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A Computer Model to Determine Location of Stormwater Management Practices

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A COMPUTER MODEL TO DETERMINE
LOCATION OF STORMWATER MANAGEMENT PRACTICES

BY

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THESIS

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ABSTRACT

To optimize the placement of stormwater management systems, a Radio Shack BASIC computer program "SELECT" was written. The program selects locations for berms, detention ponds, retention ponds, and underground percolation tanks based upon minimum marginal cost (total present value cost per pound of nutrient removed annually). Either nitrogen or phosphorus can be chosen as the selected nutrient. The selections occur until the desired percentage removal is obtained. Five output tables show the results of the selection process.

The computer model was used to evaluate stormwater management locations for the Lake Tohopekaliga watershed in Florida. Input data consisting of soil types, land costs, and construction costs were obtained. "SELECT" was run to determine stormwater management locations for different nitrogen and phosphorus percentage removals. Sensitivity analyses upon land costs, nutrient loading, and removal efficiencies for the 45 percent removal cases of nitrogen and phosphorus were evaluated.

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CHAPTER I

INTRODUCTION

Lake eutrophication is one of the most significant water pollu-
tion problems today (Clark et al. 1977). The word "eutrophication"
comes from the Greek word "eutrophos" meaning well nourished (Chan-
lett 1973). A well nourished lake condition comes from excessive
nutrients, mostly nitrogen and phosphorus. The increased input of
nitrogen and phosphorus is the by-product of increasing population,
industrial development, and agriculture in the lake's watershed
(Clark et al. 1977).

A nutrient increase into receiving water bodies can produce ex-
cessive growths of algae and aquatic plants. Should blue-green al-
gae populate a lake, problems with drinking water supplies may de-
velop. Taste and odor problems, reduced transparency, and an odor-
ous scum can result from blue-green algae (Clark et al. 1977).

A plant production increase will decrease dissolved oxygen
content because of accompanying plant decomposition. Fish that
have high food value have a difficult time surviving in this un-
favorable environment. Clearly, eutrophication is an unfavorable
environmental condition.

To slow eutrophication, the preferred technique is to limit
the most critical component in aquatic plant growth. Major plant
nutrients include orthophosphate, inorganic nitrogen (as nitrate

and ammonia), and carbon dioxide. Trace elements include iron, silica, and organic compounds such as vitamins. In most lakes, nitrogen or phosphorus is the limiting factor, the others being relatively more abundant. In addition, phosphorus is considered the limiting nutrient, since some algal species can fix atmospheric nitrogen. Therefore, most efforts to stop eutrophication involve the reduction of phosphorus into receiving water bodies (Clark et al. 1977).

One of the major ways to stop nutrients from entering receiving water bodies is to treat stormwater runoff. The removal of nutrients is obtained by diverting stormwater runoff into treatment ponds or bermed areas where the nutrients will be taken up by plant growth at the site. For a large watershed, many differently sized treatment ponds would be needed to handle stormwater runoff. All possible locations within the watershed would need to be considered also. These requirements can be met by a computer generated solution. Also, input data for a computer program are not always well known. Thus, sensitivity analyses on key input parameters would be beneficial in establishing the accuracy for measuring these data and their variability to maintain a selected minimum cost solution. Future changes in the data on land use and treatment options can be incorporated.

A computer can be programmed to handle the calculations required to make a decision on stormwater treatment pond locations. In selecting location, it can also be instructed to pick the most economical locations based upon cost. In this manner, the most

cost effective approach in reducing lake eutrophication with the use of stormwater management techniques can be accomplished.

CHAPTER II

OBJECTIVES

The main objective of this project is to develop a procedure for the selection of stormwater management practices which are most cost effective for pollution control. A computer program was developed to aid in the selection of the least-cost alternatives. The program is interactive and designed to run on a Radio Shack computer. The location selection procedure is based upon lowest marginal cost. Stormwater management practices studied consisted of berms, detention ponds, underground percolation tanks, retention ponds, and stream fencing.

A second objective is to use the computer model to evaluate stormwater management locations for nutrient reductions into Lake Tohopekaliga. For the watershed, cost estimates are determined for different percentages of nutrient removal. Additionally, a sensitivity analysis of key parameters will be performed upon one of the solution sets.

In the sensitivity analysis, land cost, loading and removal efficiency are varied until the solution set is changed. In this manner, observations about the effect of changes in data related to land cost, loading, and nutrient removal efficiencies can be made.

CHAPTER III

PREVIOUS STORMWATER MANAGEMENT STUDIES

The quantity of information on stormwater runoff pollution impacts is not very extensive. Also, information on stormwater management practices and their efficiency is scarce. Often, the previous research on stormwater runoff and pollution effects is in disagreement. A literature search illustrates the differences in professional opinion, or use of specific indicators for pollution.

Benefits of Stormwater Management

Different opinions regarding the benefits of stormwater management practices exist. Graham (1978) states that lakes and floodplain zones will have water quality improvement through the use of impoundments for stormwater drainage. Conversely, Freedman (1980), through the use of a mathematical model, did not recommend a control program for combined sewer overflows, which would include stormwater. The model evaluated disinfection and removal of objectionable solids. Significant improvements in water quality were not predicted for Onondaga Lake in New York. Wycoff (1980) evaluated data at Chester, Pennsylvania using CSPSS (continuous stormwater pollution simulation system) to conclude the greatest improvement in water quality results from wastewater treatment plant control. Stormwater runoff control was not as cost effective when considering DO

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values in receiving water. Johnson (1979) states that sewage treat-
ment is the least costly means of reducing phosphorus loading in
central New York state. In second place is the control of barnyard
runoff.

Computer Models

To further explore the question of stormwater runoff impact,
computer programs have been written and used. Hopkinson (1980)
utilized the EPA Stormwater Management Model to evaluate the effects
of runoff from uplands bordering a swamp in Louisiana. The effect
of changing land pattern was examined. Urbanization was shown to
increase stormwater flow rates up to 400% in a 20-year period.
Likewise, nutrient runoff will increase by 28 percent for nitrogen
and 16 percent for phosphorus. Characklis (1979) modified SWMM
to allow for: (1) separate sewer systems, (2) effect of urbaniza-
tion of base flows, and (3) performance efficiency and cost effec-
tiveness of natural drainage systems. Smith (1980), of Metcalf
and Eddy, utilized a simplified mathematical model for stormwater
runoff plans in San Francisco Bay region. Urban runoff was empha-
sizes in his model.

Loading Rates

Regarding loading and runoff values due to stormwater, varia-
bility in data reported is evident. Polls (1980) sampled storm-
water runoff in northeastern Illinois. He collected data from
sixteen different land uses and concluded that the mean runoff

concentrations of most constituents did not vary significantly.

The data did show commercial land use to have the highest pollutant

concentrations and forest the lowest. For soluble nitrate-N and

soluble phosphorus, the mean concentrations are less than secondary

effluent for wastewater. Mattraw (1977) evaluated the runoff in a

single family residential neighborhood in Broward County, Florida.

During 231 rainfall periods, approximately 5 to 10 percent of the

rainfall became runoff. Because of large pervious areas, gentle

slopes, and grassy swales, loading values for this residential area

were low. Estimated annual loads were 1.30 lb/acre for total nitro-

gen and 0.18 lb/acre for total phosphorus. Coote (1979) presented

ranges and median loading values for agricultural land in Ontario,

Canada. The median values were 0.70 lb/acre year for total phos-

phorus and 15.2 lb/acre year for total nitrogen. Ostry (1982) also

reported loading data for Ontario. For the Grand River and Sawgeen

Rivers in Ontario, he calculated mean unit area total phosphorus

loads of 1.25, 0.80, 0.07 lb/acre-year and mean unit area total

nitrogen loads of 7.57, 10.40, 4.63 lb/acre-year for urban, rural

and wooded/idle land uses, respectively.

Wanielista (1979) collected runoff data from the Lake Eola

watershed in Orlando, Florida. Results are summarized in Table 1.

Tied into the loading values is the first flush effect. Sim-

ply defined, it is the concept that the initial samples of storm-

water runoff will contain a higher concentration of pollutants than

later samples. Once again, a difference in judgement exists.

Browman (1979) monitored urban runoff of phosphorus from storm

sewer systems draining residential areas of Madison, Wisconsin. He

concluded a significant proportion of phosphorus enters a lake due

to first flush after a long dry period. Ford (1979) collected sam-

ples of stormwater runoff and noted that antecedent dry periods

affected pollutant loading. Highest concentrations occurred from

15 minutes to 2 hours after runoff began. On the other hand,

Whipple (1977) reported that urban runoff did not show a relation-

ship between loading and antecedent dry periods for ten small storms.

His interest was primarily the metals lead, zinc and copper, but

phosphorus was also monitored.

TABLE 1

CONCENTRATION AND LOADING RATE RUNOFF SUMMARY
(Hydrograph Related and Composite Sampling Programs)

Parameter	Sample Size (storms)	Average Loadings* (kg/ha-yr)
Suspended Solids	14	991
Volatile Suspended	7	538
NVSS	7	453
BOD_5	8	98
COD	6	711
TOC	13	946
TKN	10	27.8
Ammonia-N	12	4.1
Total Phosphorus	14	4.8
Zinc	9	3.7
Cadmium	9	0.28
Nickel	9	0.28
Copper	9	0.68
Magnesium	8	9.86
Iron	9	9.52
Lead	9	4.26
Chromium	9	0.25
Calcium	9	308

* both commercial and residential

Treatment Efficiencies

Another area of examination is the removal efficiency of storm-water detention ponds. Data in this area is limited. Wanielista (1979) reports on removal efficiencies for many control technologies in his text. In addition, three other studies have been reviewed. Chambers (1980) presented an evaluation of stormwater impoundments in Winnipeg, Manitoba. During the summers of 1976 and 1977, two stormwater impoundments were monitored for suspended solids and BOD_5 removal. The Southdale facility in Winnipeg had average reductions of 94% for suspended solids and 75% for BOD_5. The corresponding values for the Fort Richmond facility in Winnipeg were 85% and 30%. At Southdale, the pond area represented 9% of the service area, while at Fort Richmond 3%. The American Public Works Association (1981) published some preliminary information from the U.S. EPA National Urban Runoff Program at East Lansing, Michigan. For total phosphorus and total Kjeldahl nitrogen the average removal efficiencies were 58% and 31%, respectively. The data also showed greater than 50% nutrient removal in the ponds 8 of 14 times for phosphorus and 7 of 14 times for TKN. Wanielista (1979) conducted studies on the use of berms as a method of reduction of nutrients. His studies showed berms to reduce nitrogen by 60% to 80%, depending upon pond size available to handle the diverted flow. For phosphorus, the values are 80% and 90%, respectively. Baldwin (1977) indicates similar results.

In writing the computer program, a decision had to be made about which data to use. It was decided to use Wanielista's (1979) text for pond sizing, nutrient removal efficiencies and costs. These data were incorporated into the computer program.

Grassy land barriers with fencing also can be used to avoid stream degradation (Draper et al. 1979). The concept is to use grass barriers to treat runoff as it approaches the stream and fencing to keep animals out of the stream. Fencing operations would involve purchase of land since this property would be taken out of production. In addition, fencing would need to be installed, inspected and maintained.

Fencing concept was not placed in the computer program as a management method. However, it was not ignored as a possible option. For the Lake Tohopekaliga analysis, an example of fencing strategy is listed in Appendix C. Draper (1979) suggests removal efficiencies of 85% for barriers of 100 to 400 feet in width, based upon experimental studies of phosphorus removal.

CHAPTER IV

MODELING CONCEPTS

The Computer Program - "SELECT"

To minimize construction funding for the project, a computer
program was written to determine the location of the stormwater prac-
tices based upon the minimum expenditure of dollars per pound of
nutrient removed. The computer program selects the regions of con-
struction of stormwater facilities for a desired percentage of pol-
lutant removal.

The program will provide the user with a minimum cost solution
for the removal of a nutrient (nitrogen or phosphorus) for a selected
percentage (from 0 to 100%). The interactive computer program will
prompt the user for input, then proceed to tabulate the solution and
print the results of the computations. The required input consists
of (1) selecting the nutrient for removal, (2) selecting a removal
percentage, (3) a code number representing land use, (4) the curve
number for that land use, (5) the number of acres involved, and (6)
the cost of land ($/acre) for the given land use. The results con-
sist of five tables. Table 2 is a listing of the input values.
Table 3 contains a listing of the marginal costs (in $/lb nutrient
removed) for all entries. The dollars are expressed in present va-
lue terms and the pounds are average annual values. Table 4 prints

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TABLE 2

INPUT VALUES

Entry Number	Land Use	Soil Type	Curve Number	Number of Acres	Land Cost ($/acre)
1	Commercial	A	80	293.2	7,000
2	Commercial	A	80	306	3,500
3	Commercial	A	80	913.3	10,000
4	Commercial	D	75	1,530	3,500
5	Commercial	D	95	3,570	11,500
6	Residential	A	65	9,792	11,500
7	Residential	A	65	1,435.4	5,000
8	Residential	A	65	1,492.9	7,000
9	Residential	A	65	1,868.1	3,000
10	Residential	D	85	758.1	4,500
11	Residential	D	85	49.9	4,000
12	Citrus	A	55	5,444.8	0
13	Rangeland	D	75	42,276.6	0
14	Rangeland	A	55	1,734	0
15	Flatwoods	D	70	8,348.7	3,000
16	Flatwoods	D	70	7.752.5	2,000
17	Flatwoods	D	70	7,140	3,500
18	Pasture	A	55	8,468.8	0
19	Pasture	D	75	14,931.9	0

Desired Percent Removal = 45   Selected Pollutant is Phosphorus

SOURCES: Soil Conservation Service, 1960, 1975 and 1979.

TABLE 3

MARGINAL COST TABLE

Marginal Cost (in $/lb removed)
Structure Diversion Depth

Entry	.25 inch	.50 inch	.75 inch	1.00 inch
1	108	276	369	433
2	158	232	309	363
3	214	314	420	493
4	420	646	815	993
5	305	931	1175	1432
6	320	469	627	736
7	241	353	471	553
8	265	388	519	609
9	216	317	423	497
10	607	937	1184	1445
11	591	912	1153	1407
12	1387	2027	2706	3175
13	461	462	732	733
14	272	273	460	461
15	7907	12233	15523	18979
16	7417	11472	14557	17798
17	8152	12613	16005	19570
18	22	23	37	38
19	37	38	60	61

TABLE 4

MINIMUM COST SOLUTION BASED
UPON PHOSPHORUS

Land Use	Soil Type	Curve Number	Number of Acres	Land Cost ($/ac)	Marginal Cost ($/lb)
Pasture	A	55	8,468.8	0	38
Pasture	D	75	14,931.9	0	61
Residential	A	65	1,435.4	5,000	241
Residential	A	65	1,492.9	7,000	265
Rangeland	A	55	1,734	0	273
Commercial	A	80	293.2	7,000	276
Commercial	A	80	306	3,500	309
Commercial	A	80	913.3	10,000	314
Residential	A	65	1,868.1	3,000	317
Residential	A	65	9,792	11,500	320

those land uses which are in the solution set. Table 5 is a summary of nutrient loadings and associated removal values for each entry. Table 6 contains the cost of the stormwater practice consisting of land cost, construction cost, and operation, repair and maintenance costs.

The computer program arrives at a solution in a straight forward technique. The program utilizes the input data to calculate pond size required for 250 acres of each land use in the input data. Pond and berm sizes correspond to pond volumes required to divert either 0.25, 0.50, 0.75 or 1.00 inch of runoff. In addition, percentages of nutrient removals are specified within the program at each diversion volume. Total yearly loading of nutrients is based upon an average loading factor, one for each land use. The program can then calculate the nutrient loading removed from a receiving water body by multiplying the pond removal efficiency times the average loading factor for the land use in the subwatershed in which the pond is located. All possible pond sizes are calculated for each combination of land use and diversion volume.

Each pond size has an associated marginal cost. The program calculates a total present value cost based upon land cost, construction cost, and present value cost of operation and maintenance. Once the total present value cost is obtained, the value is divided by the annual ammount of nutrients removed for that pond size. The marginal cost value is the result.

TABLE 5

POLLUTANT LOADING AND REMOVAL VALUES

Entry	Pollutant Loading		Removal of:		
	Nitrogen (lbs/yr)	Phosphorus (lbs/yr)	Nitrogen (lbs/yr)	Phosphorus (lbs/yr)	Water (%)
1	3,528	703	3,176	633	50
2	3,683	734	3,427	681	60
3	10,991	2,190	9,892	1,973	50
4	18,413	3,668	0	0	0
5	42,963	8,559	0	0	0
6	57,577	15,652	1,374	373	45
7	8,440	2,294	6,752	1,835	45
8	8,778	2,386	7,024	1,909	45
9	10,984	2,986	9,886	2,690	67
10	4,453	1,212	0	0	0
11	293	80	0	0	0
12	21,344	967	0	0	0
13	82,862	3,754	0	0	0
14	3,399	154	2,039	123	0
15	16,363	741	0	0	0
16	15,195	688	0	0	0
17	13,994	634	0	0	0
18	54,278	9,024	43,423	8,130	0
19	97,702	15,911	76,561	14,335	0
Totals	473,245	72,338	163,552	32,683	3

Percentage Pollutant Removal = 45.2

TABLE 6

COST TABLE - IN THOUSANDS OF DOLLARS

Entry	Land Use	Land Cost	Construction Cost	ORM Cost	Total
1	Commercial	45	82	15	142
2	Commercial	32	118	22	172
3	Commercial	201	255	47	503
6	Residential	42	46	9	97
7	Residential	89	227	42	358
8	Residential	130	236	44	410
9	Residential	116	409	90	695
14	Rangeland	0	14	15	28
18	Pasture	0	169	118	287
19	Pasture	0	299	532	831
Totals		656	1936	933	3524
Engineering and Legal=					881
Total Expense =					4405

Once all marginal cost values are known, a logic sequence is started to find the combination of lowest marginal costs which satisfy the requirement of total amount of nutrient removed. The sequence involves finding the lowest marginal cost, adding its nutrient removal value to a running total, and comparing the total to the desired removed nutrient value. When the desired value is obtained, the program prints the output tables. Documentation of the program is presented in Appendix A and a flow chart appears in Appendix B.

Management Methods

The most useful management methods from a pollution reduction viewpoint were established. These are shown in Table 7.

TABLE 7

STORMWATER METHODS

Land Use	Method	Land Use	Method
Residential & Commercial	Retention or Detention/Filter	Dairy & Crop land	Field Retention with reuse
Pasture & Rangeland	Berm with bank infiltration	Citrus & Swamp	Retention or impoundment

Berms in pasture lands are constructed with perforated piping in the banks. These pipes remove water from behind the berms, thus reducing the standing water and enhancing crop growth behind the berm. Thus, land cost is not a factor as a cost selection criteria. A graphic sketch of the berm is shown in Figure 1. A

LEGEND

– – – – WATERSHED BOUNDARIES

· · · · · · · · CONSTRUCTION CONTOURS

———— EXISTING CONTURES

SPECIFICATIONS

4 STRAND BARB WIRE FENCE
AROUND BAHIA / BERMUDA MIX
LIME OF BERM AREA
PANGOLA / CLOVER IN GRAZING AREA

GRAZING AREA

75

70

67

73

BERM

70

65

LAKE

ALONG BORROW AREA
CANE / CATAILS   PANGOLA / CLOVER COVER

70 —

69 —

SECTION A-A   CROSS-SECTION OF GRAZING / WATER CONTROL AREA.

VARIABLE
MIN. 5'

1
5

GRAVEL

FILTER FABRIC

1
5

MINIMUM 1'-6'   PERFORATED PIPE

EXCAVATED AREA   ORIGINAL GROUND LEVEL

SECTION B-B   CROSS-SECTION OF BERM

Fig. 1.   Berms in pasture lands.

structural design for retention in ground level ponds is shown in
Figure 2. These ponds require land for the purpose of stormwater
control, thus land cost is included in the analysis. When land cost
is very high and water tables are low, underground percolation sys-
tems are used. In areas where the water table is high and percola-
tion rates are low, detention systems with effluent filtration are
useful. The retention and detention system designs are shown in
Figures 2 through 4. Each of these methods have a removal effec-
tiveness which are assumed and then varied in the sensitivity analy-
sis.
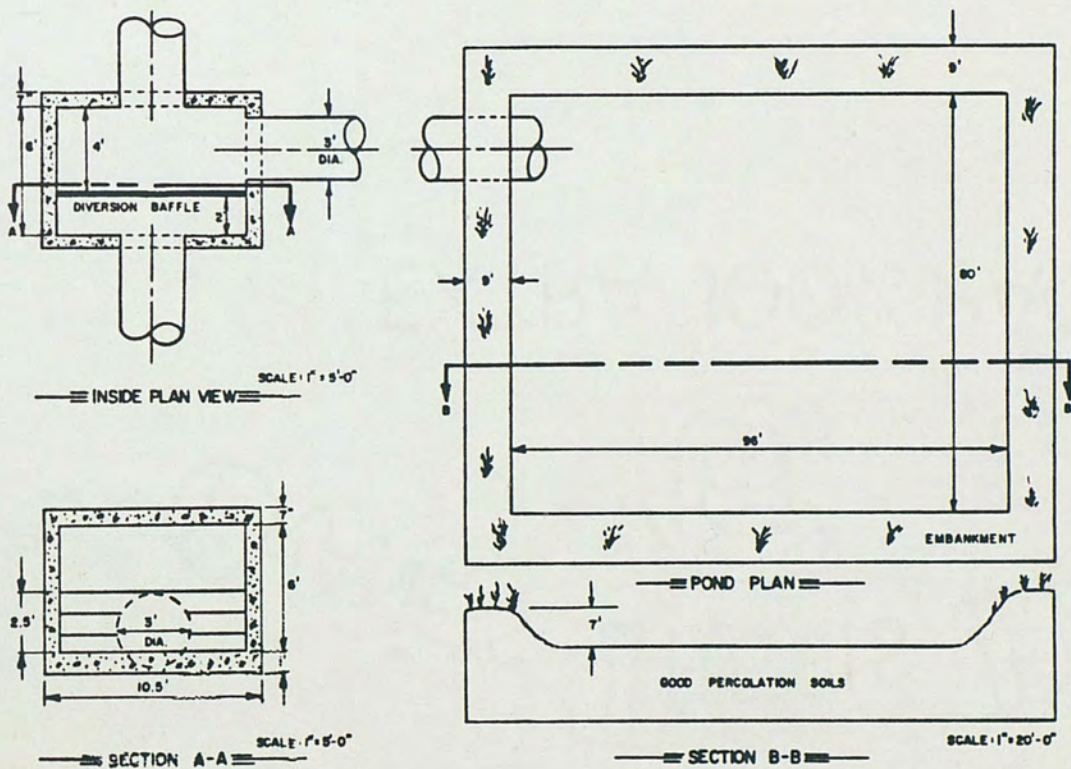
Fig. 2. Diversion structure/percolation pond.
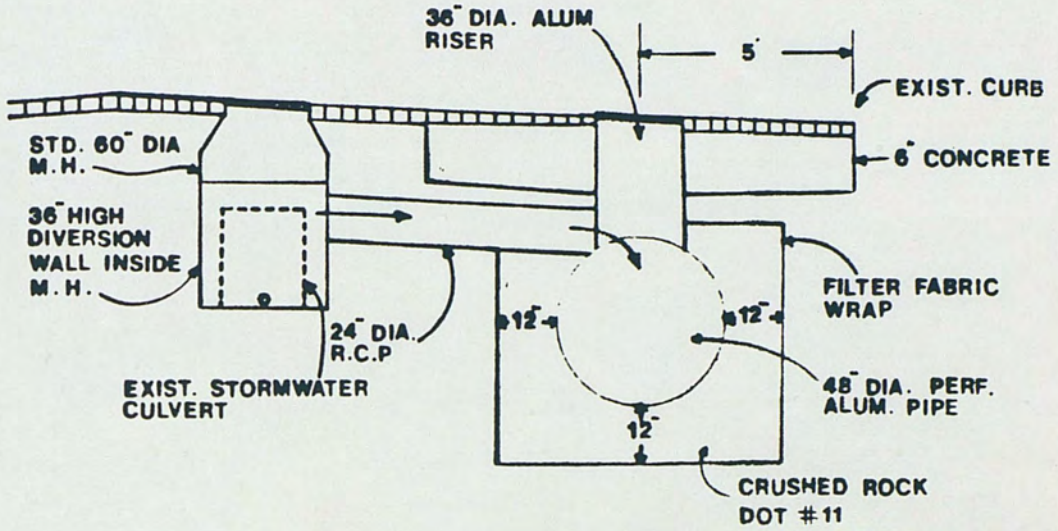
Fig. 3. Underground percolation system section.
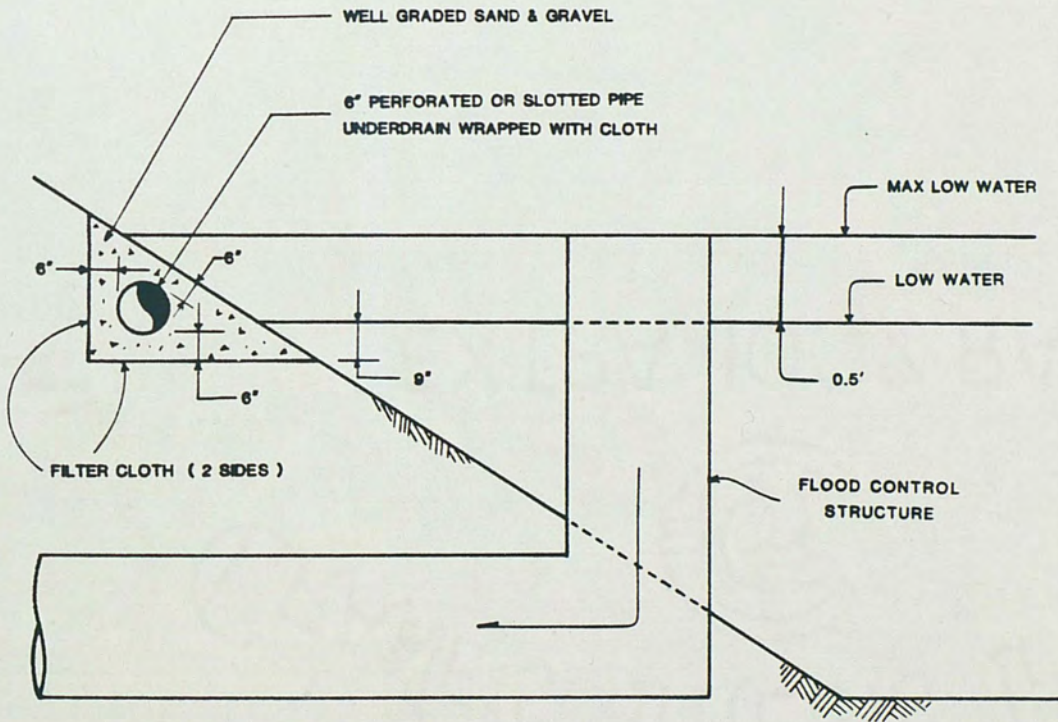
Fig. 4. Detention/effluent filtration (on top of lake).

Costs

Cost data from similar stormwater management bid sheets were used to estimate construction costs. Annual operation replacement and maintenance costs were estimated from city and county records. All were discounted to a present value using a 20-year planning horizon and an interest rate of 10%. Land costs were estimated for those areas in which the management method would only be used for stormwater, that is, residential, commercial, dairy and crop land. For pasture, citrus and woodland areas, the management methods are expected to enhance crop growths and, thus, land costs are not included.

Construction costs are different for retention ponds and berms. For retention ponds, construction costs were determined to be $12,700 per acre of pond at five foot depths. For berms, construction costs were estimated at $8 per contributing acre at 0.50 inch diversion depth and $20 per contributing acre at 1.00 inch diversion depth. Also, fixed annual ORM costs are different for urban and rural areas. Those values are $275 per contributing acre for urban areas and $50 per contributing acre for rural areas. A summary of those costs is presented in Table 8.

Whenever SELECT is utilized, three additional concepts are required. These concepts within the program are pond size, percentage removal for nitrogen and phosphorus, and water removed by diversion stormwater practices. Previous research (Wanielista 1979) was utilized to provide the values.

TABLE 8

SUMMARY OF COSTS

Cost	Value
Construction	
Detention and Retention pond	$12,700 per acre of pond
Berm	$8/contributing acre at 0.50 inch or $20/contributing acre at 1.00 inch
ORM (20 yr, 10%)	
Urban	$275/contributing acre-year
Rural	$50/contributing acre-year

The first concept, pond size, is important since it requires
funds to purchase land and construct the pond. Pond size is a
function of soil type, curve number, and diversion depth for the
land use under consideration. Equations have been developed and
written into SELECT to calculate pond size based upon the above
parameters. Factors which result in larger ponds are "D" type soils,
higher curve numbers, and higher runoff diversion depth. Table 9
summarizes the reasons for larger ponds.

TABLE 9

POND SIZE FACTORS

Parameter	Comment
"D" Type Soil	Larger pond due to higher water table and less deep pond
Higher Curve Number	More rainfall runoff
Runoff Diversion Depth	Deeper pond, larger pond

The second concept is the percent removal of phosphorus, nitrogen and water for each diversion depth. The computer program utilizes berms for rangeland and pasture regions and detention ponds for the remaining land uses. Berms have values for only two treatment volumes, 0.5 inch and 1.0 inch. Table 10 lists the values utilized in the program for pollutant removal.

TABLE 10

PERCENT POLLUTANT REMOVED

Land Use/Parameter		Diversion (Treatment) Volume			
		.25 inch	.50 inch	.75 inch	1.00 inch
Pasture } Rangeland	Nitrogen	--	60	--	80
	Phosphorus	--	80	--	90
Commercial Residential Citrus Swamp Flatwoods	Nitrogen	80	90	93	95
	Phosphorus	80	90	93	95

The third concept, water removed, is a relationship among retention treatment depth, runoff values, and storm frequency and intensity. "SELECT" used storms recorded at the Orlando jetport to yield the number of storms and intensity, then calculates runoff from those storms on regions with curve numbers 65, 75, 85 and 95. The procedure is similar to that used by Wanielista (1979). The volume of water treated at .25, .50, .75 and 1.00 inch depths was calculated from the runoff values for the storms. Since berms and detention with filtration allow the stormwater to reach surface sources, its water removal value is assumed at zero. Table 11 summarizes the calculations.

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TABLE 11

YEARLY RUNOFF WATER AND WATER REMOVED
FROM DIRECT DISCHARGE BY RETENTION

CN	Yearly Runoff as a Function of Rainfall		Water Removed by Retention for Diversion Depths (Percentage of Runoff)			
	inches*	%	.25 inch	.50 inch	.75 inch	1.00 inch
60	16.0	32	45	67	80	87
75	22.5	45	38	58	70	79
85	32.5	65	35	50	60	68
95	42.0	84	33	50	60	68

* Based on 50"/year of rainfall

NOTES: Since pasture and rangeland utilize berms, the water removed equals zero. Values in the table were developed applying the Soil Conservation Service Curve Number Methodology and the frequency distribution of rainfall at the Orlando Jetport.

CHAPTER V

LAKE TOHOPEKALIGA WATERSHED DATA

The information deemed necessary to determine the least-cost
analysis of stormwater management was based on land use, pollutant
loadings, water quality impacts, management methods, and costs.
All these data are then incorporated into decisions on the choice
of management methods which will provide a stated pollutant removal
at minimum cost.

Land Use

Approximately 620 square miles of land drain into Lake Tohope-
kaliga. Almost fifty percent, or 308 square miles, drain through
East Lake Tohopekaliga making the discharge from East Lake Tohope-
kaliga to Lake Tohopekaliga significant in terms of flow. However,
concentrations of pollutants appear to be relatively low. Using a
comparison of loadings from nonpoint sources, the relative phos-
phorus contributions from East Lake Tohopekaliga was only two per-
cent of the total. However, there was reported a 32 percent nitro-
gen contribution. A land area of 29 percent, or about 180 square
miles, is drained by Shingle Creek as it discharges to Lake Tohope-
kaliga. Another sixteen percent or about 100 square miles of the
watershed is drained by natural and man-made pipes, canals, and
ditches which flow directly into the lake. The lake itself forms

approximately five percent, or 32 square miles, or the watershed.
The drainage area is defined by the discharge to the South Port
Canal from the lake. This report excludes the East Lake Tohopeka-
liga watershed because of its significant size which apparently
produces low phosphorus discharge concentrations. However, the need
for stormwater management in the East Lake Tohopekaliga watershed
may and probably does exist.

The majority of the developed land is in cattle production,
both rangeland and pasture. Rangeland forms the major part of the
cattle producing lands. In order of decreasing land size, the de-
veloped area, of which information is known, is shown in Table 12.
The non-developed areas are essentially swamp, canals and flatwoods
which comprise the remaining area excluding the East Lake Tohopeka-
liga watershed.

The loading values used in the Lake Tohopekaliga study utilized
the more conservative loading values in Table 12 rather than data
from Lake Eola watershed, Table 1.

Within the estimates for acreage associated with each land use,
it was noted that two areas were not typical of the nearly 200,000
acres of the watershed. These areas were a citrus grove operation
near Shingle Creek, north of Route 530, and a dairy operation east
of Mills Slough. These areas were considered not typical because
of the visual appearance of the discharge waters. Samples of the
dairy operation effluent defined the loading rates. Since these
areas are highly suspect, it is suggested that the approximately

TABLE 12

WATERSHED AREA AND LOADING RATES

Land Use	Approximate Area (acres)	Loading Rates (lbs/ac-yr)	
		Total Nitrogen	Total Phosphorus
Developed Area			
Rangeland	44,000	2.0	0.1
Pasture	23,400	6.5	1.2
Residential	15,400	6.0	1.8
Commercial	6,600	12.3	2.7
Citrus	5,400	4.0	0.2
Dairy	250	9.0	4.2
Undeveloped Area			
Flatwoods	23,200	2.0	0.1
Swamps, Canals	61,400	0.0	0.0

SOURCES: East Central Florida Regional Planning Council, 1978
South Florida Water Management District, 1980
Wanielista et al. 1982

120 acres of citrus land and the approximately 250 acres of dairy land should be controlled. Most likely, these operations fall under an existing permit system. To further substantiate the control decision, the dairy lands situation is calculated in Appendix D.

Pollutant Loadings

Each land use has an associated pollutant loading. These loadings must be estimated. Total nitrogen and phosphorus were the water quality measures of interest. Data to quantify these loadings was taken from the "208" and other regional studies conducted by the East Central Florida Regional Planning Council and the South Florida Water Management District. These data are shown in Table 12. Later in this report, these loadings will be modified to illustrate the sensitivity of the selected best management practices if the assumed loadings of Table 12 were estimated incorrectly by 50 percent and 200 percent.

CHAPTER VI

ANALYSIS AND RESULTS

"SELECT" Solution for Lake Tohopekaliga Data for
Phosphorus Removal of 45% and Sensitivity Analysis of Solution

The South Florida Water Management District expressed an interest in exploring the feasibility of a stormwater management project to improve the water quality of Lake Tohopekaliga. A reduction of 45 percent in phosphorus and/or nitrogen into Lake Tohopekaliga was chosen as a reasonable value. At this level, it is believed that water quality problems can be reduced.

For any computer model, the solution is as accurate as the data and assumptions contained within it. For "SELECT", the key parameters which could affect the solution were considered to be land cost, nutrient loading, and pond (or berm) removal efficiency. A sensitivity analysis should be conducted with these parameters. The information obtained from the sensitivity analysis is used to determine the variability in the members of the solution set. A sensitivity analysis would need to be evaluated for each desired percentage nutrient removal level. However, a sensitivity analysis at the 45 percent removal level will be presented as an example of allowed changes in land cost, nutrient loading, and removal efficiency without changing the solution set.

Given the concepts of Chapter IV, and the Lake Tohopekaliga input data of Chapter V, at 45 percent phosphorus removal, Table 13 presents the minimum cost solution.

TABLE 13

PHOSPHORUS MINIMUM COST SOLUTION FOR 45% REMOVAL

Land Use	Soil Type	Number of Acres	Land Cost ($)	Treatment (inches)	Marginal Cost ($/lb)
Pasture	A	8,470	0	1.0	38
Pasture	D	14,931	0	1.0	61
Dairy	A/D	250	0	1.0	153
Residential	A	1,435	5,000	.25	241
Residential	A	1,493	7,000	.25	265
Rangeland	A	1,734	0	.5	273
Commercial	A	293	7,000	.5	276
Commercial	A	306	3,500	.75	309
Commercial	A	913	10,000	.5	314
Residential	A	1,868	3,000	.5	317
Residential	A	9,792	11,500	.25	320

It is noted from Table 13 that the dairy operation is included in the managed decision and, in fact, can be done with a relatively low cost. This verifies initial field investigations of the dairy operation when visual contact of the discharge waters indicated a possible problem. A summary of the cost assumptions for land spreading the runoff waters is shown in Appendix D.

Once the solution is known, a sensitivity analysis can be run to evaluate the conditions under which the solution will change. Of interest are the nutrient loadings for each land use in the solution and the cost of land in that region. The question which

arises is: "How much can the nutrient loading and land cost vary until the region falls out of the solution set?"

For the Lake Tohopekaliga watershed phosphorus case, the loading and land costs were varied and compared to the marginal cost (in $/lb removed) to the next lowest value not in the solution set. For the phosphorus case, the lowest marginal cost not in the solution set (not managed areas) was rangeland, "D" type soil, 0.50 inch diversion depth, at $462/lb removed.

It is desired to vary the loading and land cost to determine the point at which each member of the minimum cost solution set would be replaced by the rangeland marginal cost value of $462, which is the lowest marginal cost for those practices not in the solution. In this manner, the sensitivity analysis was run on the loading and land cost parameters for the Lake Tohopekaliga watershed.

The results of the sensitivity analysis were plotted and shown in Figures 5 through 7. The graphs illustrate a linear relationship between loading and land cost for each land use to remain in the solution set. Whenever the combination of land cost and loading results in a marginal cost less than $462, the land use will remain in the solution set, and is labeled "MANAGE" on the graph. Whenever it is greater than $462, the land use falls into the "DON'T MANAGE" region on the graph.

One approach to evaluate the relationship is to solve for the minimum loading for a given land cost, then compare the minimum loading to the loading of interest. The relationship can be

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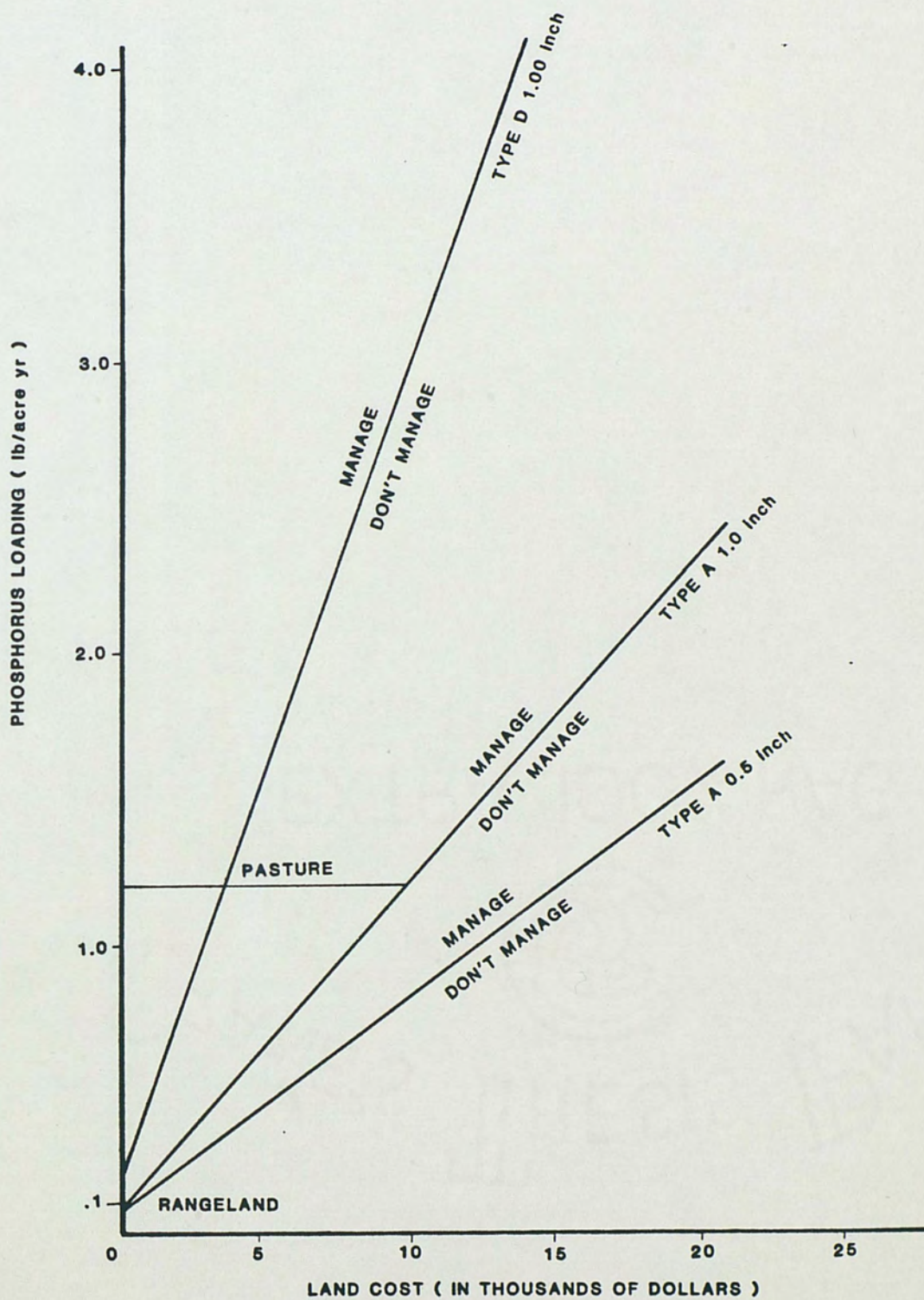
Fig. 5. Sensitivity plot for 45% phosphorus removal.

RESIDENTIAL AREA 'A' TYPE SOIL CURVE NUMBER 95
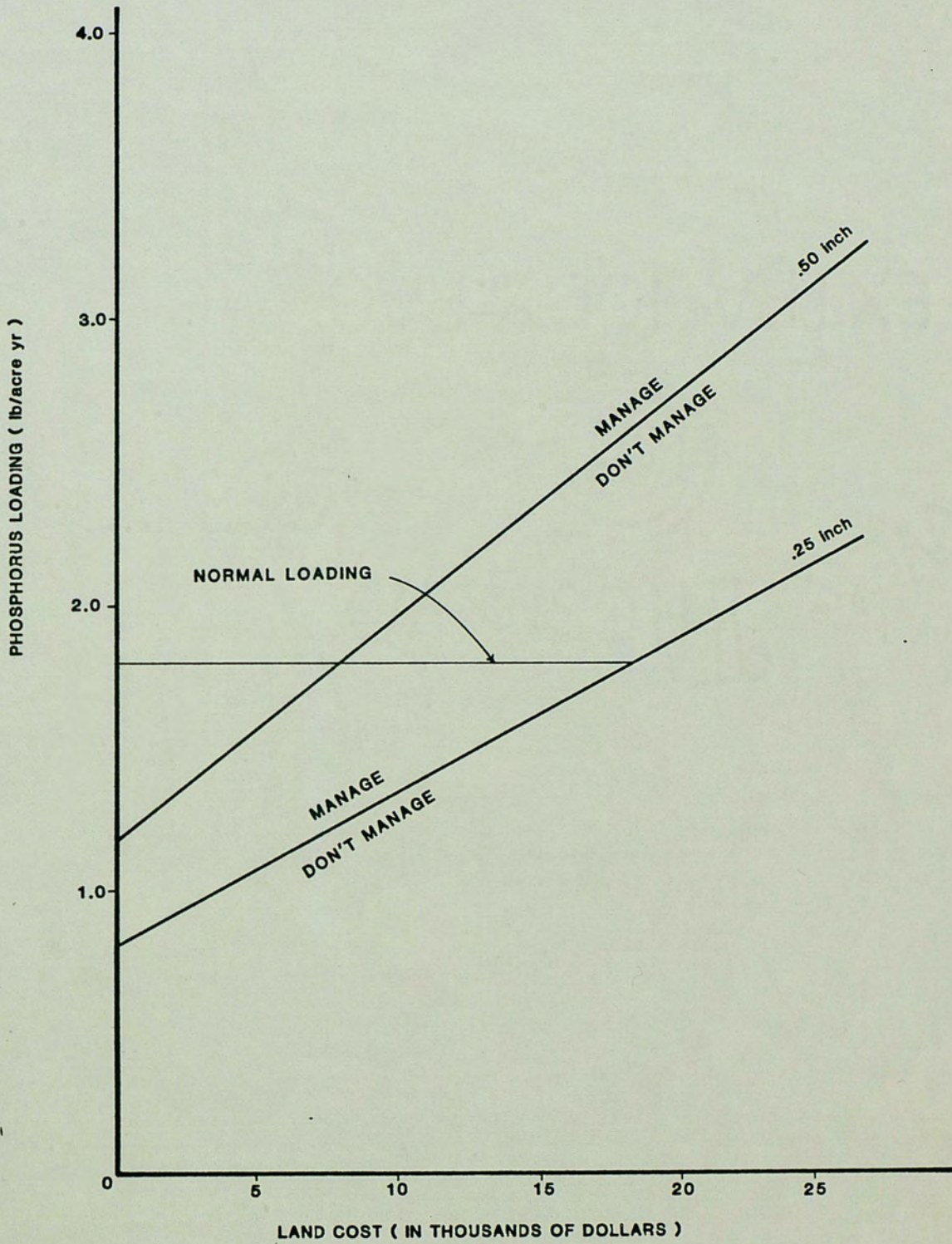
Fig. 6. Sensitivity plot for 45% phosphorus removal.

COMMERCIAL AREA "A" TYPE SOIL CURVE NUMBER 80
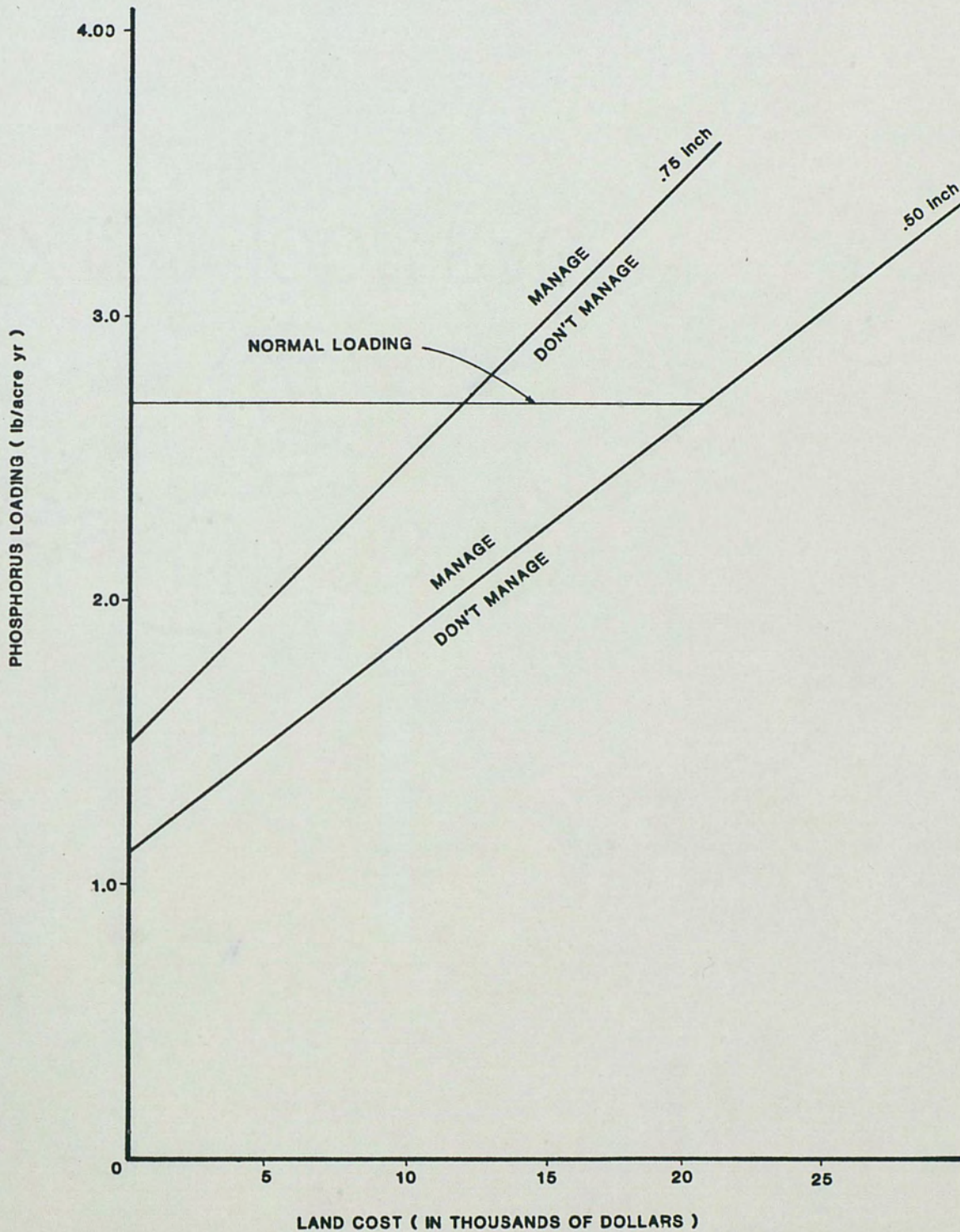
Fig. 7. Sensitivity plot for 45% phosphorus removal.

algebraically expressed as:

$$\text{Load} \geq Y_{min} = (M) \times (\text{land cost}) + b \qquad (1)$$

where:

Load = pollutant loading (lb/acre/year) being evaluated

Land Cost = land cost in land use region ($1,000/acre)

M = slope of line (lb/$1000-yr)

b = y intercept (lb/acre-year)

Y_{min} = minimum pollutant loading to keep the stormwater practice (land use) in solution set

Whenever Load $\geq Y_{min}$, the combination of loading and land cost will remain in the solution set.

An examination of Figures 5-7 yields the values presented in Table 14 for M and b for each member of the solution set from equation 1.

TABLE 14

PHOSPHORUS CASE (45% REMOVAL), SLOPE AND INTERCEPT
VALUES FOR REMAINING IN SOLUTION SET

Land Use	Soil Type	Diversion Volume (inches)	M	b
Pasture	A	1.0	.11	.10
Pasture	D	1.0	.28	.16
Residential	A	.25	.05	.80
Residential	A	.50	.08	1.16
Commercial	A	.50	.08	1.10
Commercial	A	.75	.11	1.47
Rangeland	A	.50	.07	.06

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It is simple now to examine when a management practice will no

longer fit into the solution set. Graphically, the solution set is

labeled "MANAGE". Those combinations not in the solution set are

labeled "DON'T MANAGE". As an example of the use of equation 1,

the most prevalent solution land use, Pasture, will be explored.

Given are three scenarios:

1. Land cost is not $0, but $3500/acre, load = 1.2 lb/ac-yr

2. Loading is not 1.2 lb/ac-yr, but 50% of that value with

land cost = $0/acre

3. Land cost = $3500/acre and loading = .6 lb/acre/year

QUESTION: Will Pasture Type A and D remain in solution set?

EQUATIONS:　　　　Pasture Land Type "A"　　Y_{min} = .11X + .10

　　　　　　　　　Pasture Land Type "D"　　Y_{min} = .28X + .16

Scenario #1

Type "A"　　　　　　　　　　Y_{min} = .11 (3.5) + .10 = .485

Type "D"　　　　　　　　　　Y_{min} = .28 (3.5) + .15 = 1.14

Load is equal to 1.2 and is greater than Y_{min}. The equations

show these values to be in the solution, and graphically they fall

in the "MANAGE" region.

Scenario #2

Load = 0.6 lb/ac-yr　　　　　Cost = 0

Type "A"　　　　　　　　　　Y_{min} = .11 (0.) + .10 = .10

Type "D"　　　　　　　　　　Y_{min} = .28 (0.) + .16 = .16

Since Load $> Y_{min}$, both Type "A" and Type "D" are in the solution set and in the "MANAGE" region.

Scenario #3

Load = .6 lb/ac-yr   Cost = \$3,500/acre

Type "A" Y_{min} = .485 so load $> Y_{min}$ and Type "A" remains

Type "D" Y_{min} = 1.14 so load $> Y_{min}$ and Type "D" leaves solution

In this scenario, Pasture Type "D" leaves the solution, graphically it falls into the "DON'T MANAGE" region.

As a result of calculations similar to the ones above and on the previous page, a table of land costs to keep the solution set for two-fold changes in loading is presented. Table 15 uses the equations derived earlier.

TABLE 15

HIGHEST LAND COST ALLOWED IN SOLUTION SET
FOR CHANGES IN PHOSPHORUS LOADING

Land Use	Soil Type	Treatment Volume (inches)	Loading (lb/ac-yr)	Highest Land Cost Allowed in Solution		
				.5X Loading	Load	2X Loading
Pasture	A	1.0	1.2	\$4,500	\$10,000	\$32,000
Pasture	D	1.0	1.2	1,500	3,500	8,000
Residential	A	.25	1.8	2,000	17,500	56,000
Residential	A	.50	1.8	NIS*	8,000	30,500
Commercial	A	.50	2.7	3,500	21,000	53,800
Commercial	A	.75	2.7	NIS	12,000	35,700
Rangeland	A	.50	.1	NIS	300	1,500

*NIS = not in solution

In addition to estimating land costs and loading rates, one must estimate the removal efficiency for each stormwater management practice. The solution set has been determined using an assumed efficiency. If one were not accurate in the estimation of the removal efficiency, will the selected stormwater management practices still be in the solution set? The minimum removal efficiencies necessary for each stormwater management practice on the associated land use to maintain the selected combination of best "least cost" practices can be calculated.

The marginal cost is defined as total present value cost divided by pounds of nutrient removed per year. The pounds of nutrient removed can be expressed as a removal efficiency times the nutrient loading. For phosphorus, a land use with a marginal cost less than \$462/lb removed will be in the solution (or defined as managed region). A comparison of the land use's marginal cost with the \$462 marginal cost can be used to determine the minimum efficiency to keep the land use in the solution set. Mathematically the relationship is:

$$MC_M = \frac{Cost}{(lb\ removed)} = \frac{Cost}{n_M \times (loading)} \tag{2}$$

$$MC_{DM} > \frac{Cost}{(lb\ removed)} = \frac{Cost}{n_{MIN} \times (loading)} \tag{3}$$

where:

MC_M = marginal cost for "MANAGE" decision

MC_{DM} = marginal cost for "DON'T MANAGE"

Cost = total present value dollar cost of stormwater prac-
tice = $462

Loading = yearly nutrient loading in pounds

n_M = nutrient removal efficiency for "MANAGE" decision

n_{MIN} = minimum nutrient removal efficiency for "MANAGE"
decision

The variable of interest is minimum nutrient removal efficiency

for a "MANAGE" decision, n_{MIN}. Substituting the (cost/loading)

ratio from equation 2 into equation 3 yields:

$$MC_{MIN} > \frac{(n_M) \times (MC_M)}{n_{DM}}$$

and solving for n_{MIN}:

$$n_{MIN} > n_M \frac{(MC_M)}{(MC_{DM})} \qquad \frac{(n_M) \times (MC_M)}{462}$$

From this relationship, Table 16 was obtained which illus-

trates the sensitivity in the estimate of removal efficiencies to

maintain the selected management practice.

The last column, Minimum Removal Efficiency, of Table 16 repre-

sents the lowest removal efficiency which will keep that land use

in the solution set. As an example, the lowest marginal cost land

use, pasture at $38/lb removed, could have a treatment pond effi-

ciency of only seven percent and still be in the solution.

TABLE 16

MINIMUM REMOVAL EFFICIENCY OF PHOSPHORUS
FOR 45% REMOVAL SOLUTION SET

Land Use	Soil Type	Land Cost ($)	Treatment Depth (inches)	Marginal Cost MC_M ($/lb removed)	Assumed Removal Efficiency n_M (%)	Minimum Removal Efficiency n_{MIN} (%)
Pasture	A	0	1.0	38	90	7
Pasture	D	0	1.0	61	90	12
Residential	A	5,000	.25	241	80	42
Residential	A	7,000	.25	265	80	46
Rangeland	A	0	.50	273	80	47
Commercial	A	7,000	.50	276	90	54
Commercial	A	3,500	.75	309	93	62
Commercial	A	10,000	.50	314	90	61
Residential	A	3,000	.50	317	90	62
Residential	A	11,500	.25	320	80	55

At the other extreme, residential at $320/lb removed, would not be in the solution if pond removal efficiency drops below 55 percent. Since all structures will be constructed similarly, it is improbable that ponds (or berms) in pasture lands will remove seven percent while the same type of structure in a residential area removes 80% (or even 55%). In other words, if the actual removal efficiency for pasture was closer to 60 percent, then the actual value for residential should be about 50 percent and the same solution set results with additional members. If this is not the case, then other factors such as improper construction, first flush effects, or rainfall events are the cause of the discrepancy. However, the total cost would be affected by the actual removal efficiency.

"SELECT" Solution for Lake Tohopekaliga Data for
Nitrogen Removal of 45% and Sensitivity Analysis of Solution

The same sensitivity analysis was performed for the 45% removal

of nitrogen solution. The parameters of nitrogen loading and land

cost were varied to explore the regions of solution and non-solution.

For the nitrogen case, the lowest marginal cost not in the

solution set was citrus, "A" type soil, .25 inch diversion depth,

with a marginal cost of $62/lb removed. The solution set for nitro-

gen at 45% removal is presented in Table 17.

TABLE 17

NITROGEN SOLUTION SET AT 45% REMOVAL

Land Use	Soil Type	Number of Acres	Land Cost ($)	Diversion Depth (inches)	Marginal Cost ($/lb)
Pasture	A	8,470	0	1.00	7
Pasture	D	14,931	0	1.00	11
Rangeland	A	1,734	0	1.00	24
Rangeland	D	42,276	0	1.00	37
Commercial	A	913	10,000	.25	43
Commercial	A	306	3,500	.50	46
Dairy	A/D	250	0	.50	53
Commercial	A	293	7,000	.50	55
Residential	A	1,868	3,000	.25	59

Once again, the loadings and land cost were varied to test the

solution set. The marginal cost of $62/lb removed was the value

used for comparison. The comparisons were made, graphs plotted,

and the parameters for straight line plots derived. The parameters

are listed in Table 18.

TABLE 18

PARAMETERS FOR NITROGEN EQUATIONS

Land Use	Soil Type	Diversion Depth (inches)	M	b
Pasture	A	1.00	.82	.76
Pasture	D	1.00	2.12	1.20
Rangeland	A	1.00	.82	.76
Rangeland	D	1.00	2.12	1.20
Commercial	A	.25	.31	5.00
Commercial	A	.50	.50	7.00
Residential	A	.25	.33	4.80

Once again, the graphs were assigned regions related to the
"MANAGE" and "DON'T MANAGE" decisions. Figures 8 through 10 contain
the graphs. One can follow the principles outlined in the phosphorus
section for varying the nitrogen loading or land cost to arrive at
a judgement regarding the manage decision.

As in the phosphorus case, a table can be constructed illus-
trating the highest land cost for one-half the assumed, and twice
the assumed loading for the nitrogen case. These results are pre-
sented in Table 19 and illustrate the variability of both land cost
and loading estimates which would maintain the same stormwater
management practices.

It is interesting to note the extremes illustrated by Table
19. At the assumed loading, commercial land use with "A" type
soil will fall in the manage category for any land cost less than
$20,000. At half the assumed loading, any rangeland "D" type soil
will no longer be in the solution should land cost rise above
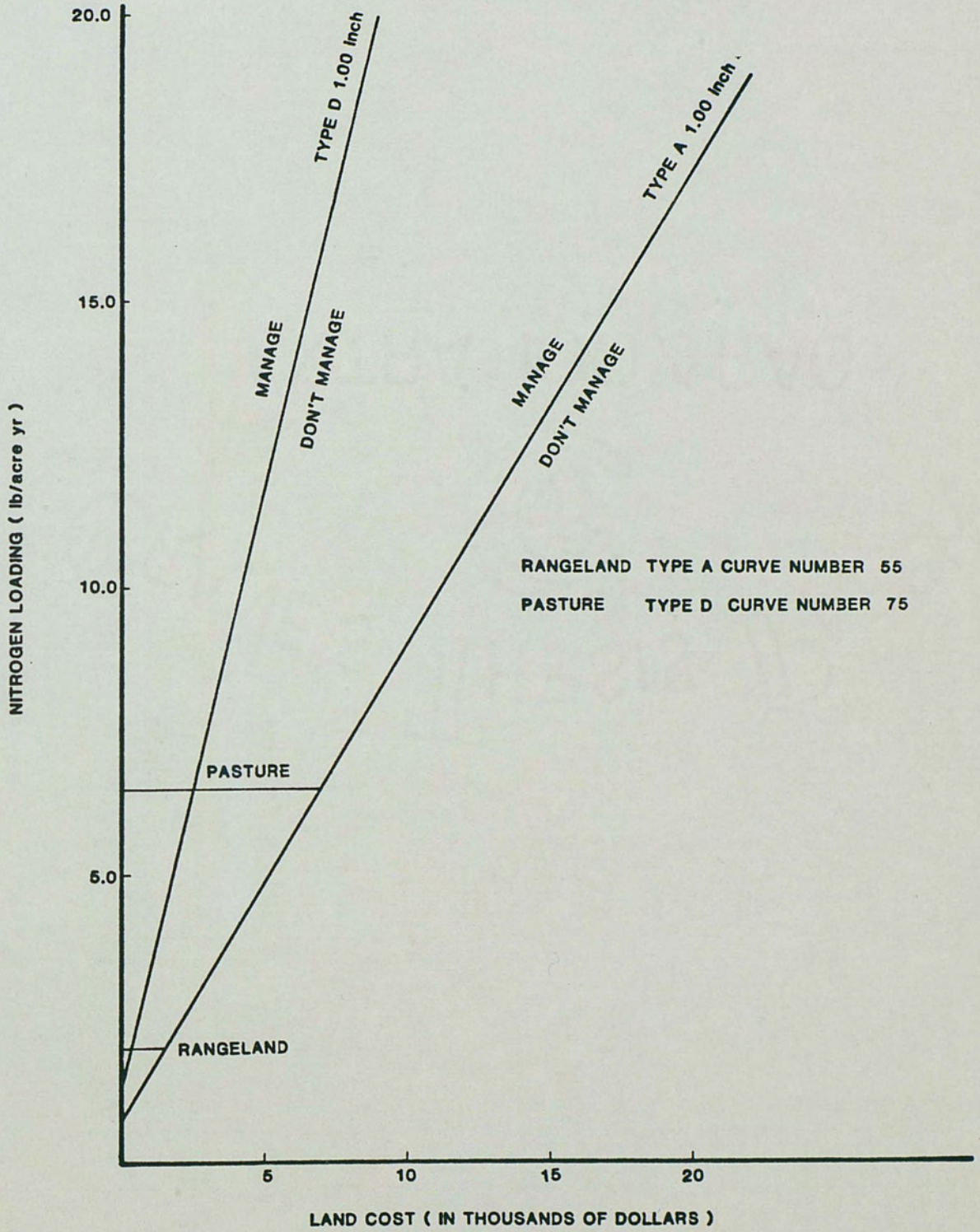
Fig. 8.   Sensitivity plot for 45% nitrogen removal.
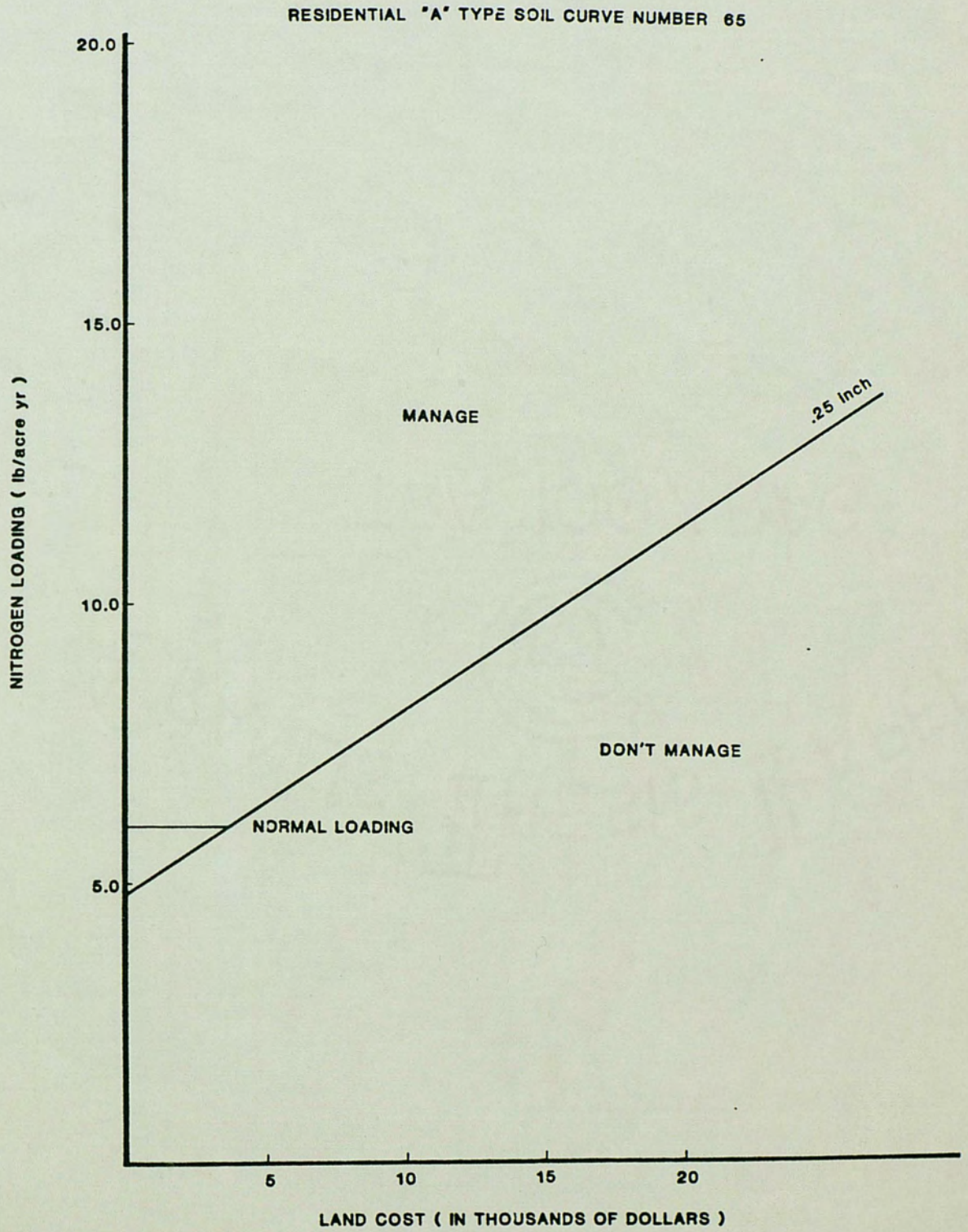
Fig. 9.   Sensitivity plot for 45% nitrogen removal.
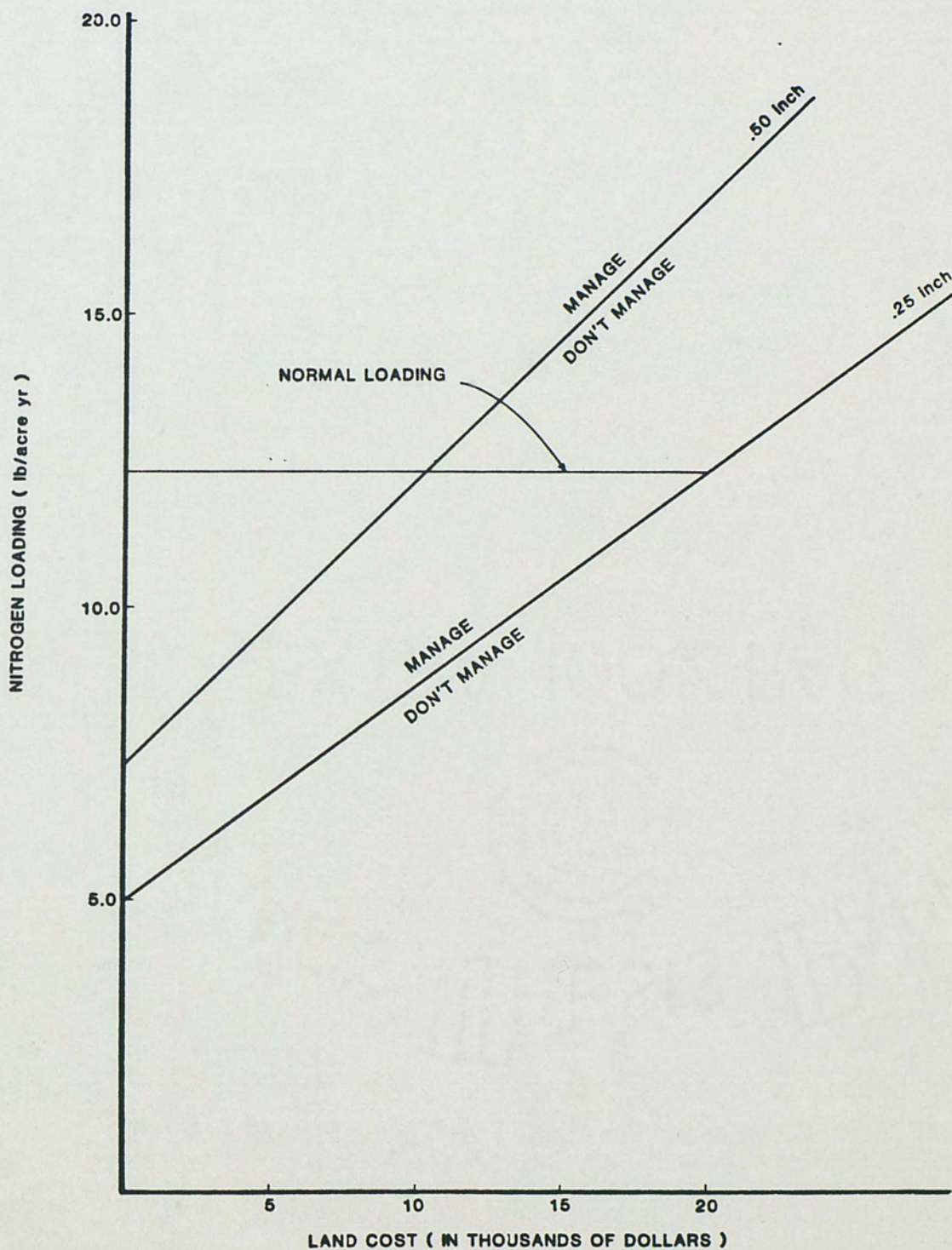
Fig. 10. Sensitivity plot for 45% nitrogen removal.

TABLE 19

HIGHEST LAND COST ALLOWED IN SOLUTION SET
FOR CHANGES IN NITROGEN LOADING

Land Use	Soil Type	Diversion Depth	Loading (lb/acre/yr)	Highest Land Cost Allowed*		
				.5X Loading	Assumed Loading	2X Loading
Pasture	A	1.00	6.5	3,000	7,000	14,708
Pasture	D	1.00	6.5	1,000	2,500	6,700
Rangeland	A	1.00	2.0	250	1,500	3,000
Rangeland	D	1.00	2.0	NIS**	250	1,250
Commercial	A	.25	12.3	3,250	20,000	62,000
Commercial	A	.50	12.3	NIS	10,250	35,000
Residental	A	.25	6.0	NIS	3,500	22,000

*   Recorded in $/acre
**   NIS = not in solution

$250/acre. Those comparisons are also illustrated graphically in Figures 8 through 10.

The basic assumption on land cost for pasture and rangeland areas was that land cost was zero. This was based on the assumption that the berm areas would not limit the use of the land. However, if the land use was limited or some government body wished to purchase the land, Table 19 would specify the maximum land cost to permit the stated solution. Since citrus land is the next management practice region for the solution set, it would most likely become a favored practice or it would be in the solution set if the land cost for rangeland and pasture land were above Table 19 stated maximums. This assumes that the loadings and zero land cost for citrus would not change.

For the minimum nitrogen removal efficiencies, the same analysis as reported for phosphorus was performed. Those results appear in Table 20. In this case, MC_{MIN} = \$62/lb removed.

TABLE 20

MINIMUM REMOVAL EFFICIENCIES OF NITROGEN
FOR 45% REMOVAL SOLUTION SET

Land Use	Soil Type	Land Cost (\$)	Treatment Depth (inches)	Marginal Cost, MC_M (\$/lb removed)	Assumed Removal Efficiency n_M (%)	Minimum Removal Efficiency n_{MIN} (%)
Pasture	A	0	1.00	7	80	9
Pasture	D	0	1.00	11	80	14
Rangeland	A	0	1.00	24	80	31
Rangeland	D	0	1.00	37	80	48
Commercial	A	10,000	.25	43	80	55
Commercial	A	3,500	.50	46	90	67
Commercial	A	7,000	.50	55	90	80
Residential	A	3,000	.25	59	80	76

Variability of Cost as Overall Phosphorus Removal Increases

What is the shape of the cost curve as the desired percentage removal is steadily increased? To answer this question, the Lake Tohopekaliga data were run in the computer program with varied phosphorus removal values. As expected, the cost curve sharply rises as a higher percentage removal is desired. This graph is presented in Figure 11 and tabulated in Table 21.

Figure 11 illustrates the relationship of increasing cost for higher percentage nutrient removal. The cost curve increases sharply for higher percent removal values, as higher marginal cost treatment locations are utilized.
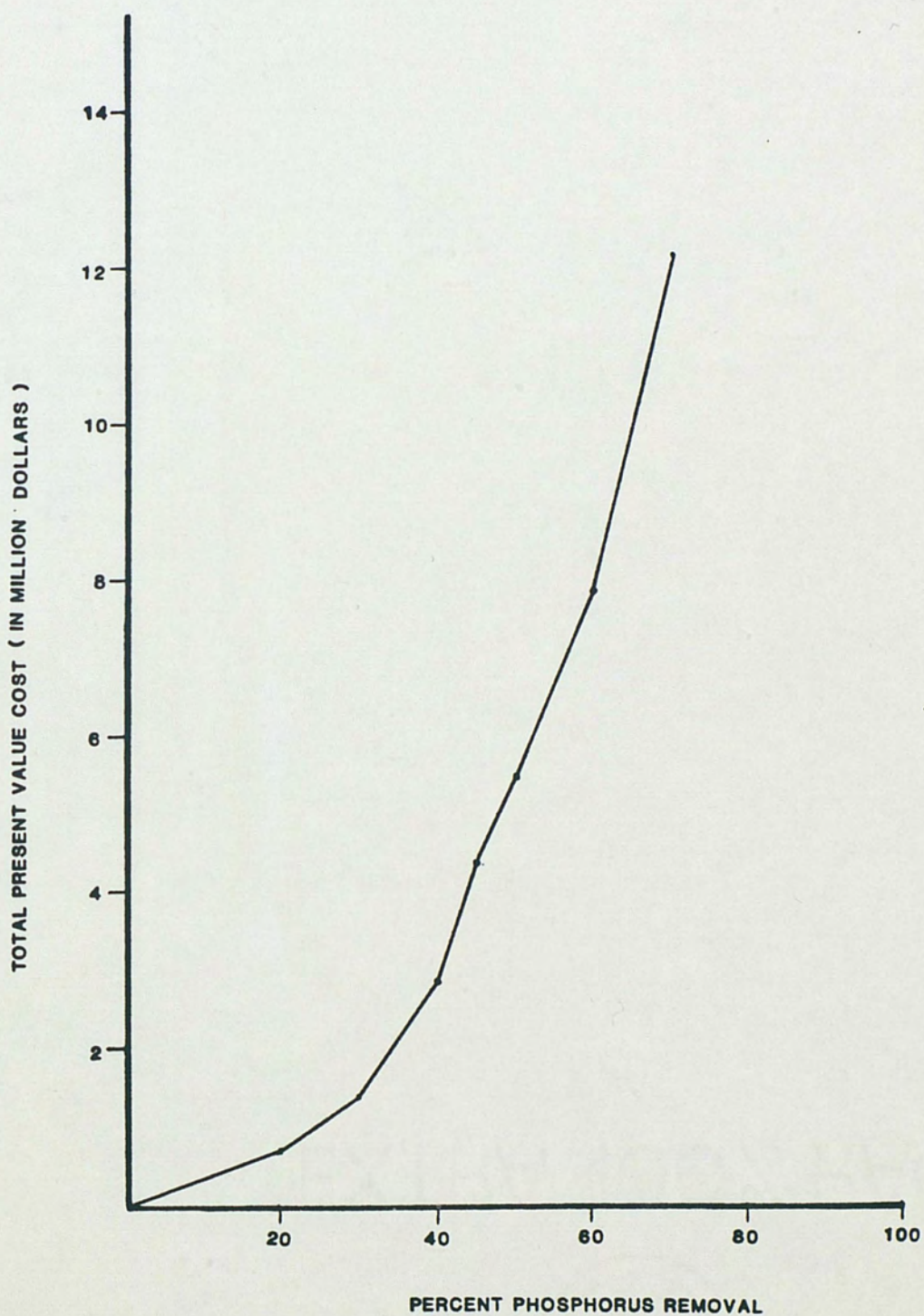
Fig. 11. Plot of total present value of stormwater practices
versus percentage phosphorus removal for Lake Tohopekaliga.

TABLE 21

PRESENT VALUE COST OF STORMWATER PRACTICES FOR
DIFFERENT PERCENTAGE OF PHOSPHORUS
REMOVAL FOR LAKE TOHOPEKALIGA

% Phosphorus Removal	Associated % Nitrogen Removal	in millions of dollars			Engineering Legal Cost	Total Cost
		Construction Cost	Land Cost	ORM Cost		
20	15	.29	0	.26	.14	.69
30	25	.47	0	.62	.27	1.36
40	31	1.20	.30	.79	.57	2.86
45	35	1.94	.66	.93	.88	4.41
50	37	2.37	1.05	1.01	1.11	5.54
60	43	3.28	1.87	1.18	1.58	7.91
70	55	5.15	2.51	2.11	2.44	12.21
80	65	7.95	4.75	2.91	3.90	19.51

From a practical viewpoint, should Lake Tohopekaliga require a low percent removal of either nutrient, stormwater management practices can provide a low cost solution to retard eutrophication. Should the problem be larger, the cost of stormwater removal practices will be quite high. At the present time, the required percent reduction of nutrients to stop eutrophication of Lake Tohopekaliga is not known.

CHAPTER VII

SUMMARY AND RECOMMENDATIONS

Summary

The objectives of this work on Lake Tohopekaliga were to (1)
develop a computer model to aid in the selection of stormwater man-
agement locations and (2) to determine the minimum cost solution
for stormwater management practices for Lake Tohopekaliga.

For each land use, estimates of the physical characteristics
of the land, cost of treatment, and efficiencies by diversion of
treatment were made. These estimates included the location of the
various types of land used with their associated acreage, the cost
of land, runoff potential with soil types, construction costs, oper-
ational and maintenance costs and yearly loading rates. From
these assumptions, the least cost treatment combinations were deter-
mined for a fixed level of nutrient removal. This was accomplished
using the computer program "SELECT".

Since it is recognized that the input data does vary, a sensi-
tivity analysis on the best combination of stormwater management
practices was done. Sensitivity analyses included changing the load-
ing rates, removal efficiencies and land costs. The results indi-
cate that stormwater management practices for pasture, residential
and commercial property should be constructed. It was determined
that high land cost in urban areas reduced the use of the stormwater

management practices. Of course, if land costs were not a factor, these practices would be more widely used.

Recommendations

1. A stormwater management construction program should be started to reduce pollutants into Lake Tohopekaliga. The priority areas identified within this report should act as a guide for implementation. Immediate action should be taken on pump discharges from impounded areas servicing crop lands.

2. Initial construction for stormwater management in urban and pasture lands should be initiated to document pollutant loadings and performance characteristics. Also, water quality impacts using the effluent waters from the berm areas in pasture lands and detention areas in residential areas should be included.

APPENDICES

APPENDIX A

COMPUTER PROGRAM "SELECT"

Documentation of Program "SELECT"

The computer program "SELECT" utilizes terminal input and data
input to accomplish its objectives. SELECT is designed to choose
the least costly areas for stormwater management practices. It
calculates the marginal costs for all entries, selects the lowest
cost combination to obtain a desired percentage removal, then prints
the output in five tables. The program was designed to minimize
interactive computer time.

The data for the computer program is broken into two categories:
terminal input and data input. Terminal input consists of the
answers to two questions. The first question pertains to selection
of pollutants for removal calculations, and answers can be either
(1) nitrogen, or (2) phosphorus. The computer program uses this
value as the basis for which pollutant to monitor for attainment
of desired goal. The second question is the desired percentage re-
moval of pollutant. The answer can be any value between 1 and 100.
No provisions have been made for erroneous entries, those values
above 100. The program will not terminate should an entry above
100 be read. The purpose of the percentage removal is to set a
value for completion of program. It also reflects the user's

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desired pollutant removal. The terminal input appears in the
program in lines 1000-1070.

Data input consists of title and numerical data of the water-
shed and appears at the end of the program. The data input is an
unchanged data group, since it consists of watershed characteristics
which do not change rapidly. This characteristic makes the creation
of data input useful in running "SELECT".

The data input (lines 5000-5220) consists of a title, up to
fifty characters in length, and watershed data. The watershed data
has four components: a code value, soil conservation service curve
number, land size and land cost. The code number represents a com-
bination of land use and soil type. A listing of code numbers ap-
pears in the remarks section of the program. The soil conservation
curve number represents the degree of imperviousness of soil. Values
range from 0 to 100. The land size is acreage for the inputted land
use. Cost of land represents the land cost in dollars per acre.
The last data input line has a code number of 999 to signal the end
of data.

The program logic will be described next. The program asks
the user for the terminal input-selected pollutant and percentage
removal. With these values, it sets all marginal cost solution code
values to zero (line 1130). Since equal sized land units are neces-
sary for marginal cost comparison, the number of 250 acre units
for each land use is calculated (lines 1150-1170). Thereafter,
the program has six major functions (1) calculation of stormwater

pond sizes, (2) nutrient loading and removal values, (3) calculation
of marginal cost, (4) determination of total and removed nutrient
loading, (5) selection of management regions for stormwater control,
and (6) printing of output.

Pond sizes are calculated in lines 1190 through 1330. Pond
size is an important parameter, since land must be purchased. Lar-
ger ponds will be more expensive, smaller ones, less. The size of
a pond depends upon soil type in the region and volume of water to
be handled. The volume of water depends upon the diversion depth
in the stormwater structure; four possibilities exist: 0.25, 0.50,
0.75 and 1.00 inch; and the amount of imperviousness in the region,
reflected by the curve number. The program handles the soil type
and curve number combination first, to calculate a number, which in
turn is multiplied by a factor for a given diversion depth to ob-
tain the pond size. As an example, for Type "A" soil, line 1200
calculates V5 from the curve number and lines 1210 through 1240
determine the acreage of pond for 0.25, 0.50, 0.75 and 1.00 inch,
respectively. For Type "A" soils, a pond depth of five feet is
utilized; for Type "D" soils, a pond depth of two feet is utilized.

After pond sizes are calculated, SELECT determines the loading
and associated nutrient load removed for the four possible pond
sizes, lines 1280-2020. The program operates by using the values
for the least polluting region, flatwoods, then applies an appro-
priate scale up factor for the other land uses. The way SELECT han-
dles the loadings is to use variables N and P to represent the scale

up factor and variable "TI" to represent the number of times passing

through the "loading" loop, lines 1390-1480. If flatwood is the

land use being read, one pass is made through the loading loop.

Otherwise, scale up factors are assigned in lines 1730-2010 and

the loadings are recalculated in the loading loop.

The values in lines 1390 through 1480 contain some assumptions.

They are (1) the loading rates for each land use and (2) pond nu-

trient removal efficiencies. These assumptions were discussed

earlier in the section on Lake Tohopekaliga Data. Should different

assumptions be made, lines 1390-1480 would be altered.

Two special cases of nutrient removal techniques exist, under-

ground percolation tanks and the use of berms to treat pasture or

rangeland runoff. For underground percolation tanks, only one mar-

ginal cost exists and the other three positions were assigned dummy

values, lines 1520-1540. Since the percolation tank operates in an

urban area and diverts the first inch of stormwater underground, a

nutrient removal of 90% was assigned for underground percolation

tanks.

For pasture and rangeland, berms are utilized. Since berms

are designed for only 0.50 and 1.00 inch stormwater flow, diversion

dummy variables are assigned for 0.25 and 0.75 inch diversions, lines

1620, 1630, 1660, and 1670. The percent removal values for berms

are mentioned in Chapter IV.

Lines 1740 through 2010 contain the logic for assignment of

the scale up factor, land use title, and routing back to loading

and nutrient removal section. When the loading and removal calcu-
lations are complete, the program takes the removed nutrient values
for the desired pollutant, either nitrogen or phosphorus, and places
them into one array of removal values for comparison purposes.
Since either nitrogen or phosphorus can be chosen, the program
utilizes one removal array to calculate the chosen pollutant mar-
ginal costs, and neglects the other array. These steps occur at
lines 2030-2070 and finish the calculation for nutrient loading and
pollutant removal.

The calculation of costs follow the loading calculations. To-
tal cost is the sum of land costs, construction cost, and operation
and maintenance costs. ORM costs are handled first, lines 2090-
2160. Line 2100 determines the ORM cost for underground percola-
tion tank. ORM costs are estimated at $12,500 per year per 250 con-
tributing acre ($50/yr-acre) times present value factor of 8.51.
For urban areas, line 2120, ORM costs equal $275 per acre times num-
ber of acres of pond times 8.51. Similarly, for rural areas, line
2160, ORM equals $50 per acre times number of pond acreage times
8.51. In SELECT, one of these calculations is made before moving
on to determining the marginal cost.

In calculating the marginal cost, three different possibilities
exist for calculation of total cost. Rangeland and pasture utiliz-
ing berms, line 2180; underground percolation tanks, line 2270;
and the remaining land use categories, line 2290; all require
slightly different calculations. For rangeland and pasture, the

cost of berms involves inlet-outlet expense ($750), excavation cost
of $20 per contributing acre ($5,000), and cost of land for the berm
(pond size times land cost).

For underground percolation tanks, the cost involves construc-
tion costs of $2,500 per impervious acre times the number of imper-
vious acres in a 250 acre region. For underground percolation tanks,
the impervious acres is derived from the data input curve number
and some assumptions. The assumptions are (1) curve number of im-
pervious area equals 98 and (2) curve number of pervious area equals
50. From the weighted curve number, the number of impervious acres
per 250 acres equals, aa x 250, where aa is the fraction of imper-
vious acres. "aa" is calculated from the formula:

CN = aa (curve number impervious) + bb (curve number pervious)

where:

   aa = fraction impervious

   bb = fraction pervious

   curve number impervious equals 98

   curve number pervious equals 50

   aa + bb = 1

Simplifying:

aa = (CN - 50)/48 or 0.0208 x (CN - 50)

For other land uses, the total cost involves inlet-outlet cost

($750), excavation cost ($12,500 per pond acre times pond size),

and land cost (pond size times land cost in acres).

Some factors which are common to all cost calculations are (1)

the increase in cost due to engineering and legal fees (value

equals 1.25) and (2) the inclusion of ORM cost term ("CR"). Once

the total present value cost is calculated, the marginal cost is

evaluated as the total present value cost divided by the nutrient

load removed in pounds per year.

At this point, a few additional calculations are made before

returning to the top of the program for the next line of data. Each

nutrient, nitrogen and phosphorus, has its total loading increased

by the amount arising from the last line of input. These calcula-

tions are shown in lines 2340 and 2350.

Once all input has been read, the desired amount of nutrients

to be reduced are determined, either line 2410 or 2430. Then, the

sequence for selection of management practices based upon minimum

marginal costs is undertaken, lines 2440-2970. In short, the pro-

gram causes a search until the lowest marginal cost is found. That

value is placed in the set of solutions, line 2590, the amount of

nutrient removed is calculated, line 2600, and checked to determine

if the nutrient removal goal is reached, line 2840. If more nu-

trient needs to be removed, the process is repeated with the follow-

ing difference. If the next selection involves the same land use

region in the solution, but at a more expensive project level, the

more expensive step is included and the less expensive level is sub-
tracted from the running totals, lines 2600, 2630, 2640, and 2650.
When the amount removed is greater than desired, the program elimi-
nates some of the highest marginal cost region acreage for stormwater
management practices to more precisely obtain the desired percentage
removal, lines 2850-2970.

Once the solution is found, the remaining requirement is an
acceptable display of the output. The output consists of five tables.
The first table is a printing of the data pertaining to the water-
shed under consideration. The second table lists all the marginal
costs calculated from the watershed data. The third table is the
minimum cost solution based upon the desired nutrient and percentage
removal. Before the third table is printed, a subroutine is utilized
to rank the solution set from lowest to highest marginal cost. The
fourth table lists all the loading and calculated removal values for
each land use entry. Table 5 displays the costs for the project
by land use and also the total cost including the engineering and
legal fees.

It should be mentioned, all of the data input is at the end of
the program, signified by the word, "DATA", lines 5010-5220. The
first DATA line is the title, the last data line is the program step
which shows all data being read, and the lines in-between represent
the watershed data. The watershed data has the format-land use
code number, SCS curve number, number of acres, land cost per acre.

It is the watershed data which is altered should different land
costs, acreage, curve number of even whole watersheds be examined.

```
10 PCLEAR 1
20 DIM DA$(35),DB$(35),DC(35),DD(35),DE(35),DF(35)
30 DIM CK(35),AM(35,4,2),AR(35,4)
40 DIM CO(35),CN(35),SI(35),LA(35)
50 DIM UN(35),PO(35,4),N(35),P(35),NR(35,4),PR(35,4),C(35)
60 DIM A$(35),B$(35)
70 REM*  LISTING OF SYMBOLS USED IN PROGRAM  *
80 REM*                                      *
90 REM* SE== SELECTION VARIABLE FOR N OR P DETERMINATION       *
100 REM* PP== PERCENT NUTRIENT REMOVAL FOR TOTAL LOADING        *
110 REM* CO(I)== CODE NUMBER FOR A GIVEN LINE OF INPUT          *
120 REM*      TABLE OF CODE VALUES OF LAND USE                  *
130 REM*                                                        *
140 REM*              SOIL       SOIL                           *
150 REM*              TYPE A     TYPE D                          *
160 REM* COMMERCIAL     1          8                            *
170 REM* RESIDENTIAL    2          9                            *
180 REM* CITRUS         3         10                            *
190 REM* RANGELAND      4         11                            *
200 REM* FLATWOODS      5         12                            *
210 REM* PASTURE        6         13                            *
220 REM* SWAMP          7         14                            *
230 REM* COMM-PERC TANK (ANY)     15                            *
240 REM* TI$== TITLE FOR OUTPUT                                 *
250 REM* I== VARIABLE FOR LINE OF INPUT                         *
260 REM* Q== VARIABLE FOR DIVERSION DEPTH (.25,.5,.75,1.00 IN.)*
270 REM* CN(I)== CURVE NUMBER OF INPUT LINE                     *
280 REM* SI(I)== LAND ACREAGE OF INPUT LINE                     *
290 REM* LA(I)== COST OF LAND ($/ACRE) FOR INPUT LINE           *
300 REM* UN(I)== NUMBER OF 250 ACRE UNITS                       *
310 REM* CK(I)== NUMBER OF 250 ACRE UNITS IN SOLUTION SET       *
320 REM* B$(I)== CHARACTER ARRAY OF SOIL TYPE                   *
330 REM* A$(I)== CHARACTER ARRAY OF LAND USE TYPE               *
340 REM* V5== POND SIZE FACTOR FOR TYPE A SOIL                  *
350 REM* V2== POND SIZE FACTOR FOR TYPE D SOILD                 *
360 REM* PO(I,Q)== POND SIZE IN ACRES                           *
370 REM* N(I)== NITROGEN LOADING (LBS/YR) FOR LAND USE I        *
380 REM* P(I)== PHOSPHORUS LOADING  (LBS/YR) FOR LAND USE I     *
390 REM* NR(I,Q)== N REMOVED (LBS/YR) FOR A DIVERSION DEPTH Q   *
400 REM* PR(I,Q)== P REMOVED (LBS/YR) FOR A DIVERSION DEPTH Q   *
410 REM* TI== NUMBER OF TIMES THROUGH LOADING CALCULATION LOOP  *
420 REM* N== NITROGEN LOADING FACTOR FOR A GIVEN LAND USE       *
430 REM* P== PHOSPHORUS LOADING FACTOR FOR A GIVEN LAND USE     *
440 REM* AR(I,Q)== ARRAY OF LB/YR REMOVED FOR SELECTED NUTRIENT*
450 REM* CR== PRESENT VALUE OF ORM COSTS                        *
460 REM* EX== EXCAVATION COST FOR POND, BERM, OR TANK           *
470 REM* LA== LAND COSTS FOR ENTRY                              *
480 REM* C(Q)== PRESENT VALUE POND COST FOR DIVERSIO DEPTH Q    *
490 REM* NT== TOTAL NITROGEN LOADING FOR ALL LAND USES          *
500 REM* PT== TOTAL PHOSPHORUS LOADING FOR ALL LAND USES        *
510 REM* RO== ROW NUMBER IN MARGINAL COST ARRAY                 *
520 REM* RI== LBS/YR OF NUTRIENT TO BE REMOVED                  *
530 REM* DO== DOWN POSITION IN MARGINAL COST ARRAY              *
```

```
540 REM* AC== ACROSS POSITION IN MARGINAL COST ARRAY               *
550 REM* AM(I,Q,1)== ARRAY OF MARGINAL COST VALUES                 *
560 REM* AM(I,Q,2)== ARRAY OF MARGINAL COST SOLUTION SET CODE      *
570 REM*   IF AM(I,Q,2)= 0 THEN VALUE IS NOT IN SOULTION    .      *
580 REM*               = 1 THEN VALUE IS IN SOLUTION               *
590 REM*               = 2 THEN VALUE IS NOT IN SOLUTION           *
600 REM* WA== PERCENTAGE OF WATER REMOVED FROM STREAM              *
610 REM* EN== ENGINEERING AND LEGAL COSTS FOR PROJECT              *
620 REM* PE== FINAL CALCULATED PERCENTAGE NUTRIENT REMOVAL         *
630 REM* CA== DOWN POSITION OF SMALLEST MC NOT IN SOLUTION SET *
640 REM* CB== ACROSS POSITION OF SMALLEST MC NOT IN SOULTION SET*
650 REM* CC== SUM OF ALL AR(I,Q) CHOSEN                            *
660 REM* CD== SUM OF ALL AR(I,Q) ELIMINATED FROM ARRAY            *
670 REM* CE== SMALLEST MARGINAL COST VALUE IN ARRAY               *
680 REM* CF== TOTAL NUTRIENT LB/YR REMOVED IN SOLUTION (CC-CD)*
690 REM* CG== TOTAL CAPITAL COST OF PROJECT                       *
700 REM* CJ== DIFFERENCE OF VARIABLES CB-CA                       *
710 REM* CL== SUM OF LAND COSTS FOR PROJECT                       *
720 REM* CM== SUM OF EXCAVATION COSTS FOR PROJECT                 *
730 REM* CN== SUM OF ORM COSTS FOR PROJECT                        *
740 REM* CT== TOTAL COST OF PROJECT                               *
750 REM* CV== TOTAL NITROGEN LB/YR REMOVED                        *
760 REM* CW== TOTAL PHOSPHORUS LB/YR REMOVED                      *
770 REM* CX== CUMMULATIVE PERCENTAGE OF WATER REMOVED             *
780 REM* CY== VALUE OF TOTAL WATER AVAILABLE                      *
790 REM* CZ== VALUE OF TOTAL WATER REMOVED                        *
800 REM* J== SUBSCRIPT OF VARIABLES IN SORT SUBROUTINE            *
810 REM* DA$(J)== SORT SUBROUTINE VALUE OF A$(I)                  *
820 REM* DB$(J)==       "          "     "    "  B$(I)           *
830 REM* DC(J)==        "          "     "    "  CN(I)           *
840 REM* DD(J)==        "          "     "    "  SI(I)           *
850 REM* DE(J)==        "          "     "    "  LA(I)           *
860 REM* DF(J)==        "          "     "    "  AM(I,Q,1)       *
870 REM* T$== TEMPORARY PLACEMENT OF DA$(J) VALUE                *
880 REM* U$==          "           "    DB$(J)    "              *
890 REM* T3==          "           "    DC(J)     "              *
900 REM* T4==          "           "    DD(J)     "              *
910 REM* T5==          "           "    DE(J)     "              *
920 REM* T6==          "           "    DF(J)     "              *
930 REM* FL== LOGIC VALUE REPRESENTING A POSITION CHANGE IN SORT*
940 REM*        FL=0  NO CHANGE                                   *
950 REM*          =1  POSITION CHANGE WAS MADE                    *
960 REM* SL== VARIABLE REPRESENTING NUMBER OF ENTRYS             *
970 NT=0 : PT=0 : LET I=1
980 REM *** SECTION FOR INPUT DATA ***
990 PRINT#-2: PRINT#-2
1000 PRINT#-2,TAB(17);"SELECTION OF POLLUTANT AND DESIRED PERCENTAGE "
1010 PRINT#-2,TAB(17);"REMOVAL UPON WHICH MINIMUM COST ROUTINE WILL"
1020 PRINT#-2,TAB(36);"BE BASED"
1030 PRINT#-2: PRINT#-2,TAB(10);"ENTER '1' FOR NITROGEN"
1040 PRINT#-2,TAB(10);"ENTER '2' FOR PHOSPHORUS"
1050 INPUT SE: PRINT#-2,SE
```

```
1060 PRINT#-2,TAB(10);"ENTER PERCENT POLLUTANT REMOVAL DESIRED"
1070 INPUT PP : PRINT#-2,PP
1080 READ TI$
1090 READ CO(I),CN(I),SI(I),LA(I)
1100 REM *** CHECK FOR ENTRY OF LAST DATA LINE ***
1110 IF CO(I)=999 THEN 2380
1120 FOR Q=1 TO 4
1130 AM(I,Q,2)=0
1140 NEXT Q
1150 REM *** CALCULATION OF 250 ACRE UNITS FOR EACH ENTRY ***
1160 UN(I)=SI(I)*.004
1170 CK(I)=UN(I)
1180 IF CO(I)>7 THEN 1280
1190 REM *** CALCULATION OF POND SIZES FOR TYPE A SOILS ***
1200 V5=0.59+0.0037*CN(I)
1210 PO(I,1)=3.75*V5
1220 PO(I,2)=6.21*V5
1230 PO(I,3)=8.56*V5
1240 PO(I,4)=10.30*V5
1250 B$(I)="A"
1260 GOTO 1360
1270 REM *** CALCULATION OF POND SIZES FOR TYPE D SOILS ***
1280 V2=0.07+0.0092*CN(I)
1290 PO(I,1)=8.30*V2+1.04
1300 PO(I,2)=14.11*V2+2.09
1310 PO(I,3)=17.90*V2+3.13
1320 PO(I,4)=22.08*V2+4.17
1330 B$(I)="D"
1340 REM *** CALCULATION OF LOADING AND REMOVAL VALUES ***
1350 REM ***   FOR FLATWOODS (THE LOWEST LOADING)   ***
1360 LET TI=1
1370 LET N=1
1380 LET P=1
1390 N(I)=N*498
1400 P(I)=P*22.2
1410 NR(I,1)=N*392
1420 PR(I,1)=P*17.76
1430 NR(I,2)=N*441
1440 PR(I,2)=P*20.0
1450 NR(I,3)=N*456
1460 PR(I,3)=P*20.6
1470 NR(I,4)=N*466
1480 PR(I,4)=P*21.1
1490 REM *** CALCULATION OF UNDERGROUND PERCOLATION TANK NUTRIENT REMOVAL ***
1500 IF CO(I)=15 THEN 1510 ELSE 1550
1510 NR(1,4)= .90*N(I)
1520 NR(I,3)=N(I)+10 : NR(I,2)=N(I)+20 : NR(I,1)=N(I)+30
1530 PR(I,4)= .90*P(I)
1540 PR(I,3)=P(I)+10 : PR(I,2)=P(I)+20 : PR(I,1)=P(I)+30
1550 IF TI=2 THEN 2020
1560 ON CO(I) GO TO 1740,1800,1840,1580,2000,1580,1930,1740,1800,1840,1580,2000,
1580,1930,1740
1570 REM *** CALCULATION OF RANGELAND AND PASTURE ***
```

```
1580 N(I)=N*490
1590 P(I)=P*22.2
1600 NR(I,2)=N*294
1610 NR(I,4)=N*392
1620 NR(I,1)=NR(I,2)/10
1630 NR(I,3)=NR(I,2)/10
1640 PR(I,2)=P*17.76
1650 PR(I,4)=P*20.0
1660 PR(I,1)=PR(I,2)/10
1670 PR(I,3)=PR(I,2)/10
1680 IF TI=2 THEN 2020
1690 REM *** SEPARATION OF PASTURE AND RANGELAND***
1700 IF CO(I)=4 THEN 1980
1710 IF CO(I)=11 THEN 1980
1720 GO TO 1880
1730 REM *** ASSIGNMENT OF SCALE UP FACTOR AND LAND USE NAME ***
1740 N=6.14
1750 P=27.0
1760 A$(I)="COMMERCIAL"
1770 IF CO(I)=15 THEN 1780 ELSE 1790
1780 A$(I)="COMM-PERC TANK"
1790 GOTO 1960
1800 N=3.0
1810 P=18.0
1820 A$(I)="RESIDENTIAL"
1830 GOTO 1960
1840 N=2.0
1850 P=2.0
1860 A$(I)="CITRUS"
1870 GOTO 1960
1880 N=3.27
1890 P=12.0
1900 A$(I)="PASTURE"
1910 TI=2
1920 GO TO 1580
1930 N=2.5
1940 P=2.0
1950 A$(I)="SWAMP"
1960 TI=2
1970 GOTO 1390
1980 A$(I)="RANGELAND"
1990 GOTO 2020
2000 A$(I)="FLATWOODS"
2010 GOTO 2020
2020 FOR Q=1 TO 4
2030 REM *** PLACEMENT OF SELECTED POLLUTANT INTO REMOVAL CALCULATIONS ***
2040 IF SE=2 THEN 2070
2050 AR(I,Q)=NR(I,Q)
2060 GOTO 2080
2070 AR(I,Q)=PR(I,Q)
2080 ON CO(I) GO TO 2120,2120,2140,2160,2140,2160,2140,2120,2120,2140,2160,2140,
2160,2140,2100
2090 REM *** CALCULATION OF ORM COSTS ***
```

```
2100 CR=8.51*12500
2110 GO TO 2270
2120 CR=275*8.51*PO(I,Q)
2130 GO TO 2290
2140 CR=50*8.51*PO(I,Q)
2150 GO TO 2290
2160 CR=50*8.51*PO(I,Q)
2170 REM *** CALCULATION OF RANGELAND OR PASTURE COST AND MARGINAL COST ***
2180 C(Q)=750+1.25*PO(I,Q)*LA(I)+CR+5000
2190 IF Q=2 THEN 2200 ELSE 2210
2200 C(Q)=C(Q)-3000
2210 AM(I,Q,1)=C(Q)/AR(I,Q)
2220 IF Q=4 THEN 2230 ELSE 2250
2230 AM(I,3,1)=AM(I,4,1)-1
2240 AM(I,1,1)=AM(I,2,1)-1
2250 GO TO 2310
2260 REM *** CALCULATION OF REMAINING CATEGORIES COST AND MARGINAL COST ***
2270 C(Q)= 1.25*2500*250*(CN(I)-50)*.0208+CR
2280 GO TO 2300
2290 C(Q)=750+15875*PO(I,Q)+1.25*PO(I,Q)*LA(I)+CR
2300 AM(I,Q,1)=C(Q)/AR(I,Q)
2310 NEXT Q
2320 REM *** CALCULATION OF TOTAL POLLUTANT LOADING ***
2330 IF CO(I)=15 THEN 2360
2340 NT=NT+N(I)*UN(I)
2350 PT=PT+P(I)*UN(I)
2360 I=I+1
2370 GOTO 1090
2380 RO=I-1
2390 IF SE=2 THEN 2430
2400 REM *** CALCULATION OF DESIRED POLLUTANT WEIGHT REMOVED ***
2410 RI=PP*NT/100
2420 GOTO 2450
2430 RI=PP*PT/100
2440 REM *** LOGIC FOR SOLUTION OF PROBLEM BASED UPON MINIMUM MARGINAL COSTS ***
2450 CC=0 : CD=0
2460 CE=1000000
2470 DO=1
2480 AC=1
2490 IF AM(DO,AC,2)=0 THEN 2500 ELSE 2540
2500 IF AM(DO,AC,1)>= CE THEN 2560
2510 CA=DO : CB=AC
2520 CE=AM(DO,AC,1)
2530 GOTO 2560
2540 IF AC=4 THEN 2560
2550 AC=AC+1: GOTO 2490
2560 IF DO=RO THEN 2590
2570 DO=DO+1
2580 GO TO 2480
2590 AM(CA,CB,2)=1
2600 CC=AR(CA,CB)*UN(CA)+CC
2610 IF CB=1 THEN 2650
```

```
2620 CJ=CB-1
2630 AM(CA,CJ,2)=2
2640 CD=AR(CA,CJ)*UN(CA)+CD
2650 CF=CC-CD
2660 GOTO 2840
2670 REM ***DEBUG PRINT COMMANDS***
2680 PRINT#-2,"CHEAP-CE",CE
2690 PRINT#-2,"DOWN-DO",DO
2700 PRINT#-2,"ACROSS-AC",AC
2710 PRINT#-2,"CA",CA
2720 PRINT#-2,"CB",CB
2730 PRINT#-2,"CB-1 OR CJ",CJ
2740 PRINT#-2,"NTOT-NT",NT
2750 PRINT#-2,"AMC-NM",AM(CA,CB,1)
2760 PRINT#-2,"C(I)",C(CA)
2770 PRINT#-2,"PTOT-PT",PT
2780 PRINT#-2,"RID-RI",RI
2790 PRINT#-2,"PP        ",PP
2800 PRINT#-2,"NREM-NR",NR(CA,CB)
2810 PRINT#-2,"NRE-CF",CF
2820 PRINT#-2,"NON-CC",CC
2830 PRINT#-2,"NOFF-CD",CD
2840 IF CF<RI THEN 2460
2850 REM ***ELIMINATION OF SOME SOLUTION SET VALUES***
2860 REM ***TO FINE TUNE THE DESIRED PERCENTAGE REMOVAL***
2870 IF CB=1 THEN 2890
2880 CD=CD-AR(CA,CJ)
2890 CC=CC-AR(CA,CB)
2900 CK(CA)=CK(CA)-1
2910 CF=CC-CD
2920 IF CF>RI THEN 2870
2930 IF CB=1 THEN 2950
2940 CD=CD+AR(CA,CJ)
2950 CC=CC+AR(CA,CB)
2960 CK(CA)=CK(CA)+1
2970 CF=CC-CD
2980 REM **PRINTING OF INPUT TABLE**
2990 FOR II=1 TO 10
3000 PRINT#-2
3010 NEXT II
3020 PRINT#-2,TAB(15);"********** ";TI$;" **********"
3030 PRINT#-2 : PRINT#-2
3040 PRINT#-2,TAB(35);"TABLE 1"
3050 PRINT#-2,TAB(33);"INPUT VALUES"
3060 PRINT#-2: PRINT#-2
3070 PRINT#-2,"ENTRY";TAB(10);"LAND";TAB(24);"SOIL";TAB(40);"CURVE";TAB(54);"NUM
BER";TAB(68);"LAND COST"
3080 PRINT#-2,"NUMBER";TAB(11);"USE";TAB(24);"TYPE";TAB(40);"NUMBER";TAB(53);"OF
 ACRES";TAB(68);"($/ACRE)
3090 PRINT#-2
3100 FOR I=1 TO RO
3110 PRINT#-2,TAB(2);I;TAB(7);A$(I);TAB(26);B$(I);TAB(42);CN(I);TAB(55);SI(I),TA
B(70);LA(I)
3120 NEXT I
3130 PRINT#-2
```

```
3140 PRINT#-2,"DESIRED PERCENT REMOVAL IS==";PP
3150 IF SE=2 THEN 3180
3160 PRINT#-2,"SELECTED POLLUTANT IS NITROGEN"
3170 GOTO 3190
3180 PRINT#-2,"SELECTED POLLUTANT IS PHOSPHORUS"
3190 REM ** PRINTING OF MARGINAL COST TABLE**
3200 FOR II=1 TO 5
3210 PRINT#-2
3220 NEXT II
3230 PRINT#-2,TAB(35);"TABLE 2"
3240 PRINT#-2,TAB(29);"MARGINAL COST TABLE"
3250 PRINT#-2 : PRINT#-2
3260 PRINT#-2,TAB(23);"MARGINAL COST (IN $/LB REMOVED)"
3270 PRINT#-2,TAB(26);"STRUCTURE DIVERSION DEPTH"
3280 PRINT#-2,TAB(4);"ENTRY";TAB(19);".25 INCH";TAB(34);".50 INCH";TAB(49);".75
INCH";TAB(63);"1.00 INCH"
3290 PRINT#-2
3300 FOR I=1 TO RO
3310 PRINT#-2,TAB(5);I;:
3320 PRINT#-2,TAB(20):PRINT#-2,USING"######.";AM(I,1,1);:
3330 PRINT#-2,TAB(35):PRINT#-2,USING"######.";AM(I,2,1);:
3340 PRINT#-2,TAB(50):PRINT#-2,USING"######.";AM(I,3,1);:
3350 PRINT#-2,TAB(65):PRINT#-2,USING"######.";AM(I,4,1)
3360 NEXT I
3370 REM **PRINTING OF SELECTION TABLE**
3380 FOR II=1 TO 5
3390 PRINT#-2
3400 NEXT II
3410 PRINT#-2,TAB(35);"TABLE 3"
3420 PRINT#-2,TAB(23);"MINIMUM COST SOLUTION BASED UPON"
3430 IF SE=2 THEN 3460
3440 PRINT#-2,TAB(35);"NITROGEN"
3450 GO TO 3470
3460 PRINT#-2,TAB(34);"PHOSPHORUS"
3470 PRINT#-2 : PRINT#-2
3480 PRINT#-2,TAB(3);"LAND";TAB(15);"SOIL";TAB(25);"CURVE";TAB(35);"NUMBER";TAB(
45);"LAND COST";TAB(56);"MARGINAL COST
3490 PRINT#-2,TAB(4);"USE";TAB(15);"TYPE";TAB(25);"NUMBER";TAB(34);"OF ACRES";TA
B(45);"($/ACRE)";TAB(61);"($/LB)"
3500 PRINT#-2
3510 J=0
3520 FOR I=1 TO RO
3530 FOR Q=1 TO 4
3540 IF AM(I,Q,2)=1 THEN 3550 ELSE 3630
3550 J=J+1
3560 DA$(J)=A$(I)
3570 DB$(J)=B$(I)
3580 DC(J)=CN(I)
3590 DD(J)=SI(I)
3600 DE(J)=LA(I)
3610 DF(J)=AM(I,Q,1)
3620 Q=4
3630 NEXT Q : NEXT I
3640 GOSUB 4850
3650 REM
```

```
3660 FOR I=1 TO J
3670 PRINT#-2,DA$(I);TAB(17);DB$(I);TAB(25);DC(I);TAB(36);DD(I);TAB(47);DE(I);:
3680 PRINT#-2,TAB(61):PRINT#-2,USING"####.";DF(I)
3690 NEXT I
3700 REM
3710 REM **PRINTING OF LOADING AND REMOVAL VALUES**
3720 FOR I=1 TO 5
3730 PRINT#-2
3740 NEXT I
3750 PRINT#-2,TAB(35);"TABLE 4"
3760 PRINT#-2,TAB(22);"POLLUTANT LOADING AND REMOVAL VALUES"
3770 PRINT#-2 : PRINT#-2
3780 PRINT#-2,TAB(14);"POLLUTANT LOADING";TAB(57);"REMOVAL OF"
3790 PRINT#-2,"ENTRY        NITROGEN       PHOSPHORUS              NITROGEN        PHOSPHOR
US    WATER"
3800 PRINT#-2,TAB(12);"(LBS/YR)";TAB(27);"(LBS/YR)";TAB(45);"(LBS/YR)";TAB(60);"
(LBS/YR)";TAB(72);"(%)"
3810 PRINT#-2
3820 WA=0 : WT=0
3830 FOR I=1 TO RO
3840 FOR Q=1 TO 4
3850 IF AM(I,Q,2)=1 THEN 3890 ELSE 3860
3860 IF Q<4 THEN 4180 ELSE 3870
3870 PO(I,Q)=0 : NR(I,Q)=0 : PR(I,Q)=0 : WA(Q)=0 : CK(I)=0
3880 GOTO 3990
3890 IF CN(I)<70 THEN 3900 ELSE 3920
3900 WA(1)=45 : WA(2)=67 : WA(3)=80 : WA(4)=87
3910 GOTO 3990
3920 IF CN(I)<80 THEN 3930 ELSE 3950
3930 WA(1)=38 : WA(2)=58 : WA(3)=70 : WA(4)=79
3940 GOTO 3990
3950 IF CN(I)<90 THEN 3960 ELSE 3980
3960 WA(1)=35 : WA(2)=50 : WA(3)=60 : WA(4)=68
3970 GOTO 3990
3980 WA(1)=33 : WA(2)=50 : WA(3)=60 : WA(4)=68
3990 ON CO(I) GO TO 4010,4010,4000,4000,4010,4000,4010,4010,4010,4000,4000,4010,
4000,4010,4000
4000 WA(1)=0 : WA(2)=0 : WA(3)=0 : WA(4)=0
4010 PRINT#-2,TAB(3);I;:
4020 N(I)=N(I)*UN(I)
4030 P(I)=P(I)*UN(I)
4040 NR=NR*CK(I)
4050 PR=PR*CK(I)
4060 NR(I,Q)=NR(I,Q)*CK(I)
4070 PR(I,Q)=PR(I,Q)*CK(I)
4080 PRINT#-2,TAB(13):PRINT#-2,USING"#####.";N(I);:
4090 PRINT#-2,TAB(28):PRINT#-2,USING"#####.";P(I);:
4100 PRINT#-2,TAB(45):PRINT#-2,USING"#####.";NR(I,Q);:
4110 PRINT#-2,TAB(60):PRINT#-2,USING"#####.";PR(I,Q);:
4120 PRINT#-2,TAB(72):PRINT#-2,USING"#####.";WA(Q)
4130 CV=CV+NR(I,Q)
4140 CW=CW+PR(I,Q)
4150 CZ=CZ+WA(Q)*CK(I)
4160 CY=100*UN(I)+CY
4170 Q=4
```

```
4180 NEXT Q
4190 NEXT I
4200 CX=100*CZ/CY
4210 PRINT#-2: PRINT#-2
4220 PRINT#-2,"TOTALS";:
4230 PRINT#-2,TAB(13):PRINT#-2,USING"######.";NT;:
4240 PRINT#-2,TAB(28):PRINT#-2,USING"######.";PT;:
4250 PRINT#-2,TAB(45):PRINT#-2,USING"######.";CV;:
4260 PRINT#-2,TAB(60):PRINT#-2,USING"######.";CW;:
4270 PRINT#-2,TAB(72):PRINT#-2,USING"######.";CX
4280 IF SE=2 THEN 4310
4290 PE=100*CV/NT
4300 GOTO 4320
4310 PE=100*CW/PT
4320 PRINT#-2: PRINT#-2,"PERCENTAGE POLLUTANT REMOVAL = ";:
4330 PRINT#-2,USING"##.#";PE
4340 REM **PRINTING OF COST TABLE**
4350 FOR II=1 TO 5
4360 PRINT#-2: NEXT II
4370 PRINT#-2,TAB(36);"TABLE 5"
4380 PRINT#-2,TAB(24);"COST TABLE - IN THOUSANDS OF DOLLARS"
4390 PRINT#-2: PRINT#-2
4400 PRINT#-2,TAB(4);"ENTRY";TAB(10);"LAND USE";TAB(26);"LAND COST";TAB(37);"COI
STRUCTION COST";TAB(58);"ORM COST";TAB(72);"TOTAL"
4410 PRINT#-2
4420 LA=0: CR=0 :EX=0 :CT=0
4430 FOR I=1 TO RO
4440 FOR Q=1 TO 4
4450 IF AM(I,Q,2)=1 THEN 4460 ELSE 4710
4460 ON CO(I) GO TO 4510,4510,4530,4530,4530,4530,4530,4510,4510,4530,4530,4530,
4530,4530,4470
4470 CR=8.51*12500*CK(I)/1000
4480 EX=2500*250*(CN(I)-50)*CK(I)*0.0208/1000
4490 LA=LA(I)*CK(I)/1000
4500 GO TO 4630
4510 CR=2340*PO(I,Q)*CK(I)/1000
4520 GO TO 4610
4530 CR=425.5*PO(I,Q)*CK(I)/1000
4540 IF CO(I)=4 THEN 4580
4550 IF CO(I)=6 THEN 4580
4560 IF CO(I)=11 THEN 4580
4570 IF CO(I)=13 THEN 4580 ELSE 4610
4580 IF Q>2 THEN 4600
4590 EX=2*UN(I) : GO TO 4620
4600 EX=5*UN(I) : GO TO 4620
4610 EX=12700*PO(I,Q)*CK(I)/1000
4620 LA=PO(I,Q)*LA(I)*CK(I)/1000
4630 CT=CR+EX+LA
4640 PRINT#-2,TAB(5);I;:
4650 PRINT#-2,TAB(9);A$(I);:
4660 PRINT#-2,TAB(27):PRINT#-2,USING"######.";LA;:
4670 PRINT#-2,TAB(42):PRINT#-2,USING"######.";EX;:
4680 PRINT#-2,TAB(59):PRINT#-2,USING"######.";CR;:
4690 PRINT#-2,TAB(71):PRINT#-2,USING"######.";CT
```
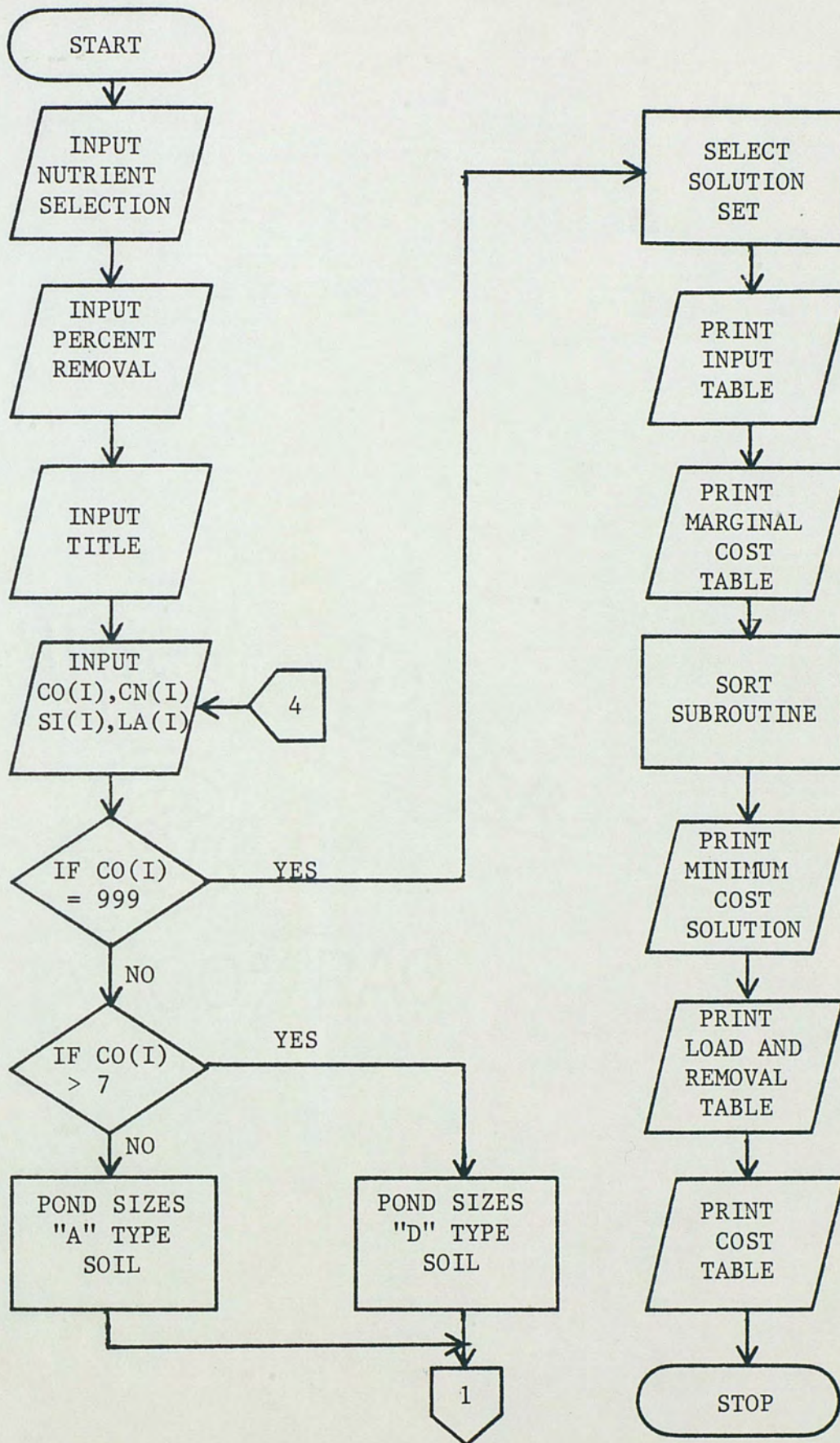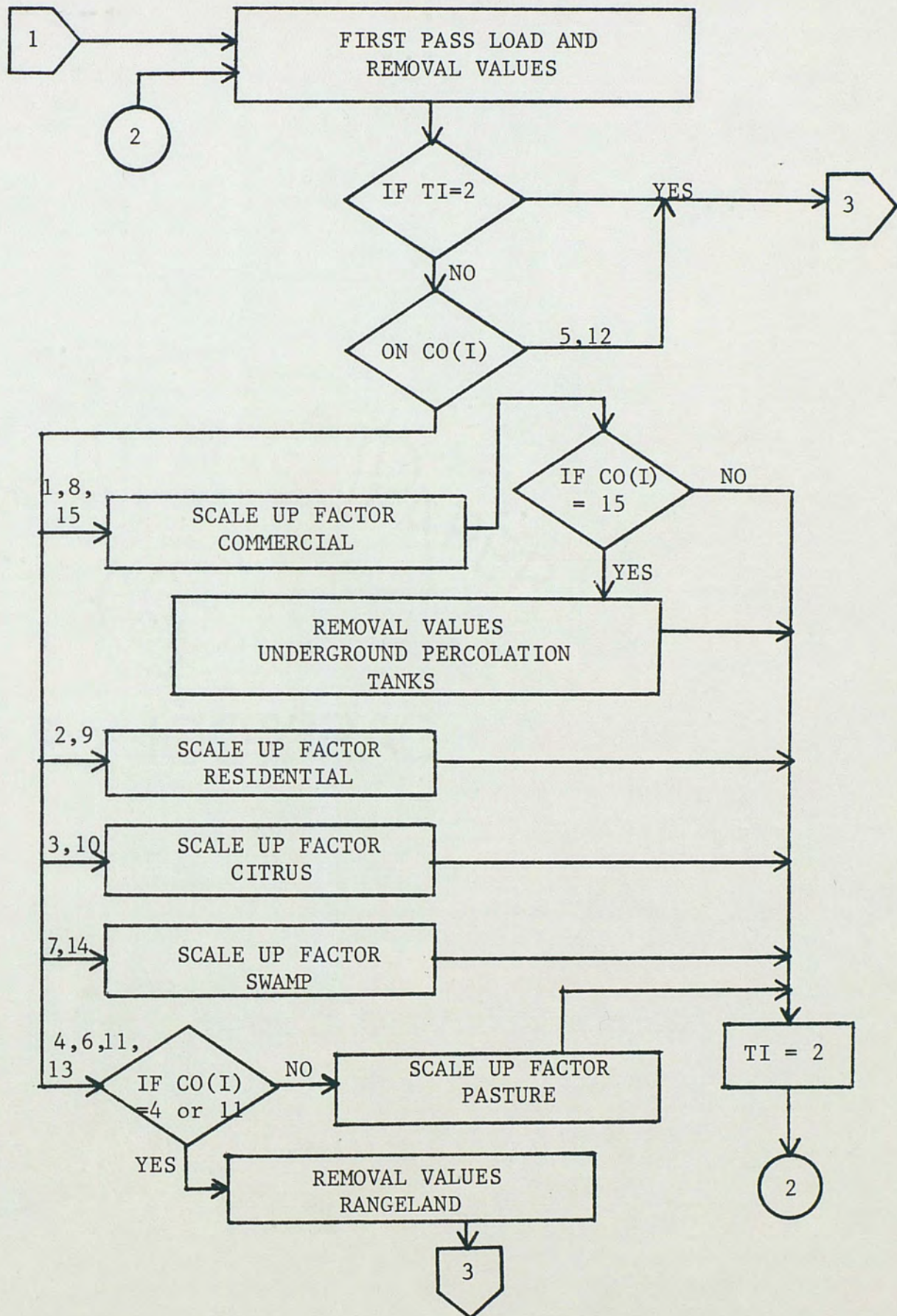
```
4700 CL=CL+LA : CM=CM+EX : CN=CN+CR : CO=CO+CT
4710 NEXT Q : NEXT I
4720 PRINT#-2
4730 PRINT#-2,"TOTALS";:
4740 PRINT#-2,TAB(27):PRINT#-2,USING"######.";CL;:
4750 PRINT#-2,TAB(42):PRINT#-2,USING"######.";CM;:
4760 PRINT#-2,TAB(59):PRINT#-2,USING"######.";CN;:
4770 PRINT#-2,TAB(71):PRINT#-2,USING"######.";CO
4780 EN=.25*CO
4790 PRINT#-2: PRINT#-2
4800 PRINT#-2,"ENGINEERING AND LEGAL = ";:
4810 PRINT#-2,TAB(71):PRINT#-2,USING"######.";EN
4820 CO=CO+EN
4830 PRINT#-2:PRINT#-2,"TOTAL EXPENSE = ";:
4840 PRINT#-2,TAB(71):PRINT#-2,USING"######.";CO
4850 REM *** SOLUTION SORT SUBROUTINE ***
4860 FL=0
4870 SL=J
4880 FOR J=1 TO SL-1
4890 IF DF(J)<DF(J+1) THEN 4980
4900 T$=DA$(J+1) : U$=DB$(J+1) : T3=DC(J+1)
4910 T4=DD(J+1) : T5=DE(J+1) : T6=DF(J+1)
4920 DA$(J+1)=DA$(J) : DB$(J+1)=DB$(J) : DC(J+1)=DC(J)
4930 DD(J+1)=DD(J) : DE(J+1)=DE(J)
4940 DF(J+1)=DF(J)
4950 DA$(J)=T$ : DB$(J)=U$ : DC(J)=T3
4960 DD(J)=T4 : DE(J)=T5 : DF(J)=T6
4970 FL=1
4980 NEXT J
4990 IF FL=1 THEN 4860
5000 RETURN
5010 DATA LAKE TOHOPEKALIGA WATERSHED
5020 DATA 1,80,293.2,7000
5030 DATA 1,80,306,3500
5040 DATA 1,80,913.3,10000
5050 DATA 8,95,1530,3500
5060 DATA 8,95,3570,11500
5070 DATA 2,65,9792,11500
5080 DATA 2,65,1435.4,5000
5090 DATA 2,65,1492.9,7000
5100 DATA 2,65,1868.1,3000
5110 DATA 9,85,758.1,4500
5120 DATA 9,85,49.9,4000
5130 DATA 3,55,5444.8,0
5140 DATA 11,75,42276.6,0
5150 DATA 4,55,1734,0
5160 DATA 12,70,8348.7,3000
5170 DATA 12,70,7752.5,2000
5180 DATA 12,70,7140,3500
5190 DATA 6,55,8468.8,0
5200 DATA 13,75,14931.9,0
5210 DATA 15,80,293.2,0
5220 DATA 999,999,999,999
```
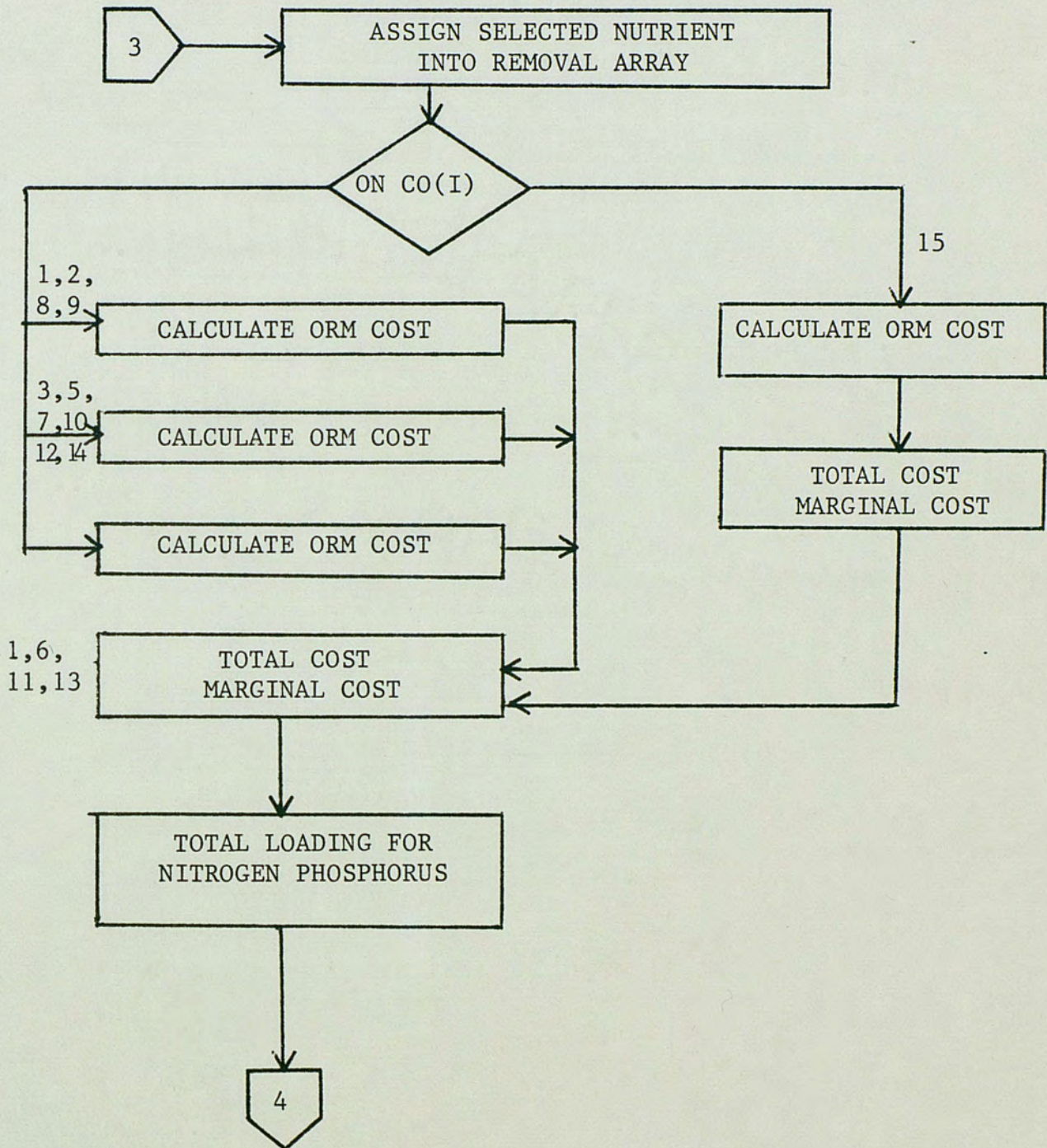
APPENDIX B

"SELECT" FLOW CHART

START

INPUT
NUTRIENT
SELECTION

INPUT
PERCENT
REMOVAL

INPUT
TITLE

INPUT
CO(I),CN(I)
SI(I),LA(I) ← 4

IF CO(I)
= 999 → YES

NO

IF CO(I)
> 7 → YES

NO

POND SIZES
"A" TYPE
SOIL

POND SIZES
"D" TYPE
SOIL

1

SELECT
SOLUTION
SET

PRINT
INPUT
TABLE

PRINT
MARGINAL
COST
TABLE

SORT
SUBROUTINE

PRINT
MINIMUM
COST
SOLUTION

PRINT
LOAD AND
REMOVAL
TABLE

PRINT
COST
TABLE

STOP

APPENDIX C

FENCING WITH GRASSY BARRIER AS AN
OPTIONAL MANAGEMENT METHOD

The Johnson property near Kissimmee, Florida is used as an example. To be in the solution set, a marginal cost for nitrogen at 45% removal must be less than $62 per pound removed.

Given:

1. size of watershed   =   1600 acres

2. land use   =   rangeland

3. stream length in watershed =   7000 feet

4. barrier width   =   100 feet

5. fencing cost   = $1 per 1 foot of fence

DETERMINE:

Cost of land to make fencing a recommended option:

$$\text{Land required} = \frac{(7000 \text{ ft length}) \times (2 \times 100 \text{ ft width})}{(43,560 \text{ ft}^2/\text{acre})} = 32.14 \text{ acre}$$

Maximum fencing cost:

($62/lb N removed)(1.80 lb N/acre)(1600 acre) x

$$(\frac{.85 \text{ lb N removed}}{\text{lb N load}}) = \$148,400$$

Elimination of engineering and legal fees:

$$= \$148,400 \ (\frac{1}{1.25}) = \$118,722$$

79

Determination of land cost:

= $118,722 - construction cost - ORM cost

= $118,722 - (7000 ft stream)$(\frac{2 \text{ ft fence}}{\text{foot stream}})(\frac{\$1}{1 \text{ ft fence}})$

   $- (\frac{\$50}{\text{acre/yr}})(32.14 \text{ acre})(8.51 \text{ present value factor})$

= $118,722 - $14,000 - $13,700

= $91,022

Land cost per acre = $91,022/32.14 acre

                   = $2832/acre

Therefore, if stream bank land can be purchased for less than $2832/acre, fencing with grassy barrier is recommended.

APPENDIX D

COST VALUES FOR DAIRY LAND USE

The dairy land runoff waters are collected from the lagoons and the pasture lands. These runoff waters are collected into a central ditch from which waters are pumped into Lake Tohopekaliga. One treatment measure would be to landspread these waters back on the pasture lands. Two pumps with a system of pipes are suggested with an application rate of 1" per week or less during "wet" conditions. The following summarizes the assumptions in calculating cost.

Size of Dairy Operation = 250 acres

Nutrient Loading	lb/acre-year	lb/year
Nitrogen	9.0	2250
Phosphorus	4.2	1000

Treatment Depth for Nutrient Selection

Phosphorus	1.00
Nitrogen	.50

Amount of Nutrient Removed (lb/year)

	Selected Nutrient	
	Phosphorus	Nitrogen
Nitrogen	2138	2025
Phosphorus	950	900

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Construction Cost

Nitrogen Case	$40,000
Phosphorus Case	$70,000

Present Value, ORM and Operating Costs   Present Value (20 yr,10%)

ORM	$2,000/yr	17,020
Operating (pumping)	$6,000/yr	51,060

Marginal Cost ($/lb removed)

Nitrogen	$ 53
Phosphours	$153

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