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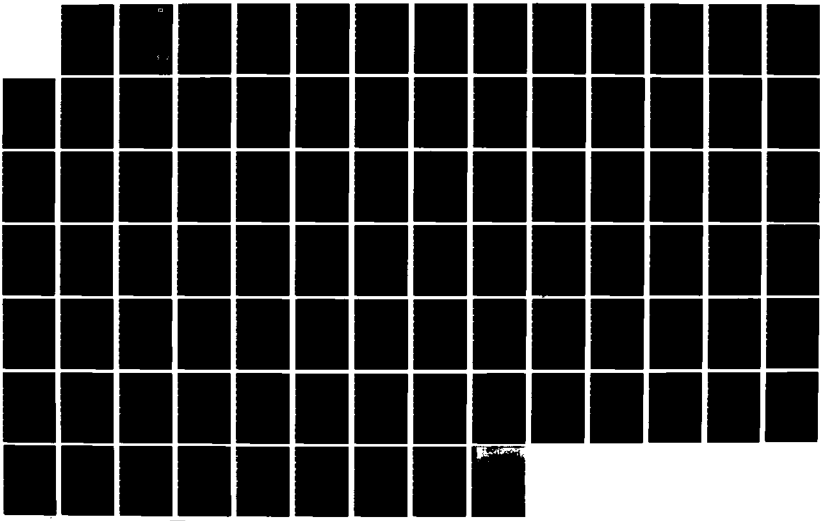

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Special Report 83-26

September 1983

US Army Corps of Engineers
Cold Regions Research & Engineering Laboratory

Land treatment processes within CAPDET

(Computer-assisted procedure for the design and evaluation of wastewater treatment systems)

C.J. Merry, M.W. Corey, J.W. Epps, R.W. Harris and M.J. Cullinane, Jr.

Prepared for
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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: Special Report 83-26
2. GOVT ACCESSION NO.: AD-A134 766
3. RECIPIENT'S CATALOG NUMBER:
4. TITLE (and Subtitle): LAND TREATMENT PROCESSES WITHIN CAPDET (COMPUTER-ASSISTED PROCEDURE FOR THE DESIGN AND EVALUATION OF WASTEWATER TREATMENT SYSTEMS)
5. TYPE OF REPORT & PERIOD COVERED:
6. PERFORMING ORG. REPORT NUMBER:
7. AUTHOR(s): C.J. Merry, M.W. Corey, J.W. Epps, R.W. Harris and M.J. Cullinane, Jr.
8. CONTRACT OR GRANT NUMBER(s): CWIS 31633
9. PERFORMING ORGANIZATION NAME AND ADDRESS: U. S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire 03755
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS:
11. CONTROLLING OFFICE NAME AND ADDRESS: Office of the Chief of Engineers, Washington, D.C. 20314
12. REPORT DATE: September 1983
13. NUMBER OF PAGES: 90
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):
15. SECURITY CLASS. (of this report): Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:

16. DISTRIBUTION STATEMENT (of this Report): Approved for public release; distribution unlimited.
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report):
18. SUPPLEMENTARY NOTES:
19. KEY WORDS (Continue on reverse side if necessary and identify by block number):
    - Computer aided design
    - Computerized simulation
    - Land treatment
    - Wastewater treatment
20. ABSTRACT (Continue on reverse side if necessary and identify by block number):

A summary of the first-, second-, and third-order design steps for the three land treatment unit processes (slow infiltration, rapid infiltration and overland flow) within the CAPDET model is presented. The first-order design, consisting of the basic sanitary engineering processes for slow infiltration, rapid infiltration, and overland flow, is described in terms of the selected procedures and the computer format. The second-order design is a description of the quantities and sizes calculated for each land treatment process. The third-order design is the calculation of the unit process costs by applying prices to the quantities and sizes calculated during the second-order design step.

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PREFACE

This report was prepared by Carolyn J. Merry, Geologist, Earth Sciences Branch, Research Division, U.S. Army Cold Regions Research and Engineering Laboratory (Part 1); Dr. Marion W. Corey and Dr. James W. Epps, Department of Civil Engineering, Mississippi State University (Part 2); and Roy W. Harris, Clark, Dietz and Associates-Engineers, Inc., and M. John Cullinane Jr., Environmental Laboratory, Waterways Experiment Station (Part 3). The study was funded by the Directorate of Civil Works, Office of the Chief of Engineers, under the Corps of Engineers Civil Works Project CWIS 31633 as part of the Corps of Engineers Land Treatment of Wastewater Research Program. The cost estimation system development was sponsored jointly by the Environmental Protection Agency, Office of Water Program Operations, and the Directorate of Civil Works, Office, Chief of Engineers.

The authors express their appreciation to Patricia A. Spaine (Waterways Experiment Station) for her assistance in ensuring that the land treatment design formulations were compatible with the CAPDET program format; Dr. Paul T. Sun for his assistance in development of the cost estimating system for the CAPDET program; Dr. Harlan L. McKim for his invaluable guidance as program manager of the Land Treatment of Wastewater Research and Development Program; Thomas F. Jenkins, C. James Martel and Antonio J. Palazzo for their constructive comments and useful discussions on designing land treatment systems; and to C. James Martel, Antonio J. Palazzo and Dr. Charles Daley for technical review of this report.

The contents of this report are not to be used for advertising or promotional purposes. Citation of brand names does not constitute an official endorsement or approval of the use of such commercial products.

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LIST OF SYMBOLS

A_v	ammonia volatilization
ABZ	area required for buffer zone
ADR	area for ditches and roads
AR	application rate, determined by such factors as soils, geology and crop need
ASL	area for storage lagoons
$(Av)_f$	percent of total nitrogen applied lost to volatilization
C_b	applied BOD_5 concentration
C_n	applied nitrogen concentration
C_p	percolate nitrogen concentration
C_{pp}	percolate PO_4 concentration
C_{rb}	runoff BOD_5 concentration
C_{rn}	runoff nitrogen concentration
C_{rp}	runoff water PO_4 concentration
CAGH	area which requires heavy clearing
CAGL	area which requires light clearing
CAGM	area which requires medium clearing
CDIA	diameter of underdrain collection header pipe
CDIAHN	diameter of segments of header pipe
CDIAN	diameter of concrete drain pipe
CF	correction factor for other minor construction costs
CHPCN	installed cost of various size header pipes for center pivot
COCP	cost of a center pivot sprinkler system capable of irrigating 200 acres
COSP	cost per ft of 12-in.-diam welded steel pipe in-place
COSTBV	installed cost of butterfly valves
COSTCG	cost for clearing and grubbing site
COSTCP	total cost of center pivot system
COSTE	cost of earthwork
COSTEL	cost of earthwork for levees
COSTEN	cost per sprinkler
COSTF	installed cost of fencing
COSTL	cost of land for facility
COSTLP	cost of lateral pipe of diameter DIAL
COSTLV	installed cost of lateral valves
COSTM	cost of monitoring wells
COSTMP	cost of pumps for monitoring wells
COSTMW	total cost of monitoring wells
COSTN	installed cost of nozzles
COSTOD	cost of runoff collection by open ditch
COSTHP	cost of header pipe of diameter PIPE
COSTP	cost of pipe of diameter DIAL as percent of cost of standard size lateral pipe
COSTPB	cost of pump building
COSTPD	cost of pumps and drivers
COSTPN	cost of pipe of diameter DIAHN as percent of cost of standard size header pipe
COSTPS	cost of standard size pump (3,000 gpm)

COSTRC	cost of center pivot system of size SCP as percent of standard size system
COSTRL	cost of lateral pipe of diameter DIAL as percent of cost of standard size pipe
COSTRLV	cost of lateral valve of size DLV as percent of cost of standard size valve
COSTRN	cost of drain pipe of size CDIAN as percent of cost of standard size (24-in.-diam) drain pipe
COSTRO	cost of pump and drivers of capacity GPMP, as percent of cost of standard size pump
COSTRP	cost of header pipe of diameter PIPE as percent of cost of standard size pipe
COSTRV	cost of butterfly valve of size DBV as percent of standard size valve
COSTRW	total cost of recovery wells
COSTS	installed cost of sprinklers
COSTSBS	cost of standard 3,000 scfm at 8 psig capacity rotary positive displacement blower
COSTSBM	cost of standard 12,000 scfm at 8 psig capacity vertically split multistage centrifugal blower
COSTSBL	cost of standard 50,000 scfm at 8 psig capacity pedestal-type single-stage centrifugal blower
COSTSC	cost of standard size pipe (24-in.-diam reinforced concrete pipe)
COSTSSP	cost of standard size pipe (12-in. diam)
COSTSP	cost of standard size system (200 acres)
COSTSV	cost of 12-in. standard size butterfly valve
COSTU	cost of underdrain system
COSTUC	cost of underdrain collection header pipe of diameter CDIA as percent of cost of standard size pipe
COSTUL	installed cost of underdrain laterals
COSTW	cost of recovery wells
COSTWP	cost of pumps for recovery wells
D_f	nitrogen loss as a percent of total applied nitrogen
D	denitrification
DBV	diameter of butterfly valves
DC	depth of cut
DF	depth of fill
DIAHN	diameter of header pipe
DIAL	diameter of lateral pipe
DLV	diameter of lateral valves
DMW	depth of monitoring wells
DPIPE	length of 6-in. drain pipe required
DPW	days per week treatment system is operated
DW	depth of recovery wells
E_f	percent of total applied wastewater lost through evaporation
E	water loss due to evaporation
EBF	fraction of pipe cost for trenching and backfilling
EBFD	cost for trenching and backfilling as fraction of pipe cost
ET	potential evapotranspiration
FAP	field application period
FLOW	actual daily flow to spray field
FLOWR	wastewater flow to each basin
FPC	firm pumping capacity
FPH	flow per header
FPL	flow per lateral

FPS	flow per sprinkler
GPM	design capacity of pumps
GPMB	design flow per battery
GPMP	design capacity of the individual pumps
GF	average daily generated design flow
HPD	hours per day treatment system is operated
IBA	area of individual infiltration basins
ICHPN	installed cost of various size header pipes
ICRCN	installed cost of each size drain pipe
ICUCH	installed cost of underdrain collection header pipes
IPC	installed pumping equipment cost
KWH	electrical energy required
L_b	wastewater BOD_5 loading
L_{BOD_5}	total BOD_5 loading
L_n	wastewater nitrogen loading
L_p	wastewater phosphorus loading
$L(SBOD_5)$	soluble BOD_5 loading
L_t	wastewater-nitrogen (total) loading
L_w	wastewater hydraulic loading
L	length of one side of lagoon cell
LB	length of one side of infiltration basin
LCDIAN	length of segment of header pipe of diameter CDIAHN
LDCH	length of underdrain collection header pipe of diameter CDIA
LDIAHN	length of header pipe of diameter DIAHN
LDIAL	length of lateral pipe required
LDIAN	length of drain pipe of given diameter
LDIT	total length of ditches for system
LDP	length of drain pipe
LF	length of fence required
LL	length of laterals
LLAT	length of lateral pipe of diameter DIAL
LPIPE	length of header pipe required
LTA	length of one side of treatment area
MAR	maximum application rate
MMH	maintenance power requirement
MSECI	current Marshall and Swift Equipment Cost Index
MWPR	cost of well pump as fraction of cost of standard pump
N	number of laterals
NB	number of batteries
NBV	number of butterfly valves
NCDIAN	number of points where same diameter pipe was chosen
NCP	number of center pivot systems
NF	number of points at which flow is removed from header
NH	number of headers
NIB	number of infiltration basins
NLC	number of lagoon cells
NLH	number of laterals per header
NLV	number of lateral valves
NMW	number of monitoring wells
$(NO_2)_i$	nitrite-nitrogen concentration in applied wastewater
$(NO_3)_i$	nitrate-nitrogen concentration in applied wastewater
NO	number of points where the same diameter pipe was chosen
NP	number of pumps required to handle design flow
NS	number of sprinklers
NSH	number of sprinklers per header

NSL	number of sprinklers per lateral
NW	number of recovery wells
OMH	operating manpower required
OMMC	operation and maintenance material and supply cost
OMMHD	operation and maintenance manpower for distribution system
OMMHM	operation and maintenance manpower for monitoring well
OMMHO	operation and maintenance manpower for runoff collection by open ditch
OMMHP	operation and maintenance manpower for runoff collection by gravity pipe
OMMHU	operation and maintenance manpower for underdrain system
OMMHW	operation and maintenance manpower for water recovery by wells
OMMP	operation and maintenance material and supply cost, as percent of total bare construction cost
OMMPD	operation and maintenance material costs for distribution system as percent construction cost of distribution system
OMMPGP	operation and maintenance material costs for runoff collection by gravity pipe as percent construction cost for gravity pipe system
OMMPM	operation and maintenance material costs as percent of construction cost of monitoring wells
OMMPO	operation and maintenance material costs for runoff collection by open ditch as percent construction cost for open ditch system
OMMPU	operation and maintenance material cost as percent of construction cost of underdrain system
OMMPW	operation and maintenance material cost for water recovery wells as percentage of construction cost of recovery wells
P_n	nitrogen in the precipitation
Pr	precipitation
PBA	pump building area
PCAGH	percentage of treatment area requiring heavy clearing
PCAGL	percentage of treatment area requiring light clearing
PCAGM	percentage of treatment area requiring medium clearing
PIPE	diameter of header pipe
Q	average wastewater flow
R	net runoff from the site
RMWC	cost of well as fraction of cost of standard pipe
RS	replacement schedule
RSE	replacement schedule for equipment
RSP	replacement schedule for sprinklers
RSS	replacement schedule for structures
RWC	recovery well cost as fraction of cost of standard pipe
$(\Sigma N)_L$	sum of total nitrogen lost
$(\Sigma P)_L$	sum of phosphorus lost
S_e	spray evaporation
S_p	soil percolate
S_r	soil retention of phosphorus
$(SBOD_5)_i$	soluble BOD_5 concentration in applied wastewater
$(SBOD_5)_p$	soluble BOD_5 concentration in percolate
$(SBOD_5)_r$	soluble BOD_5 concentration in runoff
$(SCOD)_i$	soluble COD concentration in applied wastewater
$(SCOD)_p$	total COD concentration in percolate
$(SCOD)_r$	soluble COD concentrationin runoff
SCP	size of center pivot system
SPH	number of sprinklers per header
SR	storage period

$(SRP)_f$	percent of total applied phosphorus removed by the soil
$(SS)_i$	suspended solids concentration in applied wastewater
$(SS)_p$	suspended solids concentration in percolate
$(SS)_r$	suspended solids concentration in runoff
SUM	number of points with the same diameter
SV	volume of required storage
SVC	storage volume per cell
TA	land treatment area required at the application site
TBCC	total bare construction cost
TBCCOF	total bare construction cost for overland flow land treatment
TBCCRI	total bare construction cost for rapid infiltration land treatment
TBCCSR	total bare construction cost for slow infiltration land treatment
$(TBOD_5)_i$	total BOD_5 concentration in applied wastewater
$(TBOD_5)_p$	total BOD_5 concentration in percolate
$TBOD_5)_r$	total BOD_5 concentration in runoff
TCDCP	total cost of distribution system for center pivot system
TCDS	total cost of distribution system
TCDSS	total cost of distribution system for solid set sprinklers
TCHPC	total cost of header pipe for center pivot
$(TCOD)_i$	total COD concentration in applied wastewater
$(TCOD)_p$	total COD concentration in percolate
$(TCOD)_r$	total COD concentration in runoff
TCUS	total cost of underdrain system
TICLP	total installed cost of lateral pipe
TICHP	total installed cost of header pipes
TICRC	total installed cost of runoff collection by gravity pipe
$(TKN)_i$	total Kjeldahl nitrogen concentration in applied wastewater
TLA	total land area required
TLL	total length of lateral pipe
TNP	total number of pumps per battery, including spare
$(TP)_i$	total phosphorus concentration in applied wastewater
TTA	total treatment area
U_p	crop phosphorus uptake
U	crop nitrogen uptake
UPIBC	unit price for building cost
UPICG	unit price for heavy clearing and grubbing
UPIEW	unit price for earthwork, assuming hauled from off-site and compacted
UPIF	unit price for fencing
UPIL	unit price for land
UPIPP	unit price for 6-in. perforated PVC drain pipe
V	velocity of water in system
VC	volume of cut
VEF	volume of earthwork required to construct levees for infiltration basins
VET	volume of earthwork for terraces
VEW	volume of earthwork required
VF	volume of fill
VLEW	volume of earthwork required for lagoon construction
VSEW	volume of earthwork required for slope constructon
W_p	percolating water
W_r	runoff water
WBZ	width of buffer zone
WDIA	diameter of recovery wells

$(WP)_f$	percent of applied wastewater lost to percolation
WPR	cost of well pump as fraction of cost of standard pump
WWGP	wastewater generation period

LAND TREATMENT UNIT PROCESSES WITHIN CAPDET (COMPUTER-ASSISTED PROCEDURE FOR THE DESIGN AND EVALUATION OF WASTEWATER TREATMENT SYSTEMS)

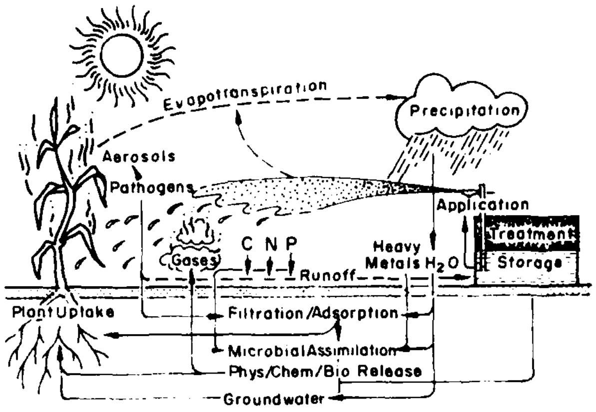
by

C.J. Merry, M.W. Corey, J.W. Epps, R.W. Harris and M.J. Cullinane, Jr.

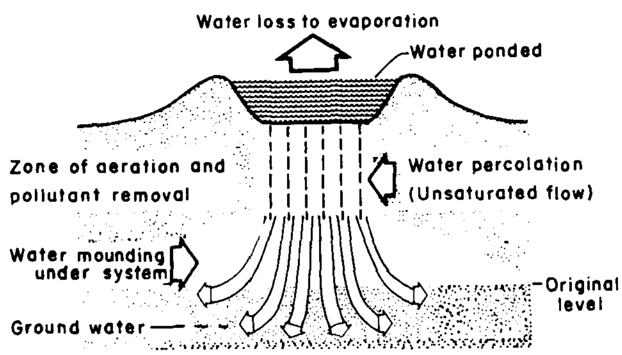
INTRODUCTION

Land treatment is an alternative to conventional methods of treating wastewater. Vegetation, in conjunction with the soil system, is an integral part of a land treatment system for removing nutrients such as nitrogen and phosphorus. The use of the nutrients by crops has been documented at many land treatment sites (U.S. EPA et al. 1977). In many instances, revenue from the sale of these crops can offset some of the operating costs. Land treatment systems can be cost effective because operation and maintenance costs and energy requirements are generally lower than for conventional wastewater treatment systems.

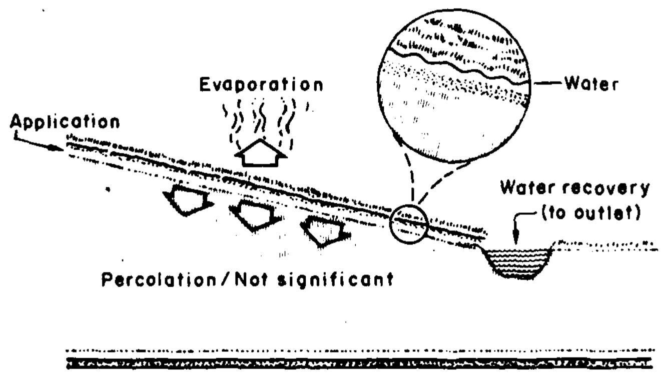
There are three types of land treatment systems: slow infiltration, rapid infiltration and overland flow (Fig. 1). In slow infiltration systems the water is renovated as it moves slowly through a permeable soil, such as a loam. Vegetation plays an important role in slow infiltration systems by removing nitrogen and phosphorus. In rapid infiltration systems the water is renovated as it moves rapidly through a very deep permeable soil, such as a sand or coarse gravel. Rapid infiltration systems are operated year-round, and normally vegetation is not grown. In overland flow systems the wastewater is applied near the top of slopes normally ranging from 2 to 8%. The water is renovated as it moves slowly over the surface of a relatively impermeable soil, such as a clay. Grasses are usually grown on overland flow systems. The runoff from overland flow systems is normally collected and routed to a receiving water. In some cases these methods of land treatment are combined to achieve a very low nutrient discharge. A more detailed discussion of the three land treatment processes can be found in U.S. EPA et al. (1977).



a. Slow infiltration.



b. Rapid infiltration.



c. Overland flow.

Figure 1. Schematic diagrams of land treatment methods.

The computer model CAPDET (Computer-Assisted Procedure for the Design and Evaluation of Wastewater Treatment Systems) was originally conceived in 1972 to complement a U.S. Army Corps of Engineers design manual on wastewater management (U.S. Army 1980) and to assist engineers in evaluating designs and costs for various wastewater treatment alternatives. The major development of the model and the cost estimating concept now used in CAPDET were initiated in 1976. The 1976 version of the land treatment module was derived from "Costs of Wastewater Treatment by Land Application" (U.S. EPA 1975).

In response to field users' requests for design information on land treatment, three unit processes for land treatment were developed and included in CAPDET during 1978. The revised version of the land treatment subroutine included the new information contained in the "Process Design Manual for Land Treatment of Municipal Wastewater" (U.S. EPA et al. 1977) and recent land treatment research findings. The subroutines included 1) water, nitrogen, and phosphorus balances, 2) crop uptake equations, and 3) percolate water quality predictions.

This report presents a summary of the revised version of the three land treatment unit processes. In addition, the report serves as a user's guide to the land treatment module of CAPDET.

DESCRIPTION OF THE CAPDET PROGRAM

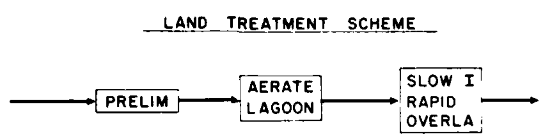
There are currently over 90 unit processes available in CAPDET that have been programmed with standard sanitary engineering design formulations. When running CAPDET, a user may input design parameters for a project design or use standard parameters for any unknown characteristic. The user may also set effluent quality limits on any of 20 wastewater characteristics, thereby screening out treatment alternatives that do not satisfy water quality standards.

CAPDET is a screening tool for quickly comparing a wide range of treatment designs that have a common economic design base, and each design is capable of meeting specified effluent water quality criteria. CAPDET is also a planning tool in the design and evaluation of wastewater treatment alternatives. The CAPDET model can simultaneously rank wastewater treatment alternatives on the basis of cost-effectiveness. In addition, schemes for conventional wastewater treatment can be ranked against land treatment designs to compare costs and treatment efficiency. The land treatment unit processes within CAPDET generate three major types of output: 1) required land treatment application area based on nitrogen and/or hydraulic loadings, 2) percolate water quality predictions, and 3) costs (capital, annual equivalent, and operation and maintenance).

Unit process design criteria must be included for each land treatment system evaluated. An example of a land treatment scheme is shown in Figure 2a and is translated in Figure 2b to CAPDET format. This input, if processed through the CAPDET system, would predict the land area required, the costs, and the percolate water quality for six treatment alternatives (Table 1). These alternatives would be ranked according to annual equivalent cost.

The CAPDET user's guide (U.S. Army 1980) is necessary for proper computer coding of the wastewater treatment unit processes. This report addresses only the land treatment unit processes, but other wastewater treatment unit processes are available in CAPDET for cost comparisons with land treatment.

There are four major inputs for the land treatment unit processes included in CAPDET: design criteria, wastewater flow, wastewater characteristics and unit cost data. There are 20 wastewater characteristics to be specified, or the user can use the typical, or default, data contained within CAPDET (Table 2).



a. Block diagram of a land treatment scheme.

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TITLE   LAND TREATMENT SCHEME

LIQUID LINE

BLOCK     PRELIM

BLOCK     AERATE LAGOON

BLOCK     SLOW I RAPID  OVERLA
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b. CAPDET format of the same scheme.

Figure 2. Example of CAPDET input.

Table 1. The six wastewater treatment alternatives shown in Figure 2.

Scheme 1	Scheme 2	Scheme 3
Preliminary treatment*	Preliminary treatment	Preliminary treatment
Aerated lagoon	Aerated lagoon	Aerated lagoon
Slow infiltration	Rapid infiltration	Overland flow
Scheme 4	**Scheme 5**	**Scheme 6**
Preliminary treatment	Preliminary treatment	Preliminary treatment
Stabilization pond†	Stabilization pond	Stabilization pond
Slow infiltration	Rapid infiltration	Overland flow

* Preliminary treatment includes a mechanically cleaned bar screen, an aerated grit chamber and comminution.

† Stabilization pond is coded as LAGOON in CAPDET format.

Table 2. Input data on wastewater for CAPDET (from U.S. Army 1980).

<u>Wastewater flow data</u>	Minimum flow (mgd)
	Average flow (mgd)
	Maximum flow (mgd)
<u>Default data for municipal wastewater</u>	
Temperature	18°C
Suspended solids	200 mg/L
Volatile suspended solids	60 % of suspended solids
Settleable solids	15 mg/L
BOD_5 (total)	250 mg/L
BOD (soluble)	75 mg/L
COD (total)	500 mg/L
COD (soluble)	400 mg/L
pH	7.6
Cations	160 mg/L
Anions	160 mg/L
Phosphorus (as PO_4)	10 mg/L
Total Kjeldahl nitrogen (TKN)	40 mg/L
Ammonia-nitrogen (NH_3)	25 mg/L
Nitrite-nitrogen (NO_2)	0.0 mg/L
Nitrate-nitrogen (NO_3)	0.0 mg/L
Oil and grease	80 mg/L

A cost element estimating approach is used in CAPDET to provide a planning level cost estimate. Unit prices that are input by the user are applied to cost elements. Cost elements have been determined for various components of the total land treatment cost. If the user does not want to determine the unit prices, the data in Table 3 can be used. Additional information on the cost element approach can be found in Cullinane (1980).

Table 3. Unit cost data used in CAPDET (from U.S. Army 1980).

Cost data	Default value	Cost data	Default value
Building cost	\$48.00/ft^2	Blowers**	
Excavation cost	\$1.20/yd^3	COSTSBS	\$16,000/unit
Wall concrete	\$207.00/yd^3	COSTSBM	\$45,000/unit
Slab concrete	\$91.00/yd^3	COSTSBL	\$300,000/unit
Marshall and Swift Index*	577	Miscellaneous nonconstruction costs	5.0 %
Crane rental	\$67.00/hr	Administration/legal costs	2.0 %
Canopy roof cost	\$15.75/ft^2	201 planning cost	3.5 %
Labor rate	\$13.40/hr	Inspection cost	2.0 %
Operator II labor rate	\$7.50/hr	Contigency cost	8.0 %
Electricity cost	\$0.04/kWh	Profit and overhead costs	22.0%
Chemicals		Technical cost	2.0 %
lime [$Ca(OH)_2$]	\$0.03/lb	Land costs	\$1000.00/acre
alum (49% liquid)	\$0.04/lb	Special foundations††	
iron (49% liquid iron salt)	\$0.06/lb	Pumping for effluent††	
polymer	\$1.62/lb	Diffuser for outfall††	
Engineering News Record index	2886	Mobilization††	
Hand rail cost	\$25.50/ft	Clearing and grubbing and site preparation††	
Pipe cost index	295.2	Site electrical††	
Pipe installation labor rate	\$14.70/hr	Yard piping††	
Eight-inch pipe cost	\$9.08/ft	Lab and maintenance and administrative building††	
Bend	\$86.82/unit	Raw waste pumping††	
Tee	\$128.49/unit	Instrumentation and control††	
Valve	\$1346.16/unit	Effluent piping††	
Large or small city EPA index†	132		

* Available from Chemical Engineering magazine.

† Use large city or small city index, but not both; if the proper index is not known, use the large city index.

** COSTSBS = Cost of standard 3,000 scfm at 8 psig capacity rotary positive displacement blower.

COSTSBM = Cost of standard 12,000 scfm at 8 psig capacity vertically split multistage centrifugal blower.

COSTBL = Cost of standard 50,000 scfm at 8 psig capacity pedestal-type single-stage centrifugal blower.

†† Optional data cards which should be used only when these items are required in the design.

The required land treatment design data will be described in later sections. A more detailed description of the computer format for each land treatment unit process is available in U.S. Army (1980).

There are several basic differences in the requirements for input data for the three land treatment unit processes in CAPDET. Land treatment systems are extremely site-specific. There are many factors in the planning stage that must be taken into account but are not quantifiable or easily adapted to computer procedures. The designer must make a number of decisions on input land treatment design data prior to using CAPDET. A major input for each land treatment unit process is the application rate. Therefore, the designer should have the site selected and be familiar with the soils, geology, climate and land use. Additional information on evaluating an area for potential land treatment sites and evaluating a soil's suitability for land treatment can be found in Merry (1978), Moser (1978) and Ryan and Loehr (1981).

The CAPDET program format uses a three-step procedure for design and cost estimating and involves three levels of effort. The first-order design is the basic sanitary engineering process for the proposed land treatment system. The first-order design for the three land treatment processes will be described in Section 1 of this report. Section 2 of this report describes how the first-order design was formatted into computer code for input into CAPDET. Section 3 of this report describes the second- and third-order design for the three land treatment processes. The second-order design is the identification and quantification of the major cost items. The third-order design is the calculation of unit process costs by applying the prices to the quantities and sizes calculated during the second-order design step.

PART 1. DESCRIPTION OF THE FIRST-ORDER DESIGN PROCEDURE FOR THE THREE LAND TREATMENT UNIT PROCESSES

INTRODUCTION

This section of the report describes the first-order design formulation for the slow infiltration, rapid infiltration, and overland flow methods of land treatment. Equations were developed to account for the water, nitrogen, and phosphorus balance equations for the three land treatment processes. In addition, equations for a BOD balance were incorporated into the overland flow process. The research rationale to support these equations is also described in the text. The amount of land area required and the percolate water quality predictions for each land treatment process are also described in this section.

SLOW INFILTRATION

The basic framework for developing the first-order design formulation consists of the water balance, nitrogen balance and phosphorus balance equations as described in U.S. EPA et al. (1977) and Loehr et al. (1979). The water and nitrogen balance equations are used to determine the loading rate of wastewater to the slow infiltration system.

The relationship between the nitrogen loading rate and the wastewater hydraulic loading rate is

$$L_t = 0.1\ C_n L_w \tag{1}$$

or

$$L_w = \frac{L_t}{0.1\ C_n} \tag{2}$$

where L_t = wastewater-nitrogen (total) loading (kg/ha yr)

C_n = applied nitrogen concentration (TKN + NH_3 + NO_3 + NO_2) (mg/L)

L_w = wastewater hydraulic loading (cm/yr).

Water balance

The water balance equation is

$$L_w + Pr = ET + W_p + R \tag{3}$$

or

$$W_p = L_w + Pr - ET - R \tag{4}$$

where Pr = precipitation (cm/yr)

ET = potential evapotranspiration (or crop consumption use of water) (cm/yr)

W_p = percolating water (cm/yr)

R = net runoff from the site (cm/yr).

For general use of this equation, the precipitation and evapotranspiration values should be determined for a year in which wetter-than-normal conditions occurred (Crites 1978). An example in the Process Design Manual uses climatic data on a monthly basis for the worst year in 10 (U.S. EPA et al. 1977). In slow infiltration systems, runoff is negligible or equal to zero.

The user must input an application rate (cm/wk) and schedule (wk/yr). The computer program uses these two values to determine the yearly loading rate. An application rate can be estimated using the soil permeability value at the selected site and Figure 3.3 from U.S. EPA et al. (1977). The long-term application rate can safely range from 4-10% of the permeability of the most limiting layer in the soil profile (Loehr et al. 1979).

Nitrogen balance

The nitrogen balance equation is

$$L_t = L_n + P_n = U + D + A_v + 0.1\ W_p C_p \tag{5}$$

where L_n = wastewater nitrogen loading (kg/ha yr)

P_n = nitrogen in the precipitation (mg/L)

U = crop nitrogen uptake (kg/ha yr)

D = denitrification, which is calculated by determining the fraction of L_n that is denitrified (%×10^{-2})

A_v = ammonia volatilization, which is calculated by determining the fraction of L_n that is volatilized as ammonia (%×10^{-2})

C_p = percolate nitrogen concentration (mg/L).

For general use of the nitrogen balance equation, it is assumed that precipitation contains an average of 0.5 mg/L of nitrogen. Nitrogen removal in slow infiltration systems is mostly by crops and immobilization of organic nitrogen in the soil. The crop nitrogen uptake values are shown in

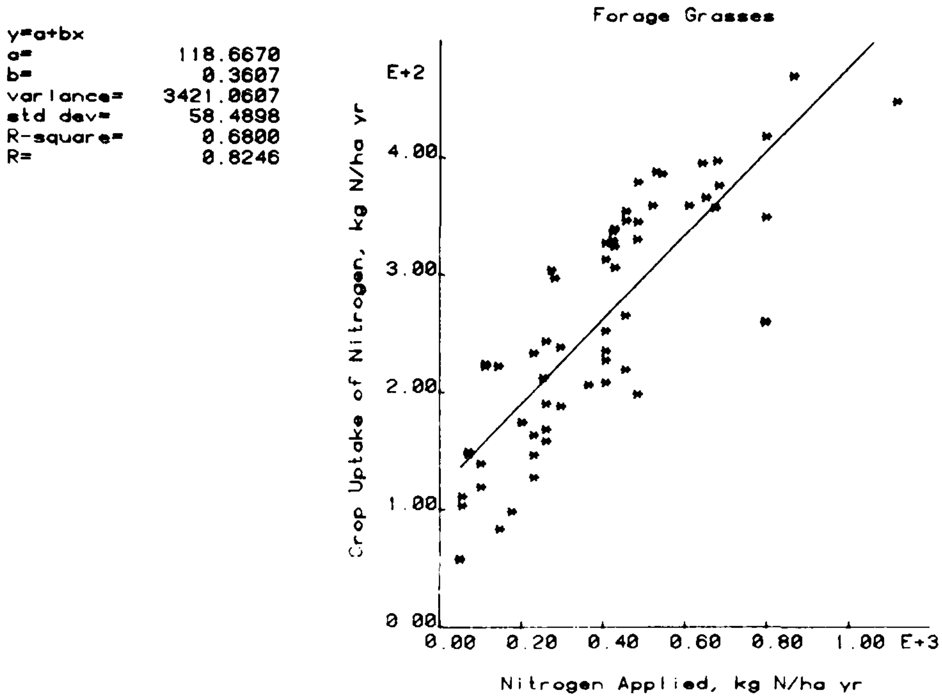

Figure 3. Crop nitrogen uptake for reed canarygrass in slow infiltration systems (Clapp et al. 1978, Palazzo and McKim 1978).

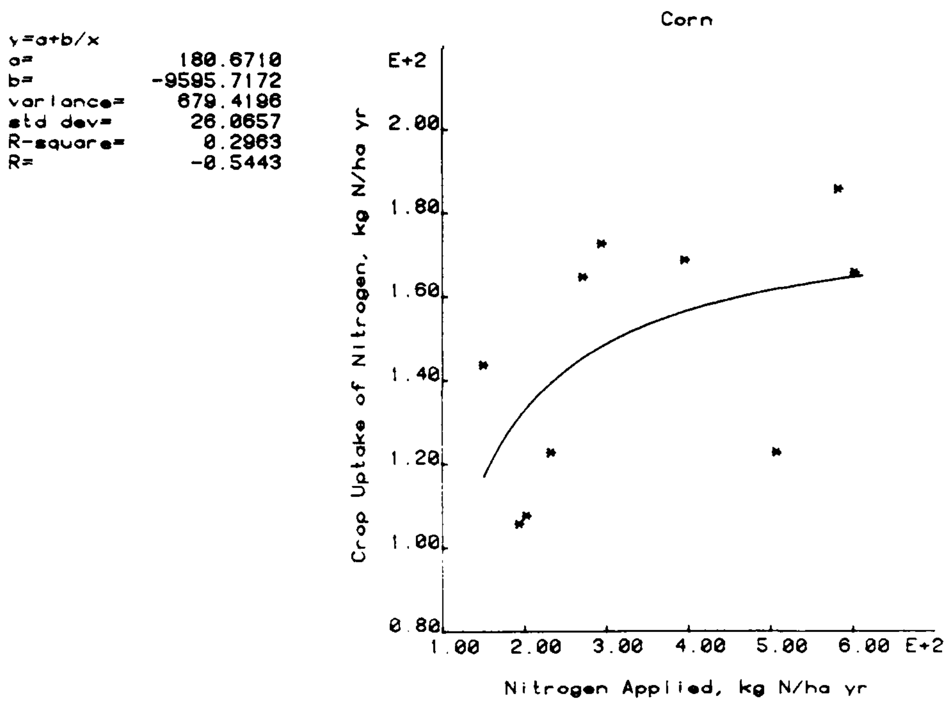

Figure 4. Crop nitrogen uptake for corn in slow infiltration systems (Clapp et al. 1978).

Figures 3 and 4 using data from research findings (Clapp et al. 1978, Palazzo and McKim 1978). The appropriate crop uptake value is selected by the computer, based on the total amount of nitrogen applied in the wastewater. For slow infiltration systems, denitrification can range from 15% to 25% of the applied nitrogen (U.S. EPA et al. 1977). The default value used in CAPDET is 20%. Ammonia volatilization can range from 20% to 50% of L_n. Nitrogen can also be removed by organic uptake of mineral nitrogen and ammonium adsorption on soil particles (Loehr et al. 1979). The default value for maximum nitrogen removal by slow infiltration is set at 99% in CAPDET.

It has been found that nitrate (NO_3^--N) concentrations in percolate correlate well with the application rate (Jenkins and Palazzo 1981). With a total nitrogen concentration of 27.5 mg/L in the effluent, a 5-cm/wk application rate resulted in 5 to 6 mg/L of NO_3^--N in the percolate and a 7.5-cm/wk application resulted in 9 to 10 mg/L of NO_3^--N in the percolate. Therefore, an application rate of 7.5 cm/wk seems feasible for wastewater with a mean total nitrogen content of about 25 mg/L if the mean percolate nitrate limit of 10 mg/L recommended by the EPA is the performance criterion to be met (Jenkins and Palazzo 1981).

Phosphorus balance

The phosphorus balance equation is combined with the water balance equation to find the total phosphorus loading to the land treatment site (U.S. EPA et al. 1977, Loehr et al. 1979). The procedure is similar to that used with the nitrogen balance equation.

The phosphorus balance equation is

$$L_p = U_p + S_r + R + 0.1\ W_p\ C_{pp} \qquad (6)$$

where L_p = wastewater phosphorus loading (kg/ha yr)

U_p = crop phosphorus uptake (kg/ha yr)

S_r = soil retention of phosphorus (kg/ha yr)

C_{pp} = percolate PO_4 concentration (mg/L).

Crop phosphorus uptake values are shown in Figure 5. A maximum of 99% removal of the phosphorus in wastewater is assumed for slow infiltration systems. The phosphorus concentration in the percolate from slow infiltration systems depends only slightly on the application rate, with phosphorus removal usually greater than 99% (Jenkins and Palazzo 1981). Plant uptake

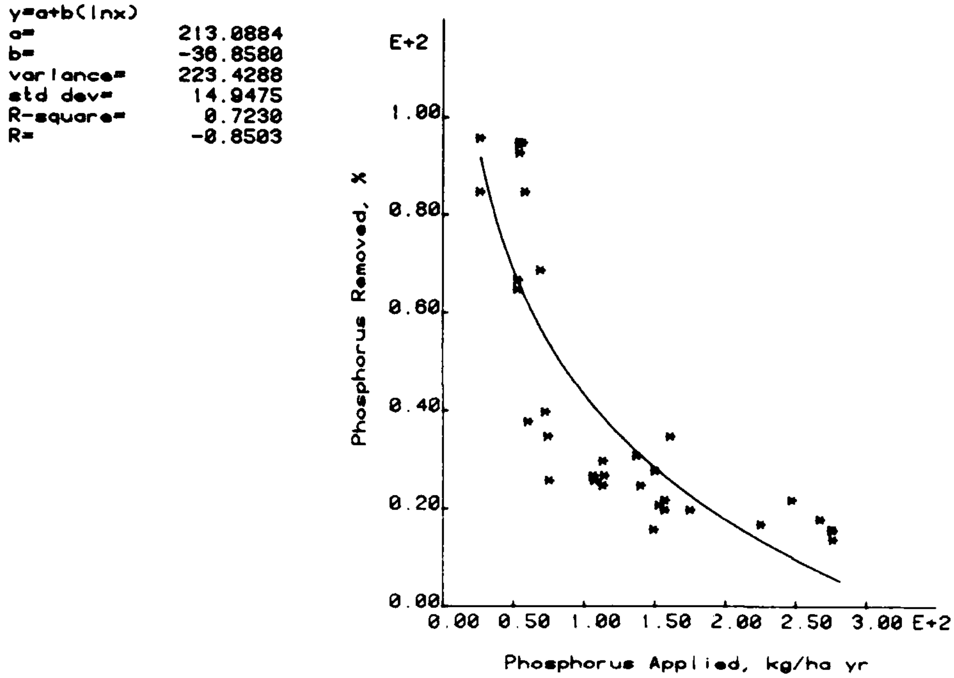

Figure 5. Plant uptake of phosphorus for slow infiltration systems (unpublished figure by A.J. Palazzo, CRREL, 1978).

was the dominant phosphorus removal mechanism at loading rates of 75 kg/ha yr, with soil removal of phosphorus dominant at higher loading rates (Jenkins and Palazzo 1981).

Land area

The amount of land needed for slow infiltration is

$$TA = \frac{GF\ (36.84)\ WWGP}{AR\ (FAP)} \tag{7}$$

where TA = land treatment area required at the application site (acres)

GF = average daily generated design flow (mgd)

WWGP = wastewater generation period (day/yr)

AR = application rate, determined by such factors as soils, geology and crop need (in./wk)

FAP = period when the field and application apparatus are available and operational (wk/yr).

An input parameter is also required by CAPDET for the number of storage days for a slow infiltration land treatment system. The CAPDET default value for storage has been set to 0 days. In cold climates a value of three months would be more appropriate.

Table 4. Determination of the percolate water quality parameters for slow infiltration.

Water quality parameter	Predictions using slow infiltration
BOD_5	95% removal
BOD_5 soluble	98% removal
COD	98% removal
COD soluble	98% removal
Temperature	no change in value
Oil and grease	0.0 mg/L
pH	no change in value
Cations	no change in value
Anions	no change in value
Suspended solids	97% removal
Volatile solids	97% removal
Settleable solids	0.0 mg/L

Percolate water quality

The calculations determined for the remaining water quality parameters are described in Table 4.

The 98% removal rate for BOD_5 was selected as the percent removal of BOD_5 on a mass basis, since BOD_5 ranged from 95-98% of the BOD_5 applied in the wastewater (Jenkins and Palazzo 1981). There was not any correlation between the percolate BOD_5 and the wastewater loading rate or the degree of preapplication treatment.[1] Even at a high application rate of 15 cm/wk, the CRREL test cells were still underloaded in regard to BOD_5.[2]

The treatment for total and volatile suspended solids was as good as that for BOD_5 (Jenkins and Palazzo 1981). The percent removal by mass generally ranged from 95-99% removal (Jenkins and Palazzo 1981). The removal of volatile solids was set at 50% of the suspended solids removal; therefore, it is 50% of the 97% removal rate for suspended solids.

The nitrogen in the percolate will be in the nitrate form. The nitrite, ammonia, and total Kjeldahl portions of nitrogen were set at 0.0 mg/L in the percolate water predictions.

RAPID INFILTRATION

The basic framework for developing the first-order design formulation

[1] A.J. Palazzo, CRREL, unpublished report, 1979.
[2] T.F. Jenkins, CRREL, pers. comm., 1979.

for the rapid infiltration process consists of the water, nitrogen and phosphorus balance equations (U.S. EPA et al. 1977, Loehr et al. 1979).

Water balance

For the rapid infiltration process the relationship between the nitrogen loading and the hydraulic loading remains the same as used in the slow infiltration process (eq 1). The water balance equation also remains the same (eq 4).

Nitrogen balance

The nitrogen balance equation in the rapid infiltration process remains essentially the same as used in slow infiltration except that there is no crop uptake; therefore, U is set to zero (eq 5). Nitrogen removal in rapid infiltration normally occurs by denitrification, which varies with the application rate. For example, under conditions of 2 to 3 weeks of flooding and 10 to 20 days of drying, maximum hydraulic loading rates of about 90 to 120 m/yr resulted in the removal of 30% of the total nitrogen (Bouwer and Rice 1978). With cycles of 9 days of flooding and 12 days of drying and loading rates ranging from 60 to 75 m/yr, 60% of the nitrogen was removed. Therefore, a value of 45% is used as a default value.

A maximum value of nitrogen removal in rapid infiltration systems is assumed at 80%. There is no check on maximum nitrogen loading to the system, as the maximum value of wastewater loading is based on hydraulic considerations.

Phosphorus balance

The phosphorus balance equation in the rapid infiltration process is essentially the same as used in the slow infiltration process except that plant uptake, U_p, is assumed to be zero (eq 6).

Phosphorus removal curves were based on data from Flushing Meadows, Arizona, and Ft. Devens, Massachusetts (Fig. 6). The maximum value of phosphorus removal is set at 90% in CAPDET.

Land area

The land treatment area determination equation in the rapid infiltration process remains the same as in slow infiltration (see eq 7).

Percolate water quality

The remaining water quality percolate predictions are summarized in Table 5. The removal rates for BOD_5, BOD_5 soluble, suspended solids and

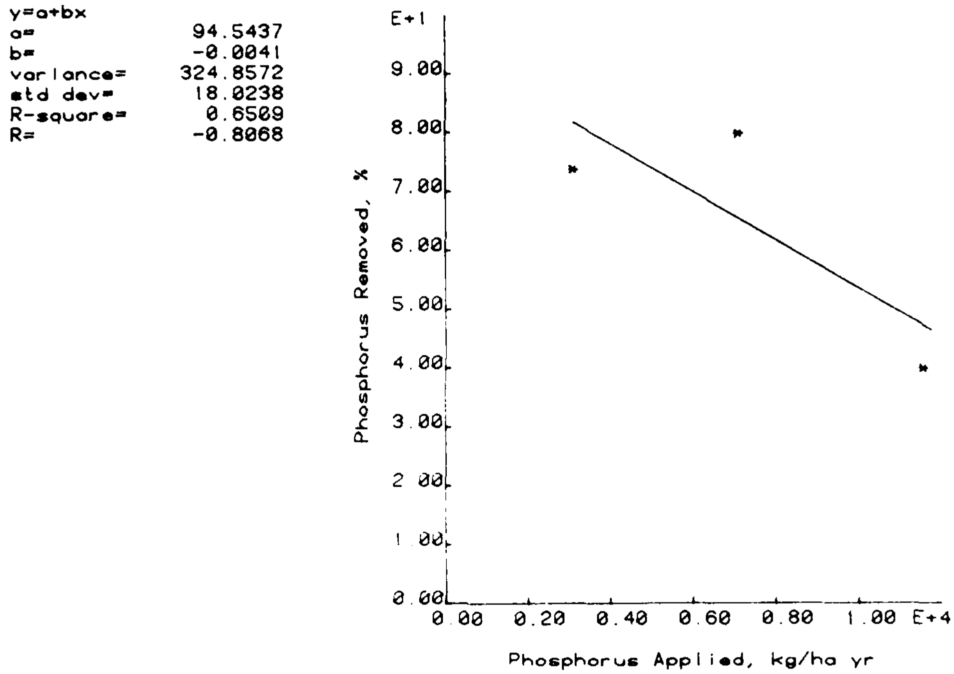

Figure 6. Phosphorus removal data for rapid infiltration systems. (Data from Satterwhite et al. 1976 and Bouwer et al. 1980.)

Table 5. Determination of the percolate water quality parameters for rapid infiltration.

Water quality parameter	Predictions using rapid infiltration
BOD_5	95% removal
BOD_5 soluble	95% removal
COD	50% of non-BOD portion
COD soluble	50% of non-BOD portion
Temperature	no change
Oil and grease	0.0 units
pH	no change
Cations	no change
Anions	no change
Suspended solids	97% removal
Volatile solids	97% removal
Settleable solids	0.0 mg/L

volatile solids were selected based on data from Bouwer and Rice (1978), Satterwhite et al. (1976), and Bouwer et al. (1980).

OVERLAND FLOW

The basic framework for developing the first-order design formulation is the water balance, BOD balance, nitrogen balance and phosphorus balance equations (U.S. EPA et al. 1977, Loehr et al. 1979). The water and BOD balance equations are used to determine the loading rate of wastewater to the overland flow system.

BOD balance

Overland flow systems are usually designed on the basis of BOD_5 removal. A maximum value for BOD_5 loading to an overland flow site has not been determined. For example, the Paris, Texas, system uses a 10-cm application rate of raw wastewater containing 300 mg/L of BOD_5 and has not experienced any problems in system operation. A 95% removal of BOD_5 is an optimum value. A design limitation of 15 mg/L BOD_5 in the runoff water is conservative and a higher value can be used if needed.

The relationship between BOD loading and hydraulic loading is

$$L_b = 0.1\ C_b\ L_w \qquad (8)$$

where L_b = wastewater BOD_5 loading (kg/ha yr)

C_b = applied BOD concentration (mg/L).

By using the water balance equation (eq 3), the following equation, L_b can be calculated:

$$L_b = 0.90\ L_b + 0.1\ W_r\ C_{rb} \qquad (9)$$

where W_r = runoff water (cm/yr)

C_{rb} = runoff BOD_5 concentration (mg/L).

The 0.90 L_b factor assumes 90% removal of BOD_5 (Thomas et al. 1976, Jenkins et al. 1978, Law et al. 1969, 1970).

Water balance

In overland flow systems the water balance equation is also used. There is a slight variation of the equation from that used in slow and rapid infiltration systems (Law et al. 1969):

$$L_w + Pr = ET + W_r + S_e + S_p \qquad (10)$$

or $$W_r = L_w + Pr - ET - S_e - S_p \qquad (11)$$

where S_e = spray evaporation (cm/yr)

S_p = soil percolate (cm/yr).

The runoff water W_r will range from 40% to 80% of the applied wastewater, depending on S_p, Pr, S_e and ET (U.S. EPA et al. 1977, p. 5-76).

The relationship between nitrogen loading and hydraulic loading is the same as in the slow infiltration process (eq 2). There are several assumptions and conditions suggested for general use of the water balance equation for overland flow systems. The user needs to know the application rate AR (in./wk) and schedule FAP (wk/yr). The computer will then convert these values to a yearly value (in./yr). In overland flow systems different application rates may be required for different seasons. The treatment efficiency of BOD_5 is unacceptable at soil temperatures below 4°C and nitrogen treatment declines rapidly below 14°C (Jenkins and Martel 1978). Therefore, wastewater application should stop whenever the soil temperature on the overland flow site decreases to 4°C (Jenkins et al. 1978). However, this may not be true for the southern United States as wastewater may be renovated at soil temperatures below 4°C.[3]

Direct evaporation from sprinklers (S_e) can range from 2% to 8%, as determined at the Campbell Soup Co. overland flow system in Paris, Texas (Law et al. 1969, Peters and Lee 1978). Therefore, S_e can be estimated from 0.02 L_w. In CAPDET, S_e is assumed to vary from 0.0 to the value of L_w. Also, S_e can be estimated from information on conventional agricultural irrigation. If gated pipes are used, S_e would be set to zero. In addition, S_p can range from 0% to 8%, depending on the type of soil (U.S. EPA et al. 1977, p. 8-13).

Nitrogen balance

The nitrogen balance equation is

$$L_t = L_n + P_n = U + D + A_v + 0.1W_r\ C_{rn} \qquad (12)$$

or $$C_{rn} = \frac{L_t - U - D - A_v}{0.1\ W_r} \qquad (13)$$

where C_{rn} = runoff nitrogen concentration (mg/L).

[3] C.R. Lee, USAE Waterways Experiment Station, pers. comm., 1979.

In overland flow systems, 90% removal of nitrogen has been reported from crop uptake (U), denitrification (D) or other removal mechanisms, i.e. ammonia volatilization, immobilization in soil, etc., for a 32-wk/yr application period and 75 to 90% for systems operating throughout the year (U.S. EPA et al. 1977, p. 5-19 and 8-13). Other research on overland flow systems indicates an average of 80% removal of total nitrogen (Thomas et al. 1976, Law et al. 1969, 1970, Jenkins et al. 1978, Bendixen et al. 1969, Peters and Lee 1978, McPherson 1978). Overall, nitrogen removal is assumed to be 80%; therefore $U + D = 0.80\ L_t$.

Nitrogen removal in overland flow systems occurs by crop removal, denitrification and ammonia volatilization. There is not any literature on the crop uptake of nitrogen in overland flow systems. CRREL has obtained data on the crop uptake of nitrogen in overland flow systems (Palazzo et al. 1982). However, at the time that the equations were being developed for this land treatment process, there were not enough data points to generate a curve.[4] Therefore, for the CAPDET model the forage grass curve from the slow infiltration process at a maximum nitrogen removal of 80% is used for the overland flow process (Fig. 3). It was reported that annual plant uptake of nitrogen and phosphorus during seasons of wastewater application ranged between 210 to 332 kg/ha and 27 to 48 kg/ha, respectively (Palazzo et al. 1982).

Phosphorus balance

The phosphorus balance equation is essentially the same as that used in the slow infiltration process

$$L_p = U_p + S_r + R + 0.1\ W_r\ C_{rp} \tag{14}$$

where C_{rp} = runoff water PO_4 concentration (mg/L).

In general, phosphorus removal in overland flow systems ranges between 60% and 80%. The crop uptake data for grasses for overland flow systems are shown in Figure 7. It is assumed that $U_p + S_r + R$ represents 50% of the phosphorus removal for overland flow systems or $0.05\ L_p$ (U.S. EPA et al. 1977, p. 8-14). If vegetation is used, then $U_p + S_r + R$ will increase; therefore, a maximum value of $0.80\ L_p$ is assumed.

[4] A.J. Palazzo and T.F. Jenkins, CRREL, pers. comm., 1979.

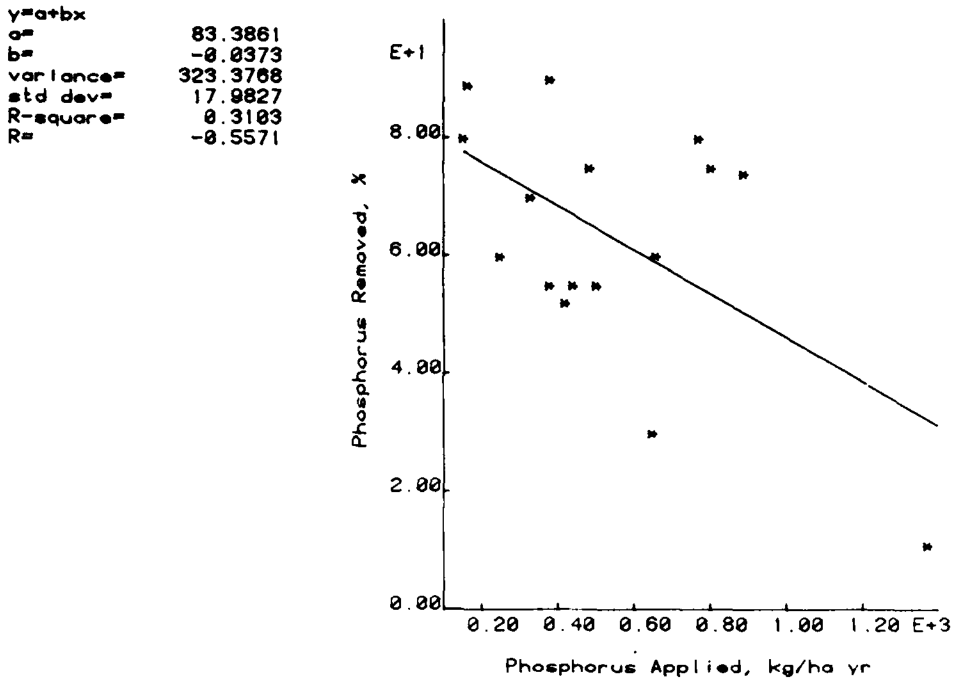

Figure 7. Phosphorus removal data for overland flow systems (data from Bendixen et al. 1969, Law et al. 1969, 1970, Thomas et al. 1970, Ehlert 1975, Thomas et al. 1976, Jenkins et al. 1978, Jenkins and Martel 1978, Lee and Peters 1978, McPherson 1978, Overcash et al. 1978, Peters and Lee 1978, and Thomas 1978).

Table 6. Determination of the percolate water quality parameters for overland flow.

Water quality parameter	Predictions using overland flow
BOD_5 soluble	same value as for BOD_5
COD	90% of the non-BOD_5 portion
COD soluble	90% of the non-BOD_5 portion
Temperature	no change
Oil and grease	0.0 mg/L
pH	no change
Cations	0.0 mg/L
Anions	0.0 mg/L
Suspended solids	93% removal
Volatile solids	95% removal
Settleable solids	0.0 mg/L

Land area and runoff water quality

The land treatment area determination remains the same as in slow infiltration systems (eq. 7). The runoff water quality predictions are summarized in Table 6.

PART 2. COMPUTERIZATION OF THE FIRST-ORDER DESIGN PROCEDURE FOR THE THREE LAND TREATMENT UNIT PROCESSES IN CAPDET

Part 2 of this report deals with the computer format of the three land treatment processes within CAPDET. The design calculations included in the computer program for the water, nitrogen, phosphorus, and BOD_5 (overland flow only) balances, land treatment area calculations, and the percolate (or runoff for overland flow systems) water quality predictions are outlined here. Part 1 dealt with the rationale based on current results and research findings of how these calculations were developed. Part 2 deals with how these calculations were programmed into the computer for the CAPDET program. In addition, the required input data that need to be determined by the user of the CAPDET program are described in Part 2.

SLOW INFILTRATION

Design data

The input data required for use in the slow infiltration unit design process are summarized in Table 7. Although the design calculations for the slow infiltration treatment process in Part 1 were described in the metric system, the required format within the CAPDET program is the English system. Therefore, the equations that were programmed within CAPDET and that will be described here will contain the proper conversion constants for the English system.

Detailed calculations

The detailed calculations and procedures accomplished by the computer program for the slow infiltration unit process are described below. The required input data from the user for the slow infiltration process are listed in Table 7.

1. Calculate total nitrogen concentration in the applied wastewater, C_n, mg/L:

$$C_n = (TKN)_i + (NO_2)_i + (NO_3)_i \qquad (15)$$

Table 7. Input data requirements for the slow infiltration land treatment process.

Input parameter	Range of data or select option	Default value
Crop classification	Forage grass or corn	Forage grass
Application rate, L_w	0.5-4.0 in./wk	2.0 in./wk
Maximum application rate	0.1-0.5 in./hr	0.2 in./hr
Precipitation rate, P_r		0.8 in./wk
Desired nitrate percolate	0.1-10.0 mg/L	10 mg/L
Evapotranspiration rate, ET		0.4 in./wk
Runoff, R		0.0 in./wk
Wastewater generation period, WWGP		365 days/yr
Field application period, FAP		52.0 wk/yr
Piping classification	Solid set or center pivot piping	Solid set piping
Storage requirements	Minimum storage (days/yr) or no storage	30 days
Liner required	Should only be used with storage	$\$/ft^2$
Embankment protection	Should only be used with storage	$\$/yd^3$
Recovery system	Underdrain recovery or no recovery system	No recovery
Buffer zone width	0-500 ft	0.0 ft
Current ground cover		
Forest (requires heavy clearing)		20.0%
Brush (requires medium clearing)		30.0%
Pasture (requires light clearing)		50.0%
Slope of site		2.0%
Slope on cultivated land		
Slope on noncultivated land	$\leq$40%	
Number and depth of monitoring wells		9 wells at 10 ft/well
Cost of fencing		$2.75/ft
Fraction of nitrogen loading denitrified, D	15-2	20.0% of total applied N
Ammonia volatilization, A_v	0-50%	0.0% of total applied N
Soil removal of phosphorus, S_r	maximum of 80%	80.0% of applied P
Days per week operation		7.0 days/wk
Hours per day operation		8.0 hr/day
Cost of standard 3,000 gpm pump and driver unit		$17,250.00
Cost of 12-in. welded steel pipe in-place		$12.80/ft
Cost of 12-in. standard size butterfly valve		$952.10
Cost of 6-15 gpm impact type full circle sprinkler		$61.65
Cost of clearing and grubbing (assumed for heaving, clearing and grubbing)		$3,000.00/acre
Cost of 4-in. water well		$8.00/ft
Cost of center pivot 100-acre sprinkler system		$27,690.00
Unit price for fencing		$2.75/ft

where $(TKN)_i$ = total Kjeldahl nitrogen concentration in applied wastewater, mg/L

$(NO_2)_i$ = nitrite-nitrogen concentration in applied wastewater, mg/L

$(NO_3)_i$ = Nitrate-nitrogen concentration in applied wastewater, mg/L.

2. Calculate wastewater nitrogen loading, L_n, lb/acre-yr:

$$L_n = C_n(\text{mg/L})\ L_w(\text{in./wk})\left(\frac{1\ \text{mg}}{1000\ \text{mg}}\right)\left(3.785\ \frac{1}{\text{gal}}\right)\left(\frac{1\ \text{lb}}{454\ \text{gm}}\right)$$

$$\times \left(\frac{1\ \text{ft}}{12\ \text{in}}\right)\left(52\ \frac{\text{wks}}{\text{yr}}\right)\left(7.48\ \frac{\text{gal}}{\text{ft}^3}\right)\left(43{,}560\ \frac{\text{ft}^2}{\text{acre}}\right) \tag{16}$$

or

$$L_n = (C_n)(L_w)11.77\ . \tag{17}$$

3. From water balance equation (eq 4), calculate percolating water rate, W_p (in./wk).

4. Calculate total nitrogen loading, L_t, lb/acre-yr:

$$L_t = L_n + 11.77\ (P_r)(0.5) \tag{18}$$

where 0.5 = Assumed total nitrogen concentration in precipitation, mg/L.

5. Calculate crop nitrogen uptake, U, lb/acre-yr:

For forage grasses:

$$U = [118.68 + 0.36\ L_t]\ \text{kg/ha-yr}\ \left(2.2\ \frac{\text{lb}}{\text{kg}}\right)$$

$$\times \left(\frac{1\ \text{ha}}{2.47\ \text{acre}}\right)\ (\text{from Fig. 3}) \tag{19}$$

or

$$U = 0.891\ [(118.68 + 0.36\ L_t)]\ \text{lb/acre-yr.} \tag{20}$$

For corn:

$$U_N = 0.891\ [(80.67) - \frac{9595.72}{L_t}]\ \text{lb/acre-yr (from Fig. 4).} \tag{21}$$

6. Calculate nitrogen loss through denitrification, D, lb/acre-yr:

$$D = (D_f)(L_t)/(100) \tag{22}$$

where D_f = nitrogen loss as a percent of total applied nitrogen, %.

7. Calculate nitrogen loss due to volatilization, A_v, lb/acre-yr:

$$A_v = (A_v)_f \, L_t/(100) \tag{23}$$

where $(A_v)_f$ = percent of total nitrogen applied lost to volatilization, %.

8. Calculate sum of nitrogen losses, $(\Sigma N)_L$, lb/acre-yr:

$$(\Sigma N)_L = U + D + A_v \tag{24}$$

where $(\Sigma N)_L$ = sum of total nitrogen lost, lb/acre-yr.

9. Check total nitrogen losses against 0.99 L_t:

$$(\Sigma N)_L \leq 0.99 \, L_t \tag{25}$$

$$\text{if } (\Sigma N)_L > 0.99 \, L_t\text{, then set } (\Sigma N)_L = 0.99 \, L_t \;. \tag{26}$$

10. From nitrogen balance, calculate nitrogen concentration in percolate, C_p, mg/L:

$$L_t = (11.77)(W_p)(C_p) + (\Sigma N)_L \tag{27}$$

or

$$C_p = [L_t - (\Sigma N)_L]/(11.77)(W_p) \;. \tag{28}$$

11. Calculate required treatment area, TA, acres:

$$TA = Q \text{ (mgd)}\left(\frac{10^6 \text{ gal}}{\text{mil. gal}}\right)\left(\frac{1 \text{ ft}^3}{7.48 \text{ gal}}\right)\left(\text{WWGP } \frac{\text{days}}{\text{yr}}\right)$$

$$\times \left(\frac{1 \text{ acre}}{43{,}560 \text{ ft}^2}\right)\left(\frac{12 \text{ in.}}{\text{ft}}\right)\left(\frac{1 \text{ yr}}{52 \text{ wks}}\right)/(L_w)\left(\text{FAP } \frac{\text{wks}}{\text{yr}}\right) \tag{29}$$

or

$$TA = (36.83)(Q)(\text{WWGP})/(L_w)(\text{FAP}) \tag{30}$$

where Q = average wastewater flow, mgd. (Note: The treatment area based on nitrogen loading requirements is also determined. If the treatment area based on nitrogen loading requirements is greater than the treatment area based on the hydraulic loading requirements, then the larger value of acreage is used.)

12. Check storage calculated, SR, and calculate volume of storage, acre-ft:

$$SV = (SR) \text{ (days) } Q \text{ (mgd) } 10^6/\left(7.48 \frac{\text{gal}}{\text{ft}^3}\right)\left(43{,}560 \frac{\text{ft}^2}{\text{acre}}\right) \tag{31}$$

where SR = storage period, days/yr

SV = volume of required storage, acre-ft.

13. Calculate phosphorus loading, L_p, lb/acre-yr:

$$L_p = 11.77\ (TP)_i(L_w) \qquad (32)$$

where $(TP)_i$ = total phosphorus concentration in applied wastewater, mg/L.

14. Calculate soil removal of phosphorus, lb/acre-yr:

$$(S_r) = (SRP)_f\ (L_p)/(100) \qquad (33)$$

where $(SRP)_f$ = percent of total applied phosphorus removed by the soil, %.

15. Calculate plant uptake of phosphorus, U_p, lb/acre-yr:

$$(U)_p = 213.09 - 36.86 \log_e L_p \text{ (kg/ha-yr)(from Fig. 5)} \qquad (34)$$

or

$$\text{or } U_p = 0.891\ [213.09 - 36.86 \log_e (L_p)] \text{ (lb/acre-yr).} \qquad (35)$$

16. Calculate sum of phosphorus losses:

$$(\Sigma P)_L = (S_r) + U_p \qquad (36)$$

where $(\Sigma P)_L$ = sum of phosphorus lost, lb/acre-yr.

17. Check total phosphorus losses against 0.99 (L_p):

$$(\Sigma P)_L \leq 0.99\ (L_p) \qquad (37)$$

$$\text{if } (\Sigma P) > 0.99\ (L_p)\text{, then set } (\Sigma P)_L = 0.99\ (L_p). \qquad (38)$$

18. From phosphorus mass balance, calculate phosphorus concentration of percolate water, C_{pp}, mg/L:

$$L_p = (\Sigma P)_L + (C_{pp})\ (W_p)(11.77) \qquad (39)$$

or

$$C_{pp} = [(L_p) - (\Sigma P)_p]/(11.77)(W_p). \qquad (40)$$

19. Calculate percolate rate, W_p, mgd:

$$W_p \text{ (mgd)} = [(W_p)\text{in./wk } (\frac{1 \text{ ft}}{12 \text{ in.}})(\frac{1 \text{ wk}}{7 \text{ days}})] \text{ (TA) acre}$$

$$\times\ (43{,}560\ \frac{ft^2}{acre})(7.48\ \frac{gal}{ft^3})\ (1/10^6). \qquad (41)$$

20. Calculate suspended solids concentration in percolate, mg/L, assuming 97% removal:

$$(SS)_p = (0.03)(SS)_i \quad (42)$$

where $(SS)_p$ = suspended solids concentration in percolate, mg/L

$(SS)_i$ = suspended solids concentration in applied wastewater, mg/L.

21. Calculate total and soluble BOD_5 concentration in percolate, assuming 95% removal of total BOD_5 and 98% removal of soluble BOD_5:

$$(TBOD_5)_p = (TBOD_5)_i\ (0.05) \quad (43)$$

$$(SBOD_5)_p = (SBOD_5)_i\ (0.02) \quad (44)$$

where $(TBOD_5)_p$ and $(TBOD_5)_i$ = total BOD_5 concentration in percolate and applied wastewater, respectively, mg/L

$(SBOD_5)_p$ and $(SBOD_5)_i$ = soluble BOD_5 concentration in percolate and applied wastewater, respectively, mg/L.

22. Calculate total and soluble COD concentration in percolate, mg/L, assume COD removal of 98%:

$$(TCOD)_p = (TCOD)_i\ (0.02) \quad (45)$$

$$(SCOD)_p = (SCOD)_i\ (0.02) \quad (46)$$

where $(TCOD)_p$ and $(TCOD)_i$ = total COD concentration in percolate and applied wastewater, respectively, mg/L

$(SCOD)_p$ and $(SCOD)_i$ = soluble COD concentration in percolate and applied wastewater, respectively, mg/L.

RAPID INFILTRATION

Design data

The input data required from the user for design parameters in the rapid infiltration unit process are summarized in Table 8.

Detailed calculations

The detailed calculations and procedures accomplished by the computer program for the rapid infiltration unit process are described below. The required input data from the user for the rapid infiltration process are listed in Table 8.

Table 8. Input data requirements for the rapid infiltration land treatment process.

Input parameter	Range of data or select option	Default value
Application rate, L_w	4.0-150.0 in./wk	35.0 in./wk
Precipitation rate, P_r		0.8 in./wk
Evapotranspiration, ET		0.4 in./wk
Runoff, R		0.4 in./wk
Wastewater generation period, WWGP		365 days/yr
Field application period, FAP		52 wk/yr
Recovery system	Recovery wells, number (NW), diameter (WDIA), depth (DW)	No recovey system
Underdrain		
	No recovery system	
Buffer zone	0-500 ft	
Monitoring wells	Number, depth/well	9 wells at 10 ft/well
Fraction of nitrogen loading denitrified, D	30-60%	45% of total applied N
Ammonia volatilization, A_v		0% of total applied N
Removal of phosphorus		90% of applied P
Cost of 12-in. welded steel pipe in-place		\$12.80/ft
Cost of 12-in. standard size butterfly valve		\$952.10
Cost of 6-in. perforated PVC drain pipe		\$6.94/ft
Cost of 24-in. reinforced concrete drain pipe		\$10.20/ft
Cost of 4-in. water well		\$8.00/ft
Cost of standard 3,000-gpm pump and driver unit		\$17,250.00
Unit price for fencing		\$2.75/ft

1. Calculate total nitrogen concentration in the applied wastewater, C_n, using eq 15.
2. Calculate wastewater nitrogen loading, L_n, using eq 17.
3. From water balance equation (eq 4), calculate percolating water rate, W_p.
4. Calculate total nitrogen loading, $(L_t)_N$, using eq 18.
5. Assume crop nitrogen uptake, $(U)_N$, = 0.0.
6. Calculate nitrogen loss through denitrification, D, using eq 22.
7. Calculate nitrogen loss due to volatilization, A_v, using eq 23.
8. Calculate sum of nitrogen losses, $(\Sigma N)_L$, using eq 24.
9. Check total nitrogen losses against 0.8 (L_t):

$$(\Sigma N)_L \leq 0.8\,(L_t) \qquad (47)$$

$$\text{if } (\Sigma N)_L > 0.8\ (L_t)\ , \quad \text{then set } (\Sigma N)_L = 0.8\ (L_t) \tag{48}$$

10. From the nitrogen balance, calculate nitrogen concentration in percolate, C_p, using eq 28.

11. Calculate required treatment area, TA, using eq 30.

12. Calculate minimum storage period requirement, SR:

$$(SR) = [(WWGP) - 7(FAP)] \tag{49}$$

(Note that if storage is less than 7 days, then storage will not be calculated.)

13. Calculate volume of required storage, SV, using eq 31.

14. Calculate phosphorus loading, L_p, using eq 32.

15. Calculate removal of phosphorus, U_p:

$$U_p = 94.544 - 0.0041\ Lp\ (\text{kg/ha-yr})\ (\text{from Fig. 7}) \tag{50}$$

$$\text{or } U_p = 0.891\ [(94.544 - 0.0041)(Lp)]\ (\text{lb/acre-yr}) \tag{51}$$

16. From phosphorus mass balance, calculate phosphorus concentration of percolate water:

$$L_p = (SRP) + (U)_p + C_{pp}\ (W_p)(11.77) \tag{52}$$

$$\text{or } C_{pp} = [(L_p) - (SRP) - (U)_p]/(11.77(W_p) \tag{53}$$

(Note that $C_{pp} \geq (0.01)(TP)_i$)

17. Calculate percolate ra[illegible], W_p, using eq 41.

18. Calculate suspended solids concentration in percolate, assuming 97% removal, using eq 42.

19. Calculate total BOD_5 concentration in percolate, mg/L, from eq 43 and calculate soluble BOD_5 concentrations in percolate, mg/L, assuming 95% removal of soluble BOD_5:

$$(SBOD_5)_p = (SBOD_5)_i\ (0.05) \tag{54}$$

20. Calculate total and soluble COD concentration in percolate, assuming COD removal of 95%:

$$(TCOD)_p = [(TCOD)_i - (TBOD_5)_i]\ (0.5) + 0.05\ (TBOD_5)_i \tag{55}$$

$$(SCOD)_p = [(SCOD)_i - (SBOD_5)_i]\ (0.5) + 0.05\ (SBOD_5)_i \tag{56}$$

OVERLAND FLOW

Design data

The input data requirements from the user for use in the overland flow unit process are summarized in Table 9.

Detailed calculations

The detailed calculations and procedures accomplished by the computer program for the overland flow process are described below. The required input data from the user for the overland flow process are listed in Table 9.

1. Calculate water loss due to evaporation, E:

$$E = (E_f)(L_w)/(100) \tag{57}$$

where E = water loss due to evaporation, in./wk

E_f = percent of total applied wastewater lost through evaporation, %.

2. Calculate percolation rate, W_p:

$$W_p = (W_p)_f(L_w)/(100) \tag{58}$$

where $(WP)_f$ = percent of applied wastewater lost to percolation, %.

3. Calculate runoff, R, in./wk, from water balance equation (eq 4):

$$R = L_w + P_r - ET - W_p - E \tag{59}$$

4. Calculate BOD_5 loading, L_{BOD_5}:

$$L_{BOD_5} = (TBOD_5)_i \text{ mg/L } (L_w)\text{in./wk}\left(\frac{1 \text{ gm}}{1000 \text{ gal}}\right)\left(3.785 \frac{1}{\text{gal}}\right)$$

$$\times \left(\frac{1 \text{ lb}}{454 \text{ gm}}\right)\left(\frac{1 \text{ ft}}{12 \text{ in}}\right)\left(52 \frac{\text{wk}}{\text{yr}}\right)\left(7.48 \frac{\text{gal}}{\text{ft}^3}\right)(43{,}560 \text{ ft}^2/\text{acre}) \tag{60}$$

or

$$L_{BOD_5} = (11.77)(TBOD_5)_i(L_w) \tag{61}$$

where L_{BOD_5} = total BOD_5 loading, lb/acre-yr.

5. Calculate total BOD_5 in runoff, $(TBOD_5)_r$:

$$(TBOD_5)_r = L_{BOD_5}/(R)(11.77) \tag{62}$$

where $(TBOD_5)$ = total BOD_5 concentration in runoff, mg/L.

Table 9. Input data requirements for the overland flow land treatment process.

Input parameter	Range of data or select option	Default value
Application rate, L_w	Screened wastewater 2.5-6.0 in./wk Lagoon or secondary effluent 6-16 in./wk	3.5 in./wk
Precipitation rate, P_r		0.8 in./wk
Desired nitrate percolate	0.1-10.0 mg/L	10.0 mg/L
Desired BOD_5 percolate	0.1-30.0 mg/L	
Evapotranspiration, ET		0.4 in./wk
Runoff, R		0.0 in./wk
Wastewater generation period, WWGP		365 days/yr
Field application period, FAP		52 wk/yr
Spray evaporation rate	2-8% of application rate	5.0%
Percolate rate of soil	0-8% of application rate	5.0%
Storage requirements	No storage Minimum storage	30 days
Liner required	Only used with storage	
Embankment protection	Only used with storage	
Recovery system	Gravity pipe or Open channel recovery system	Open channel recovery system
Buffer zone width	0-500 ft	0.0 ft
Current ground cover	Forest Brush Pasture	20% forest 30% brush 50% pasture
Slope of land	2-8%	2%
Monitoring wells	Number and depth/well	9 wells at 10 ft/well
Fraction of nitrogen loading denitrified, D	75-90%	90.0% of total applied N
Ammonia volatilization, A_v		0.0% of total applied N
Removal of phosphorus		80.0% of total applied P
Hours per day operation		8.0 hr/day
Days per week operation		7.0 days/wk
Cost of standard 3,000-gpm pump and driver unit		$17,250.00
Cost of 12-in. welded steel pipe in-place		$12.80/ft
Cost of 12-in. standard size butterfly valve		$952.10
Cost of 6 to 15-gpm impact type full circle sprinklers		$61.65
Cost of clearing and grubbing (assumed for heavy clearing and grubbing)		$3,000.00/acre
Cost of 4-in. water well		$8.00/ft
Cost of 24-in. reinforced concrete drain pipe		$10.20/ft
Unit price for fencing		$2.75/ft

6. Calculate soluble BOD_5 loading, $L(SBOD_5)$:

$$L(SBOD_5) = (11.77)(SBOD_5)_i(L_w) \quad (63)$$

where $L(SBOD_5)$ = soluble BOD_5 loading, lb/acre-yr.

7. Calculate soluble BOD_5 concentration in runoff, $(SBOD_5)_r$:

$$(SBOD_5)_r = L(SBOD_5)/(R)(11.77) \quad (64)$$

where $(SBOD_5)_r$ = soluble BOD_5 concentration in runoff, mg/L.

8. Calculate total nitrogen concentration, C_n, in applied wastewater using eq 15.
9. Calculate wastewater nitrogen loading, using eq 17.
10. Calculate total nitrogen loading, $(L_t)_N$, using eq 18.
11. Calculate crop nitrogen uptake rate, $(U)_N$, with forage grass for ground cover, from Figure 3, using eq 20.
12. Calculate nitrogen loss through denitrification, D, using eq 22.
13. Calculate nitrogen loss due to volatilization, AV, using eq 23.
14. Calculate sum of nitrogen losses, $(\Sigma N)_L$, using eq 24.
15. From nitrogen mass balance, calculate nitrogen concentration in runoff, C_{rn}:

$$C_{rn} = [(L_t)_N - (\Sigma N)_L]/(R)(11.77). \quad (65)$$

16. Calculate required field area, TA, using eq 30.
17. Calculate minimum storage period requirement:

$$(SR) = [(WWGP) - 7(FAP)](1/2). \quad (66)$$

Check storage evaluated in eq 66 against minimum specified storage and select larger of two periods.

18. Calculate volume of required storage using eq 31.
19. Calculate phosphorus loading, L_p, using eq 32.
20. Calculate soil removal of phosphorus, using eq 33.
21. Calculate removal of phosphorus, U_p, from Figure 7:

$$U_p = (83.386) - (0.0373)(L_p) \text{ kg/ha-yr} \quad (67)$$

$$\text{or } U_p = 0.891\ [(83.386) - (0.0373)(L_p)] \text{ lb/acre-yr.} \quad (68)$$

22. From phosphorus mass balance, calculate phosphorus concentration in runoff:

$$L_P = (SRP) + (U_P) + (C_P)_R(11.77)(R) \qquad (69)$$

$$\text{or } (C_P)_R = [(L_P) - (SRP) - (U_P)]/(11.77)(R) \qquad (70)$$

$(C_P)_R$ has to be $\geq (0.01)(TP)_i$.

23. Calculate volume of runoff, R, in mgd:

$$R(\text{mgd}) = [(R)\text{in./wk } (\frac{1 \text{ in.}}{12 \text{ ft}})(\frac{1 \text{ wk}}{7 \text{ day}})](TA) \text{ acre}$$

$$\times (43{,}560 \frac{\text{ft}^2}{\text{acre}})(7.48 \frac{\text{gal.}}{\text{ft}^3})(1/10^6). \qquad (71)$$

24. Calculate suspended solids concentration in runoff, mg/L, assuming 93% SS removal:

$$(SS)_r = (SS)_i(0.07) \qquad (72)$$

where $(SS)_r$ = suspended solids concentration in runoff.

25. Calculate total and soluble COD in runoff, assuming 90% of the non-BOD portion:

$$(TCOD)_r = [(TCOD)_i - (TBOD_5)_i]\ (0.9) + (TBOD_5)_r \qquad (73)$$

$$(SCOD)_r = [(SCOD)_i - (SBOD_5)_i]\ (0.9) + (SBOD_5)_r \qquad (74)$$

where $(TCOD)_r$ = total COD concentration in runoff

$(TBOD_5)_r$ = total BOD_5 concentration in runoff

$(SCOD)_r$ = soluble COD concentration in runoff

$(SBOD_5)_r$ = soluble COD concentration in runoff.

PART 3. SECOND- AND THIRD-ORDER DESIGN PROCEDURE FOR THE THREE LAND TREATMENT UNIT PROCESSES IN CAPDET

This section deals with the second- and third-order design equations for the three land treatment unit processes. These equations cover the required quantities and the costs for each land treatment process. The computer program calculates these quantities and costs based on the design and cost input parameters developed by the user that were summarized in Tables 7-9.

SLOW INFILTRATION

Quantity calculations

The following section describes the computer calculations of the quantities required for the slow infiltration unit process. Input parameters required of the user were listed in Table 7.

Distribution pumping. User must input the operating schedule which includes the days per week (DPW) and hours per day (HPD) of operation.

1. Calculate the design flow:

$$FLOW = \frac{(Q)\ (WWGP)(24)}{(FAP)\ (DPW)\ (HPD)} \qquad (75)$$

where FLOW = actual daily flow to spray field, mgd

DPW = days per week treatment system is operated

HPD = hours per day treatment system is operated

24 = conversion from days to hours, hrs/day.

From the flow calculated above (FLOW), the distribution system will be sized and the cost estimated from the unit process entitled, "Intermediate Pumping" (see U.S. Army 1980).

2. Calculate design capacity of pumps:

$$GPM = \frac{(Q)\ (2)\ (10^6)}{1440} \qquad (76)$$

where GPM = design capacity of pumps, gpm

2 = excess capacity factor to handle peak flows.

3. Determine the type, number and size of pumps required. For the purposes of this program it has been assumed the pumps will be horizontal single-stage, single-suction, split-casing centrifugal pumps designed for sewage applications. Also, the head required is assumed to be 40 ft for all applications. All pumps will be assumed to be the same size with variable speed drives and the convention of sparing the largest pump will be adhered to. The pumps will be arranged in identical batteries, with each battery handling a maximum flow of 80,000 gpm.

a. The number of batteries will be calculated by trial and error; begin with NB = 1. If GPM/NB > 80,000, go to NB = NB + 1 and repeat until GPM/NB < 80,000. Then:

$$GPMB = \frac{GPM}{NB} \tag{77}$$

where NB = number of batteries

GPMB = design flow per battery, gpm.

b. The number of pumps per battery will be calculated by trial and error. Start with N = 2. If GPMB/N > 20,000 gpm, go to N = N + 1 and repeat until GPMB/N < 20,000 gpm. Then:

$$GPMP = \frac{GPMB}{NP} \tag{78}$$

$$TNP = NP + 1 \tag{79}$$

where GPMP = design capacity of the individual pumps, gpm

NP = number of pumps required to handle design flow

TNP = total number of pumps per battery, including spare.

4. Determine area of pump building:

$$PBA = [0.0284 \, (GPMB) + 640] \, NB \tag{80}$$

where PBA = pump building area, ft^2.

5. Calculate volume of earthwork required. The pumping building is usually a bilevel building with the pumps below ground and all electrical and control facilities above ground. It is assumed that the average depth of excavation would be 8 ft. The volume of earthwork will be estimated by

$$VEW = (8)(PBA) \tag{81}$$

where VEW = volume of earthwork required, ft^3.

6. Calculate operation manpower required. The operation manpower can be related to the firm pumping capacity.

Calculate firm pumping capacity:

$$FPC = \frac{(GPM)(1440)}{10^6} \qquad (82)$$

where FPC = firm pumping capacity, mgd.

$$\text{If } 0 < FPC \leq 7 \text{ mgd:} \quad OMH = 440\ (FPC)^{0.1285} \qquad (83)$$

$$\text{If } 7 < FPC \leq 30 \text{ mgd:} \quad OMH = 294.4\ (FPC)^{0.3350} \qquad (84)$$

$$\text{If } 30 < FPC \leq 80 \text{ mgd:} \quad OMH = 40.5\ (FPC)^{0.8661} \qquad (85)$$

$$\text{If } FPC > 80 \text{ mgd:} \quad OMH = 21.3\ (FPC)^{1.012} \qquad (86)$$

where OMH = operating manpower required, man-hours/yr.

7. Calculate maintenance manpower:

$$\text{If } 0 < FPC \leq 7 \text{ mgd:} \quad MMH = 360\ (FPC)^{0.1478} \qquad (87)$$

$$\text{If } 7 < FPC \leq 30 \text{ mgd:} \quad MMH = 255.2\ (FPC)^{0.3247} \qquad (88)$$

$$\text{If } 30 < FPC \leq 80 \text{ mgd:} \quad MMH = 85.7\ (FPC)^{0.6456} \qquad (89)$$

$$\text{If } FPC > 80 \text{ mgd:} \quad MMH = 30.6\ (FPC)^{0.8806} \qquad (90)$$

where MMH = maintenance power requirement, man-hours/yr.

8. Calculate electrical energy required:

$$KWH = 67{,}000\ (Q)^{0.9976} \qquad (91)$$

where KWH = electrical energy required, kWh/yr

9. Calculate operation and maintenance material and supply costs. This item covers the cost of lubrication oils, paint, repair and replacement parts, etc. It is expressed as a percentage of the total bare construction costs:

$$OMMP = 0.7\% \qquad (92)$$

where OMMP = operation and maintenance material and supply cost, as percent of total bare construction cost.

10. The useful service life or replacement schedule for pumping facilities of this type is 25 yrs:

$$RS = 25 \quad (93)$$

where RS is the replacement schedule, yr.

11. Calculate other minor construction cost items. From the calculations approximately 85% of the construction costs have been accounted for. Other minor items such as piping, overhead crane, site cleaning, seeding, etc., would be 15%:

$$CF = \frac{1}{0.85} = 1.18 \quad (94)$$

where CF = correction factor for other minor construction costs.

Storage requirements. The slow infiltration system, like overland flow, is dependent upon weather. Also, if crops are grown it is dependent upon the growing season. The user must input the number of days of storage required based on anticipated crops and climatic data for the particular area.

1. Calculate storage volume:

$$SV = (SR)\ (Q \times 10^6) \quad (95)$$

2. Calculate size and number of storage lagoons. The following assumptions are made in determining the size and number of lagoons:

A minimum of 2 lagoon cells will always be used.

An even number of lagoon cells will be used, such as 2, 4, 6, 8, etc.

The largest single lagoon cell will be 40 acres which represents approximately 85 million gallons of storage volume.

If SV $\leq$ 170,000,000 gal., then NLC = 2. If SV < 170,000,000 gal., a trial and error solution for NLC will be used. Assume NLC = 4; if SV/NLC > 85,000,000 gal. Redesignate NLC = NLC + 2 and repeat calculation until SV/NLC $\leq$ 85,000,00 where NLC = number of lagoon cells.

3. Calculate storage volume per cell:

$$SVC = \frac{SV}{(NLC)(7.48)} \quad (96)$$

where SVC = storage volume per cell, ft^3

7.48 = conversion from gal. to ft^3, gal./ft^3.

4. Calculate lagoon cell dimensions. The following assumptions are made concerning lagoon construction:

The lagoon cells will be square.
Common levee construction will be used where possible.
Lagoons will be constructed using equal cut and fill.
Lagoon depth will be 10 ft with 8-ft water depth and 2-ft freeboard
Minimum water depth will be 1.5 ft.
Side slopes will be 3 to 1.
A 30% shrinkage factor will be used for fill.

$$L = \frac{(0.615\ SVC - 1521)^{0.5} + 60}{2} \tag{97}$$

where L = length of one side of lagoon cell, ft

5. Calculate volume of earthwork required for lagoons. The volume of earthwork must be determined by trial and error using the following equations:

$$DC + DF = 10 \tag{98}$$

where DC = depth of cut, ft
DF = depth of fill, ft

6. Calculate the volume of fill:

$$VF = [3\ (DF)^2 + 10(DF)][\frac{5(NLC)}{2} + 2]\ (L) \tag{99}$$

where VF = volume of fill, ft^3

7. Calculate the volume of cut:

$$VC = (1.3)(NLC)(DC)\ [L^2 - (6)(DF)(L) + 12\ (DF)^2 + 120(DF) - 60(L) + 1200] \tag{100}$$

where VC = volume of cut, ft^3.

Assume that DC is equal to 1 ft. From the equations calculate the VF required and the VC required. Compare VC and VF. If VC < VF then assume DC > 1 and recalculate VC and VF. If VC > VF then assume DC < 1 ft and recalculate VC and VF. Repeat this procedure until VC = VF. This is the volume of earthwork required for the storage lagoon:

$$VC = VF = VLEW \tag{101}$$

where VLEW = volume of earthwork required for lagoon construction, ft^3.

Slow infiltration distribution system. In a slow infiltration land treatment system the wastewater is usually applied to the field in one of two ways: buried solid set sprinklers or center pivot sprinkler systems. Both of these distribution methods will be addressed.

1. The selection of the optimum buried solid set sprinkler type, size and spacing is very dependent on the site conditions. Certain assumptions will be made on these parameters to simplify the calculations. While these assumptions, if used to design some systems, would drastically affect performance, they will have little effect on the overall costs.

Assume:

The treatment area will be square.

The spacing between laterals will be 50 ft.

The spacing between sprinklers will be 50 ft.

Sprinklers will be arranged in square patterns.

a. Calculate dimensions of treatment area:

$$LTA = [(TA)\ (43{,}560)]^{0.5} \qquad (102)$$

where LTA = length of one side of treatment area, ft

43,560 = conversion from acres to ft^2, ft^2/acre.

b. Calculate flow per sprinkler:

$$FPS = \frac{2{,}500\ (MAR)}{96.3} \qquad (103)$$

where FPS = flow per sprinkler, gpm

MAR = maximum application rate, in./hr. (Must be input by user based on crop and infiltration rate)

2,500 = application area for each sprinkler, ft^2

96.3 = combined conversion factors.

c. Calculate number of headers. This will be a trial and error process. The governing assumption will be that the header pipes will be of less than 48-in. diameter. Assume NH = 1.

d. Calculate length of laterals:

$$LL = \frac{LTA}{2(NH)} \qquad (104)$$

where LL = length of laterals, ft

NH = number of headers

e. Calculate number of sprinklers per lateral:

$$NSL = \frac{LL}{50} \qquad (105)$$

where NSL = number of sprinklers per lateral (must be an integer)

50 = spacing of sprinklers along lateral, ft

f. Calculate number of laterals per header:

$$NLH = \frac{LTA}{50} \tag{106}$$

where NLH = number of laterals per header (must be an integer)

50 = spacing of laterals on header, ft.

g. Calculate number of sprinklers per header:

$$NSH = (NLH)(NSL) \tag{107}$$

where NSH = number of sprinklers per header.

h. Calculate flow per header:

$$FPH = (FPS)(NSH) \tag{108}$$

where FPH = flow per header, gpm.

If FPH > 16,000 gpm; assume NH = NH + 1 and recalculate FPH until FPH $\leq$ 16,000 gpm.

i. Calculate pipe size for laterals:

$$DIAL = 0.286\ [(NSL)\ (FPS)]^{0.5} \tag{109}$$

where DIAL = diameter of lateral pipe, in.

0.268 = combined conversion factors.

DIAL must be one of the following: 2, 3, 4, 6, 8, 10, 12, 14, 16, 18, 20, 24, 30, 36, 42, 48. Always use the next larger diameter above the calculated diameter.

j. Calculate quantity of lateral pipe required:

$$TLL = (LL)\ (NLH)\ (NH) \tag{110}$$

where TLL = total length of lateral pipe, ft

k. Calculate pipe sizes for headers. The header pipe normally decreases in size due to decreasing volume of flow as each lateral pipe removes part of the flow from the header pipe. The header size will be calculated after each lateral on the header:

$$DIAHN = 0.286\ [FPH - (N)\ (FPL)]^{0.5} \tag{111}$$

where DIAHN = diameter of header pipe, in.

N = number of laterals

FPL = flow per lateral, gpm

0.286 = combined conversion factors.

Begin calculation with N = 0. This will give the diameter of the header (DIAH 0) before any flow is removed. Then set N = N + 1 and repeat the calculation. This will give the diameter (DIAH 1) of the header after the first lateral has removed a part of the flow. Repeat the calculation each time redesignating N until N = NLH. DIAHN must be one of the following: 2, 3, 4, 6, 8, 10, 12, 14, 16, 18, 20, 24, 30, 36, 42, 48.

l. Calculate length of header pipe:

$$LDIAHN = (50)(SUM)(NH) \quad (112)$$

where LDIAHN = length of header pipe of diameter DIAHN, ft

SUM = the number of points with the same diameter

50 = spacing between laterals, ft.

m. Calculate number of butterfly valves for distribution system. There will be a butterfly valve in each header for flow control. These valves will be in the header upstream from the spray field and will be the same as the initial size calculated for the header.

$$NBV = NH \quad (113)$$

$$DBV = DIAHN \quad (114)$$

where NBV = number of butterfly valves

DBV = diameter of butterfly valves, in.

n. Calculate number of valves for lateral lines. There will be a plug valve in each lateral line which will be automatic, but will be either fully open or fully closed. They will be the same size as the size calculated for the lateral pipes.

$$NLV = (NLH)\ (NH) \quad (115)$$

$$DLV = DIAL \quad (116)$$

where NLV = number of lateral valves

DLV = diameter of lateral valves, in.

o. Calculate number of sprinklers:

$$NS = (NSL)\ (NLH)\ (NH) \quad (117)$$

where NS = number of sprinklers

2. Center pivot system.

a. Determine size and number of center pivot systems. Center pivot systems are available in sizes which cover from 2 to 450 acres. Because of weight and structural considerations, the largest pipe available in the system is 8 in. For this reason, hydraulics sometimes control the sizing rather than area of coverage. The following assumptions will be made:

The system will operate 24 hrs/day, 7 days/week.

A minimum of 2 units will be used.

10% of the treatment area will not be irrigated because of the circular configuration.

$$SCP = \frac{(TA)\ (1.1)}{NCP} \tag{118}$$

where SCP = size of center pivot system, acres

NCP = number of center pivot systems

V = velocity of water in system, ft/s

0.017 = combined constants and conversion factors.

Begin with NCP = 2 and if SCP > 450, redesignate NCP = NCP + 1 and recalculate. Because of hydraulic considerations, check system velocity.

$$V = (0.017)\ (AR)\ (SCP) \tag{119}$$

If V > 10 fps, redesignate NCP = NCP + 1 and recalculate SCP and V. When V < 10 fps, use the calculated SCP and NCP.

b. Determine size of header pipe. Assume each center pivot system takes flow from header consecutively.

$$CDIAHN = 0.832\ [(NCP)\ (AR)\ (SCP)]^{0.5} \tag{120}$$

where CDIAHN = diameter of segments of header pipe, in.

This gives the header size to the first unit. DIAHN must be one of the following: 2, 3, 4, 6, 8, 10, 12, 14, 16, 18, 20, 24, 30, 36, 42, 48 in. Always use next higher pipe size. Set NCP = NCP - 1 and repeat the calculation. This gives the diameter of the header pipe between the first and second unit. Redesignate NCP after each calculation until NCP = 0.

c. Determine length of segments of header pipe:

$$LCDIAN = 235.5\ (SCP)^{0.5} \tag{121}$$

where LCDIAN = length of segment of header pipe of diameter CDIAHN, ft

235.5 = combined constants and conversion factors.

Each segment of header pipe is approximately the same length and is essentially equal to the diameter of the center pivot system.

Underdrain system for groundwater control. Practical drainage systems for wastewater applications will be at depths of 4 to 8 ft and spaced 200 ft apart. The following assumptions will be made concerning the drainage system:

6-in.-diameter perforated PVC pipe will be used.

Spacing will be 200 ft.

Depth of burial will be 4 to 8 ft.

$$LDP = [\frac{LTA}{200} + 2]^{LTA} \quad (122)$$

where LDP = length of drain pipe, ft.

Land preparation. Unlike overland flow systems, there is very little land forming required for slow infiltration systems. The land will, however, require clearing and grubbing. For clearing and grubbing the areas will be classified in three categories: heavy, medium and light. "Heavy" refers to wooded areas with mature trees, "medium" to occasional mature trees with numerous small trees and bushes, and "light" refers to only small trees and bushes. The user must specify the type of clearing and grubbing required, as well as the percent of the treatment area requiring clearing and grubbing.

$$CAGH = \frac{PCAGH}{100} (TA) \quad (123)$$

$$CAGM = \frac{PCAGM}{100} (TA) \quad (124)$$

$$CAGL = \frac{PCAGL}{100} (TA) \quad (125)$$

where CAGH = area which requires heavy clearing, acres

PCAGH = percentage of treatment area requiring heavy clearing, %

CAGM = area which requires medium clearing, acres

PCAGM = percentage of treatment area requiring medium clearing, %

CAGL = area which requires light clearing, acres

PCAGL = percentage of treatment area requiring light clearing, %.

Determine total land requirement. The land requirement will be different depending on which application method is used (center pivot or fixed sprinklers):

1. Total treatment area:

a. Center pivot. The actual treatment area for the center pivot system will be increased by 10% because there will be unwetted areas due to the circular configuration.

$$TTA = (TA) (1.1) \quad (126)$$

where TTA = total treatment area, acres

1.1 = factor for unwetted area.

b. Buried solid set sprinklers. The treatment area will be increased by approximately 5% for service roads:

$$TTA = (1.05)\ (TA) \tag{127}$$

where 1.05 = factor for service roads.

2. Area for storage lagoons:

$$ASL = \frac{(1.2)\ (NLC)\ (L)^2}{43{,}560} \tag{128}$$

where ASL = area for storage lagoons, acres

1.2 = additional area required for cross levee.

3. Area for buffer zone. Assume that the buffer zone will be around the entire treatment area and that the facility will be square:

$$ABZ = \frac{4\ WBZ\ [(43{,}560\ \ TTA)^{0.5} + WBZ]}{43{,}560} \tag{129}$$

where ABZ = area required for buffer zone, acres

WBZ = width of buffer zone (must be input by user), ft

4. Total land area:

$$TLA = TTA + ASL + ABZ \tag{130}$$

where TLA = total land area required, acres.

Calculate fencing required. Assume that the entire facility is to be fenced and the facility is square:

$$LF = 834.8\ (TLA)^{0.5} \tag{131}$$

where LF = length of fence required, ft

834.8 = combined conversion factors and constants.

Calculate operation and maintenance manpower.

1. Distribution system.

a. Solid set sprinkler.

$$\text{If } TA \le 60,\ OMMHD = 158.32\ (TA)^{0.4217}. \tag{132}$$

$$\text{If } TA < 60,\ OMMHD = 26.73\ (TA)^{0.8561}. \tag{133}$$

b. Center pivot.

$$\text{If } TA \le 100,\ OMMHD = 209.86\ (TA)^{0.4467}. \tag{134}$$

$$\text{If TA} > 100, \text{ OMMHD} = 32.77\ (\text{TA})^{0.8481} \tag{135}$$

where OMMHD = operation and maintenance manpower for distribution system, man-hr/yr.

2. Underdrain system.

$$\text{If TA} \leq 80, \text{ OMMHU} = 54.71\ (\text{TA})^{0.2414}. \tag{136}$$

$$\text{If TA} > 80, \text{ OMMHU} = 10.12\ (\text{TA})^{0.6255}. \tag{137}$$

where OMMHU = operation and maintenance manpower for underdrain system, man-hr/yr.

3. Monitoring wells.

$$\text{OMMHM} = 6.39\ (\text{NMW})(\text{DMW})^{0.2760} \tag{138}$$

where OMMHM = operation and maintenance manpower for monitoring well, man-hr/yr

NMW = number of monitoring wells

DMW = depth of monitoring wells, ft.

<u>Calculate operation and maintenance material costs</u>

1. Distribution system.

a. Solid set sprinklers.

$$\text{OMMPD} = 0.906\ (\text{TA})^{-0.0860}. \tag{139}$$

b. Center pivot.

$$\text{If TA} \leq 175, \text{ OMMPD} = 1.06\ (\text{TA})^{0.0696}. \tag{140}$$

$$\text{If TA} > 175, \text{ OMMPD} = 2.92\ (\text{TA})^{-0.1261}. \tag{141}$$

where OMMPD = operation and maintenance material costs for distribution system as percent construction cost of distribution system,%.

2. Underdrain system.

$$\text{If TA} \leq 200, \text{ OMMPU} = 14.13\ (\text{TA})^{-0.1392}. \tag{142}$$

$$\text{If TA} > 200, \text{ OMMPU} = 30.95\ (\text{TA})^{-0.2860} \tag{143}$$

where OMMPU = operation and maintenance material costs as percent of construction cost of underdrain system, %.

3. Monitoring wells.

$$OMMPM = 2.28\ (DMW)^{0.0497} \tag{144}$$

where OMMPM = operation and maintenance material costs as percent of construction cost of monitoring wells, %

Replacement schedule.

1. The service life for sprinklers is approximately 8 yr:

$$RSP = 8 \tag{145}$$

where RSP = replacement schedule for sprinklers, yr.

2. The service life of the equipment is approximately 30 yr.

$$RSE = 30 \tag{146}$$

where RSE = replacement schedule for equipment, yr.

3. The service life for structures is approximately 40 yr:

$$RSS = 40 \tag{147}$$

where RSS = replacement schedule for structures, yr.

Other construction cost items. The quantities computed account for approximately 85% of the construction cost of the systems. Other miscellaneous costs such as connecting piping for lagoons, lagoon influent and effluent structures, miscellaneous concrete structure, etc., make up the additional 15%:

$$CF = \frac{1}{0.85} = 1.18. \tag{148}$$

Cost calculations

The following section describes the computer calculations of the costs required for the slow infiltration unit process. Input parameters required of the user were listed in Table 7.

Cost of distribution pumping. The cost routine is the same as that in "Immediate Pumping," (see U.S. Army 1980).

1. Cost of earthwork:

$$COSTE = \frac{(VEW)(UPIEW)}{27} \tag{149}$$

where COSTE = cost of earthwork, \$

UPIEW = unit price input for earthwork, assuming hauled from off-site and compacted, \$/yd.

2. Cost of pump building:

$$COSTPB = (PBA)(UPIBC) \tag{150}$$

where COSTPB = cost of pump building, \$

UPIBC = unit price input for building cost, \$/sq ft.

3. Cost of pumps and drivers:

$$COSTPD = \frac{COSTRO}{100} (COSTPS)(NP)(NB) \tag{151}$$

where COSTPD = cost of pumps and drivers, \$

COSTRO = cost of pump and drivers of capacity GPMP, as percent of cost of standard size pump, %

COSTPS = cost of standard size pump (3,000 gpm), \$.

a. Calculate COSTRO:

If $0 < GPMP \leq 5000$ gpm, COSTRO is calculated by:

$$COSTRO = 2.39\ (GPMP)^{0.4404} \tag{152}$$

If $GPMP > 5000$ gpm, COSTRO is calculated by:

$$COSTRO = 0.0064\ (GPMP)^{1.16} \tag{153}$$

b. Calculate purchase cost of standard size pump and driver. A 3,000-gpm pump was selected as a standard. The cost of a 3,000-gpm pump and driver for the first quarter of 1977 is:

$$COSTPS = \$17,250. \tag{154}$$

For better cost estimation, COSTPS should be obtained from the vendor and treated as a unit price input. If this is not done, the cost will be adjusted using the Marshall and Swift Equipment Cost Index:

$$COSTPS = \$17,250\ \frac{MSECI}{491.6} \tag{155}$$

where MSECI = current Marshall and Swift Equipment Cost Index

491.6 = Marshall and Swift Equipment Cost Index first quarter 1977.

4. Installed equipment costs. Typically, the installation costs of pumps is approximately 100% of the equipment cost. This includes cost of piping, concrete, steel, electrical, paint and installation labor:

$$IPC = (COSTP)(2.0) \tag{156}$$

where IPC = installed pumping equipment cost, \$.

5. Total bare construction cost:

$$TBCC = [COSTE + COSTPB + IPC]\ CF \tag{157}$$

where TBCC = total bare construction cost, $.

6. Operation and maintenance material and supply costs:

$$OMMC = (TBCC)\left(\frac{OMMP}{100}\right) \tag{158}$$

where OMMC = operation and maintenance material and supply cost, $

OMMP = operation and maintenance material and supply cost, as a percent of total bare construction cost, from second order design output, %.

Cost of earthwork.

$$COSTE = \frac{(VLEW)(UPIEW)}{27} \tag{159}$$

Cost of distribution system for solid set sprinklers

1. Cost of header pipes.

   a. Calculate total installed cost of header pipe:

$$TICHP = \sum ICHPN \tag{160}$$

where TICHP = total installed cost of header pipes, $

ICHPN = installed cost of various size header pipes, $

   b. Calculate installed cost of each size header pipe:

$$ICHPN = (LDIAHN)\,\frac{COSTPN}{100}\,(COSTSSP) \tag{161}$$

where COSTPN = cost of pipe of diameter DIAHN as percent of cost of standard size pipe, %

COSTSSP = cost of standard size pipe (12-in. diameter), $/ft.

   c. Calculate COSTPN:

$$COSTPN = 6.842\,(DIAHN)^{1.2255} \tag{162}$$

   d. Determine COSP. COSP is the cost per foot of 12-in.-diam. welded steel pipe. This cost is $13.50/ft for the 4th quarter, 1977.

2. Cost of lateral pipes.

   a. Calculate total installed cost of lateral pipe:

$$TICLP = (TLL)\,\frac{(COSTP)}{100}\,(COSTSSP) \tag{163}$$

where TICLP = total installed cost of lateral pipe, $

COSTP = cost of pipe of diameter DIAL as percent of cost of standard size lateral pipe, %

b. Calculate COSTP:

$$COSTP = 6.842\ (DIAL)^{1.2255} \tag{164}$$

c. Determine COSP. COSP is the cost per foot of 12-in.-diam. welded steel pipe. This cost is $13.50/ft in the 4th quarter, 1977.

3. Calculate cost of butterfly valves.

a. Calculate installed cost of butterfly valves:

$$COSTBV = \frac{(COSTRV)\ (COSTSV)\ (NBV)}{100} \tag{165}$$

where COSTBV = installed cost of butterfly valves, $

COSTRV = cost of butterfly valve of size DBV as percent of standard size valve, %

COSTSV = cost of 12-in. standard size butterfly valve, $.

b. Calculate COSTRV:

$$COSTRV = 3.99\ (DBV)^{1.395} \tag{166}$$

c. Determine COSTSV. COSTSV is the cost of a 12-in.-diam. butterfly valve suitable for water service. This cost is $1,004 for the 4th quarter, 1977.

4. Calculate cost of lateral valves.

a. Calculate installed cost of lateral valves:

$$COSTLV = \frac{(COSTRLV)\ (COSTSV)\ (NLV)}{100} \tag{167}$$

where COSTLV = installed cost of lateral valves, $

COSTRLV = cost of lateral valve of size DLV as percent of cost of standard size valve, %

b. Calculate COSTRLV:

$$COSTRLV = 15.33\ (DLV)^{1.053} \tag{168}$$

c. Determine COSTSV. COSTSV is the cost of a 12-in.-diam. butterfly valve suitable for water service. This cost is $1,004 for the 4th quarter of 1977.

5. Calculate cost of sprinklers.

a. Calculate installed cost of sprinklers:

$$COSTS = 1.2\ (NS)\ COSTEN \tag{169}$$

where COSTS = installed cost of sprinklers, $

COSTEN = cost per sprinkler, \$

1.2 = 20% for cost of installation.

b. Determine COSTEN. COSTEN is the cost of an impact type rotary pop-up, full circle sprinkler with a flow from 6 to 15 gpm. This cost is \$65.00 for the 4th quarter of 1977.

$$COSTEN = \$65.00 \qquad (170)$$

For better cost estimation, COSTEN should be obtained from an equipment vendor and treated as a unit price input. Otherwise, for future escalation the equipment cost should be adjusted by using the Marshall and Swift Equipment Cost Index:

$$COSTEN = \$65.00 \; \frac{MSECI}{518.4} \qquad (171)$$

where 518.4 = Marshall and Swift Equipment Cost Index, 4th quarter of 1977.

6. Calculate total cost of distribution system for solid set sprinklers:

$$TCDSS = TICHP + TICLP + COSTBV + COSTLV + COSTS \qquad (172)$$

where TCDSS = total cost of distribution system for solid set sprinklers, \$.

Cost of distribution system for center pivot system.

1. Cost of center pivot system.

a. Calculate cost of center pivot system:

$$COSTCP = \frac{(NCP)(COSTRC)\ (COSTSP)}{100} \qquad (173)$$

where COSTCP = total cost of center pivot system, \$

COSTRC = cost of center pivot system of size SCP as percent of standard size system, %

COSTSP = cost of standard size system (200 acres), \$.

b. Calculate COSTRC:

$$COSTRC = 12.25\ (SCP)^{0.4559} \qquad (174)$$

c. Determine COCP. COCP is the cost of a center pivot sprinkler system capable of irrigating 200 acres. The cost is \$29,200 for the fourth quarter of 1977:

$$COCP = \$29,200. \qquad (175)$$

For better cost estimation, COSTSP should be obtained from an equipment vendor and treated as a unit price input. Otherwise, for future escalation the equipment cost should be adjusted by using the Marshall and Swift Equipment Cost Index:

$$COSTSP = \$29,200\ \frac{MSECI}{518.4} \tag{176}$$

where 518.4 = Marshall and Swift Cost Index, 4th fourth quarter of 1977.

2. Cost of header pipe for center pivot.

   a. Total cost of header pipe:

$$TCHPC = \sum CHPCN \tag{177}$$

where TCHPC = total cost of header pipe for center pivot, $

CHPCN = installed cost of various size header pipes for center pivot, $.

   b. Calculate cost of each size header pipe:

$$CHPCN = \frac{(LCDIAN)\ (COSTPN)\ (COSP)}{100} \tag{178}$$

   c. Calculate COSTPN:

$$COSTPN = 6.842\ (CDIAHN)^{1.2255} \tag{179}$$

   d. Determine COSP. COSP is the cost per foot of 12-in.-diam. welded steel pipe. This cost is $13.50/ft in the 4th quarter of 1977.

3. Calculate total cost of distribution system for center pivot system:

$$TCDCP = COSTCP + TCHPC \tag{180}$$

where TCDCP = total cost of distribution system for center pivot system, $.

<u>Cost of underdrain system</u>.

$$COSTU = (LDP)(UPIPP)(1.1) \tag{181}$$

where COSTU = cost of underdrain system, $

UPIPP = unit price for 6-in. perforated PVC drain pipe, $/ft

1.1 = 10% adjustment for trenching and backfilling.

<u>Calculate cost of clearing and grubbing</u>.

$$COSTCG = (CAGH + 0.306\ CAGM + 0.092\ CAGL)\ UPICG \tag{182}$$

where COSTCG = cost for clearing and grubbing site, $

UPICG = unit price cost for heavy clearing and grubbing, $/acre

<u>Calculate cost of fencing</u>.

$$COSTF = (LF)\ (UPIF) \tag{183}$$

where COSTF = installed cost of fencing, $

UPIF = unit price for fencing, $/ft.

Calculate land costs.

$$COSTL = (TLA)\ (UPIL) \tag{184}$$

where COSTL = cost of land for facility, \$

UPIL = unit price for land, \$/acre.

Cost of monitoring wells and pumps

1. Calculate cost of wells.

a. Calculate COSTM:

$$COSTM = (RMWC)(DMW)(NMW)(COSP) \tag{185}$$

where COSTM = cost of monitoring wells, \$

RMWC = cost of well as fraction of cost of standard pipe, \$

b. Calculate RMWC:

$$RMWC = 160.4\ (DMW)^{-0.7033}. \tag{186}$$

c. Determine COSP. COSP is the cost per foot of 12-in.-diam. welded steel pipe. This cost for the first quarter of 1977 is \$13.50/ft. For the best cost estimate, COSP should be a current price input from a vendor. However, if this is not done, the cost will be updated using the Marshall and Swift Equipment Cost Index:

$$COSP = \$13.50\ \frac{MSECI}{491.6}. \tag{187}$$

2. Calculate cost of pumps for monitoring wells.

a. Calculate COSTMP:

$$COSTMP = (COSTPS)(MWPR)(NMW) \tag{188}$$

where COSTMP = cost of pumps for monitoring wells, \$

MWPR = cost of well pump as fraction of cost of standard pump.

b. Calculate MWPR:

$$MWPR = 0.0551\ (DMW)^{0.658}. \tag{189}$$

c. Determine COSTPS. COSTPS is the cost of a 3,000 gpm pump. The cost is \$17,250 for the first quarter of 1977. For the best cost estimate, the user should input a current value of COSTSP; however, if this is not done the cost will be updated using the Marshall and Swift Equipment Cost Index:

$$COSTPS = \$17,250\ \frac{MSECI}{491.6}\ . \tag{190}$$

3. Calculate total cost of monitoring wells.

$$COSTMW = COSTM + COSTMP \qquad (191)$$

where COSTMW = total cost of monitoring wells, $.

Operation and maintenance material costs.

$$OMMC = \frac{(OMMPD)(TCDSS)+(OMMHD)(TCDCP)}{100}$$

$$+\frac{(OMMPU)(COSTU)+(OMMPM)(COSTMW)}{100} \qquad (192)$$

Total bare construction cost.

$$TBCCSR = (1.18)\ (TCDSS + TCDCP + COSTU + COSTE + COSTCG + COSTF + COSTMW) \qquad (193)$$

where TBCCSR = total bare construction cost for slow infiltration land treatment, $

RAPID INFILTRATION

Quantity calculations

The following section describes the computer calculations of the quantities required for the rapid infiltration unit process. Input parameters required of the user were listed in Table 8.

Distribution pumping. The computer calculations for distribution pumping are the same as for the slow infiltration unit process. Equations 75-94 should be used.

Number and size of basins required.

1. Assume: Use minimum depth of 4 ft.
   Use a minimum of 4 infiltration basins.
   Infiltration basins will be a maximum of 10 acres in area and will be square.

2. If $TA \leq 4$ acres, then NIB = 2 and:

$$IBA = \frac{TA}{2}\ . \qquad (194)$$

If $IBA < 0.1$, set $IBA = 0.1$

where NIB = number of infiltration basins

IBA = area of individual infiltration basins, acres

3. If $4 < TA \leq 40$ acres, use four equal-sized basins; then NIB = 2 and:

$$IBA = \frac{TA}{4} . \tag{195}$$

4. If TA > 40 acres, then:

$$NIB = \frac{TA}{10} . \tag{196}$$

provided that NIB must be an integer and

$$IBA = \frac{TA}{NIB} . \tag{197}$$

Volume of earthwork for basins.

1. Assume: Levees will be built on top of natural ground with fill hauled in from off the site.
   Levee side slopes will be 3:1.
   Top of the levee will be 10 ft wide.
   Basins will be 4 ft deep.
   Basins will be square.
2. Calculate dimensions of basins.

$$LB = 208.7\ (IBA)^{0.5} \tag{198}$$

where LB = length of one side of infiltration basin.

3. Volume of earthwork.

$$VEF = NIB\ [(352)(L) + 11{,}968)] \tag{199}$$

where VEF = volume of earthwork required to construct levees for infiltration basins.

Header size to feed infiltration basins. If GF $\leq$ 40 mgd calculate PIPE using GS; if GF > 40 mgd, calculate PIPE using GF/2. Assume velocity (V) = 4 fps.

$$PIPE = 8.41\ (GF)^{0.5} \tag{200}$$

where PIPE = diameter of header pipe, in.

PIPE must be one of the following: 2, 3, 4, 6, 8, 10, 12, 14, 16, 18, 20, 24, 30, 36, 42, 48.

Check velocity (V) using selected pipe size.

$$V = \frac{(283.6)(GF)}{(PIPE)^2} \text{ or } \frac{(283.6)\ (GF/2)}{(PIPE)^2} \tag{201}$$

If V $\leq$ 1 fps, use next smallest diameter.

If V > 5 fps, use next largest diameter.

Quantity of header pipe required. If GF $\leq$ 40 mgd:

$$LPIPE = (NIB)(L). \quad (202)$$

If GF > 40 mgd:

$$LPIPE = 2(NIB)(L) \quad (203)$$

where LPIPE = length of header pipe required, ft.

Calculate pipe size for lateral to each infiltration basin

1. Calculate flow:

$$FLOWR = (0.012)(AR)(IBA) \quad (204)$$

where FLOWR = wastewater flow to each basin, ft^3/s.

If FLOWR $\leq$ 62 ft^3/s, calculate DIA using FLOWR.

If FLOWR > 62 ft^3/s, calculate DIA using FLOWR/2.

2. Calculate diameter:

Assume velocity (V) = 4 fps.

$$DIAL = 6.77\ (FLOWR)^{0.5}. \quad (205)$$

DIAL must be one of the following: 2, 3, 4, 6, 8, 10, 12, 14, 16, 18, 20, 30, 36, 42, 48. Select diameter closest to the calculated diameter.

3. Check the velocity (V) using the selected diameter.

$$V = \frac{(183.3)\ FLOWR}{(DIAL)^2} \quad (206)$$

If V < 1 fps, use next smallest diameter.

If V > 5 fps, use next largest diameter.

Size and number of valves for distribution system. Assume that each lateral will have a valve to cut off flow to that infiltration basin, that valves will be butterfly valves suitable for use in water service, and that valves will be the same size as lateral pipe (DIAL).

If FLOWR $\leq$ 62 ft^3/sec, then NBV = NIB. (207)

If FLOWR > 62 ft^3/sec, then NBV = 2 (NIB). (208)

Calculate quantity of lateral pipe required.

If FLOWR $\leq$ 62 ft^3/s, LLAT = (100) (NIB) (209)

If FLOWR > 62 ft^3/s, LLAT = (2) (100) (NIB) (210)

where LLAT = length of lateral pipe of diameter DIAL.

Recovery of renovated water. Two recovery systems are commonly used, underdrains and recovery wells. The user must designate which system is to be used, if the water is to be recovered.

1. Underdrain system. It is assumed that perforated PVC pipe 6 in. in

diameter will be used for underdrain laterals in basins, 100% of the applied wastewater will be recovered, the 6-in. pipe will be laid on 1% slope and assumed to flow 1/2 full, and concrete sewer pipe will be used as collection headers.

a. Calculate quantity of underdrain pipe required:

$$DPIPE = (0.0105)(LB)(IBA)(AR)(NIB) \quad (211)$$

where DPIPE = length of 6-in. drain pipe required, ft

LB = length of one side of infiltration basin, ft

0.0105 = accumulated constants.

b. Calculate size and quantity of collection header pipe. It is assumed that class III concrete sewer pipe will be used, pipe will be laid on 1% slope, pipe will be sized by Manning formula, assumed flowing half full with "N" factor = 0.013:

$$CDIA = 9.56\ (FLOWR)^{0.375} \quad (212)$$

where CDIA = diameter of underdrain collection header pipe, in.

9.56 = accumulated constants.

The length of the underdrain pipe is:

$$LDCH = (LB)(NIB) \quad (213)$$

where LDCH = length of underdrain collection header pipe of diameter CDIA, ft.

2. Recovery wells. User must specify number of wells (NW), size of wells (WDIA, in.), and depth of recovery wells (DW, ft).

Monitoring system. Monitoring wells shall be of 4-in. diameter. User must specify the number of monitoring wells (NMW) and depth of monitoring wells (DMW, ft).

Operation and maintenance manpower

1. Distribution system.

$$\text{If } TA \leq 15,\ OMMHD = 128.5\ (TA)^{0.6285}. \quad (214)$$

$$\text{If } TS > 15,\ OMMHD = 78.8\ (TA)^{0.8092}. \quad (215)$$

2. Water recovery by wells.

$$OMMHW = 384.64\ (GF)^{0.5981} \quad (216)$$

where OMMHW = operation and maintenance manpower for water recovery by wells, man-hr/yr.

3. Water recovery by underdrains.

$$\text{If TA} \leq 80,\ \text{OMMHU} = 54.71\ (\text{TA})^{-0.2414}. \tag{217}$$

$$\text{If TA} > 80,\ \text{OMMHU} = 10.12\ (\text{TA})^{0.6255}. \tag{218}$$

4. Monitoring wells.

$$\text{OMMHM} = 6.39(\text{NMW})(\text{DMW})^{0.2760} \tag{219}$$

Operation and maintenance materials cost. This item includes repair and replacement material costs. It is expressed as a percentage of the capital costs for the various areas of construction of the rapid infiltration system.

1. Distribution system.

$$\text{If TA} \leq 19,\ \text{OMMPD} = 2.64\ (\text{TA})^{-0.2102} \tag{220}$$

$$\text{If TA} > 19,\ \text{OMMPD} = 1.59\ (\text{TA})^{-0.0399} \tag{221}$$

2. Water recovery by wells:

$$\text{If GF} \leq 5,\ \text{OMMPW} = 1.53\ (\text{GF})^{0.6570} \tag{222}$$

$$\text{If } 5 < \text{GS} \leq 10,\ \text{OMMPW} = 2.76\ (\text{GF})^{0.2894}. \tag{223}$$

$$\text{If GF} < 10,\ \text{OMMPW} = 4.55\ (\text{GF})^{0.0715} \tag{224}$$

where OMMPW = operation and maintenance material cost for water recovery wells as percentage of construction cost of recovery wells.

3. Water recovery by underdrains:

$$\text{If TA} \leq 200,\ \text{OMMPU} = 14.13\ (\text{TA})^{-0.1392} \tag{225}$$

$$\text{If TA} > 200,\ \text{OMMPU} = 30.95\ (\text{TA})^{-0.2860} \tag{226}$$

4. Monitoring wells:

$$\text{OMMPM} = 2.28\ (\text{DMW})^{0.0497} \tag{227}$$

Electrical energy requirements for recovery wells. Assume that pump efficiency is 60%, motor efficiency is 90%, and total head is equal to the well depth plus 40 ft:

$$KWH = (12.6)(GF)(DW+40)(DPW)(HPD) \quad (228)$$

Replacement schedule.

1. Equipment. The service life of the equipment is approximately 30 years (eq 146).

2. Structures. The service life of the structure is approximately 40 years (eq 147).

Other construction cost items. The quantities and items computed account for approximately 85% of the cost of the systems. Other miscellaneous items such as concrete head walls, pneumatic piping, etc., make up the other 15% (eq 148).

Cost calculations

The following section describes the computer calculations of the costs required for the rapid infiltration unit process. Input parameters required of the user were listed in Table 8.

Cost of distribution pumping. These costs are the same as for slow infiltration; see equations 149-158.

Cost of earthwork.

$$COSTEL = \frac{(VEF)(UPIEW)}{27} \quad . \quad (229)$$

where COSTEL = Cost of earthwork for levees, $

Cost of header pipe.

1. Calculate installed cost header pipe (excluding trenching and backfilling).

$$COSTHP = \frac{(COSP)(COSTRP)}{100} \quad (230)$$

where COSTHP = cost of header pipe of diameter PIPE, $/ft

COSTRP = cost of header pipe of diameter PIPE as percent of cost of standard size pipe, %.

2. Calculate COSTRP.

$$COSTRP = 5.48\ (PIPE)^{1.1655} \quad (231)$$

3. Determine COSTSSP. COSTSSP is the cost per foot of 12-in.-diam. welded steel pipe in place (excluding cost for trenching and backfilling).

4. Calculate cost for trenching and backfilling. This cost is computed as a fraction of the cost of the pipe.

$$\text{If PIPE} \leq \text{12-in., EBF} = 0.334\ (\text{PIPE})^{-0.6840} \quad (232)$$

$$\text{If PIPE} > \text{12-in., EBF} = 0.061 \quad (233)$$

where EBF = fraction of pipe cost for trenching and backfilling.

5. Total installed cost of header pipe:

$$\text{TICHP} = (1 + \text{EBF})(\text{COSTP})(\text{LPIPE}) \quad (234)$$

Cost of lateral piping to infiltration basins.

1. Calculate installed cost of lateral piping (excluding trenching and backfilling):

$$\text{COSTLP} = \frac{(\text{COSP})(\text{COSTRL})}{100} \quad (235)$$

where COSTLP = cost of lateral pipe of diameter DIAL, $/ft

COSTRL = cost of lateral pipe of diameter DIA as percent of cost of standard size pipe, %.

2. Calculate COSTRL:

$$\text{COSTRL} = 5.48\ (\text{DIA})^{1.1655} \quad (236)$$

3. Calc late cost of trenching and backfilling. This cost is computed as a fraction of the cost of the pipe. If DIAL $\leq$ 12-in., then use eq 232 for EBF. If DIAL > 12-in., then use eq 233 for EBF.

4. Total installed cost of lateral pipe:

$$\text{TICLP} = (1 + \text{EBF})\ (\text{COSTLP})\ (\text{LLAT}). \quad (237)$$

Cost of butterfly valves. To calculate installed cost of butterfly valves, see slow infiltration eq 165-166.

Total cost of distribution system

$$\text{TCDS} = \text{COSTE} + \text{TICHP} + \text{TICLP} + \text{COSTBV} \quad (238)$$

where TCDS = total cost of distribution system, $.

Cost of underdrain system.

1. Cost of underdrain laterals:

$$\text{COSTUL} = (\text{DPIPE})(\text{UPIPP})(1.1)$$

where COSTUL = installed cost of underdrain laterals, $

1.1 = 10% adjustment for trenching and backfilling.

2. Cost of underdrain collection header pipe:

$$ICUCH = \frac{(COSTUC)(COSTSC)(LDCH)(1 + EBFD)}{100} \quad (239)$$

where ICUCH = installed cost of underdrain collection header pipes.

COSTUC = cost of underdrain collection header pipe of diameter CDIA as percent of cost of standard size pipe, %

COSTSC = cost of standard size pipe (24-in.-diam. reinforced concrete pipe), $/ft

EBFD = cost for trenching and backfilling as fraction of pipe cost.

a. Calculate COSTUC:

$$COSTUC = 0.489\ (CDIA)^{1.686} . \quad (240)$$

b. Determine COSTSC: COSTSC is the cost per foot of 24-in.-diam. Class III reinforced concrete sewer pipe with gasket joints.

c. Calculate EBFD:

$$EBFD = 0.392\ (CDIA)^{-0.2871} . \quad (241)$$

3. Calculate total cost of underdrain system:

$$TCUS = COSTUL + ICUCH \quad (242)$$

where TCUS = total cost of underdrain system, $

Calculate cost of recovery wells and pump.

1. Calculate cost of well.

a. Calculate COSTW:

$$COSTW = (RWC)(DW)(NW)(COSP) \quad (243)$$

where COSTW = cost of recovery wells, $

RWC = recovery well cost as fraction of cost of standard pipe.

b. Calculate RWC:

$$\text{If } 4 \text{ in.} \leq WDIA \leq 10 \text{ in., then } RWC = 160.4\ (DW)^{-0.7033} . \quad (244)$$

$$\text{If } 12 \text{ in.} \leq WDIA \leq 20 \text{ in., then } RWC = 159.8\ (DW)^{-0.6209} . \quad (245)$$

$$\text{If } 24 \text{ in.} \leq WDIA \leq 34 \text{ in., then } RWC = 142.7\ (DW)^{-0.5286} \quad (246)$$

$$\text{If } 36 \text{ in.} \leq WDIA \leq 42 \text{ in., then } RWC = 206.5\ (DW)^{-0.4450} \quad (247)$$

c. Determine COSP, see slow infitration eq 187.

2. Calculate cost of pump for recovery wells.

a. Calculate COSTWP:

$$COSTWP = (COSTPS)(WPR)(NW) \quad (248)$$

where COSTWP = cost of pumps for recovery wells, $

WPR = cost of well pump as fraction of cost of standard pump.

b. Calculate WPR:

$$WPR = 0.00048\ (WDIA)^{1.791}\ (DW)^{0.658} \quad (249)$$

c. Determine COSTPS, see slow infiltration, eq 190.

3. Calculate total cost of recovery wells.

$$COSTRW = COSTW + COSTWP \quad (250)$$

where COSTRW = total cost of recovery wells, $.

<u>Cost of monitoring wells and pumps</u>. See slow infiltration, eq 185-191.

<u>Operation and maintenance material cost</u>.

$$OMMC = \frac{(TCDS)(OMMPD)+(TCUS)(OMMPW)+(COSTRW)(OMMPW)+(COSTMW)(OMMPM)}{100}$$

<u>Land costs</u>.

$$COSTL = \frac{(TA)}{0.8}\ (UPIL) \quad (251)$$

<u>Total bare construction cost</u>,

$$TBCCRI = (TCDS + TCUS + COSTRW + COSTMW)(1.18) \quad (252)$$

where TBCCRI = total bare construction cost for rapid infiltration land treatment, $.

OVERLAND FLOW

<u>Quantity calculations</u>

The following section describes the computer calculations of the quantities required for the overland flow unit process. Input parameters required of the user were listed in Table 9.

<u>Distribution pumping</u>. The computer calculations for distribution pumping are the same as for the slow infiltration unit process. Equations 75-95 should be used.

Storage requirements. Overland flow, unlike rapid infiltration, is dependent upon weather. Storage is required to hold the wastewater generated when application is not possible due to cold weather or heavy rains. This, of course, varies greatly for different parts of the country with different climates.

For purposes of this program the number of days of storage required will be assumed to be 50% of the number of days during which wastewater cannot be applied to the field. To calculate storage volume:

$$SV = (0.5)\ [365 - (FAP)(7)][(GF)(10^6)] \qquad (253)$$

The remaining equations required for determining storage are the same as for slow infiltration (eq 96-101).

Overland flow distribution system. In an overland flow treatment system the wastewater is usually applied to the field with fixed sprinklers. The pipes are normally buried and impact type sprinklers with flow from 6 to 15 gpm per sprinkler are used. There are many ways to lay out a sprinkler field, and the natural topography of the site dictates the layout where there are slopes of greater than 2% available. Although every layout is different, the amount and size of pipe and sprinklers used will not vary greatly. The following assumptions are made concerning the spray field layout: 1) the field will be square, 2) arrangement of headers and laterals will be as shown in Figure 2.35-4 (U.S. Army 1980), and 3) the treatment area will be increased by 15% to account for additional area for drainage ditches and service roads.

1. Calculate number of headers. The number of headers will be selected based on the following:

$$FLOW < 1\ mgd;\ NH = 1 \qquad (254)$$

$$1\ mgd < FLOW \leq 2\ mgd;\ NH = 2 \qquad (255)$$

$$2\ mgd < FLOW \leq 4\ mgd;\ NH = 3 \qquad (256)$$

$$FLOW > 4\ mgd;\ NH = 4. \qquad (257)$$

2. Calculate flow per header:

$$FPH = \frac{(FLOW) \times (10^6)}{(NH)(HPD)(60)}\ . \qquad (258)$$

3. Calculate flow per sprinkler:

$$FPS = \frac{4{,}051.7\ (AR)}{(DPW)(HPD)(FAP)} \qquad (259)$$

where 4,051.7 = combined conversion factors.

4. Calculate number of sprinklers per header.

$$SPH = \frac{FPH}{FPS} \tag{260}$$

where SPH = number of sprinklers per header.

If SPH < 1, then set SPH = 1. If flow is not sufficient, then reduce the operating period specification.

5. Calculate number of laterals per header:

$$NLH = SPH/Q \tag{261}$$

NLH must be an integer. If NLH < 1, set NLH = 1 and recalculate the number of required sprinklers:

$$NSL = \frac{FPH}{FBS} . \tag{262}$$

6. Calculate flow per lateral:

$$FPL = \frac{FPH}{NLH} . \tag{263}$$

7. Calculate lateral diameter:

$$DIAL = 0.286 \, (FPL)^{0.5} . \tag{264}$$

DIAL must be one of the following: 2, 3, 4, 6, 8, 10, 12, 14, 16, 18, 20, 24, 30, 36, 42, 48. Always use the next larger diameter above the calculated diameter.

8. Calculate header pipe sizes. The header pipe normally decreases in size due to decreasing volume of flow as each set of lateral pipes removes part of the flow from the header pipe. There will normally be four laterals taken off from approximately the same location. The header size will be calculated after each group of laterals:

$$DIAHN = 0.286 \, [FPH - (NF) \, (4) \, (FPL)]^{0.5} \tag{265}$$

where NF = number of points at which flow is removed from header.
DIAHN must be one of the following: 2, 3, 4, 6, 8, 10, 12, 14, 16, 18, 20, 24, 30, 36, 42, 48. Begin calculation with N = 0. This will give the diameter (DIAH 0) of header before the first group of laterals remove any flow. Then set N = N + 1 and repeat the calculation. This will give the diameter (DIAH 1) of the header after flow has been removed by the first group of laterals. Repeat the calculation each time redesignating N until

the expression: FPH-(N)(4)(FPL) is equal to zero or yields a negative number. The "N" used in this last calculation will be the number of slopes which must be constructed.

9. Determine length of lateral pipe:

$$LDIAL = (SPH)(50)(NH) \quad (266)$$

where LDIAL = length of lateral pipe required, ft

50 = distance between sprinklers, ft.

10. Determine length of header pipes. As can be seen from Figure 2.35-4 (U.S. Army 1980), the spray field is laid out such that the distance between lateral take-off points is 400 ft. Therefore, to determine the length of each size of pipe required for a single header, sum the number of points at which the diameter is the same and multiply by 400 ft. To determine the amount of each size header pipe for the entire field, multiply by the number of headers since they are identical:

$$LDIAHN = (NH)(400) \sum NO \quad (267)$$

where NO = number of points where the same diameter pipe was chosen. For the length of pipe from pump station to the spray field, use the number of headers times the width of the spray field. The diameter will be the diameter calculated before any flow is removed from the header.

11. Calculate number of butterfly valves for distribution system. These equations are the same as in the slow infiltration process, eq 113-116.

Construction of overland flow slopes. Overland flow systems must have slopes from 2-8%, must be clear of trees and brush, and must be leveled to a constant slope. Not many land areas meet this criteria, and therefore in many cases the area must be cleared, slopes formed, and leveled.

1. Determine amount of clearing and grubbing. These calculations are the same as the slow infiltration process (eq 123-125).

2. Determine earthwork required. For areas which are flat (0-2% slope), the overland flow slopes must be formed by moving earth. For areas where slopes of from 2-8% exist, very little earth moving is required. The following assumptions are made to estimate the quantities of earthwork required for slopes from 0-2%.

The slopes shall be as indicated in Figure 2.35-4 (see U.S. Army 1980). Equal cut and fill will be used. To calculate volume of earthwork:

$$VSEW = (55,100)(TA) \quad (268)$$

where VSEW = volume of earthwork required for slope construction, ft^3

55,100 = volume of earthwork required per acre, ft^3.

Runoff collection. The overland flow system does not depend on infiltration for treatment and much of the water runs off. This water must be collected and monitored. There are basically two types of collection systems: open ditch and buried drain pipe. With both systems, the runoff from each individual slope is carried to the main collection system by small ditches or terraces.

1. Determine earthwork required for terraces:

$$VET = (NF+2)(NH)(1{,}000)(5) \qquad (269)$$

where VET = volume of earthwork for terraces, ft^3

1000 = length of individual slope

5 = volume of earthwork required per foot of terrace length.

2. Main runoff collection system. As stated before, there are two systems which may be used, open ditches or buried drain pipe. One or the other would be used, but never both.

a. Buried drain pipe. Since an overland flow facility would not normally be operated when the site received a rainfall in excess of 0.5 in. in 24 hrs, this criteria will be used to size the drainage system. The assumption of 100% runoff will be made for design purposes.

The pipe size will vary as runoff from each slope is added. Using the layout shown in Figure 2.35-4 (see U.S. Army 1980) and the assumed rainfall, the flow from one slope would be 0.145 ft^3/s. The following assumptions are made: 1) pipe will be concrete drain pipe, 2) pipe will be flowing half full, 3) pipe will be laid on a 0.2% slope, and 4) friction factor is 0.013.

Calculate pipe size:

$$CDIAN = 6.38(NF)^{0.375} \qquad (270)$$

where CDIAN = diameter of concrete drain pipe, in. CDIAN must be one of the following: 12, 15, 18, 21, 24, 27, 30, 33, 36, 42, 48, 54, 60, 66, 72, 78, 84, 90 or 96 in.

As in sizing the header pipe, the collection pipe will vary in size. Start with N = 1 and calculate pipe size. Then set N = N + 1 and repeat the calculation. Redesignate N in this manner until N is equal to total number of takeoff points in header pipe calculation.

Again, the length of each size pipe required will be determined by summing the number of points at which the same diameter is calculated and multiplied by 400 ft. To determine the amount of pipe for the entire field, multiply by NH + 1 since there will be NH +1 identical collection lines.

$$LDIAN = (400)(NH + 1) \sum NCDIAN \qquad (271)$$

where LDIAN = length of drain pipe of given diameter, ft

NCDIAN = number of points where same diameter pipe was chosen

b. Open ditches. Assume that the ditches will be all cut and erosion control will be required in construction:

$$LDTI = (NF)(400)(NH + 1) \qquad (272)$$

where LDIT = total length of ditches for system, ft

400 = length of ditch between slopes, ft.

Total land area required.

1. Ditches and service roads. Increase the area by 15%:

$$ADR = (0.15)(TA) \qquad (273)$$

where ADR = area for ditches and roads, acres.

2. Calculate area for storage lagoons. This is the same as for slow infiltration, eq 128.

3. Calculate area for buffer zone. Assume that the buffer zone will be around entire treatment area and that the facility will be essentially square.

a. Calculate dimensions of treatment area:

$$LTA = \left[\frac{TA + ADR + ASL}{43,560}\right]^{0.5} \qquad (274)$$

b. Calculate area for buffer zone:

$$ABZ = 4(WBZ)(LTA + WBZ) \qquad (275)$$

4. Total land area.

$$TLA = TA + ADR + ASL + ABZ \qquad (276)$$

Fencing required. See slow infiltration, eq 131.

Operation and maintenance manpower.

1. Distribution system:

$$\text{If } TA \leq 70,\ OMMHD = 77.91\ (TA)^{0.5373}. \qquad (277)$$

$$\text{If TA} > 70,\ OMMHD = 18.12\ (TA)^{0.8814}. \qquad (278)$$

2. Runoff collection by gravity pipe:

$$\text{If TA} \leq 100,\ OMMHP = 6.65\ (TA)^{0.4224}. \qquad (279)$$

$$\text{If TA} > 100,\ OMMHP = 2.41\ (TA)^{0.6434} \qquad (280)$$

where OMMHP = operation and maintenance manpower for runoff collection by gravity pipe, man-hr/yr.

3. Runoff collection by open ditch:

$$\text{If TA} \leq 150,\ OMMHO = 36.9\ (TA)^{0.3578}. \qquad (281)$$

$$\text{If TA} > 150,\ OMMHO = 8.34\ (TA)^{0.6538} \qquad (282)$$

where OMMHO = operation and maintenance manpower for runoff collection by open ditch, man-hr/yr.

Operation and maintenance material costs.

1. Distribution system:

$$\text{If TA} \leq 500,\ OMMPD = 0.783\ (TA)^{-0.0673} \qquad (283)$$

$$\text{If TA} > 500,\ OMMPD = 9.46\ (TA)^{-0.47} \qquad (284)$$

2. Runoff collection by gravity pipe:

$$\text{If TA} \leq 225,\ OMMPGP = 0.9566\ (TA)^{-0.2539} \qquad (285)$$

$$\text{If TA} > 225:\ OMMPGP = 0.242\% \qquad (286)$$

where OMMPGP = operation and maintenance material cost for runoff collection by gravity pipe as percent construction cost for gravity pipe system, %.

3. Runoff collection by open ditch:

$$\text{If TA} \leq 60,\ OMMPO = 25.4\ (TA)^{-0.1383} \qquad (287)$$

$$\text{If TA} > 60,\ OMMPO = 14.42 \qquad (288)$$

where OMMPO = operation and maintenance material costs for runoff collection by open ditch as percent construction cost for open ditch system, %.

Replacement schedule.

1. Sprinkler. See slow infiltration, eq 145.
2. Equipment. See slow infiltration, eq 146.
3. Structures. See slow infiltration, eq 147.

Other construction cost items. The quantities computed account for approximately 90% of the construction cost of the system. Other miscellaneous costs such as final land leveling, connecting piping for lagoons, miscellaneous concrete structures, etc., make up the additional 10%:

$$CF = \frac{1}{0.9} 1.11 \quad . \tag{289}$$

Cost calculations

The following section describes the computer calculations of the costs required for the overland flow unit process. Input parameters required of the user were listed in Table 9.

Cost of distribution pumping. The cost routine was the same as for "Intermediate Pumping," (see U.S. Army 1980). See slow infiltration, eq 149-158.

Cost of earthwork.

$$COSTE = \frac{VLEW + VSEW + VET}{27} UPIEW. \tag{290}$$

Cost of header pipes. See slow infiltration, eq 160-162. COSP is the cost per foot of 12-in.-diam. welded steel pipe ($13.50/ft for the fourth quarter, 1977).

Cost of lateral pipes.

1. Calculate total installed cost of lateral pipes:

$$TICLP = (LDIAL) \frac{(COSTP)}{100} (COSTSP). \tag{291}$$

2. Calculate COSTP. See slow infiltration, eq 164.
3. Determine COSP. COSP is the cost per foot of 12-in.-diam. welded steel pipe. This cost is $13.50/ft in the fourth quarter of 1977.

Cost of butterfly valves. See slow infiltration, eq 165-166. COSTSV is the cost of a 12-in.-diam. butterfly valve suitable for water service. This cost is $1,004 for the fourth quarter of 1977.

Cost of lateral valves. See slow infiltration, eq 167-168.

Cost of sprinklers. See slow infiltration, eq 169-171.

Total cost of distribution system.

$$TCDS = TICHP + TICLP + COSTBV + COSTLV + COSTN \tag{292}$$

Determine cost of runoff collection by open ditch.

$$COSTOD = (0.57)(LDIT)(UPIEW) \tag{293}$$

where COSTOD = cost of runoff collection by open ditch, $

Determine cost of runoff collection by gravity pipe.

1. Calculate total installed cost of collection system.

$$TICRC = \sum ICRCN \tag{294}$$

where TICRC = total installed cost of runoff collection by gravity pipe, $

ICRCN = installed cost of each size drain pipe, $

2. Calculate installed cost of each size drain pipe.

$$ICRCN = \frac{(LCDIAN)(COSTRN)(COSTSC)}{100} \tag{295}$$

where COSTRN = cost of drain pipe of size CDIAN as percent of cost of standard size (24-in.-diam.) drain pipe, %

3. Calculate COSTRN.

$$COSTRN = 0.7044\ (CDIAN)^{1.6587} \tag{296}$$

4. Determine COSTCP. COSTCP is the cost per foot of 24-in.-diam. reinforced concrete drain pipe with gasket joints. This cost for the fourth quarter of 1977 is $10.76/ft:

$$COSTCP = \$10.76/ft \tag{297}$$

Cost for clearing and grubbing. See slow infiltration, eq 182.

Cost of fencing. See slow infiltration, eq 183.

Land costs. See slow infiltration, eq 184.

Operation and maintenance material costs.

$$OMMC = \frac{(OMMPD)(TCDS)+(OMMPGP)(TICRC)+(OMMPO)(COSTOD)}{100} \tag{298}$$

Total bare construction cost.

$$TBCCOF = (1.11)(TCDS + TICRC + COSTOD + COSTE + COSTCG + COSTF + COSTL) \tag{299}$$

where TBCCOF = total bare construction cost for overland flow land treatment, $.

Table 10. Costs of land treatment alternatives using the default input data in CAPDET for a 1.0 mgd flow.

Unit process	Capital ($)	Operation and maintenance ($)	Equivalent annual ($)
Rapid infiltration	325,881	46,698	75,670
Overland flow	1,871,799	48,172	220,960
Slow infiltration	1,595,698	79,563	224,303

EXAMPLE COMPUTER OUTPUT

The default data for the three land treatment unit processes were used for a typical run of the CAPDET model. This computer output is shown in Appendix A. Table 10 shows a cost comparison of the three land treatment processes for a 1.0-mgd flow.

AVAILABILITY OF THE PROGRAM

The CAPDET program is available to nongovernment users through Boeing Computer Services. CAPDET is available to EPA and state agency users through the EPA computer system (COMNET) and interested personnel should contact Dr. Wen Huang (202-426-4443). Copies of the CAPDET program on a computer compatible tape are available from the EPA. Department of Defense users can gain access to CAPDET through Corps of Engineers computers.

Technical questions on the total CAPDET program should be addressed to M. John Cullinane, Environmental Engineering Division, Environmental Laboratory, Waterways Experiment Station (601-636-3111, ext 3723, 3734; FTS 542-3723 or -3724). Training courses/workshops for using CAPDET are scheduled throughout the year. Questions on these courses should be directed to M. John Cullinane.

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APPENDIX A. COMPUTER OUTPUT EXAMPLE FROM CAPDET OF THE THREE LAND TREATMENT UNIT PROCESSES

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***** ******************** ***** *******
* MISSISSIPPI STATE UNIVERSITY *
*     VERSION DATED 0?/?2/?1     *
***** ******************** ***** *******
TITLE  LAND TREATMENT EXAMPLES
LIQUID LINE
BLOCK      SLOW I RAPID  OVERLA
WASTE INFLUENT
AVERAGE  1.0 MGD
DESIRED EFFLUENT
UNIT COSTS
END
CONTROL CARDS
ANALYZE
OUTPUT QUANTITIES
GO         I=?.5?    ?? YEARS


     ANALYSIS INPUT PARAMETERS
       INTEREST RATE                         8.500 PERCENT
       PLANNING PERIOD                         20 YEARS


   UNIT PRICES AND COSTS INDICES

 D BUILDING                                48.00  $/SQFT
 D EXCAVATION                               1.20  $/CUYD
 D WALL CONCRETE                          207.00  $/CUYD
 D SLAB CONCRETE                           91.00  $/CUYD
 D MARSHALL AND SWIFT INDEX               577.00
 D CRANE RENTAL                            57.00  $/HR
 D EPA CONSTRUCTION COST INDEX            167.00
 D CANOPY ROOF                             15.75  $/SQFT
 D LABOR RATE                              13.40  $/HR
 D OPERATOR CLASS II                        7.50  $/HR
 D ELECTRICITY                               .04  $/KWHR
 D CHEMICAL COSTS
     LIME                                    .03  $/LB
     ALUM                                    .24  $/LB
     IRON SALTS                              .06  $/LB
     POLYMER                                1.62  $/LB
 D ENGINEERING NEWS RECORD COST INDEX    2886.00
 D HANDRAIL                                25.?0  $/FT
 D PIPE COST INDEX                        295.20
 D PIPE INSTALLATION LABOR RATE            14.70  $/HR
 D EIGHT INCH PIPE                          9.08  $/FT
 D EIGHT INCH PIPE BEND                    86.82  $/UNIT
 D EIGHT INCH PIPE TEE                    128.49  $/UNIT
 D EIGHT INCH PIPE VALVE                 1346.16  $/UNIT


LAND TREATMENT EXAMPLES                         ANALYZE   1  TRAIN NO   1
                               INFLUENT


                           LIQUID CHARACTERISTICS
FLOW       (MGD)     SOLIDS     (MG/L)              (MG/L)          (MG/L)
MAXIMUM    1.0000    SUSPENDED  200.00     BOD5     250.00     TKN 45.00
AVERAGE    1.0000    VOLATILE    60.00 %   BOD5S     75.00     NH3 25.00
MINIMUM    1.0000    SETTLEABLE  15.00     COD      500.00     NO2   .00
                                           CODS     400.00     NO3   .00
TEMP (W)   10.0 C    OIL & GREASE 80.00    PO4       18.00
TEMP (S)   23.0 C    CATIONS     160.00
PH          7.6      ANIONS      160.00

                           SLUDGE CHARACTERISTICS
                             PRIMARY        SECONDARY        CHEMICAL
   VOLUME (GAL/D)              .00             .00              .00
     % SOLIDS                  .00             .00              .00
     % VOLATILE                .00             .00              .00
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SLOW INFILTRATION LAND TREATMENT

D HOURS PER DAY OPERATION                          .800+01 HOURS
D DAYS PER WEEK OPERATION                          .700+01 DAYS
D FORAGE GRASSES
D APPLICATION RATE                                 .200+01 IN/WEEK
D MAXIMUM APPLICATION RATE                         .500+00 IN/HOUR
D EVAPOTRANSPORATION RATE                          .400+00 IN/WEEK
D PRECIPITATION RATE                               .500+00 IN/WEEK
D DESIRED NITRATE LOADING (MAXIMUM)                .100+02 MG/L
D PERCENT DENITRIFIED                              .200+02 PERCENT
D PERCENT AMMONIA VOLATILIZATION                   .000    PERCENT
D REMOVAL OF PHOSPHORUS                            .900+02 PERCENT
D WASTEWATER GENERATION PERIOD                     .365+03 DAYS/YR
D FIELD APPLICATION PERIOD                         .520+02 WEEKS/YR
D SOLID SET PIPING AND PUMPING
D MINIMUM STORAGE SPECIFIED                        .700+02 DAYS
  CALCULATED STORAGE REQUIRED                      .921+02 ACRE-FT
D NO RECOVERY SYSTEM
D BUFFER ZONE WIDTH                                .000    FEET
D CURRENT GROUND COVER
      FOREST                                       .250+02 PERCENT
      BRUSH                                        .250+02 PERCENT
      PASTURE                                      .500+02 PERCENT
D SLOPE OF SITE                                    .200+01 PERCENT
D NUMBER OF MONITORING WELLS                             9 WELLS
D DEPTH OF MONITORING WELLS                        .100+02 FEET
D COST OF FENCING                                  .275+01 $/FT
  TREATMENT AREA REQUIRED                          .159+03 ACRES

  TREATMENT AREA WILL BE CONTROLLED BY NITROGEN LOADING

  ADJUSTED HYDRAULIC APPLICATION RATE              .173+01 IN/WEEK
  CROP UPTAKE OF NITROGEN                          .477+03 LB/ACRE/YEAR
  CROP UPTAKE OF PHOSPHORUS                        .702+02 LB/ACRE/YEAR
  VOLUME OF PERCOLATE                              .124+01 MGD
  QUALITY OF PERCOLATE
      SUSPENDED SOLIDS                             .600+01 MG/L
      VOLATILE SOLIDS                              .400+02 PERCENT
      BOD5                                         .125+02 MG/L
      BOD5 SOLUBLE                                 .375+01 MG/L
      COD                                          .250+02 MG/L
      COD SOLUBLE                                  .200+02 MG/L
      PO4                                          .144+01 MG/L
      TKN                                          .000    MG/L
      NO2                                          .000    MG/L
      NO3                                          .112+02 MG/L
      OIL AND GREASE                               .000    MG/L


QUANTITIES FOR SLOW INFILTRATION LAND TREATMENT

APPLIED FLOW                                       .301+01 MGD
BURIED SOLID SET SPRINKLER DISTRIBUTION SYSTEM
STORAGE VOLUME PER CELL                            .201+07 GAL
NUMBER OF STORAGE CELLS                                  2
LENGTH OF STORAGE CELL                             .505+03 FEET
DEPTH OF CUT FOR STORAGE LAGOONS                   .160+01 FEET
LAGOON EARTHWORK                                   .117+07 CU FT
NUMBER OF HEADERS                                        1
FLOW PER HEADER                                    .209+04 GPM
NUMBER OF LATERALS PER HEADER                           52
FLOW PER LATERAL                                   .402+02 GPM
DIAMETER OF LATERAL PIPE                           .400+01 INCHES
LENGTH PER LATERAL                                 .128+04 FEET
LENGTHS AND DIAMETERS OF HEADER PIPE
                          .600+02 FEET OF          .200+01 INCH PIPE
                          .600+02 FEET OF          .300+01 INCH PIPE
                          .120+03 FEET OF          .400+01 INCH PIPE
                          .360+03 FEET OF          .600+01 INCH PIPE
                          .540+03 FEET OF          .800+01 INCH PIPE
                          .660+03 FEET OF          .100+02 INCH PIPE
                          .780+03 FEET OF          .120+02 INCH PIPE
                          .840+03 FEET OF          .140+02 INCH PIPE
NUMBER OF SPRINKLERS PER LATERAL                        26
DIAMETER OF BUTTERFLY VALVES                       .140+02 INCHES
NUMBER OF BUTTERFLY VALVES                               1
LAND AREA FOR SERVICE ROADS                        .757+01 ACRES
LAND AREA FOR STORAGE LAGOONS                      .182+02 ACRES
LAND AREA FOR BUFFER ZONES                         .000    ACRES
TOTAL LAND AREA                                    .178+03 ACRES
TOTAL LENGTH OF FENCE                              .111+05 FEET
ANNUAL O & M FOR DISTRIBUTION SYSTEM               .197+04 MAN-HRS/YR
DISTRIBUTION SYSTEM MATERIAL COST                  .588+00 PERCENT
ANNUAL O & M FOR MONITORING WELLS                  .117+02 MAN-HRS/YR
MONITORING WELL MATERIAL COSTS                     .256+01 PERCENT

QUANTITIES FOR INTERMEDIATE PUMPING

AVERAGE DAILY PUMPING RATE                         .301+01 MGD
TOTAL PUMPING CAPACITY                             .301+01 MGD
DESIGN CAPACITY PER PUMP                           .104+04 GPM
NUMBER OF PUMPS                                          3
NUMBER OF BATTERIES                                      1
AREA OF PUMP BUILDING                              .259+03 SQ FT
VOLUME OF EARTHWORK REQUIRED                       .207+04 CU FT
FIRM PUMPING CAPACITY                              .301+01 MGD
OPERATING MANPOWER REQUIRED                        .507+03 MAN-HOURS/YR
MAINTENANCE MANPOWER REQUIRED                      .424+03 MAN-HOURS/YR
ELECTRICAL ENERGY REQUIRED                         .668+05 KWHR/YR
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                         LIQUID CHARACTERISTICS
FLOW        (MGD)       SOLIDS     (MG/L)                  (MG/L)           (MG/L)
MAXIMUM     .2000       SUSPENDED        .00      BOD5       .00     TKN     .00
AVERAGE     .2000       VOLATILE         .00 %    BOD5S      .00     NH3     .00
MINIMUM     .2000       SETTLEABLE       .00      COD        .00     NO2     .00
                                                  CODS       .00     NO3     .00
TEMP (W)      .0 C      OIL & GREASE     .00      PO4        .00
TEMP (S)    23.0 C      CATIONS          .00
PH            .0        ANIONS           .00

                        SLUDGE CHARACTERISTICS
                        PRIMARY            SECONDARY          CHEMICAL
VOLUME (GAL/D)            .00                 .00                .00
% SOLIDS                  .00                 .00                .00
% VOLATILE                .00                 .00                .00
```

LIQUID SLOW 2 COST SUMMARY

UNIT	CAPITAL COST $	AMMORT COST $/YR	OPER LABOR COST $/YR	MAINT LABOR COST $/YR	POWER COST $/YR	MATERIAL COST $/YR	CHEMICAL COST $/YR	TOTAL O & M COST $/YR
SLOW INF	964514	89150	8629	4208	0	2782	0	15619
INT PUMP	104495	10518	3687	2254	2672	731	0	9344
SUB TOTAL	969010	99668	12316	6462	2672	3513	0	24963

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DIRECT COSTS
 PROFIT/OVERHEAD                      213182 $

   SUB TOTAL (OTHER DIRECT)           213182 $        TOTAL CONSTRUCTION COST   1182192 $

INDIRECT COSTS
 MISC NON CONST COSTS                  59109 $
 ADMIN/LEGAL                           27643 $
 201 PLANNING                          41776 $
 A/E DESIGN FEE                        87094 $
 INSPECTION                            23643 $
 CONTINGENCIES                         94575 $
 TECHNICAL COSTS                       27643 $

   SUB TOTAL (INDIRECT)               353083 $

LAND COSTS                            177816 $     ( 178. ACRES)
INTEREST DURING CONSTRUCTION               0 $

ADMINISTRATIVE COST                     2355 $/YR
LABORATORY COST                        20212 $/YR

TOTAL PROJECT COST   1713091 $      TOTAL CONSTRUCTION COST   1182192 $
FINAL YEAR O & M       57573 $/YR   TOTAL STEP III COST       1584621 $
INITIAL YEAR O & M     57573 $/YR   PRESENT WORTH (APP. A)    2281613 $

USER CHARGE SUMMARY

D EPA GRANT                                                  .850+02 PERCENT
D STATE GRANT                                                .000    PERCENT
D ALLOWANCE FOR FINANCING                                    .300+01 PERCENT
  BONDS                        PERCENT   RATE   LIFE
D   REVENUE                    100.00   10.00    30
D   GENERAL OBLIGATION            .00     .00    30
D   OTHER                         .00     .00    30
D NUMBER OF BILLING UNITS                                    .365+06
D EXISTING SEWER RATE                                        .000    $/TGAL
D PERSONS PER HOUSEHOLD                                      .350+01
D GALLONS/CAPITA/DAY (WATER USE)                             .100+03 GPCPD
D CURRENT ANNUAL O & M COST                                  .000    $/YEAR
  TOTAL PROJECT COST                                         .171+07 $
  EPA ELIGIBLE COST                                          .171+07 $
  LOCAL SHARE                                                .265+06 $
  ANNUAL DEBT SERVICE                                        .281+05 $/YEAR
  PRINCIPAL AND INTEREST RESERVE                             .401+04 $/YEAR
  CONTINGENCY RESERVE                                        .401+04 $/YEAR
  TOTAL ANNUAL OPERATING COST                                .896+05 $/YEAR
  TREATMENT COST
    COST PER 1000 GALLONS TREATED (NEW SYSTEM)               .246+00 $/TGAL
    COST PER 1000 GALLONS TREATED (TOTAL SYSTEM)             .245+00 $/TGAL
    COST PER BILLING UNIT (NEW SYSTEM)                       .246+00 $/TGAL
    COST PER BILLING UNIT (TOTAL SYSTEM)                     .246+00 $/TGAL
    COST PER HOUSEHOLD (NEW SYSTEM)                          .258+01 $/MONTH
    COST PER HOUSEHOLD (TOTAL SYSTEM)                        .258+01 $/MONTH
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

LAND TREATMENT EXAMPLES                      ANALYZE   2  TRAIN NO   2

                              INFLUENT

                         LIQUID CHARACTERISTICS
FLOW        (MGD)       SOLIDS     (MG/L)                  (MG/L)           (MG/L)
MAXIMUM     1.0000      SUSPENDED     200.00      BOD5     250.00     TKN   45.00
AVERAGE     1.0000      VOLATILE       60.00 %    BOD5S     75.00     NH3   25.00
MINIMUM     1.0000      SETTLEABLE     15.00      COD      500.00     NO2     .00
                                                  CODS     400.00     NO3     .00
TEMP (W)    10.0 C      OIL & GREASE   80.00      PO4       18.00
TEMP (S)    23.0 C      CATIONS       160.00
PH           7.6        ANIONS        160.00
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SLUDGE CHARACTERISTICS	PRIMARY	SECONDARY	CHEMICAL
VOLUME (GAL/D)	.00	.00	.00
% SOLIDS	.00	.00	.00
% VOLATILE	.00	.00	.00

RAPID INFILTRATION LAND TREATMENT

NO COVER CROP		
D APPLICATION RATE	.[illegible]+02	IN/WEEK
D EVAPOTRANSPORATION RATE	.400+00	IN/WEEK
D PRECIPITATION RATE	.[illegible]+00	IN/WEEK
D PERCENT DENITRIFIED	.4[illegible]+[illegible]	PERCENT
D PERCENT AMMONIA VOLATILIZATION	.000	PERCENT
SOIL UPTAKE OF PHOSPHORUS	.5[illegible]+02	LB/ACRE/YEAR
D WASTEWATER GENERATION PERIOD	.365+03	DAYS/YR
SURFACE FLOODING		
D NO RECOVERY SYSTEM		
D BUFFER ZONE WIDTH	.000	FEET
D NUMBER OF MONITORING WELLS	9	WELLS
D DEPTH OF MONITORING WELLS	.100+02	FEET
D COST OF FENCING	.275+01	$/FT
TREATMENT AREA REQUIRED	.730+01	ACRES
VOLUME OF PERCOLATE	.10[illegible]+01	MGD
QUALITY OF PERCOLATE		
SUSPENDED SOLIDS	.200+01	MG/L
VOLATILE SOLIDS	.600+02	PERCENT
BOD5	.2[illegible]+01	MG/L
BOD5 SOLUBLE	.[illegible]50+00	MG/L
COD	.137+03	MG/L
COD SOLUBLE	.167+03	MG/L
PO4	.177+02	MG/L
TKN	.147+02	MG/L
NO2	.000	MG/L
NO3	.970+01	MG/L
NH3	.857+01	MG/L
OIL AND GREASE	.000	MG/L

QUANTITIES FOR RAPID INFILTRATION LAND TREATMENT

GENERATED FLOW	.10[illegible]+01	MGD
NUMBER OF INFILTRATION BASINS	4	
AREA OF INDIVIDUAL INFILTRATION BASIN	.1[illegible]+01	ACRES
LENGTH OF INDIVIDUAL INFILTRATION BASIN	.2[illegible]4+03	FEET
VOLUME OF EARTHWORK REQUIRED	.447+06	CU FT
HEADER PIPE DIAMETER	.100+02	INCHES
LENGTH OF HEADER PIPE REQUIRED	.113+04	FEET
HEADER PIPE DIAMETER	.600+01	INCHES
NUMBER OF VALVES REQUIRED	4	
LENGTH OF LATERAL PIPE REQUIRED	.400+03	FEET
MONITORING WELLS SPECIFIED		
NUMBER OF MONITORING WELLS	9	
DEPTH OF MONITORING WELLS	.100+02	FEET
ANNUAL O & M FOR DISTRIBUTION SYSTEM	.452+03	MAN-HRS/YEAR
MATERIAL COST FOR DISTRIBUTION SYSTEM	.[illegible]7[illegible]+01	PERCENT
ANNUAL O & M FOR MONITORING WELLS	.109+03	MAN-HRS/YEAR
MATERIAL COSTS FOR MONITORING WELLS	.256+01	PERCENT
FENCING REQUIRED	.2[illegible]4+04	FEET
LAND REQUIRED (INCLUDING BUFFER AREA)	.100+02	ACRES

QUANTITIES FOR INTERMEDIATE PUMPING

AVERAGE DAILY PUMPING RATE	.10[illegible]+01	MGD
TOTAL PUMPING CAPACITY	.101+01	MGD
DESIGN CAPACITY PER PUMP	.352+03	GPM
NUMBER OF PUMPS	3	
NUMBER OF BATTERIES	1	
AREA OF PUMP BUILDING	.220+03	SQ FT
VOLUME OF EARTHWORK REQUIRED	.176+04	CU FT
FIRM PUMPING CAPACITY	.101+01	MGD
OPERATING MANPOWER REQUIRED	.441+03	MAN-HOURS/YR
MAINTENANCE MANPOWER REQUIRED	.361+03	MAN-HOURS/YR
ELECTRICAL ENERGY REQUIRED	.6[illegible]0+05	KWHR/YR

LIQUID CHARACTERISTICS

FLOW	(MGD)	SOLIDS	(MG/L)		(MG/L)		(MG/L)
MAXIMUM	.2000	SUSPENDED	.00	BOD5	.00	TKN	.00
AVERAGE	.2000	VOLATILE	.00 %	BOD5S	.00	NH3	.00
MINIMUM	.0000	SETTLEABLE	.00	COD	.00	NO2	.00
				CODS	.00	NO3	.00
TEMP (W)	.0 C	OIL & GREASE	.00	PO4	.00		
TEMP (S)	23.0 C	CATIONS	.00				
PH	.0	ANIONS	.00				

SLUDGE CHARACTERISTICS	PRIMARY	SECONDARY	CHEMICAL
VOLUME (GAL/D)	.00	.00	.00
% SOLIDS	.00	.00	.00
% VOLATILE	.00	.00	.00

LIQUID RAPID COST SUMMARY

UNIT	CAPITAL COST $	AMMORT COST $/YR	OPER LABOR COST $/YR	MAINT LABOR COST $/YR	POWER COST $/YR	MATERIAL COST $/YR	CHEMICAL COST $/YR	TOTAL O & M COST $/YR
RAPID IN	55943	5911	3285	0	0	708	0	3993
INT PUMP	68130	6839	3206	1731	2718	476	0	8131
SUB TOTAL	124073	12651	6492	1731	2718	1185	0	12124

DIRECT COSTS
PROFIT/OVERHEAD 27296 $

SUB TOTAL (OTHER DIRECT) 27296 $ TOTAL CONSTRUCTION COST 151369

INDIRECT COSTS
MISC NON CONST COSTS 7568 $
ADMIN/LEGAL 3027 $
201 PLANNING 5297 $
A/E DESIGN FEE 14297 $
INSPECTION 3027 $
CONTINGENCIES 12109 $
TECHNICAL COSTS 3027 $

SUB TOTAL (INDIRECT) 50352 $

LAND COSTS 10000 $ (10. ACRES)
INTEREST DURING CONSTRUCTION 0 $

ADMINISTRATIVE COST 8355 $/YR
LABORATORY COST 20212 $/YR

TOTAL PROJECT COST 211721 $ TOTAL CONSTRUCTION COST 151369 $
FINAL YEAR O & M 40695 $/YR TOTAL STEP III COST 190127 $
INITIAL YEAR O & M 40695 $/YR PRESENT WORTH (APP. A) 846515 $

USER CHARGE SUMMARY

D EPA GRANT .750+02 PERCENT
D STATE GRANT .000 PERCENT
D ALLOWANCE FOR FINANCING .300+01 PERCENT

BONDS	PERCENT	RATE	LIFE
D REVENUE	100.00	10.00	30
D GENERAL OBLIGATION	.00	.00	30
D OTHER	.00	.00	30

D NUMBER OF BILLING UNITS .365+06
D EXISTING SEWER RATE .000 $/TGAL
D PERSONS PER HOUSEHOLD .350+01
D GALLONS/CAPITA/DAY (WATER USE) .100+03 GPCPD
D CURRENT ANNUAL O & M COST .000 $/YEAR
TOTAL PROJECT COST .212+06 $
EPA ELIGIBLE COST .202+06 $
LOCAL SHARE .619+05 $
ANNUAL DEBT SERVICE .657+04 $/YEAR
PRINCIPAL AND INTEREST RESERVE .939+03 $/YEAR
CONTINGENCY RESERVE .939+03 $/YEAR
TOTAL ANNUAL OPERATING COST .491+05 $/YEAR
TREATMENT COST
COST PER 1000 GALLONS TREATED (NEW SYSTEM) .135+00 $/TGAL
COST PER 1000 GALLONS TREATED (TOTAL SYSTEM) .135+00 $/TGAL
COST PER BILLING UNIT (NEW SYSTEM) .135+00 $/TGAL
COST PER BILLING UNIT (TOTAL SYSTEM) .135+00 $/TGAL
COST PER HOUSEHOLD (NEW SYSTEM) .141+01 $/MONTH
COST PER HOUSEHOLD (TOTAL SYSTEM) .141+01 $/MONTH

* *

LAND TREATMENT EXAMPLES ANALYZE 3 TRAIN NO 3

INFLUENT

LIQUID CHARACTERISTICS

FLOW	(MGD)	SOLIDS	(MG/L)		(MG/L)		(MG/L)
MAXIMUM	1.0000	SUSPENDED	200.00	BOD5	250.00	TKN	45.00
AVERAGE	1.0000	VOLATILE	60.00 %	BOD5S	75.00	NH3	25.00
MINIMUM	1.0000	SETTLEABLE	15.00	COD	500.00	NO2	.00
				CODS	400.00	NO3	.00
TEMP (W)	10.0 C	OIL & GREASE	80.00	PO4	18.00		
TEMP (S)	23.0 C	CATIONS	160.00				
PH	7.6	ANIONS	160.00				

SLUDGE CHARACTERISTICS

	PRIMARY	SECONDARY	CHEMICAL
VOLUME (GAL/D)	.00	.00	.00
% SOLIDS	.00	.00	.00
% VOLATILE	.00	.00	.00

OVERLAND FLOW LAND TREATMENT

D HOURS PER DAY OPERATION .800+01 HOURS
D DAYS PER WEEK OPERATION .700+01 DAYS
FORAGE GRASSES
D HYDRAULIC APPLICATION RATE .350+01 IN/WEEK
D EVAPOTRANSPORATION RATE .400+00 IN/WEEK
D PRECIPITATION RATE .800+00 IN/WEEK
D PERCENT DENITRIFIED .900+02 PERCENT
D PERCENT AMMONIA VOLATILIZATION .000 PERCENT
D SPRAY EVAPORATION .500+01 PERCENT
D SOIL PERCOLATE .500+01 PERCENT

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D WASTEWATER GENERATION PERIOD                     .365+03 DAYS/YR
D FIELD APPLICATION PERIOD                         .520+02 WEEKS/YR
  SOLID SET PIPING AND PUMPING
D MINIMUM STORAGE SPECIFIED                        .300+02 DAYS
  CALCULATED STORAGE REQUIRED                      .621+02 ACRE-FT
D OPEN CHANNEL RECOVERY SYSTEM
D BUFFER ZONE WIDTH                                .000    FEET
D CURRENT GROUND COVER
      FOREST                                       .200+02 PERCENT
      BRUSH                                        .300+02 PERCENT
      PASTURE                                      .500+02 PERCENT
D SLOPE OF SITE                                    .200+01 PERCENT
D NUMBER OF MONITORING WELLS                             9 WELLS
D DEPTH OF MONITORING WELLS                        .100+02 FEET
D COST OF FENCING                                  .275+01 $/FT
  TREATMENT AREA REQUIRED                          .730+02 ACRES
  MAXIMUM DESIRED NITRATE EFFLUENT                 .100+02 MG/L
  CROP UPTAKE OF NITROGEN                          .774+03 LB/ACRE/YEAR
  CROP UPTAKE OF PHOSPHORUS                        .467+02 LB/ACRE/YEAR
  VOLUME OF RUNOFF                                 .102+01 MGD
  QUALITY OF RUNOFF
      SUSPENDED SOLIDS                             .140+02 MG/L
      VOLATILE SOLIDS                              .600+02 PERCENT
      BOD5                                         .246+02 MG/L
      BOD5 SOLUBLE                                 .739+01 MG/L
      COD                                          .250+03 MG/L
      COD SOLUBLE                                  .300+03 MG/L
      PO4                                          .166+02 MG/L
      TKN                                          .222+01 MG/L
      NO2                                          .000    MG/L
      NO3                                          .667+01 MG/L
      OIL AND GREASE                               .000    MG/L

QUANTITIES FOR OVERLAND FLOW LAND TREATMENT

APPLIED FLOW                                       .301+01 MGD
STORAGE VOLUME PER CELL                            .201+07 GAL
NUMBER OF STORAGE CELLS                                  2
LENGTH OF STORAGE CELL                             .585+03 FEET
DEPTH OF CUT FOR STORAGE LAGOONS                   .160+01 FEET
LAGOON EARTHWORK                                   .117+07 CU FT
NUMBER OF HEADERS                                        3
DESIGN FLOW PER HEADER                             .870+02 GPM
DESIGN FLOW PER SPRINKLER                          .487+01 GPM
NUMBER OF LATERALS PER HEADER                            2
DESIGN FLOW PER LATERAL                            .435+02 GPM
DIAMETER OF LATERAL PIPE                           .200+01 INCHES
LENGTH OF LATERAL PIPE                             .270+04 FEET
LENGTHS AND DIAMETERS OF HEADER PIPE
                          .116+04 FEET OF          .300+01 INCH PIPE
DIAMETER OF BUTTERFLY VALVES                       .300+01 INCHES
NUMBER OF BUTTERFLY VALVES                               3
DIAMETER OF PLUG VALVES                            .200+01 INCHES
NUMBER OF PLUG VALVES                                    6
NUMBER OF SPRINKLERS PER HEADER                         18
SLOPE CONSTRUCTION EARTHWORK                       .407+07 CU FT
TERRACE CONSTRUCTION EARTHWORK                     .450+05 CU FT
TOTAL LENGTH OF DRAINAGE DITCHES                   .160+04 FEET
LAND AREA FOR DITCHES AND ROADS                    .111+02 ACRES
LAND AREA FOR STORAGE LAGOONS                      .189+02 ACRES
LAND AREA FOR BUFFER ZONES                         .000    ACRES
TOTAL LAND AREA                                    .104+03 ACRES
TOTAL LENGTH OF FENCE                              .851+04 FEET
ANNUAL O & M FOR DISTRIBUTION SYSTEM               .804+03 MAN-HRS/YR
DISTRIBUTION SYSTEM MATERIAL COST                  .586+00 PERCENT
ANNUAL O & M FOR MONITORING WELLS                  .117+02 MAN-HRS/YR
MONITORING WELLS O & M MATERIAL COST               .256+01 PERCENT
ANNUAL O & M  OPEN DITCH RECOVERY SYSTEM           .172+03 MAN-HRS/YR
OPEN DITCH RECOVERY SYSTEM MATERIAL COST           .144+02 PERCENT

QUANTITIES FOR INTERMEDIATE PUMPING

AVERAGE DAILY PUMPING RATE                         .301+01 MGD
TOTAL PUMPING CAPACITY                             .301+01 MGD
DESIGN CAPACITY PER PUMP                           .104+04 GPM
NUMBER OF PUMPS                                          3
NUMBER OF BATTERIES                                      1
AREA OF PUMP BUILDING                              .259+03 SQ FT
VOLUME OF EARTHWORK REQUIRED                       .207+04 CU FT
FIRM PUMPING CAPACITY                              .301+01 MGD
OPERATING MANPOWER REQUIRED                        .507+03 MAN-HOURS/YR
MAINTENANCE MANPOWER REQUIRED                      .424+03 MAN-HOURS/YR
ELECTRICAL ENERGY REQUIRED                         .668+05 KWHR/YR


                        LIQUID CHARACTERISTICS
FLOW        (MGD)    SOLIDS     (MG/L)            (MG/L)         (MG/L)
MAXIMUM     1.0174   SUSPENDED   14.00     BOD5    24.65     TKN   2.22
AVERAGE     1.0174   VOLATILE    60.00 %   BOD5S    7.39     NH3   2.22
MINIMUM     1.0174   SETTLEABLE    .00     COD    249.65     NO2    .00
                                           CODS   299.89     NO3   6.67
TEMP (W)    10.0 C   OIL & GREASE     .00  PO4     16.63
TEMP (S)    23.0 C   CATIONS          .00
PH           7.6     ANIONS           .00

                       SLUDGE CHARACTERISTICS
                          PRIMARY          SECONDARY          CHEMICAL
   VOLUME (GAL/D)           .00               .00                .00
        % SOLIDS            .00               .00                .00
        % VOLATILE          .00               .00                .00
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LIQUID OVER C COST SUMMARY

UNIT	CAPITAL COST $	AMMORT COST $/YR	OPER LABOR COST $/YR	MAINT LABOR COST $/YR	POWER COST $/YR	MATERIAL COST $/YR	CHEMICAL COST $/YR	TOTAL O & M COST $/YR
OVERLAND	400330	39037	7481	0	0	253	0	7734
INT PUMP	104495	10518	3687	2061	2672	731	0	9151
SUB TOTAL	504826	49556	11169	2061	2672	984	0	16885

DIRECT COSTS
PROFIT/OVERHEAD 111061 $

SUB TOTAL (OTHER DIRECT) 111061 $ TOTAL CONSTRUCTION COST 615887 $

INDIRECT COSTS

MISC NON CONST COSTS	30794	$
ADMIN/LEGAL	12317	$
201 PLANNING	21556	$
A/E DESIGN FEE	49522	$
INSPECTION	12317	$
CONTINGENCIES	49270	$
TECHNICAL COSTS	12317	$

SUB TOTAL (INDIRECT) 188093 $

LAND COSTS 104000 $ (104. ACRES)
INTEREST DURING CONSTRUCTION 0 $

ADMINISTRATIVE COST 8355 $/YR
LABORATORY COST 20212 $/YR

TOTAL PROJECT COST	907980 $	TOTAL CONSTRUCTION COST	615887 $
FINAL YEAR O & M	45455 $/YR	TOTAL STEP III COST	836902 $
INITIAL YEAR O & M	45455 $/YR	PRESENT WORTH (APP. A)	1473485 $

USER CHARGE SUMMARY

D EPA GRANT .850+02 PERCENT
D STATE GRANT .000 PERCENT
D ALLOWANCE FOR FINANCING .300+01 PERCENT

BONDS	PERCENT	RATE	LIFE
D REVENUE	100.00	10.00	30
D GENERAL OBLIGATION	.00	.00	30
D OTHER	.00	.00	30

D NUMBER OF BILLING UNITS	.365+06	
D EXISTING SEWER RATE	.000	$/TGAL
D PERSONS PER HOUSEHOLD	.350+01	
D GALLONS/CAPITA/DAY (WATER USE)	.100+03	GPCPD
D CURRENT ANNUAL O & M COST	.000	$/YEAR
TOTAL PROJECT COST	.908+06	$
EPA ELIGIBLE COST	.908+06	$
LOCAL SHARE	.140+06	$
ANNUAL DEBT SERVICE	.149+05	$/YEAR
PRINCIPAL AND INTEREST RESERVE	.213+04	$/YEAR
CONTINGENCY RESERVE	.213+04	$/YEAR
TOTAL ANNUAL OPERATING COST	.646+05	$/YEAR
TREATMENT COST		
COST PER 1000 GALLONS TREATED (NEW SYSTEM)	.177+00	$/TGAL
COST PER 1000 GALLONS TREATED (TOTAL SYSTEM)	.177+00	$/TGAL
COST PER BILLING UNIT (NEW SYSTEM)	.177+00	$/TGAL
COST PER BILLING UNIT (TOTAL SYSTEM)	.177+00	$/TGAL
COST PER HOUSEHOLD (NEW SYSTEM)	.186+01	$/MONTH
COST PER HOUSEHOLD (TOTAL SYSTEM)	.186+01	$/MONTH

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@FORMS

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