.747	0.742	0.738	0.734
210.0	0.43	0.797	0.785	0.773	0.765	0.758	0.752	0.747	0.742	0.738	0.734
212.0	1.04	0.790	0.779	0.771	0.764	0.758	0.752	0.747	0.742	0.738	0.734
214.0	0.43	0.798	0.785	0.773	0.765	0.758	0.752	0.747	0.742	0.738	0.735
216.0	1.04	0.790	0.780	0.772	0.765	0.759	0.752	0.747	0.742	0.738	0.735
218.0	0.43	0.798	0.785	0.774	0.765	0.759	0.753	0.747	0.743	0.739	0.735
220.0	1.04	0.790	0.780	0.772	0.765	0.759	0.753	0.748	0.743	0.739	0.735
222.0	0.43	0.798	0.786	0.774	0.765	0.759	0.753	0.748	0.743	0.739	0.735
224.0	1.04	0.790	0.780	0.772	0.765	0.759	0.753	0.748	0.743	0.739	0.735
226.0	0.43	0.799	0.786	0.774	0.766	0.759	0.753	0.748	0.743	0.739	0.735
228.0	1.04	0.791	0.781	0.772	0.766	0.759	0.753	0.748	0.743	0.739	0.736
230.0	0.43	0.799	0.786	0.775	0.766	0.760	0.753	0.748	0.743	0.740	0.736
232.0	1.04	0.791	0.781	0.773	0.766	0.760	0.754	0.749	0.744	0.740	0.736
234.0	0.43	0.799	0.786	0.775	0.766	0.760	0.754	0.749	0.744	0.740	0.736
236.0	1.04	0.791	0.781	0.773	0.766	0.760	0.754	0.749	0.744	0.740	0.736
238.0	0.43	0.799	0.787	0.775	0.767	0.760	0.754	0.749	0.744	0.740	0.736
240.0	1.03	0.792	0.781	0.773	0.766	0.760	0.754	0.749	0.744	0.740	0.737
242.0	0.43	0.800	0.787	0.775	0.767	0.761	0.754	0.749	0.744	0.741	0.737
244.0	1.03	0.792	0.782	0.774	0.767	0.761	0.755	0.749	0.745	0.741	0.737
246.0	0.43	0.800	0.787	0.776	0.767	0.761	0.755	0.750	0.745	0.741	0.737
248.0	1.03	0.792	0.782	0.774	0.767	0.761	0.755	0.750	0.745	0.741	0.737
250.0	0.43	0.800	0.788	0.776	0.768	0.761	0.755	0.750	0.745	0.741	0.737
252.0	1.03	0.792	0.782	0.774	0.767	0.761	0.755	0.750	0.745	0.741	0.737
254.0	0.43	0.800	0.788	0.776	0.768	0.761	0.755	0.750	0.745	0.741	0.738
256.0	1.03	0.793	0.782	0.774	0.768	0.761	0.755	0.750	0.745	0.742	0.738
258.0	0.43	0.801	0.788	0.776	0.768	0.762	0.756	0.751	0.746	0.742	0.738
260.0	1.03	0.793	0.783	0.775	0.768	0.762	0.756	0.751	0.746	0.742	0.738
262.0	0.43	0.801	0.788	0.777	0.768	0.762	0.756	0.751	0.746	0.742	0.738
264.0	1.03	0.793	0.783	0.775	0.768	0.762	0.756	0.751	0.746	0.742	0.738
266.0	0.43	0.801	0.789	0.777	0.769	0.762	0.756	0.751	0.746	0.742	0.738
268.0	1.02	0.793	0.783	0.775	0.768	0.762	0.756	0.751	0.746	0.742	0.739
270.0	0.43	0.801	0.789	0.777	0.769	0.762	0.756	0.751	0.746	0.743	0.739
272.0	1.02	0.794	0.783	0.775	0.769	0.763	0.757	0.752	0.747	0.743	0.739
274.0	0.43	0.802	0.789	0.777	0.769	0.763	0.757	0.752	0.747	0.743	0.739
276.0	1.02	0.794	0.784	0.776	0.769	0.763	0.757	0.752	0.747	0.743	0.739
278.0	0.42	0.802	0.789	0.778	0.769	0.763	0.757	0.752	0.747	0.743	0.739
280.0	1.02	0.794	0.784	0.776	0.769	0.763	0.757	0.752	0.747	0.743	0.739
282.0	0.42	0.802	0.790	0.778	0.770	0.763	0.757	0.752	0.747	0.743	0.740
284.0	1.02	0.794	0.784	0.776	0.769	0.763	0.757	0.752	0.747	0.744	0.740
286.0	0.42	0.802	0.790	0.778	0.770	0.764	0.757	0.752	0.748	0.744	0.740
288.0	1.02	0.795	0.784	0.776	0.770	0.764	0.758	0.753	0.748	0.744	0.740
290.0	0.42	0.802	0.790	0.778	0.770	0.764	0.758	0.753	0.748	0.744	0.740
292.0	1.00	0.795	0.785	0.777	0.770	0.764	0.758	0.753	0.748	0.744	0.740
294.0	0.42	0.803	0.790	0.779	0.770	0.764	0.758	0.753	0.748	0.744	0.740
296.0	1.02	0.795	0.785	0.777	0.770	0.764	0.758	0.753	0.748	0.744	0.740
298.0	0.42	0.803	0.790	0.779	0.771	0.764	0.758	0.753	0.748	0.744	0.741

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