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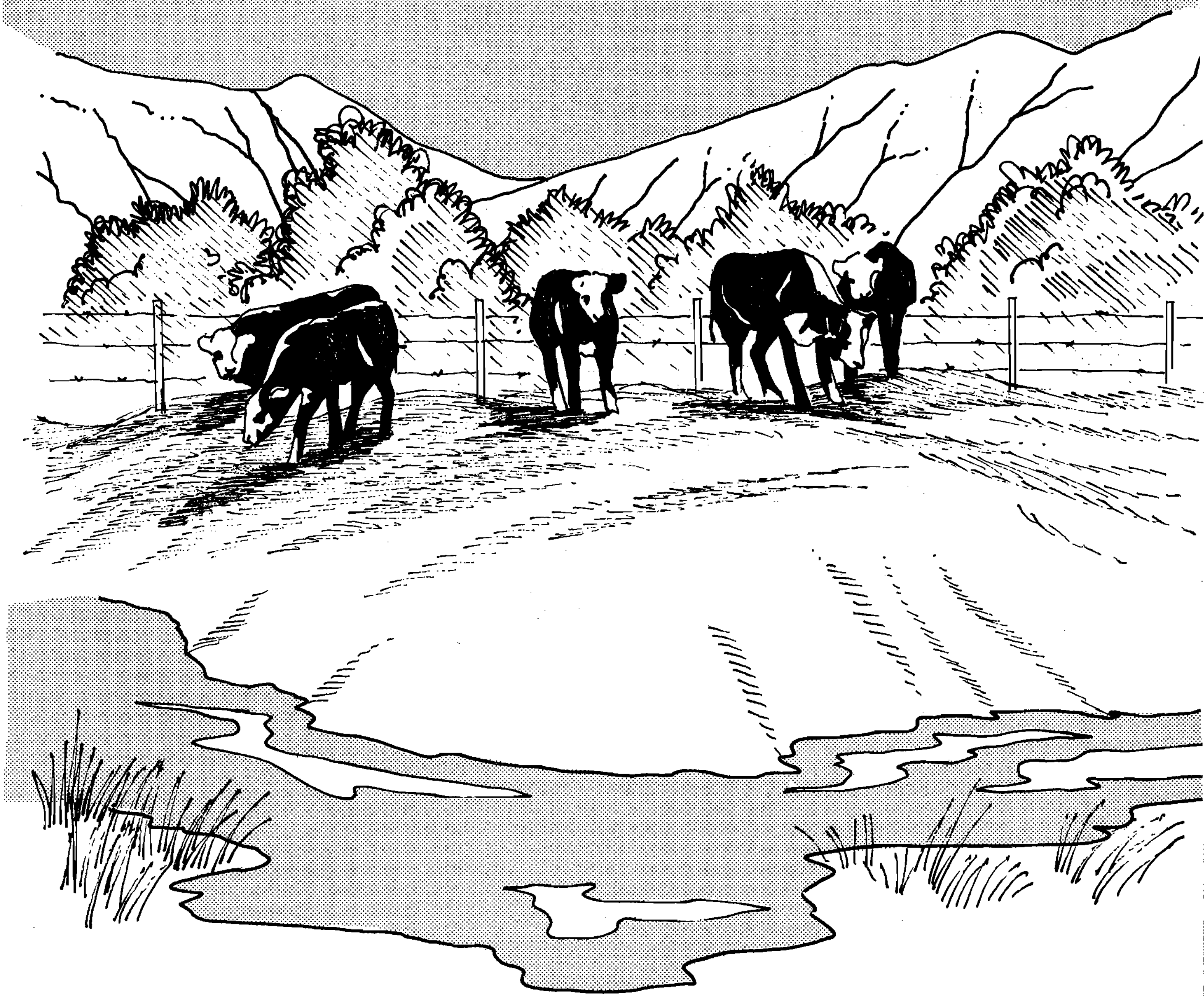
EVALUATION OF LIVESTOCK RUNOFF AS A SOURCE OF WATER POLLUTION IN NORTHERN UTAH

Stephen T. Wieneke, Dennis B. George, Daniel S. Filip, and Brad Finney



Utah Water Research Laboratory
College of Engineering
Utah State University
Logan, Utah 84322

September 1980

WATER QUALITY SERIES
UWRL/Q-80/02

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ABSTRACT

A mathematical model was developed to predict the impact of dairy and beef cattle feedlot runoff on receiving streams. The mathematical expressions used in the model describing runoff quantity and quality were not only a function of single rain or snow precipitation events but also consecutive events prior to the runoff occurrence. The runoff quantity and quality were also a function of feedlot surface. Computer simulations indicate that pollutants from feedlot runoff may have a significant impact on receiving streams during winter months. Runoff from feedlots located within the study area, however, had little impact on water quality in the summer. The computer simulations were compared with field data collected within a subdrainage system of Cache Valley, Utah. Concentrations of pollutants within the streams were higher in summer. This is believed due to mixing of stored pollutants in the stream sediments with the overlying water.

ACKNOWLEDGMENTS

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INTRODUCTION

Rationale

Livestock animal production in confined feedlot areas has become an integral part of the agricultural industry. Feedlots, as used for containment areas for both beef and dairy cattle, have been an important part of the agricultural industry for years. Both cattlemen and dairymen have seen the necessity of placing their livestock in a confined area for both convenience and practicality. As of January 1973, there were approximately 101 million beef cattle in the United States (Agricultural Statistics 1973). The population of cattle contained in feedlots was approximately 14 million (AWMTC 1978). A greater public awareness of the impact of agricultural waste discharges on the environment has developed with the encroachment of suburban areas into agricultural domains. A potential major contributor to the degradation of water quality in streams and water impoundments is waste discharges from livestock feeding operations (Kreis et al. 1972).

The research presented herein pertains to the assessment of the impact of beef and dairy cattle feedlot waste discharges on a hydrological drainage system. A mathematical model was developed as a tool to predict mass loadings of nutrients, organic matter, and other pollutants to the receiving waters.

Statement of Purpose

The purpose of this research was to develop a procedure to predict the potential impact of livestock waste runoff on receiving streams in Cache Valley, Utah.

Objectives

The specific objectives of the project were as follows:

1) Categorize all feedlots in the study area with potential discharges according to the size of facility, number of cattle, type of cattle (i.e., beef or dairy), area of lot, slope of lot, and location of facility.

2) Examine the extent and impact of pollution caused by livestock operations on receiving streams.

3) Determine feedlot runoff flow rates and contaminant mass loadings occurring during both rainfall and snowmelt events.

4) Develop a mathematical model to predict the mass loading of pollutants contained in livestock waste runoff to receiving streams within the study area.

REVIEW OF LITERATURE

Definition of a Cattle Feedlot

In accordance with the Federal Water Pollution Control Amendments of 1972 (PL 92-500), animal feedlots are designated as "point sources" of pollution (EPA 1974). Cattle feedlots are defined by the following three conditions: 1) Cattle are confined within a limited area for periods of time for the purposes of production of meat, milk, or breeding stock; 2) feeds are transported to the cattle; and 3) the limited area for confinement cannot sustain nor be available for crop or forage production (EPA 1974).

Cattle Feedlot Waste Characterization

Adult beef and dairy cattle produce urine and fecal wastes at an average rate of 18 to 27 kg (40 to 60 lbs) and 44 kg (96 lbs) per day, respectively. The mass of wet manure produced per gram of animal per day and the solids concentration of wet manures are shown in Table 1 for dairy and beef cattle. Production of manure per unit weight of animal is closely correlated with animal weight (AWMTC 1978). An average of 0.057 gram of manure per day (dry weight) per gram of animal weight (57 lbs/day/1000 lbs of animal weight) is excreted by beef cattle. This solid waste is composed of 15 to 20 percent crude protein on a dry weight basis (Hansen et al. 1976).

Physical and chemical characteristics of livestock wastes are greatly influenced by the type of animal, housing facility, and the diet consumed. Animal wastes rarely contain nitrites and nitrates (Dague and Kline 1969). Nitrogen found in these wastes is predominantly organic and ammonia nitrogen. The animal's metabolism and excretion of nutrients and minerals are dependent upon the type of animal (i.e., beef or dairy) and the feed available to the cattle (Taiganides and Hazen 1966). The major constituents in animal feedlot waste discharges are affected by the following factors (EPA 1974):

1) Surface type (i.e., soil or paved);
2) Biological products of metabolism;
3) Bedding material;
4) Microorganisms from the digestive tract;
5) Digestive juices;
6) Feed characteristics (i.e., high phosphate content);
7) Water and milking center wastes;

Table 1. Physical characteristics of livestock waste (AWMTC 1978).

Animal	Manure ($g g^{-1}$ of animal-day)	Total Solids ($g g^{-1}$ of animal-day)	Volatile Solids ($g g^{-1}$ of animal-day)	References
Cattle (Dairy)	0.071	0.0114	-	Moore 1969
(Dairy)	0.058	0.0087	-	Hart 1960
(Dairy)	-	0.0104	0.0083	Hart and Turner 1965
(Dairy)	-	0.0068	0.0057	Witzel et al., 1966
(Dairy)	-	0.0075	-	Dept. Sc. & Ind. Res. 1964
(Dairy)	0.124	0.0025	0.0018	Townsend et al. 1970
(Beef)	0.082	0.0197	-	Moore 1969
(Beef)	0.039-0.074	0.0095-0.0114	-	Taiganides and Hazen 1966
(Beef)	0.063	0.0095	-	Hart 1960
(Beef)	0.067	0.0090	0.0069	Loehr and Agnew 1967
(Beef)	-	0.0036	0.0032	Witzel et al., 1966
(Beef)	0.063	0.0050	0.0040	Townsend et al. 1970
(Beef)	-	0.0091	-	Dale and Day 1967
Average (D)	0.084	0.0079	0.0053	
Average (B)	0.066	0.0095	0.0047	
Sheep	0.072	0.016	-	Hart 1960
Ducks	-	0.016	-	FWPCA 1966

8) Feed additives;
9) Partially digested feed; and
10) Cells and cell debris from the digestive tract wall.

Nutrient and chemical characteristics of livestock waste are presented in Table 2. Average daily manure production by beef cattle is shown in Table 3 (Taiganides and Hazen 1966). The results vary substantially for all parameters listed depending on physical characteristics (i.e., soil or paved lot) of the livestock operation (EPA 1974).

Cattle Feedlot Runoff Characteristics

Pollutant levels in runoff from feedlots are quite high (Table 4). Direct feedlot runoff may have 5-day biochemical oxygen demand (BOD_5) concentrations approximately four times the levels normally found in domestic sewage (100 to 300 mg/l BOD_5) (Gilbertson et al. 1969). Concentrations of pollutants in manure runoff can range from values typical of domestic sewage to as much as 10 times greater depending on rainfall rate, temperature, and feedlot conditions (Dague and Kline 1969). Runoff from feedlots has also been reported to have high concentrations of coliform organisms, chemical oxygen demand (COD), and nitrogenous compounds.

As shown in Table 4, orthophosphate phosphorus and nitrogen concentrations in feedlot runoff can vary significantly. The variation of nutrient concentrations in runoff can be attributed to physical characteristics of the feedlot such as type of facility flooring (i.e., paved or soil) and type of precipitation (i.e., rain or snow). Concentrations of orthophosphate phosphorus in snowmelt runoff have been reported to be much lower than those observed during rainfall runoff (Filip and Middlebrooks 1976). The reverse is true for total solids (TS), volatile suspended solids (VSS), chemical oxygen demand (COD), and biochemical oxygen demand (BOD_5) where concentrations have been observed to be much higher during snowmelt runoff (Gilbertson 1969).

Table 2. Nutrient characteristics of animal wastes (AWMTC 1978).

Animal	(g/g of animal-day x 10^{-3})						References
	Biochemical Oxygen Demand (BOD_5)	Chemical Oxygen Demand (COD)	Ammonia Nitrogen	Total Nitrogen	Phosphorus (P_2O_5)	Potassium (K_2O)	
Beef cattle	-	-	-	0.36	0.115	0.274	Moore 1969
	-	-	-	0.35-0.44	0.11-0.12	0.27-0.34	Taiganides and Hazen 1966
	-	-	-	0.29	-	-	Hart 1960
	1.11-2.22	10.0	-	0.26	-	-	Loehr and Agnew 1967
	1.02	3.26	0.11	0.26	-	-	Witzel et al., 1966
	-	-	-	0.41	0.25	-	Vollenweider 1968
	1.87	15.0	-	0.16	0.31	-	Townsend et al. 1970
	1.84	-	-	-	-	-	Dale and Day 1967
Average	1.61	9.42	0.11	0.32	0.18	0.29	
Dairy cattle	-	-	-	-	0.30	-	Hart 1960
	-	1.53	19.1	-	-	-	Jeffery et al. 1963
	0.31	1.53	8.4	-	0.38	0.12	Hart and Turner 1965
	-	1.32	5.8	0.23	0.37	-	Witzel et al., 1966
	-	0.44	-	-	0.49	-	Dept. Sc. & Ind. Res. 1964
	-	0.95	5.7	-	0.16	0.11	Townsend et al. 1970
Average	0.31	1.15	9.8	0.23	0.34	0.12	

Table 3. Values for average daily manure production by cattle (Taiganides and Hazen 1966).

Item	Units	Cattle (1,000 lb)
Wet Manure	lb/day	64.0
Total Solids	% Wet Basis	16.0
Volatile Solids	% Dry Basis	80.0
Nitrogen (N)	% Dry Basis	3.7
Phosphorus (P_2O_5)	% Dry Basis	1.1
Potassium (K_2O)	% Dry Basis	3.0
BOD	lb/day/100 lb	0.13
COD	lb/day/100 lb	1.05
COD/BOD Ratio		8.07
Population Equivalent		7.0

Physical Factors Affecting Runoff from Feedlots

The concentration of pollutants in runoff is influenced to some extent by

Table 4. Feedlot runoff characteristics from cattle feedlots (after agricultural waste) (AWMTC 1978).

Range of Values for Constituents (mg/l)							References
Suspended Solids	Ortho-phosphate (PO_4)	Organic Nitrogen	Ammonia Nitrogen	Nitrate Nitrogen	BOD_5	COD	
3400-13,400	-	-	-	-	500-3300	-	Owens and Griffen 1968
-	-	6-800	2-770	0-1270	1000-12,000	2400-38,000	Wells et al. 1970
1000-7000[a]					300-6000		Norton and Hansen 1969
-	-	-	-	-	1500-9000	4000-15,000	Loehr 1969
1400-12,000	15-80	-	1-139	0.1-11	-	2500-15,000	Miner et al. 1966
-	20-30	600-630	270-410	-	5000-11,000	16,000-40,000	Loehr 1969
1500-12,000	-	-	16-140	-	-	3000-11,000	Miner 1967
1400-12,000	62-1460[b]	265-3400	-	-	800-7500	-	Townsend et al. 1970

[a]Volatile solids.

[b]Total phosphorus as PO_4.

factors such as composition of animal feed, antecedent moisture conditions, depth of manure, type of lot surface, slope of lot, and density of cattle (Texas Tech University 1971). Chemical composition of feeds used for either dairy or beef cattle is quite different. Feeds frequently fed to beef cattle are high in phosphorus content resulting in high concentrations of phosphorus in runoff. The longer manure remains wet, the better the chance of biological degradation of the pollutional compounds (AWMTC 1978). In arid climates, with rapid drying, the nutrients and organic compounds contained in manures vary little with time. If wet again and transported to a stream, the material will contribute essentially the same pollutional land as it originally discharged to the receiving stream (Gilbertson et al. 1971; Meyers et al. 1972; Filip et al. 1973).

Climatic conditions influence variations in pollutional concentrations in manures (AWMTC 1978). Under winter snowfall conditions or normal rainfall, feedlot soils tend to be high in moisture content and an increased mixing of manure and soil particles by the animals occurs. When the feedlot surface becomes covered with manure, the accumulated depth of the manure no longer affects the concentrations of the contaminants in the runoff (AWMTC 1978). This phenomenon was further emphasized by Miner (1967) who observed that the quality of the runoff was essentially the same under scraped and unscraped feedlot conditions.

Other surface parameters which affect runoff characteristics are the type of feedlot surface (i.e., paved or unpaved) and the slope of the lot. Concentrations of pollutants and amount of runoff depend more on precipitation than on the degree of feedlot slope (Gilbertson et al. 1969). The degree of the slope can influence the retention of water on the lot. However, the high concentration of pollutants in runoff is not affected by the degree of slope. The feedlot surface type does affect the quantity of feedlot runoff. Concentrations of pollutants in runoff resulting from precipitation on concrete-surfaced lots are greater than corresponding concentrations derived from dirt-surfaced lots (Miner et al. 1966; Texas Tech University 1971).

The amount of manure present on the feedlot does not significantly affect runoff characteristics (Gilbertson et al. 1971). Old rehydrated manure can have essentially the same characteristics as new manure (AWMTC 1978). Therefore, cattle density can be insignificant when compared with the influence of precipitation. Generally, this will apply only to old lots in which a mantle of manure has accumulated over the years. The concentration of pollutants and quality of feedlot runoff will be influenced largely by the rainfall intensity, water content on the feedlot, and the type of feedlot surface (Gilbertson et al. 1971).

Hydrology

Runoff from cattle feedlots begins only when the surface storage of the area has been saturated (McElroy et al. 1976). Surface storage of liquid waste is influenced by indentations made by cattle hooves and build up of soil and old manure on unpaved lots. On paved lots manure mounds created by scraping practices enhance pooling of liquid waste on and around the edge of the facility. Gilbertson et al. (1971) reported that runoff occurred only after rainfall exceeded 10.2 to 12.7 cm (0.4 to 0.5 inch) on unpaved lots. Other studies have shown that the time elapsed before runoff occurred was dependent upon the rainfall intensity, surface slope, and the moisture content of the manure mantle (Hansen et al. 1976).

The duration of runoff is dependent primarily on the continuation of precipitation. Mathematical representation of runoff as a function of precipitation has been expressed in two ways: 1) As a simple linear regression model and 2) by the Runoff Curve Number concept (RCN) (Overcash and Phillips 1978).

The following regression equations define runoff (inches) as a function of precipitation (inches):

Runoff = 0.945 Pr + (-0.34) (Loehr 1969) . . . . (1)

Runoff = 0.531 Pr + (0.135) (Gilbertson 1971) . . . . (2)

Runoff = 0.500 Pr + (-0.124) (Kreis et al. 1972) . . . . (3)

Runoff = 0.33 Pr + (-0.20) (Hansen et al. 1976) . . . . (4)

Runoff = 0.45 Pr + (-0.31) (Porter et al. 1975) . . . . (5)

Runoff = 0.365 Pr + (-0.143) (Clark et al. 1974) . . . . (6)

The mathematical relationships can be used for either paved or unpaved surfaces during rain events. The dissimilarity in the equations above, and others that are available (Shuyler et al. 1973; Clark et al. 1975), is due to differences in precipitation distribution and the type of lot studied. These regional differences caused unique relationships between runoff and precipitation for that area and time span.

The runoff curve number approach is the standard method for computing runoff by the Soil Conservation Service (SCS) (Overcash and Phillips 1978). The SCS runoff equation is used in the designs of soil and water conservation structures. The SCS runoff equation is:

$$Q = \frac{(P - 0.51\ S)^2}{P + 2.03\ S} \quad . \ . \ . \ . \ . \ . \ . \quad (7)$$

where

Q = surface runoff (cm)
P = rainfall (cm)
S = potential maximum retention of water (cm)

The value of S is determined from the equation:

$$S = \frac{1000}{CN} - 10 \quad . \ . \ . \ . \ . \ . \ . \ . \quad (8)$$

where CN = runoff curve number (Manges 1975). Runoff curve numbers can be developed for particular precipitation events and surface consideration. Runoff curve numbers of 91 and 94 for feedlot surfaces of dirt and concrete, respectively, have been used (Miner et al. 1966a). Similar CN values were developed by Gilbertson et al. (1971) and Woolhiser (1975). A comparison of Equation 4, SCS equation, and Equation 3 is shown in Figure 1. As precipitation increases, the disparity between predicted runoff per equation increases. Even at lower precipitation totals, the equations vary substantially.

There are no mathematical relationships available that deal specifically with snowmelt runoff. Conditions that occur during winter feedlot operation cause substantially different characteristics when compared to runoff resulting from rainfall (Gilbertson, personal communication). A reduced stabilization rate of the animal wastes seems to occur in low temperature winter climates. With spring thaw the manure obtains a "fresh" or refluidized state and runoff occurs (Dornbush et al. 1973). The spring thaw concept has been questioned as to whether a few major thaws occur or many lesser thaws develop after each event caused by a moderate rise in temperature (Gilbertson, personal communication).

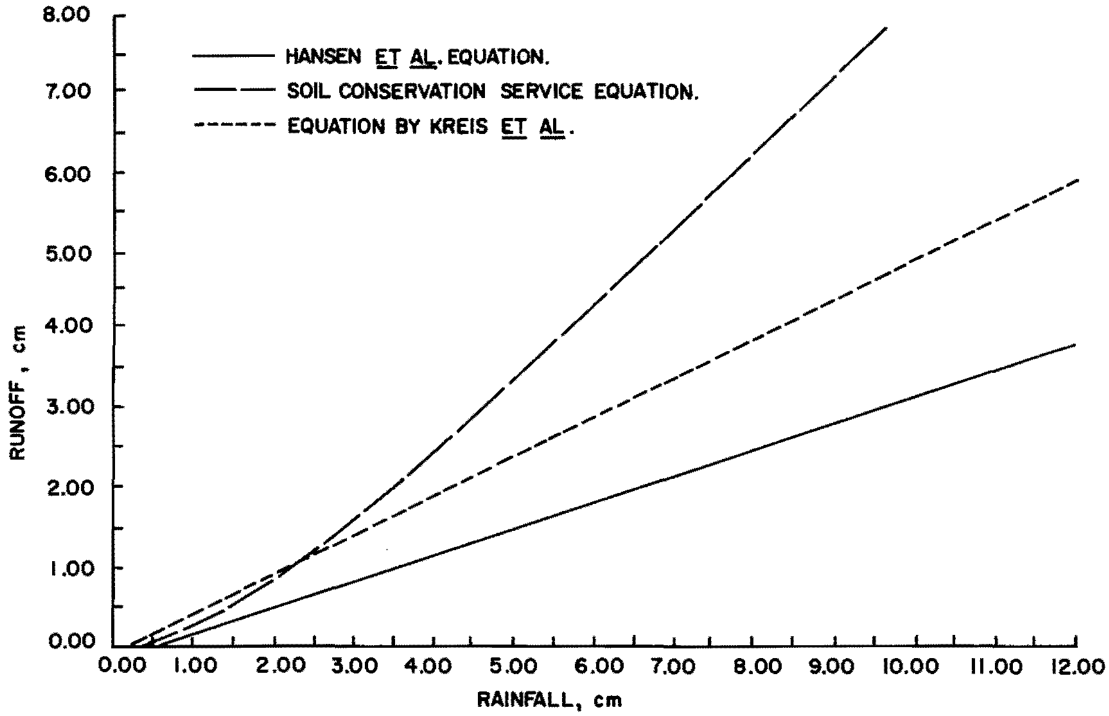


Figure 1. Rainfall-runoff relationships for beef cattle feedlots (from Overcash and Phillips 1978).

MODEL DEVELOPMENT

A mathematical model was developed to provide a predictive tool to assess the impact of runoff from livestock feeding operations on a drainage system. The model was sectioned into three parts: 1) mass loadings, 2) precipitation, and 3) transport. The mass loading functions predicted the rate at which a pollutant mass (i.e. BOD_5, COD, ammonia, etc.) was discharged from a feedlot facility. The precipitation section predicted the amount of rainfall and snowfall that occurred over a period of time. This assumed that no settling of pollutants in the stream occurred. The time step of the day was based on kinetic data and transport rates developed in this study.

Mass Loading Functions

The loading function for feedlot runoff was based upon the following equation presented by McElroy et al. (1976):

$$Y(i)_{FL} = a \cdot Q(R) \cdot C(i)_{FL} \cdot FL_d \cdot A \quad . \quad . \quad (9)$$

where

- $Y(i)_{FL}$ = loading rate of pollutant i from a livestock facility (kg/day)
- $Q(R)$ = direct runoff (cm/day)
- $C(i)_{FL}$ = concentration of pollutant, i, in runoff (mg/l)
- FL_d = delivery ratio
- A = area of livestock facility (ha), and
- a = a conversion factor (0.1 (kg-L/cm-mg-ha))

Equation 9 is applicable to feedlots that operate without runoff control facilities.

The runoff volumetric flow rate was determined by the Soil Conservation Service (SCS) equation defining runoff from unpaved surfaces. Linear regression equations were developed to predict runoff from paved facilities. Concentrations of pollutants contained in the runoff were determined from either collected field data or from average concentration values cited in the literature. Feedlot area (A) was either measured directly or determined from data supplied from the Census of Agriculture reports on statistics of cattle feedlots.

The delivery ratio (FL_d) is dependent upon the proximity of the source to the water, characteristics of the material and slope. The reported value of FL_d for feedlots within 0.2 kilometer (0.1 mile) of a permanent unobstructed waterway was equal to or greater than 0.9 with a maximum FL_d possible of 1.0 (McElroy et al. 1976). Since livestock feeding operations inventoried for input data to the proposed model were adjacent to waterways ($0.9 \leq FL_d \leq 1.0$), the delivery ratio, FL_d, was assumed to have a value of 1.0. Equation 9, therefore, reduced to:

$$Y(i)_{FL} = a \cdot Q(j) \cdot C(i,j)_{FL} \cdot A \quad . \quad . \quad . \quad (10)$$

where

- $Q(i)$ = direct runoff during a specific type event j (cm/day)
- $C(i,j)_{FL}$ = concentration of pollutant, i, in runoff
- j = specific type of event (i.e., rain or snow)

The definitions of $Y(i)_{FL}$, a and A were the same as previously defined. The McElroy equation does not differentiate between rainfall and snowmelt runoff. Neither does it distinguish between single and multiple precipitation events. These factors were found to be very important and were considered in the development of the mathematical expression defining $Q(j)$ and $C(i,j)_{FL}$.

Description of Feedlot Runoff Transport Model

The feedlot runoff transport model was developed to estimate the rate of mass loading from feedlots to an environmental sink such as a reservoir (Cutler Reservoir). For identification purposes, feedlots were assigned to various geographical regions. A region was defined to be a portion of the drainage basin adjacent to a tributary leading to the environmental sink. The model simulated the transport of ten water quality constituents from up to 300 feedlots. A maximum of ten user specified wastewater treatment schemes may be applied at any feedlot.

The model essentially performed a mass balance on all the feedlot discharges and their transport through the drainage system to the environmental sink. An assumption in the model was that all the mass leaving a feedlot reaches the environmental sink during the same day. Hydrologic data and kinetic data supporting this assumption will be presented subsequently. Referring to Figure 2, the simulation begins by the model reading program control data, quality constituent and treatment data, and feedlot description data. Using a one day time step, the flow and quality constituent concentrations (each a function of daily precipitation) were determined and the mass loadings to the environmental sink calculated. Daily precipitation was entered into the model for up to four official National Weather Service precipitation stations. Precipitation at each feedlot was calculated by summing the product of the precipitation at each station and the program variable PCOEF corresponding to each precipitation station (i.e. Pr = PCOEF x Pr station). Figure 3 presents the delineation of the various precipitation areas and the corresponding PCOEF values. A user may specify the results to be printed out after each simulation year. After the last simulation year, monthly and annual average mass loadings and standard deviation of the loadings were determined. The program concludes by writing to a disk file internal program totals enabling the reinitiation of the simulation run if necessary.

The model was written in Burroughs B6700/B7700 FORTRAN (comparable to FORTRAN IV, Level H). The program segments used to calculate flow and concentrations were placed in subroutines (FLOW and CONC, respectively) (Appendix A) so that model application to various river basins could be performed with a minimal amount of reprogramming. A description of the program structure, program unit descriptions, variable definitions, input data formats, program listing, and sample program output are provided in Appendix B.

Since the MLF equation (Equation 10) is dependent upon the type of precipitation event, entire months were designated either rainfall months or snowmelt months. Precipitation data obtained during the testing period of October 1976 through July 1978 indicated that January, February, and March were snow event months. April through December were rainfall event months. Historical precipitation data substantiated this assumption.

Kinetic Data for Determination of Beef and Dairy Cattle Degradation Rates

Beef and dairy manure degradation rates under simulated stream conditions changed little over a 24-hour period (procedure described on page 23). The time lag in the degradation of the manure was due to the microflora becoming acclimated to the 4°C and

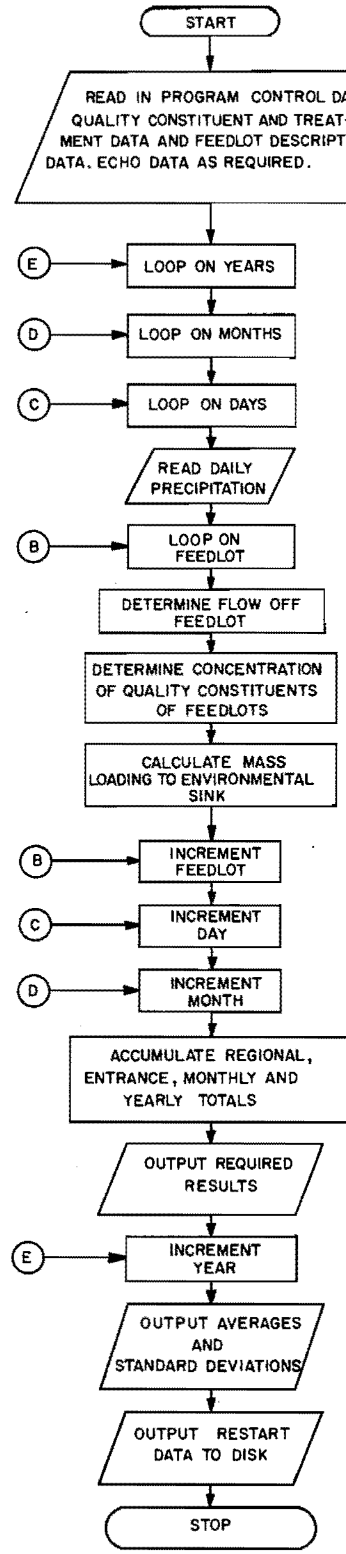


Figure 2. Feedlot runoff transport model flow chart.

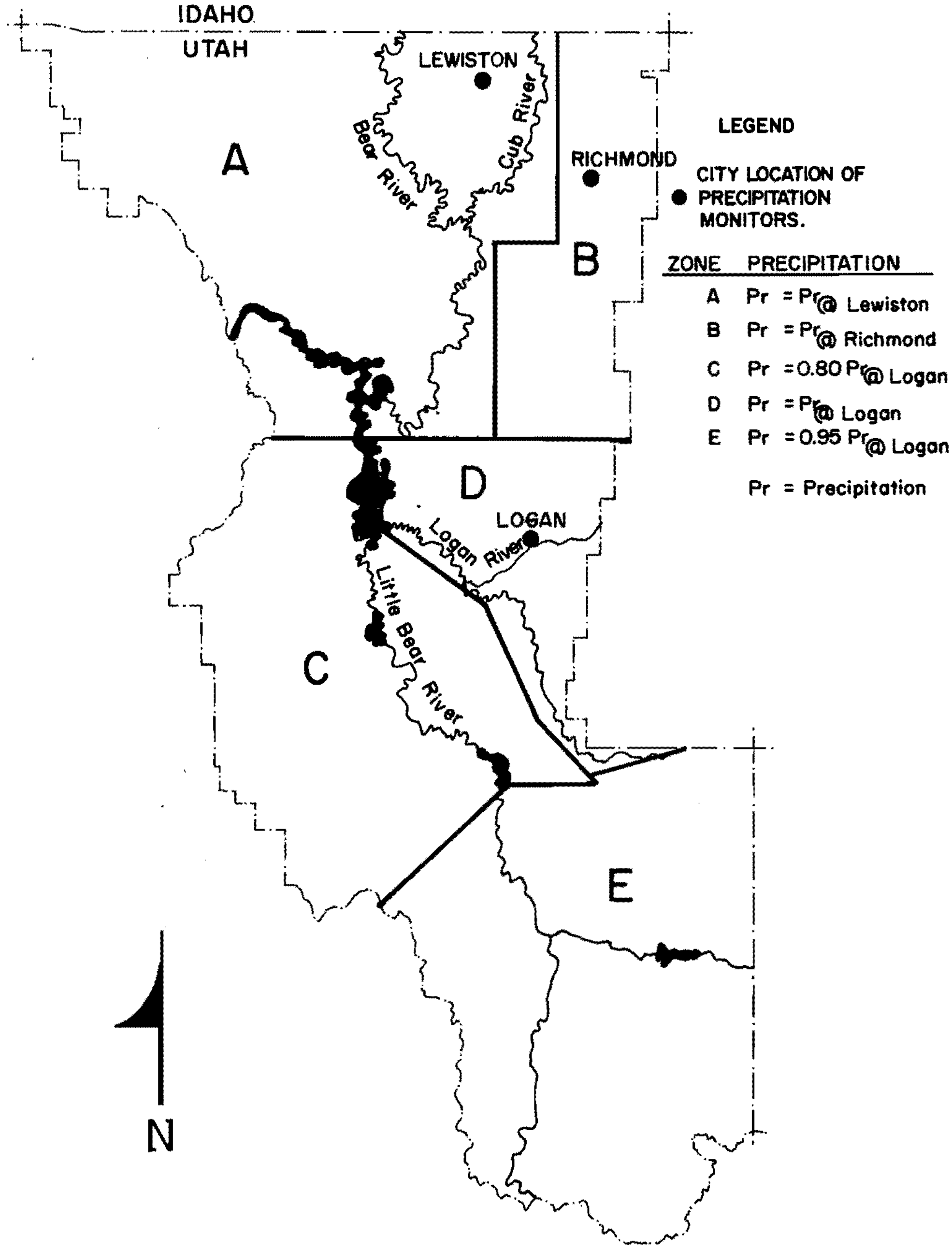


Figure 3. Feedlot precipitation coefficient (PCOEFF) determination areas.

19°C (39°F and 66°F) temperatures within manure-stream solutions. The major waterway in the study area maintain average instream winter and summer temperatures of 4°C and 19°C, respectively. The dissolved oxygen concentration of the dilute dairy cattle manure solution was reduced by 0.5 mg/l from 7.20 mg/l to 6.70 mg/l during the first 24 hours at 4°C (Figure 4). However, the dissolved oxygen level decreased substantially to 3.5 mg/l during the next 24-hour incubation. The dissolved oxygen level at 4°C in the beef manure solution was lowered by 0.5 mg/l from 7.0 mg/l to 6.6 mg/l DO during the first 24 hours with a subsequent decrease in DO to 1.5 mg/l (Figure 4). Similarly, dissolved oxygen levels in solution at 19°C for beef and dairy cattle manure decreased from 7.2 mg/l initially to 6.0 mg/l at the end of 24 hours (Figure 5).

In both beef and dairy liquid manure suspensions, at 4°C and 19°C, the NH_3-N concentrations showed little change during the first 24 hours (Figure 5). A slight increase occurred after the 48-hour period (i.e. beef 0.10 to 0.11; dairy 0.11 to 0.12). A substantial increase in the ammonia concentrations (beef, 0.78; dairy, 1.56) was noted during the remainder of the incubation period at 4°C (Figure 5). Ammonification of organic nitrogen species was the primary mechanism for this rise in the increasingly reducing environment.

Neither NO_3-N nor NO_2-N levels in either the beef or dairy manure solutions changed more than 10 percent during the incubation period at 4°C. No test was run at 19°C for NO_3-N or NO_2-N.

Transport Time

The hydraulic transport times from all feedlot locations to Cutler Reservoir were found to be less than or equal to one day at low flow (5 year monthly averages). Precipitation data obtained from NOAA consisted of daily precipitation quantities. The precipitation model, therefore, was based on a one day cycle. These facts, together with the evidence that little degradation of organic matter occurred within 24 hours, simplified the transport model to an accounting program for pollutant mass transport.

Precipitation Model

The feedlot runoff transport model permits daily precipitation input data for up to four stations. It was anticipated that the model simulation run would be longer than the historical precipitation record (25 years), thereby requiring the use of a precipitation model to generate synthetic data.

To generate synthetic hydrologic events for more than one station, a multivariate first order autoregressive (Markov) generating process is often used (Matalas 1967: Young and Pisano 1968; Moreau and Pyatt 1970; Cole and Sherriff 1972; Schaake et al. 1972). Cross-correlation of historic events at different stations as well as the mean, variance, skewness, and lag-one serial correlation for historic events at each station are considered in these generating processes. Using the notation introduced by Matalas (1967), let x^p ($p = 1, \ldots, m$) denote the random variate that pertains to the p^{th} station in a river basin. The estimates of the mean, standard deviation, coefficient of skewness, and lag-one serial correlation coefficient from historic events of x^p are denoted by $\hat{\mu}_x{}^p$, $\hat{\sigma}_x{}^p$, $\hat{\nu}_x{}^p$, and $\hat{\rho}_x{}^p(1)$, respectively. The lag-zero cross-correlation between historic events at stations p and q, $p, q = 1, \ldots, m$ is denoted by $\hat{\rho}^{pq}(0)$.

A multivariate autoregressive generating process can now be defined as

$$x_{i+1} = Ax_i + B\varepsilon_{i+1} \quad \ldots\ldots \quad (11)$$

In Equation 11, x_{i+1} and x_i are $(m \times 1)$ matrices in which the p^{th} elements are x^p_{i+1} and $x_i{}^p$, respectively. The values $x^p{}_{i+1}$ and $x_i{}^p$ denote the events of x^p at the time points i+1 and i, respectively. Note that x^p is standardized, having zero mean and unit variance. The random component, ε_{i+1}, is a $(m \times 1)$ matrix. The elements of the ε matrix are independent of x_i and have zero mean. A and B are $(m \times m)$ coefficient matrices. These elements must be defined in such a way that the synthetic events generated by Equation 11 resemble the historic events in terms of $\hat{\mu}_x{}^p$, $\hat{\sigma}_x{}^p$, $\hat{\nu}_x{}^p$, $\hat{\rho}_x{}^p(1)$, and $\hat{\rho}_x{}^{pq}(0)$ for all values of p and q.

Post multiplying both sides of Equation 11 by the transpose of x_i ($x_i{}^t$) and then taking the expectations (E[ ]), yields

$$M_1 = A\,M_0 \quad \ldots\ldots\ldots \quad (12)$$

where

$$M_0 = E\left[x_i x_i{}^t\right]$$

$$M_1 = E\left[x_{i+1} x_i{}^t\right]$$

Matalas (1967) shows that

$$A = M_1 M_0^{-1} \quad \ldots\ldots\ldots \quad (13)$$

and

$$BB^t = M_0 - M_1 M_0^{-1} M_1^t \quad \ldots\ldots \quad (14)$$

The matrix B can easily be separated from its transpose using the method suggested by Young (1968).

When using Equation 11 to generate synthetic events, most researchers have used a

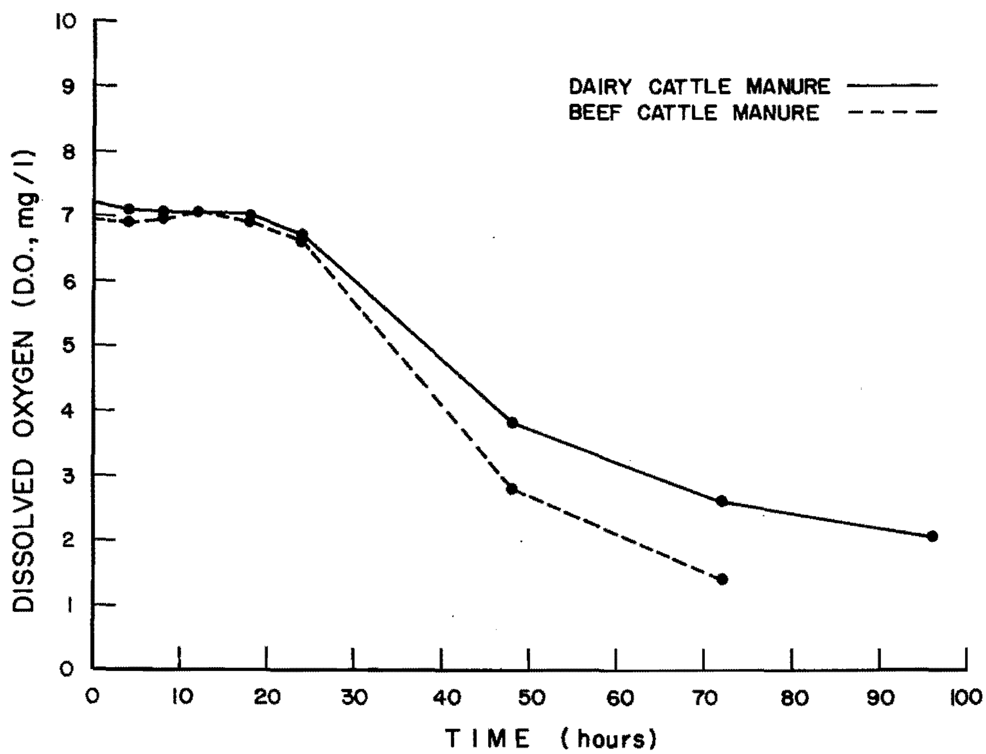


Figure 4. Variation in DO during 96-hour BOD test for beef and dairy cattle manure at 4°C.

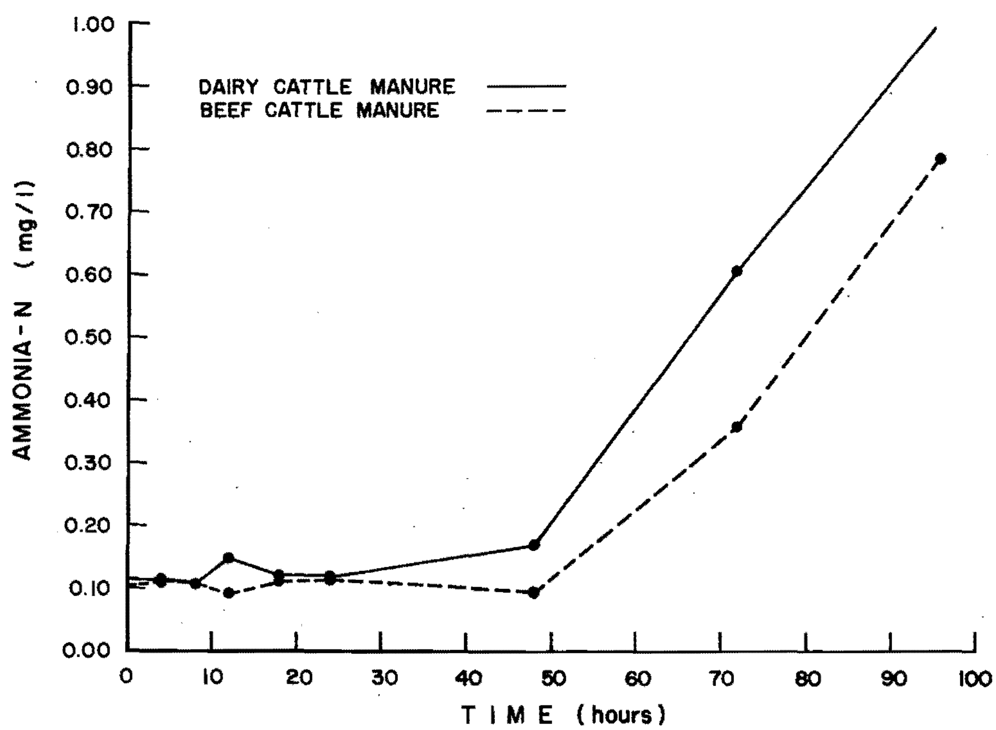


Figure 5. Variation in NH_3-N during 96-hour bioassay for beef and dairy cattle manure at 4°C.

transformation to normalize x_i and x_{i+1} so that ε_{i+1} has a standard normal distribution. Random number generators with a normal distribution can be used to choose a value of ε_{i+1} during data generation. Unfortunately, no transformation can perfectly normalize the historical events and so bias is introduced into the data generation when ε_{i+1} is drawn from a normal population. In this application of Equation 11 to generate synthetic events, the historical data were not normalized. Knowing A and B, Equation 11 was rearranged to solve for ε_{i+1} as follows:

$$\varepsilon_{i+1} = B^{-1}x_{i+1} - B^{-1}Ax_i \quad . \quad . \quad . \quad . \quad (15)$$

If the historical record was sufficiently long, the individual values of ε_{i+1} could be considered to form a continuous distribution function. During event generation, randomly choosing from the record of ε_{i+1} would yield a value of ε_{i+1} with the same distribution as the historical record.

Twenty-five years of historical data from four Cache Valley, Utah, precipitation stations (Lewiston, Utah State University, Utah State University Agricultural Experiment Station, and Richmond) were used to solve for the A, B, and ε_{i+1} matrices. The historical data were first standardized to have a zero mean and unit variance by subtracting from each event the particular month's average daily precipitation and dividing by that month's standard deviation. Equations 13 and 14 were used to determine the A and B matrices. Values of ε_{i+1} were determined by using Equation 15. The mean, standard deviation, and skew for ε_{i+1} are shown in Table 5.

Synthetic precipitation events can now be generated using the following procedure:

1. Choose an initial value of x_i.
2. Randomly choose a value of ε_{i+1} from the historic record.
3. Solve Equation 11 for x_{i+1}.
4. Repeat steps 2 and 3 for each time interval.

The values of x_{i+1} are standardized and must be converted to absolute amounts. Standardized values of x_{i+1} can be converted by multiplying by the standard deviation and then adding the mean of the daily precipitation of the month being simulated. Results from the first 1000 or so iterations should be discarded to overcome any bias introduced by the initial value of x_i used.

Table 5. Mean, standard deviation and skew from ε_{i+1}.

	Precipitation Station			
	1	2	3	4
Mean (in)	0.00	0.00	0.00	0.00
Standard Deviation (in)	1.23	1.64	1.95	1.23
Coefficient of Skewness	4.11	1.98	-0.34	2.03

After generating 100 years of synthetic precipitation events, it was observed that the mean predicted event approximated the observed data. Forty percent, however, of the generated events were negative. The negative value events had the effect of decreasing the skew and increasing the standard deviation of the generated events as compared to the observed data. The historical and predicted mean and standard deviations of daily precipitation at Lewiston, Utah, are shown in Table 6. During only two months (May and September) are the historical and predicted means significantly different at the 95 percent confidence level using the t test.

Very little information exists in the literature on dealing with generated hydrologic events that are less than zero. Chow and Ramaseshar (1965) to generate hourly rainfall sequences used a model of the form

$$x_{t+1} = r\,x_t + \varepsilon_{t+1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (16)$$

in which r is the Markov chain (or correlation) coefficient determined by least squares linear regression of observed rainfall data. ε_{t+1} can have both postive and negative values and thereby, in certain cases, yield a negative value for x_{t+1}. To correct for this an arbitrary value K was added to it so that the corrected random components were always positive.

$$\varepsilon_{t+1} = K + \varepsilon_{t+1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (17)$$

Table 6. Comparison of historical and predicted mean and standard deviation of daily precipitation.

Month	Mean		Standard Deviation	
	Historical (in/day)	Predicted (in/day)	Historical (in/day)	Predicted (in/day)
Jan.	0.0555	0.0558	0.1315	0.1621
Feb.	0.0496	0.0521	0.1177	0.1315
Mar.	0.0478	0.0451	0.1141	0.1240
Apr.	0.0620	0.0587	0.1473	0.1834
May	0.0518	0.0473[a]	0.1333	0.1365
June	0.0537	0.0516	0.1518	0.1584
July	0.0168	0.0167	0.0813	0.0867
Aug.	0.0273	0.0248	0.1126	0.1279
Sept.	0.0345	0.0299[a]	0.1171	0.1326
Oct.	0.0436	0.0392	0.1452	0.1633
Nov.	0.0473	0.0487	0.1418	0.1592
Dec.	0.0466	0.0492	0.1221	0.1419

[a]Significantly different than historical mean at 95 percent confidence level.

Negative value events can also be eliminated by merely setting them equal to zero. This procedure is sometimes used in stream flow synthesis, if the number of negative value events is small (Bowles 1978). Incorporating this procedure into the precipitation generation algorithm yielded predicted means significantly different from historical means (at the 95 percent confidence level) yet improved the predicted standard deviation as compared to the original precipitation algorithm. Table 7 shows the predicted mean and standard deviation of daily precipitation from a 100 year simulation at Lewiston, Utah, using the zeroing procedure described above.

Since the predicted mean daily precipitation closely resembled the historic mean when using the original generation procedure, a procedure that would alter the shape of the distribution yet preserve the mean of the generated events was needed. An algorithm was developed which determined a number (TNEG) that was to be subtracted from each event. After subtraction, if the event had a negative value it was set equal to zero. TNEG was chosen in such a way as not to change the mean of the generated events. The algorithm begins by setting TNEG = 0 and finding the sum of all negative value events (NEG) (Figure 6). If NEG = 0 (i.e., there are no negative value events) the algorithm ends. If NEG < 0 the absolute value of TNEG is increased by adding to it the value of NEG. All negative value events are set equal to zero and the number of non-zero positive value events is determined (NP). The value of (NEG/NP) is then added (NEG is a negative number) to each non-zero positive value event. The sum of all negative value events is determined and the above process continues till NEG = 0. A value of TNEG was determined for each precipitation station and each month using 100 years of generated events. Values of TNEG ranged from -0.028 to -0.115.

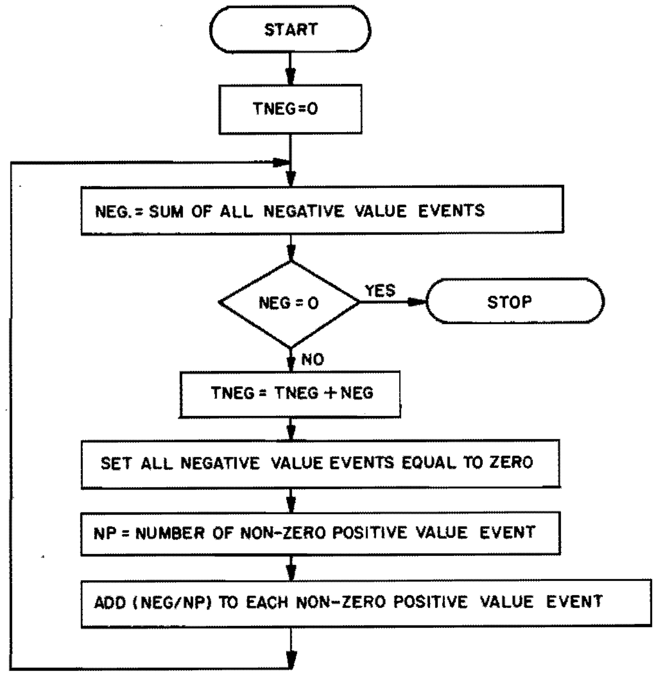


Figure 6. Algorithm used to find TNEG.

The following steps were now used to generate synthetic precipitation events (P):

1. Choose initial x_i.
2. Randomly choose ε_{i+1} from historic record.
3. Solve Equation 11 for x_{i+1}.
4. $P = [(x_{i+1})(\hat{\sigma}_x) + \hat{\mu}_x] + TNEG$.
5. If $P < 0$, $x_{i+1} = -\hat{\mu}_x/\hat{\sigma}_x$.
6. Increment time.
7. Repeat steps 2-6 for each remaining time interval.

Table 7. Comparison of historical and predicted (using zeroing procedure) mean and standard deviation of daily precipitation.

Month	Mean		Standard Deviation	
	Historical (in/day)	Predicted (in/day)	Historical (in/day)	Predicted (in/day)
Jan.	0.0555	0.0707[a]	0.1315	0.1345
Feb.	0.0496	0.0638[a]	0.1177	0.1239
Mar.	0.478	0.0596[a]	0.1141	0.1163
Apr.	0.0620	0.0755[a]	0.1473	0.1419
May	0.0518	0.0635[a]	0.1333	0.1342
June	0.0537	0.0714[a]	0.1518	0.1591
July	0.0168	0.0350[a]	0.0813	0.0833
Aug.	0.0273	0.0443[a]	0.1126	0.1029
Sept.	0.0345	0.0472[a]	0.1171	0.1037
Oct.	0.0436	0.0692[a]	0.1452	0.1658
Nov.	0.0473	0.0632[a]	0.1418	0.1396
Dec.	0.0466	0.0575[a]	0.1221	0.1145

[a]Significantly different than historical mean at 95 percent confidence level.

Using the procedure described above, 100 years of simulated precipitation were generated for the four precipitation stations. The predicted and historical mean, standard deviation, and skew of daily precipitation for Lewiston, Utah (Station 1), are compared in Table 8. The predicted means did not differ from those predicted (Table 6) by the original generation procedure. Furthermore, the standard deviations are smaller than those shown in Table 6. The comparisons between historical and predicted standard deviations in Table 8 were made at the 95 percent confidence level using the generalized jackknife statistic described by Mosteller and Tukey (1978). This removed the bias of the non-normal distribution. For each month the predicted standard deviation is less than shown in the historical data, but during only four months (June-September) is it significantly less. The skew of the predicted daily precipitation distribution is both greater and less than the historical skew, depending on the month. During the summer months (June-August) when the historical skew is at a relative high, the predicted skew is less than the historical skew. In winter months (January-April), the historical skew is at a relative low and the predicted skew is higher than the historical skew.

The lag-zero cross-correlation predicted between Lewiston, Utah (Station 1), and the three other precipitation stations used in this study are compared to the historical values in Table 9. The predicted values tend to be higher than the historical values but are probably adequate for this application.

The synthetic precipitation event generator (using TNEG) was used to provide daily precipitation input data for the feedlot runoff transport model. Sixteen hundred years of precipitation data were generated and stored on magnetic tape to be used as needed by the transport model. The statistics from the 1600 year simulation did not differ significantly from the 100 year simulation statistics shown in Tables 8 and 9.

Table 8. Comparison of historical and predicted (using TNEG) mean, standard deviation and skew of daily precipitation.

Month	Mean		Standard Deviation		Coefficient of Skewness	
	Historical (in/day)	Predicted (in/day)	Historical (in/day)	Predicted (in/day)	Historical	Predicted
January	0.0555	0.0559	0.1315	0.1348	3.30	5.02
February	0.0496	0.0520	0.1177	0.1168	3.41	4.67
March	0.0478	0.0451	0.1141	0.1085	3.06	4.60
April	0.0620	0.0587	0.1473	0.1465	3.73	5.44
May	0.0518	0.0472[a]	0.1333	0.1197	4.08	4.77
June	0.0537	0.0516	0.1518	0.1360[a]	6.11	4.38
July	0.0168	0.0167	0.0813	0.0618[a]	7.42	5.44
August	0.0273	0.0246	0.1126	0.0893[a]	7.21	5.97
September	0.0345	0.0297[a]	0.1171	0.0889[a]	4.81	4.46
October	0.0436	0.0392	0.1452	0.1257	4.96	5.44
November	0.0473	0.0487	0.1418	0.1377	4.49	4.90
December	0.0466	0.0492	0.1221	0.1205	5.04	4.75

[a]Significantly different than historical at 95 percent confidence level.

Table 9. Historical and predicted (using TNEG) lag-zero cross-correlation coefficient of daily precipitation.

Month	Historical Lag-Zero Cross-Correlation Coefficient Between Station 1[a] And			Predicted Lag-Zero Cross-Correlation Coefficient Between Station 1[a] And		
	Station 2[b]	Station 3[c]	Station 4[d]	Station 2[b]	Station 3[c]	Station 4[d]
January	0.76	0.79	0.72	0.76	0.79	0.83
February	0.76	0.71	0.72	0.76	0.76	0.79
March	0.73	0.72	0.79	0.77	0.75	0.75
April	0.82	0.82	0.85	0.74	0.79	0.79
May	0.66	0.71	0.76	0.72	0.77	0.76
June	0.80	0.73	0.75	0.71	0.75	0.78
July	0.47	0.73	0.69	0.75	0.76	0.83
August	0.66	0.68	0.48	0.72	0.78	0.81
September	0.84	0.77	0.83	0.69	0.72	0.76
October	0.78	0.69	0.74	0.72	0.75	0.78
November	0.71	0.80	0.80	0.78	0.80	0.82
December	0.82	0.76	0.76	0.74	0.75	0.78

[a]Lewiston, Utah.

[b]Utah State University, Logan, Utah.

[c]Utah State University Ag. Experimental Station, Hyrum, Utah.

[d]Richmond, Utah.

STUDY AREA DESCRIPTION

Geography

The Bear River drainage system located in Cache Valley in northern Utah was selected as the study region (Figure 7). The impact of feedlots on the water quality of the Bear River drainage area has been delineated as a significant pollutional threat (UWRL 1974).

Approximately 30 kilometers south of the Utah-Idaho border, the Bear River is joined by the Cub River. Most of the Cub River watershed lies in mountain wilderness area; however, it receives waste effluents and agricultural runoff as it flows through Cache Valley toward its confluence with the Bear River. Several small streams join the Bear River as it meanders southward in Cache Valley. The terminus of the Bear River in Cache Valley is Cutler Reservoir. Cutler Reservoir was considered in this study as the sink for the animal waste mass loadings derived from livestock feedlots.

Three additional major rivers discharge into Cutler Reservoir. The Logan River flows from a mountain watershed through the City of Logan, Utah. Adjacent to the river are residential areas and agricultural areas containing primarily beef and dairy cattle feedlots.

The Blacksmith Fork drains an area slightly smaller than that of the Logan River. In Cache Valley, the Blacksmith Fork flows mainly through agricultural land and joins the Logan River 2 kilometers southwest of Logan.

The Little Bear River is the remaining major river in Cache Valley. Porcupine Reservoir, located at the southern end of the valley, collects the drainage from the mountainous upper watershed of the East Fork of the Little Bear River. The outflow from the reservoir is regulated for irrigation and flood control. The Little Bear River travels northward from Porcupine Reservoir to Hyrum Reservoir. Within this distance, the river receives a substantial amount of nutrients which are transported to Hyrum Reservoir. These nutrients are derived from feedlots and a trout farm.

The Bear River flows downstream from Cutler Dam approximately 73 kilometers before it terminates in the Bear River Bird Refuge. The waters eventually flow into the Great Salt Lake.

Livestock Operations

The major industry of Cache Valley, Utah, is agriculture. Dairy cattle are raised principally to supply milk for several cheese producing plants. Dairy and beef cattle livestock operations in Cache Valley are generally on a small scale (30 to 150 head) and are concentrated near rivers where a consistent supply of water usually is available. The individual operators largely ignore State of Utah regulations prohibiting pollutant discharge into the river. They believe these controls to be costly, inequitable and unnecessary for their small operations.

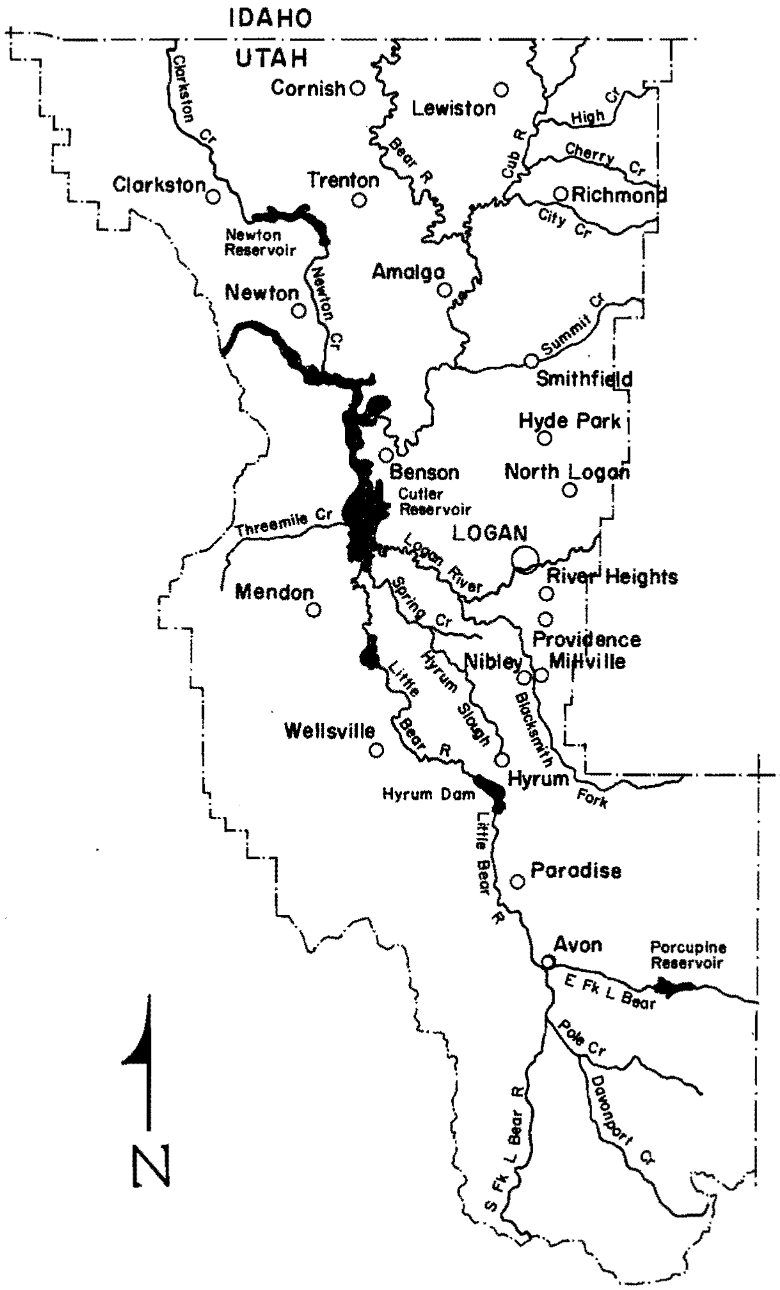


Figure 7. Cache Valley in northern Utah.

PROCEDURES

Determination of Loading Function Variables

Physical Characteristics

Feedlots with potential discharges into the drainage system of Cache Valley were inventoried and characterized. Feedlots were characterized according to area of feedlot, number and type of cattle, slope of lot, feedlot surface (paved or unpaved), and location of facility. The number of feedlots and their individual characteristics were obtained by dividing the study area into 40 sections and canvassing the area by vehicle. The feedlot operators were then interviewed in person and questioned regarding the number and type of cattle in their facility. The area of each lot was determined by pacing and/or cloth tape, and the major slope was determined using a hand level and level rod.

Concentration of Pollutants (C_i) Values

Four livestock feeding operations were isolated for intensive monitoring of pollutant concentrations in their waste discharges (see Appendix C for site descriptions). The four feedlots (two with paved surfaces and two with soil surfaces) were randomly selected from the facilities located in the valley. The facilities chosen had characteristics typical of the total feedlot population with respect to slope (1 to 6 percent) and number of cattle (20 to 50 head). Three of the facilities were dairy operations, and one was a beef cattle feedlot.

Collection of feedlot runoff for chemical analysis from both the paved and unpaved facilities was accomplished by the installation of complete collection systems (CCS) (Figure 8). The CCS consisted of 15.2 cm (6 inches) longitudinally divided PVC pipe installed along the lowest elevation of the feedlot area. Piping extended the width of the feedlot area at a minimum slope of 2 percent and terminated in a 50 liter polypropylene carboy.

A timing device was installed to determine the flow rate of slurry runoff. Ditch side walls were lined with 6 mil polyethylene to limit erosion and maintain the integrity of the ditch. The liner was taped along the length of the inside of the PVC pipe and stretched over the ditch walls. Side wall boards were installed to reinforce the earthen walls in the runoff collection system. This reinforcement prevented collapse of the earthen walls into the collection channel. Edges of the liner were kept in place by 51 cm x 102 cm (2 x 4 inch) boards and compacted topsoil (Figure 8). The channel was covered with 3.8 cm (1.5 inch) plywood boards supported by 51 cm x 102 cm (2 x 4 inch) boards. The system was designed to obtain representative runoff and prevent injury to animals. The sides of the feedlot areas were altered to channel all runoff flows toward the CCS rather than the adjacent watercourse. Samples were collected at feedlot sites as well-mixed subsamples from the 50 liter polypropylene carboy after runoff flow had ceased. The subsample was obtained by mixing the collected composite wastewater sample contained in the carboy and pouring a portion of the total sample into a 4 liter container.

All samples were transported at 4°C to the Utah Water Research Laboratory within 2 hours for subsequent analyses of parameters listed in Table 10. Samples were analyzed according to EPA accepted techniques. The Utah Water Research Laboratory is EPA accredited for all analyses listed in Table 10.

Correlations between chemical concentrations and daily precipitation were divided on the basis of such physical factors as precipitation event type (snowmelt or rainfall) and feedlot surface (paved or unpaved). Another factor considered was whether the rainfall event occurred during a single day or whether the event occurred during multiple days in succession. Mathematical relationships were developed between BOD_5 and COD, TP and COD, and SS and VSS data.

Determination of Direct Runoff Q(j) Values

A continuous record of daily precipitation events from 1945 to 1979 for the Cache Valley area was obtained from the National Oceanic and Atmospheric Administration (NOAA). Temperatures, daily precipitation, snowfall summary and monthly averages for Cache Valley were recorded.

Quantitative feedlot runoff-flow data were collected from paved and soil feedlots on 40 of the 55 sampling days. Multiple flow readings during a single event were obtained on 10 occasions during the summer months. Flow data were collected by two methods. An electrical timer was used to measure the time

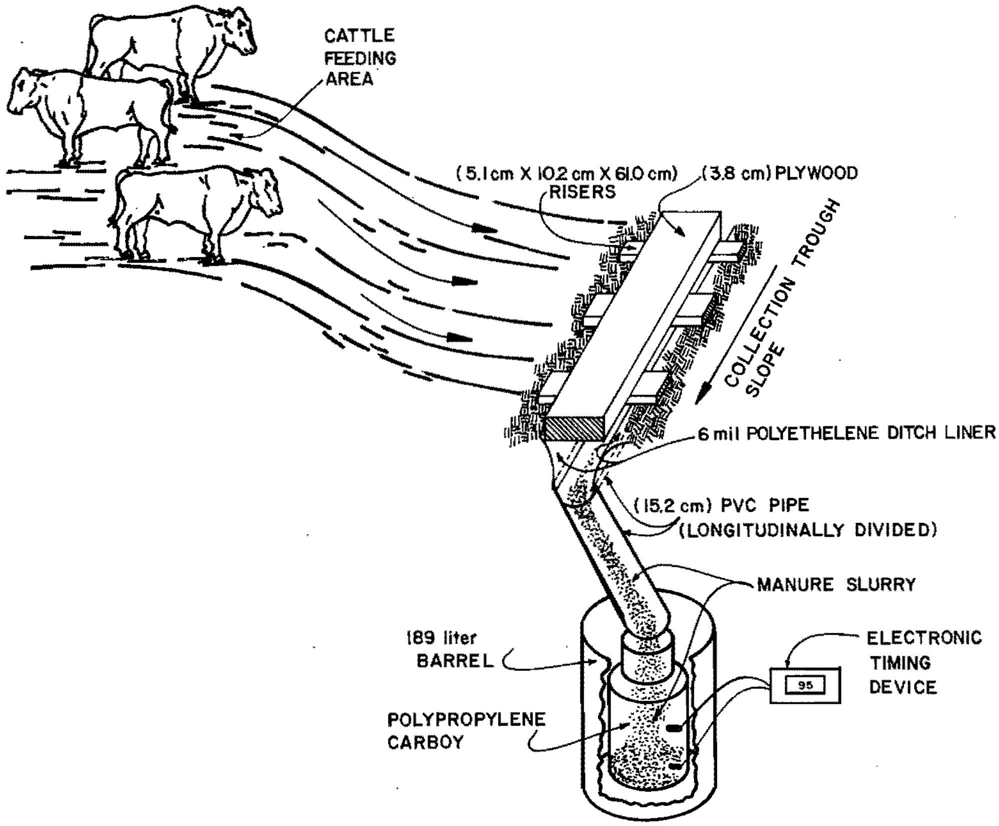


Figure 8. Diagram of feedlot runoff collection system.

Table 10. Procedures for analyses performed.

Parameter	Method of Analysis	Reference
Suspended Solids (SS)	Standard Methods	APHA et al. 1976
Volatile Suspended Solids (VSS)	Standard Methods	APHA et al. 1976
Total Phosphorus (TP)	EPA Methods	EPA 1974
Orthophosphate Phosphorus (PO_4-P)	Technicon AutoAnalyzer II (Murphy-Riley Technique)	Technicon 1973a
Ammonia (NH_3-N)	Solorzano (Indophenol)	Solorzano 1969
Biochemical Oxygen Demand (BOD_5)	Standard Methods	APHA et al. 1976
Chemical Oxygen Demand (COD)	Standard Methods	APHA et al. 1976

required to collect a known volume (12 liters) of runoff. When it was not possible to use the electrical timer because of malfunctioning, grab samples of the slurry were taken, and increases in volume of the sample were timed to determine the flow rate. No attempt was made to determine the runoff hydrograph during each precipitation event. Mathematical expressions were developed correlating the amount of feedlot runoff flow rates with precipitation during rainfall and snowmelt events. Precipitation data were measured at official U.S. weather stations in close proximity to the feedlot facilities.

Flow equations were divided into categories according to feedlot surface and type of precipitation event. During winter events (January through March), a further division was made to separate the unpaved feedlot runoff occurring during snowfall from runoff which occurred with no precipitation.

Stream Monitoring Program

A major criticism of mathematical modeling has been the lack of field data collected to calibrate and verify the model. The primary objective of the stream monitoring monitoring program was to obtain sufficient stream water quality data to test and delineate any deficiencies in the proposed model. Monitoring the stream provided information on the impact of livestock runoff on a subdrainage system.

Runoff from nine feedlots located on streams within a sub-basin of the Cache Valley drainage system (see attached map) were analyzed for all major quality parameters (Table 10). Further data were collected at a site located in Northern Cache Valley at a later time. Nine facilities were chosen: six were paved feedlots, three feedlots had unpaved surfaces, and a total of between 400 and 500 dairy and beef cattle were kept on all nine facilities. The northern facility was unpaved and contained up to 400 head of beef cattle. Physical descriptions of the feedlots and cattle numbers are shown in Table 11. Diagrams of the 8 feedlots and characteristics are shown in Appendix D.

Water samples were collected once a week over a year period to determine the effects of the nine feedlots on the streams. Stream sampling was conducted during or immediately following all precipitation events. Grab samples were collected upstream and downstream from the nine feedlot locations and at a control area. Samples were collected 30 cm (12 inches) below the surface at midstream to minimize sampling error from the disturbance of the sediments.

Flow rates were measured at the stream sampling locations adjacent to feedlot areas at monthly intervals. Flow rates were determined by measuring the time required for a half-full one liter plastic bottle of water to travel a measured distance in the stream. When possible, USGS flow measurements were used for larger streams such as the Cub River. A control area was isolated which consisted of a representative distance along a stream on which no feedlots were located within the sub-basin. All samples

Table 11. Physical description and cattle numbers at sample stream sample sites.

Site Designation	Description
A - B	Unpaved lot with approximately 100 head of mature Holstein dairy cattle. Total area was 511 sq. meters (5,505 sq. ft.).
C - D	Half paved, half unpaved lot with approximately 60 head of mature Holstein dairy cattle. Total area was 4,208 sq. meters (45,294 sq. ft.).
D - E	Unpaved lot with approximately 25 head of mature Holstein dairy cattle. Total area was 1681 sq. meters (18,100 sq. ft.).
H - I	Unpaved lot with approximately 50 head of mature Holstein dairy cattle. Total area was 1288 sq. meters (13,859 sq. ft.).
M - N	Unpaved lot with approximately 35 head of mature Holstein dairy cattle. Total area was 799 sq. meters (8,597 sq. ft.).
R - Q	Unpaved lot with approximately 100 head of mature Holstein dairy cattle. Total area was 2659 sq. meters (28,622 sq. ft.).
Y - Z	Half paved, half unpaved lot with approximately 125 head of mature Holstein dairy cattle. Total area was 1024 sq. meters (11,020 sq. ft.).
T - S	Unpaved lot with approximately 6 head of a mixture of breeds of mature cattle. Total area was 235 sq. meters (2525 sq. ft.).
U - T	Paved lot with approximately 60 head of mature dairy cattle. Total area was 1243 sq. meters (13,383 sq. ft.).
AA[a] - CC	Unpaved lot with approximately 400 head of mature beef cattle. Total area was 9755 sq. meters (105,000 sq. ft).
- G	Control area. Farmland adjacent to Hyrum slough watercourse.

[a]Northern facility.

were analyzed for NO_3-N, NO_2-N, NH_3-N, ortho and total phosphorus, COD, BOD_5, SS, and VSS.

To determine the effects of the northern facility on the water quality of the river, composite water samples were taken of the river. ISCO Model 1580 automatic samplers were employed to take samples at 10-15 minute intervals throughout each rainfall and snowmelt runoff event. In addition, the northern livestock facility was modified to test the potential of using a green belt as a management scheme to control pollutant loading to the stream. The test site was divided into cattle access and non-access areas to the stream. In the non-access area, natural vegetation was allowed to grow. Whenever a precipitation event occurred, composite stream samples were taken over a 24 hour period upstream, downstream, and between stream access and non-access areas (Figure 9) for the same parameters previously outlined.

Pollutant Transport

Hydraulic Transport

Cache Valley in northern Utah was divided into 15 regions corresponding to feedlot concentrations along major streams in the study area (Figure 10). Flow data for most of the waterways passing through the subareas were obtained from the U.S. Geological Survey (USGS). Flow data for smaller ungaged streams were gathered by field measurements (i.e., velocity probe or floating of plastic bottles).

Stream hydraulic detention times from all feedlots within Cache Valley to Cutler Reservoir were determined from 5-year monthly average flow data over a 12-month period. The distances of feedlots from Cutler Reservoir were measured on USGS quadrangle maps. Entrance points of major waterways to Cutler Reservoir were also delineated (Figure 10).

Nutrient Degradation

Degradation rates of dairy and beef manure were studied under simulated stream conditions of temperature and approximate pollutant concentrations. Manure samples were well mixed in a solution of stream water collected at or near adjacent feedlot sampling sites. Biochemical oxygen demand (BOD_5), ammonia nitrogen (NH_3-N), nitrate nitrogen (NO_3-N) and nitrite nitrogen (NO_2-N) were analyzed over a 96-hour period at temperatures of 4°C and 19°C according to procedures outlined in Table 10. Water temperatures are indicative of instream temperatures during the winter and summer months in the study area. Manure used in this control experiment was sampled at one dairy and one beef cattle feedlot. During the initial 24-hour period, samples were collected and analyzed at intervals of 4 hours. Subsequent samples were obtained at 24-hour intervals.

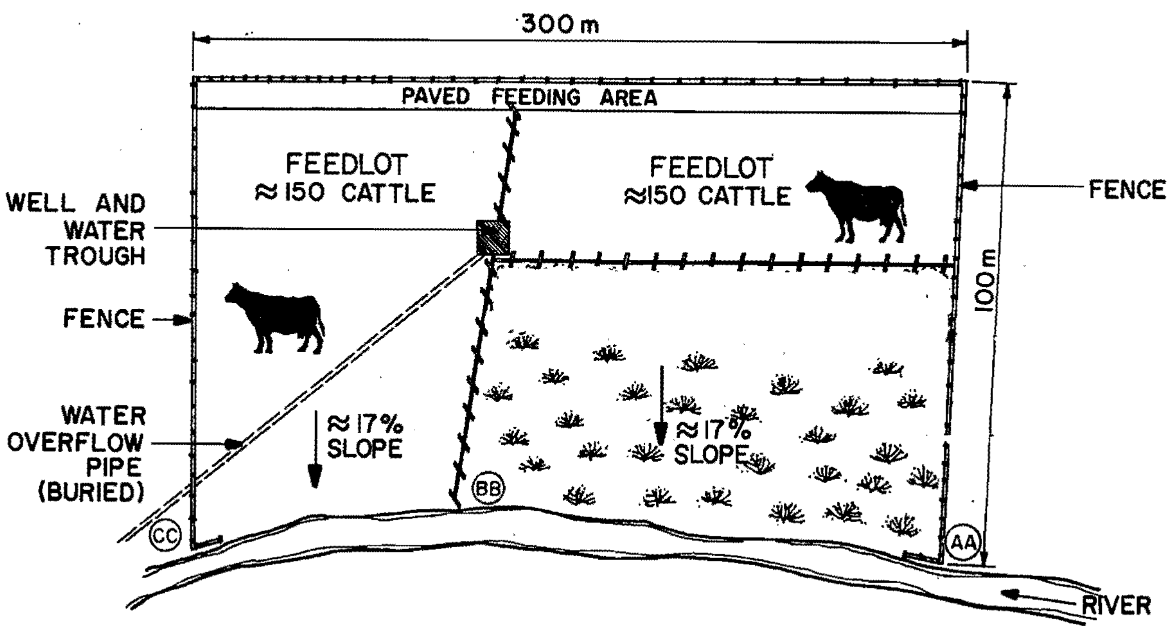


Figure 9. Diagram of sample sites AA, BB and CC.

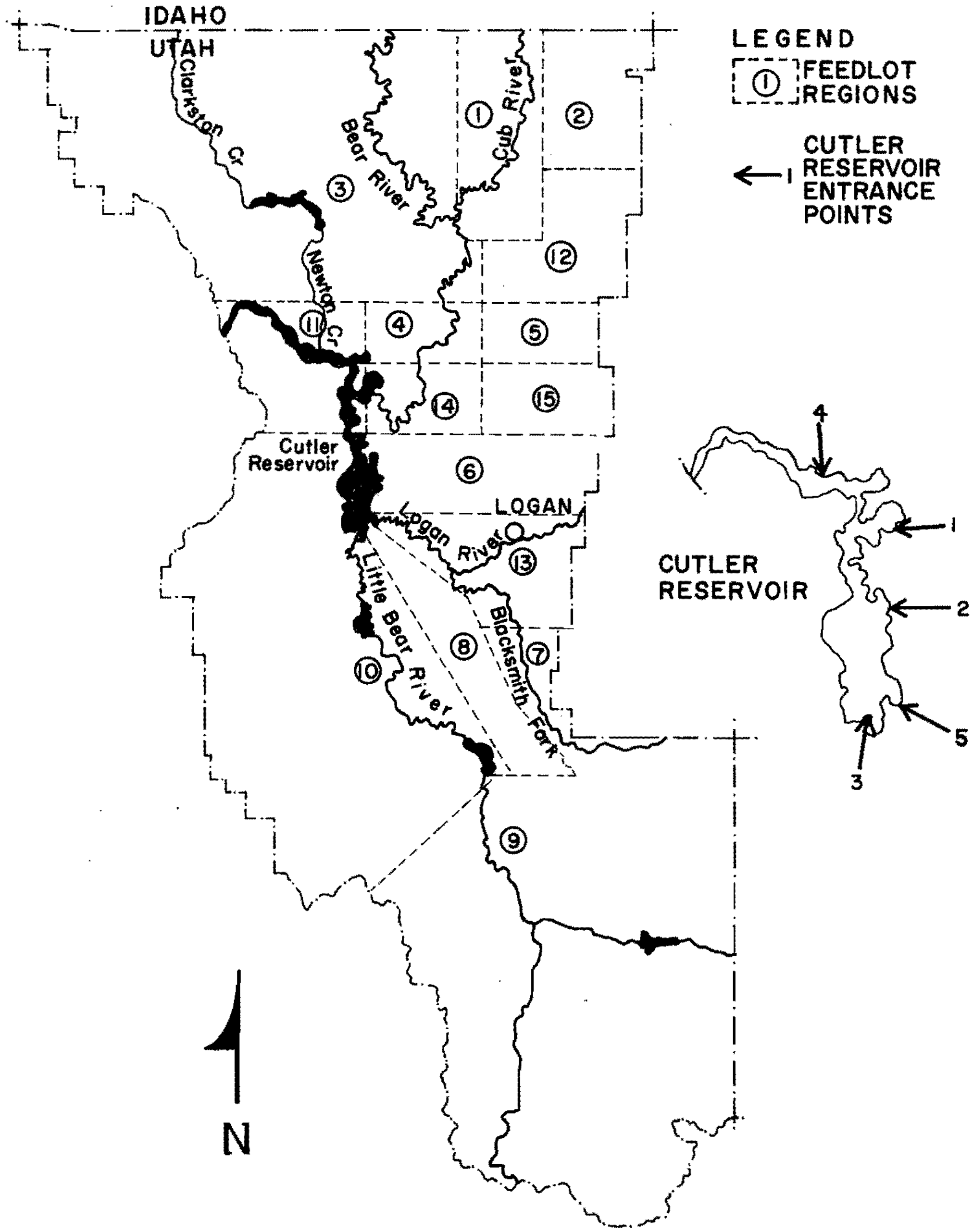


Figure 10. Subareas and entrance points within Cache Valley.

RESULTS AND DISCUSSION

Determination of Loading Functions

Area (A) Values

In Cache Valley, Utah, 220 livestock operations with the potential to discharge their livestock waste into the drainage system were located and categorized (see enclosed maps for location). Seventy percent of the feedlots (154) were classified as to the type of cattle operation (i.e., beef or dairy). These feedlots were dispersed throughout the valley and were adjacent to or near the banks of the major streams. The greatest concentration of feedlots was located in the Amalga-Benson area which is adjacent to the Bear River (enclosed map). The number of cattle per facility ranged from the minimum number of five head to a maximum number of 400 head (Table 12). The total number of cattle on the lots was 13,874. Operations with less than five head of cattle were not considered in this study.

Feedlot areas ranged from a minimum of 0.004 ha (5 head) to a maximum of 1.807 ha (400 head). The majority of operations ranged in area from 0.046 to 0.463 ha. Slopes ranged from 0 to an extreme of 32 percent. Complete information on locale and characteristics of individual feedlots is provided in Appendix E.

Sampling. Quantitative data on feedlot runoff from two paved lots and one unpaved facility were collected during the period of February 23, 1977, through December 31, 1977. One of the original two unpaved feedlots became inoperative due to the inability to maintain the ditch walls of the collection system. A total of 30 samplings were obtained with 18 rainfall runoff events and 12 snowmelt runoff occurrences. A total precipitation of 9.7 cm (3.8 inches) for the winter of 1976-1977 was approximately half of normal (19.4 cm). During the rest of the testing period (March through November 1977), the precipitation was 28.5 cm (11.2 inches). The largest daily rainfall measured during the sampling period was 2.5 cm (1.0 inch) on August 25, 1977.

When feedlot runoff occurred and was sampled, precipitation ranged from 2.5 cm (1.0 inch) to 0.33 cm (0.13 inches). The majority of winter runoff occurred in the last week of February and the first two weeks in March. A total of 2.4 cm (0.95 inch) of precipitation (snow) fell. From January to March 1977 the temperatures ranged from near -17°C to 16°C (2°F to 60°F) during the winter months (January through March). The high temperature for the summer sampling period was 38°C (100°F). During the winter months of 1977, net accumulation of snow was not observed on the feedlots.

Pollutant levels. Ranges of concentrations of pollutants contained in feedlot runoff from paved lots are presented in Table 13 for rainfall and snowmelt. Since concentrations for the two paved feedlots were similar, the data were combined. Pollutant concentrations for snowmelt runoff from the paved lots were two to four times higher than for rainfall runoff for all parameters except orthophosphate phosphorus. Concentrations of orthophosphate phosphorus (PO_4-P) were higher during rainfall runoff. Ranges of concentration of pollutants from unpaved feedlots for snowmelt are shown in Table 14.

Table 12. Number of feedlots with corresponding head sizes in Cache Valley, Utah.

Number of Cattle	Number of Feedlots
5-19	49
20-49	73
50-99	53
100-149	23
150-199	9
200-above	13
	220

Table 13. Ranges of pollutant concentration in runoff from paved feedlots (1977).

Analysis	Ranges of Concentration	
	Winter Runoff	Summer Runoff
Total Suspended Solids (mg/l)	4792-29000	864-9767
Volatile Suspended Solids (mg/l)	3048-13333	720-7333
COD (mg/l)	14628-43386	6652-17904
BOD_5 (mg/l)	3528-9240	1500-11200
PO_4-P (mg/l)	0.154-0.535	0.650-4.890
TP (mg/l)	10.9-176.4	23.9-38.9
NH_3-N (mg/l)	118.4-650.6	25.7-244.0

Table 14. Ranges of pollutant concentration in runoff from unpaved feedlots (1977).

Analysis	Ranges of Concentration	
	Winter Runoff	Summer Runoff
Total Suspended Solids (mg/l)	544-12374	654-4440
Volatile Suspended Solids (mg/l)	331-825	311-1770
COD (mg/l)	1397-17732	4056-10474
BOD_5 (mg/l)	25-907	1000-1300
PO_4-P (mg/l)	5.290-9.850	---
TP (mg/l)	18.5-66.6	10.1-53.6
NH_3-N (mg/l)	24.1-70.1	4.9-7.5

A freely flowing liquid runoff from the paved lots was observed during the summer months. During the winter, however, runoff consisted of a slurry or viscous mass which moved to the collection system relatively slowly during intermittent freezing and thawing periods of the manure slurry.

Freezing and thawing of the slurry occurred after each snow event. At night, due to freezing temperatures, snow would accumulate on the feedlot. In high temperatures or bright sunshine, thawing of the slurry would facilitate runoff from the feedlot. Subsequent freezing of the runoff would occur during the evening and night. This phenomenon was a continual daily cycle until accumulated snow was dissipated. Data obtained from the three monitored feedlots are in Appendix F.

Regression relationships. Using the field data acquired from the three livestock facilities, regression relationships were developed between various parameters. Mathematical relationships were formulated for pollutant concentrations from paved and unpaved lots during rainfall and snowmelt conditions.

The coefficient of determination (r^2) for the relationship between COD and BOD_5 was 0.84 for a paved lot during the rainfall and snowmelt, and for an unpaved lot during rainfall (Figure 11 and Table 15). The r^2 for the linear function relating COD to BOD_5 for the unpaved lot during snowmelt was 0.61 (Figure 12 and Table 15). Intermediate or higher concentrations of soil in the runoff could be the reason for the lower r^2. The r^2 value for the expression relating COD to TP was 0.85 for both paved and unpaved lots during rainfall and snowmelt (Figure 13 and Table 15). The high correlation between COD and TP indicated that a significant portion of the phosphorus was organically bound. The concentrations of COD, TP, SS, and VSS were directly influenced by the amount of organic matter accumulated on the feedlot. For both paved and unpaved lots during rainfall and snowmelt, the relationship between SS to VSS yielded a value for r^2 of 0.98 (Figure 14 and Table 15).

A very low correlation was found between orthophosphate phosphorus (PO_4-P) levels and total phosphorus (TP) concentrations. The low r^2 (0.01) value precluded the use of this relationship. Poor correlations between inorganic and total parameters such as PO_4-P to TP and others such as ammonia nitrogen (NH_3-N) to total Kjeldahl nitrogen (TKN) were found. This may be due to chemical and microbiological changes, such as changes in pH and the number or type of organisms which occurred in the manure slurry. Such chemical and biological alterations would occur as the slurry ponded on the feedlot area for an undetermined period of time. Microbiological and physical interactions within the ponded slurry during the variety of precipitation events and temperature variations contributed to the changes in PO_4-P to TP relationships.

Initially COD, SS and NH_3-N data obtained during an event were correlated with the respective daily precipitation totals. This approach resulted in a low r^2. Rainfall events were subsequently differentiated between single precipitation totals and consecutive or multiple precipitation totals. Comparing the data in this manner yielded a considerably better r^2 as shown in Figure 15 for NH_3-N concentrations discharged from a paved lot (Table 16). Further division with event type (i.e., rain or snow) and single or multiple day(s) precipitation up to 5 days in succession resulted in good r^2 values. The r^2 for the relationship between COD and precipitation, and SS and precipitation were 0.41 and 0.75 respectively for a single rain event from a paved facility (Figures 16, 17 and Table 15). A linear regression equation defining COD as a function of multiple precipitation events produced an r^2 of 0.69. A similar r^2 value resulted from a linear correlation between SS and multiple precipitation events (Figure 18, 19, and Table 16). No division was made between single and multiple precipitation events for orthophosphate (Figure 20 and Table 16). Greater correlations were achieved when single and multiple precipitation events were combined. The probable reason for this was the unstable relationship between PO_4-P and ponding of slurry on the feedlot area. Limited data were available for COD, BOD_5, NH_5-N, TP, PO_5-P, VSS and SS from unpaved feedlots for rainfall events. Blockage of the collection pipe, due to collapsing of the ditch walls, prevented sample collection for 6 to 10 events. Once the walls were reinforced with wood planks the problem was corrected. These data were therefore combined with data obtained from paved feedlots and the corresponding regression equations were developed. A full listing of loading function equations for events is in Table 16.

The concentration of pollutants contained in snowmelt runoff was influenced by surface conditions and the number of consecutive

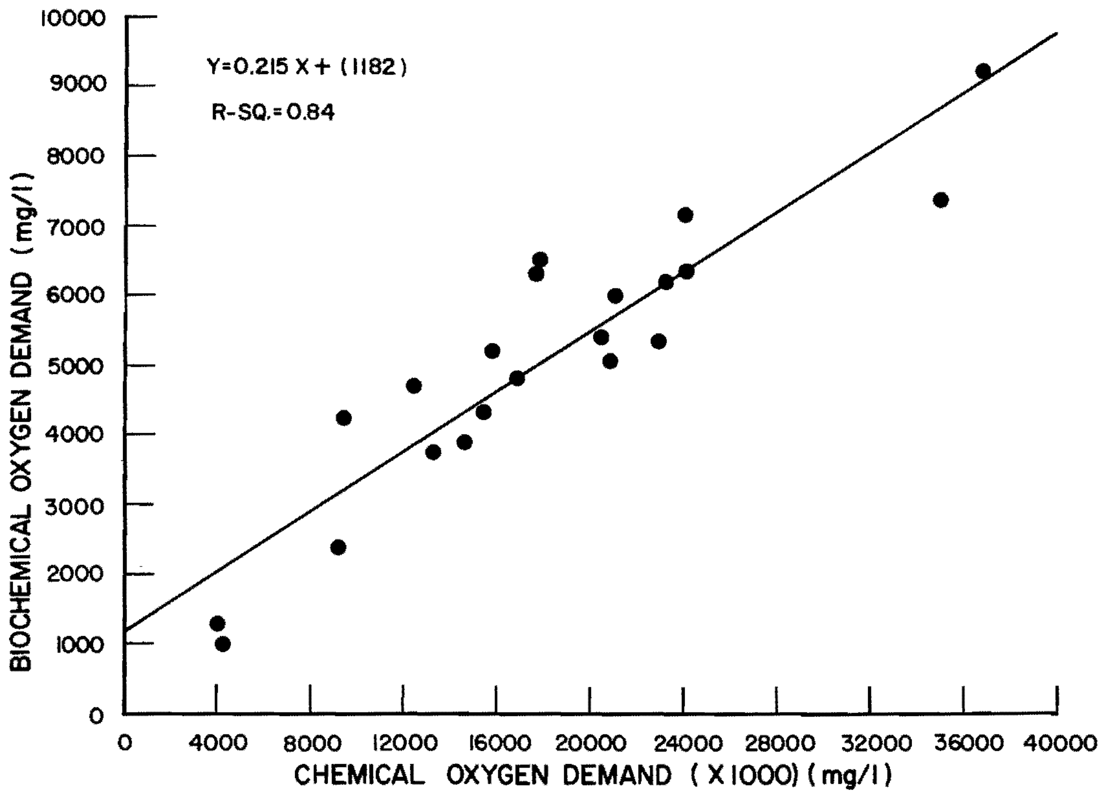


Figure 11. Relationship between BOD_5 and COD for paved lots during rainfall and snowmelt, and for unpaved lots during rainfall.

Table 15. Linear regression equations developed between selected water quality parameters.

Dependent Variable	Independent Variable	Surface	Event Type	Linear Regression Equation	Coefficient of Determination r^2
COD	BOD	Paved	Rain	0.215 Pr + 1,182	0.84
COD	BOD	Paved	Snow	0.215 Pr + 1,182	0.84
COD	BOD	Unpaved	Rain	0.215 Pr + 1,182	0.84
COD	BOD	Unpaved	Snow	0.088 Pr + 89.410	0.61
COD	TP	Paved	Rain	0.0033 Pr + 13.624	0.85
COD	TP	Paved	Snow	0.0033 Pr + 13.624	0.85
COD	TP	Unpaved	Rain	0.0033 Pr + 13.624	0.85
COD	TP	Unpaved	Snow	0.0033 Pr + 13.624	0.85
SS	VSS	Paved	Rain	0.627 Pr - 0.272	0.98
SS	VSS	Paved	Snow	0.627 Pr - 0.272	0.98
SS	VSS	Unpaved	Rain	0.627 Pr - 0.272	0.98
SS	VSS	Unpaved	Snow	0.627 Pr - 0.272	0.98

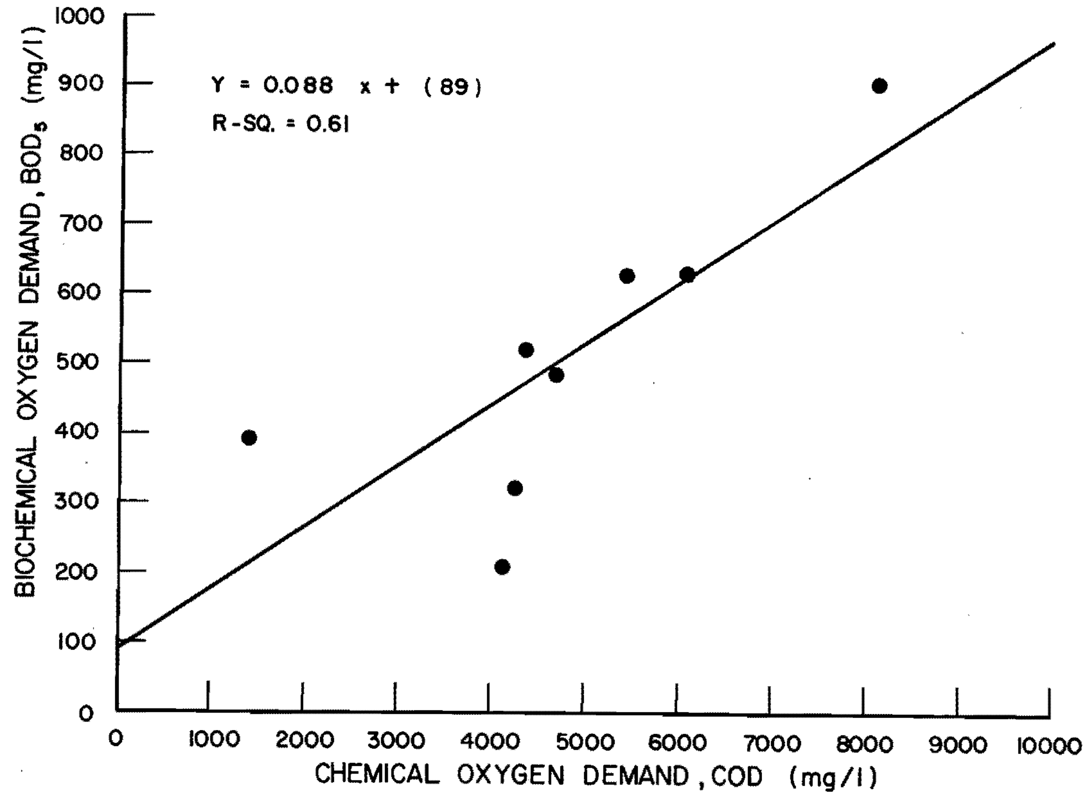


Figure 12. Relationship between BOD_5 and COD for unpaved lots during snowmelt.

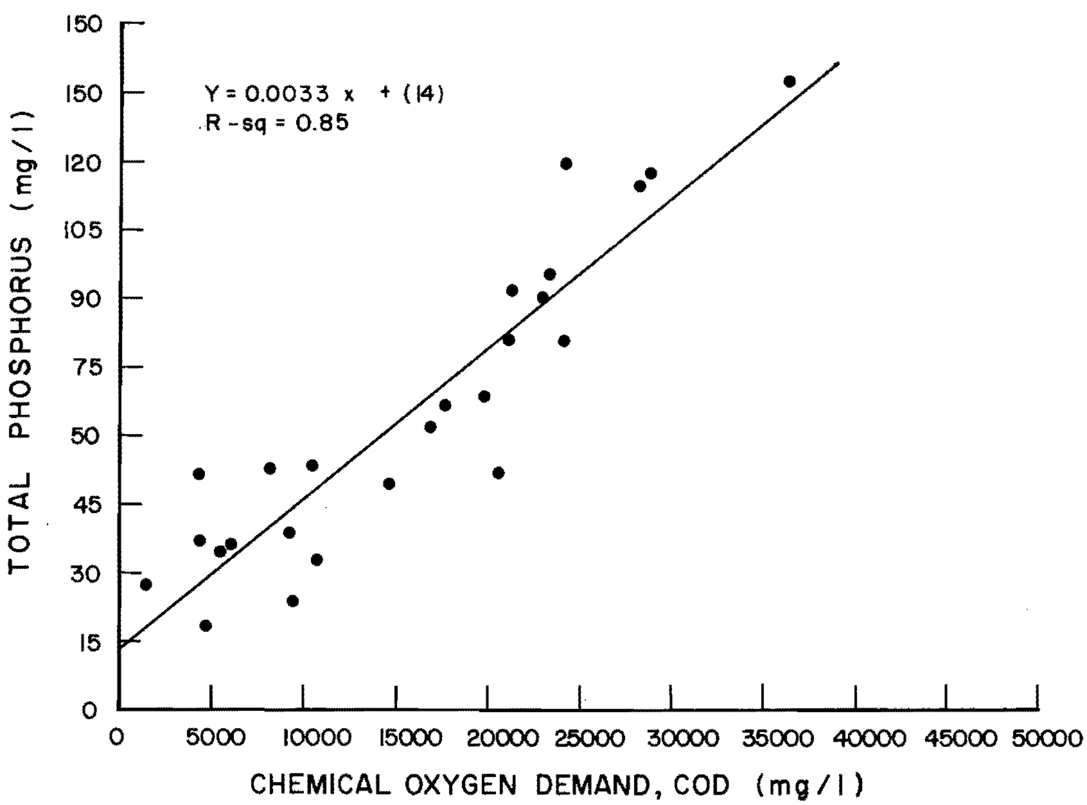


Figure 13. Relationship between TP and COD for paved and unpaved lots during rainfall and snowmelt.

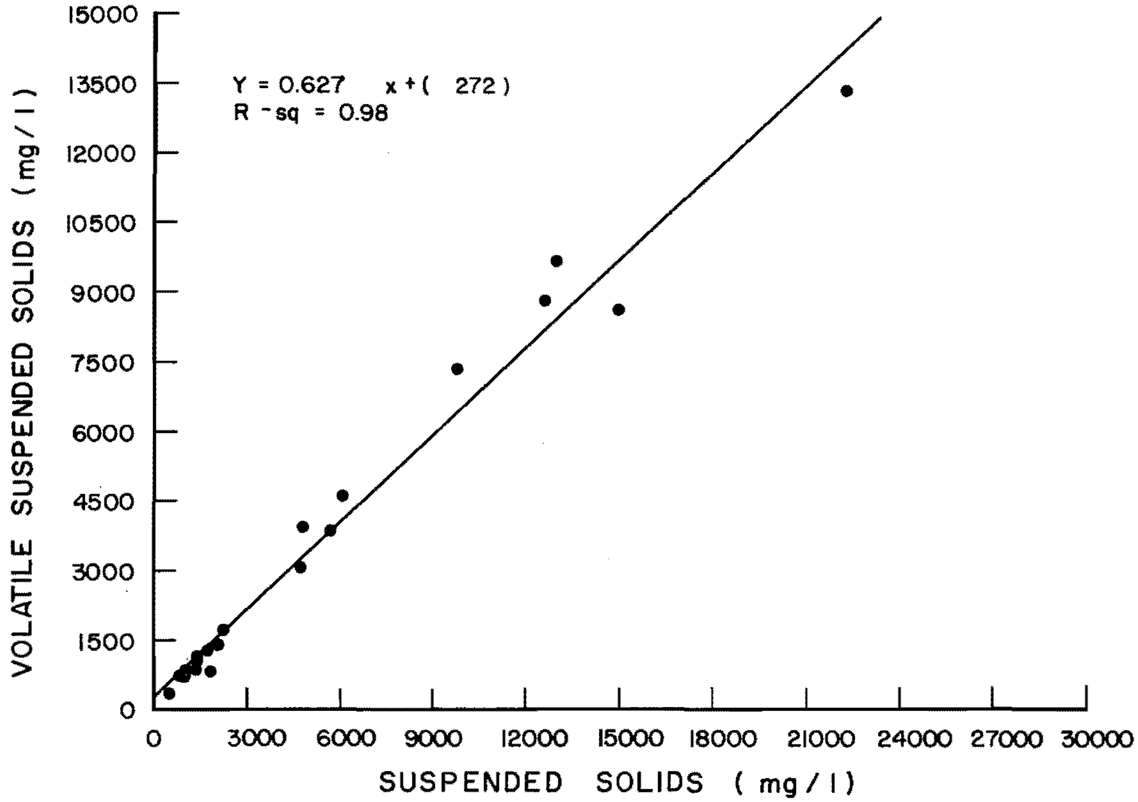


Figure 14. Relationship between VSS and SS for paved and unpaved lots during rainfall and snowmelt.

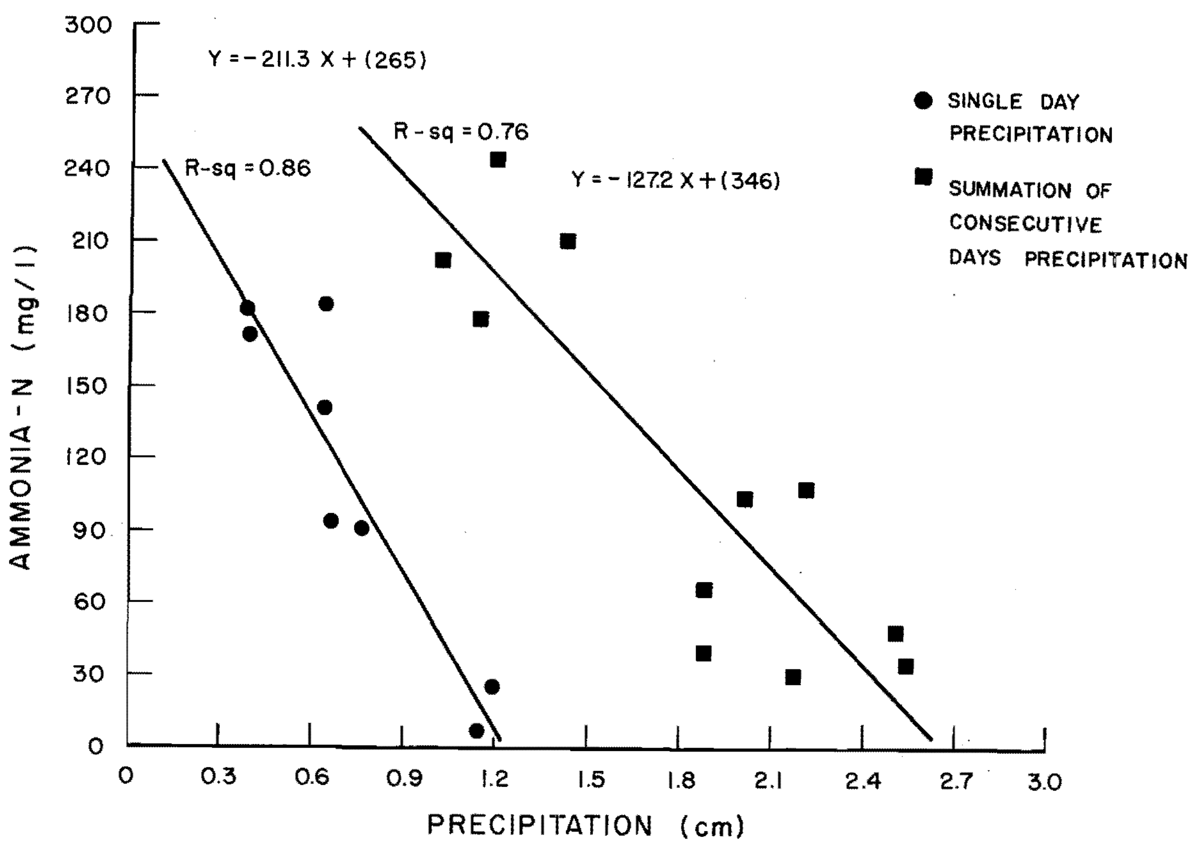


Figure 15. Relationship between NH_3-N and precipitation for paved lots during single day and consecutive day rainfall.

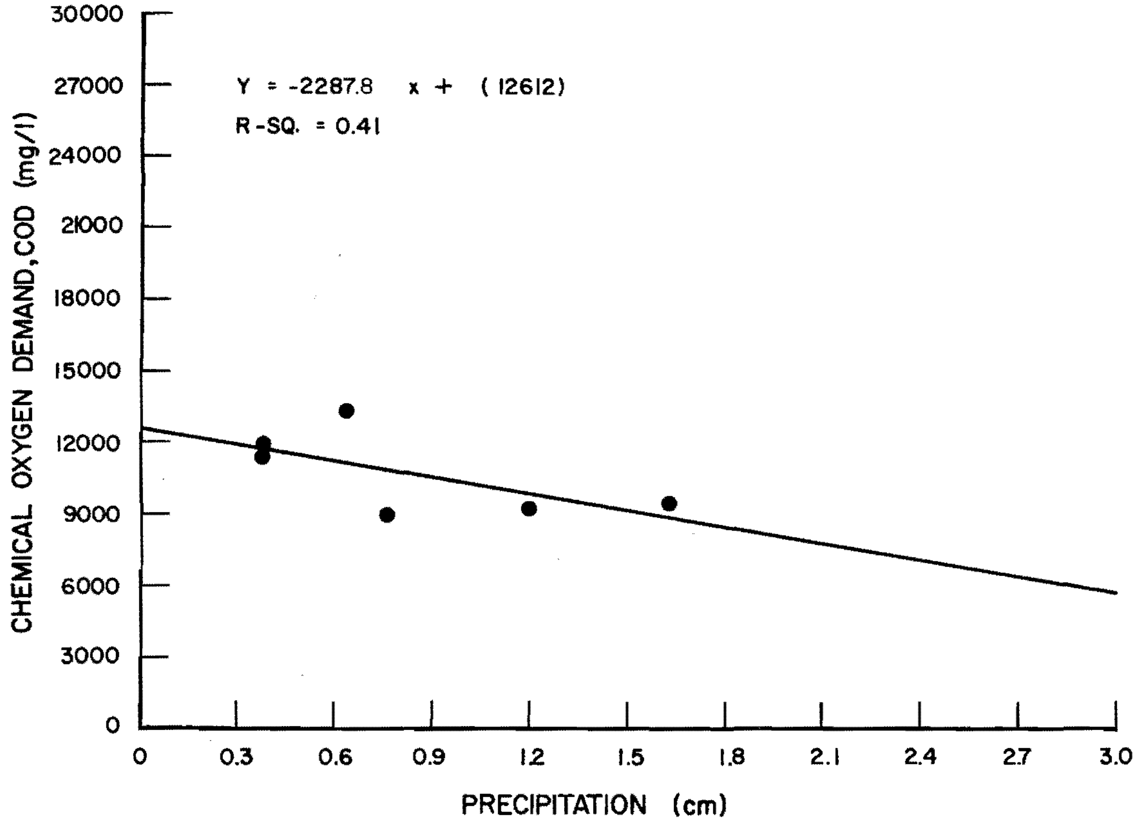


Figure 16. Relationship between COD and precipitation for paved lots during single day rain event.

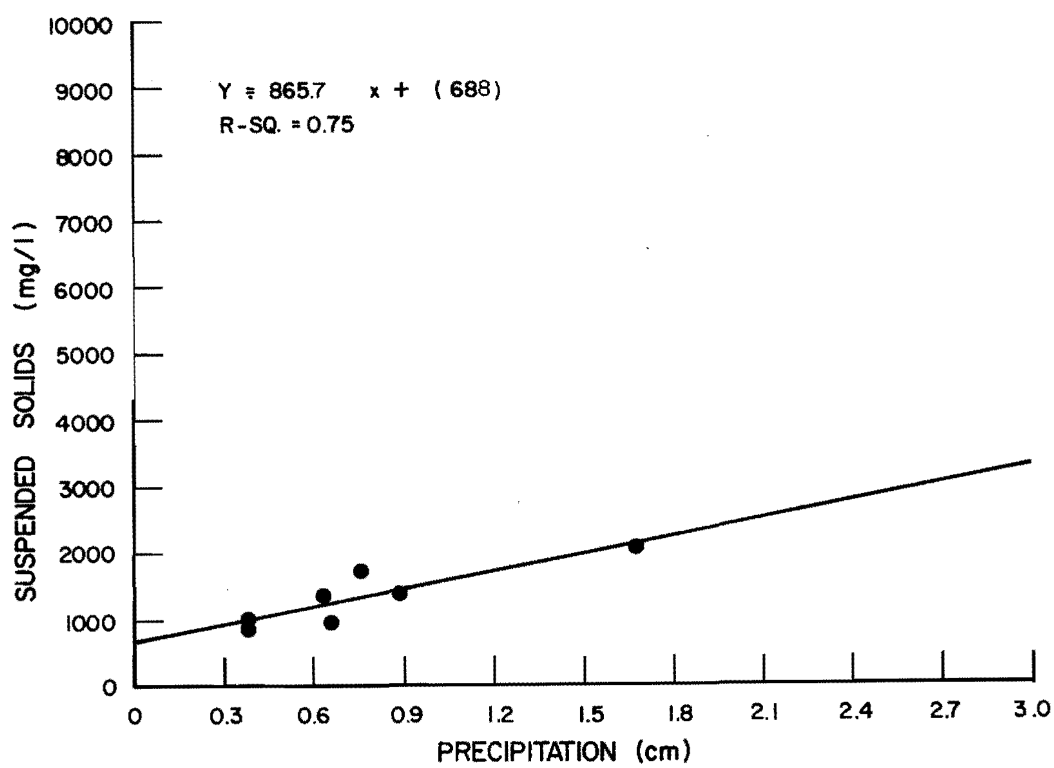


Figure 17. Relationship between SS and precipitation for paved lots during single day rain event.

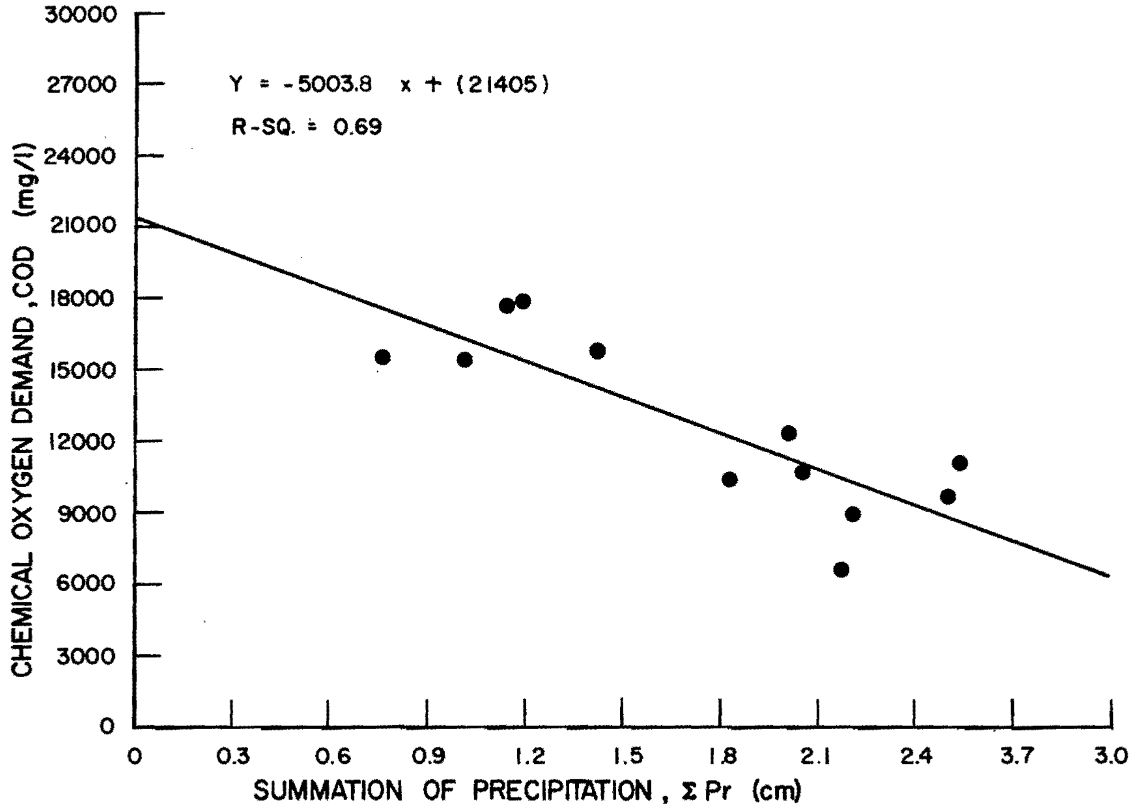


Figure 18. Relationship between COD and precipitation for paved lots during multiple rain events.

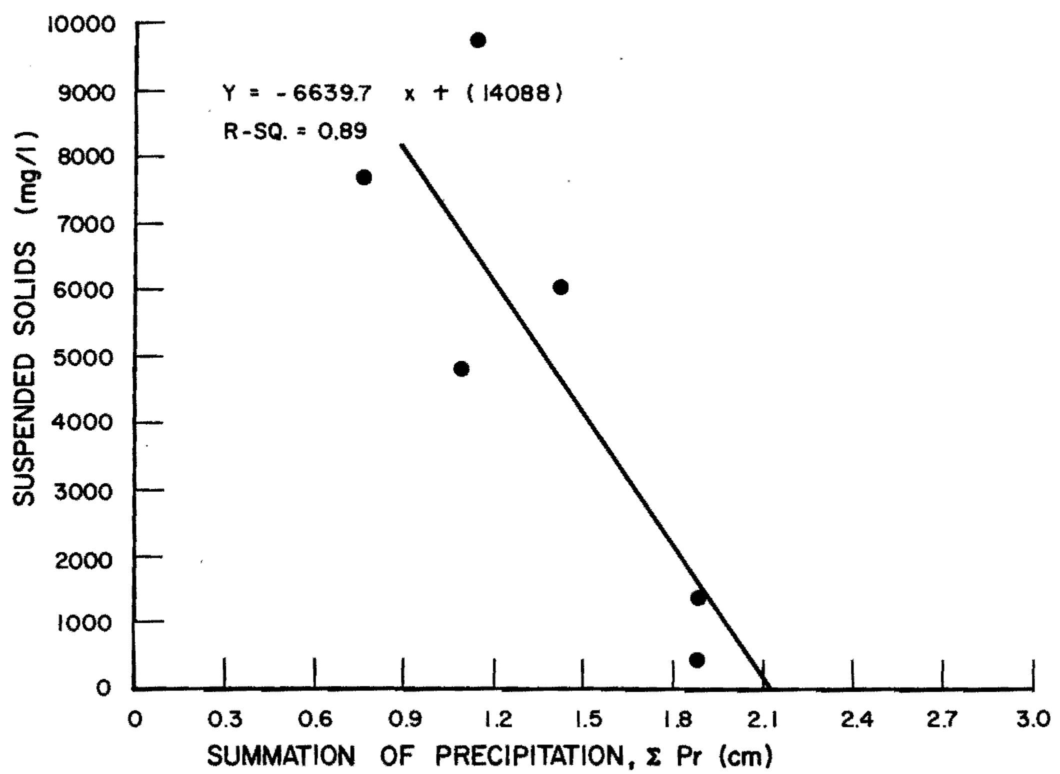


Figure 19. Relationship between SS and precipitation for paved lots during multiple rain events.

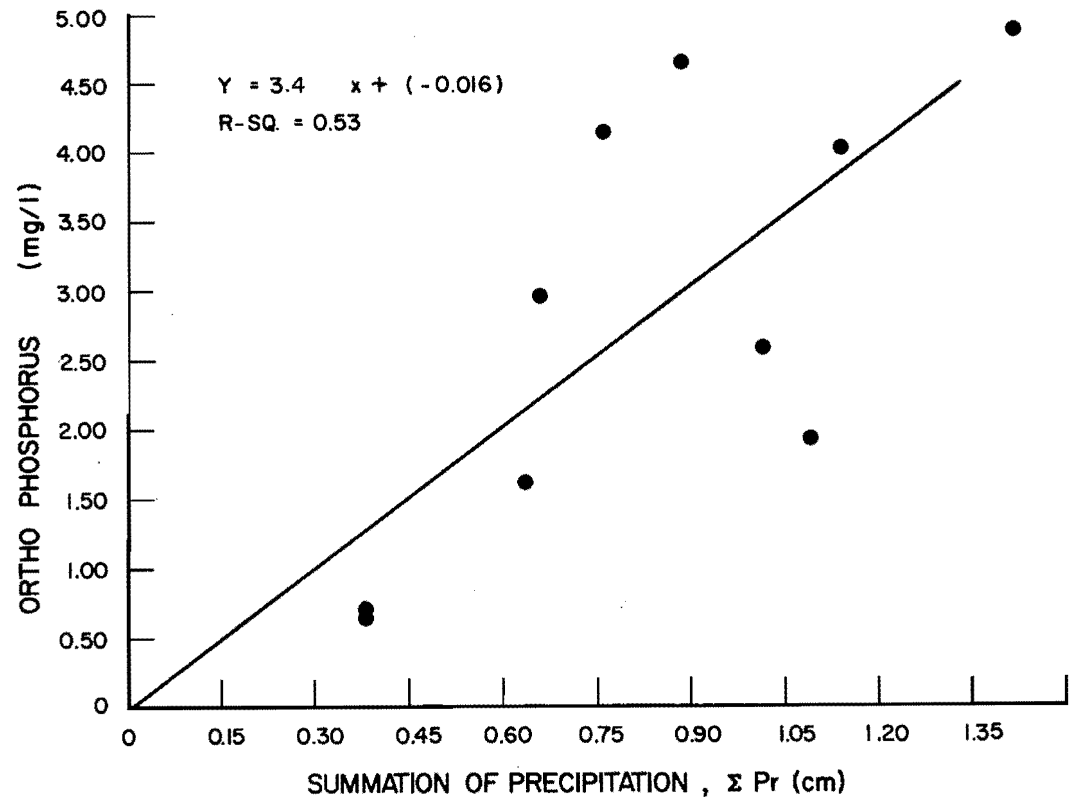


Figure 20. Relationship between orthophosphorus and precipitation for paved lots during single or multiple rain events.

Table 16. Linear regression models correlating water quality parameters with precipitation event.

Dependent Variable	Independent Variable	Surface	Event Type	Linear Regression Equation	Coefficient of Determination r^2
COD	Pr	Paved	Rain	-2287.7 Pr + 12618.8	0.41
COD	ΣPR	Paved	Rain	-5003.8 Pr + 21405.7	0.69
COD	Σ(3 days)	Paved	Snow	34674.6 Pr + 2379.5	0.61
COD	Σ(4 days)	Unpaved	Snow	-20846.3 Pr + 21560.1	0.91
SS	Pr	Paved	Rain	865.7 Pr + 687.6	0.75
SS	ΣPr	Paved	Rain	-6639.7 Pr + 14088.0	0.89
SS	Σ(3 days)	Paved	Snow	1.483 ln Pr + 9.933	0.66
SS	Σ(4 days)	Unpaved	Snow	-16298.5 Pr + 14926.6	0.90
NH_3-N	Pr	Paved	Rain	-211.34 Pr + 265.26	0.86
NH_3-N	ΣPr	Paved	Rain	-127.23 Pr + 346.23	0.76
NH_3-N	Σ(3 days)	Paved	Snow	-553.08 Pr + 773.81	0.41
NH_3-N	Σ(4 days)	Unpaved	Snow	61.21 Pr + 15.44	0.63
PO_4-P	Pr & ΣPr	Paved	Rain	3.381 Pr + (-0.016)	0.53
PO_4-P	Σ(3 days)	Paved	Snow	-0.349 Pr + 0.534	0.43
PO_4-P	Σ(4 days)	Unpaved	Snow	4.775 Pr + 3.437	0.42

preceding days of precipitation. Comparisons were made between each parameter and the number of consecutive days of precipitation. The total number of days of consecutive precipitation that was used in the regression analysis varied depending upon the parameter and feedlot surface condition. Highest values of r^2 were achieved for the functional expression relating to COD (unpaved), SS (unpaved), NH_3-N (paved) and orthophosphate (unpaved) data to 4 days of consecutive precipitation. The r^2 for these relationships were 0.91, 0.90, 0.41, and 0.42 respectively as shown in Figures 21, 22, 23 and 24. Table 16 presents the equation for these relationships. A combination of 3 days' consecutive precipitation was used for COD (paved), SS (paved) and orthophosphate (paved) with r^2 of 0.61, 0.66 and 0.43 respectively (Figures 25, 26 and 27 and Table 16). Ammonia-nitrogen (unpaved) was a function of 100 percent precipitation the first day, and 50 percent of the daily precipitation for the preceding 3 days. The r^2 for NH_3-N was 0.63 (Figure 28). A full listing of loading function equations for snow events is presented in Table 16.

The regression equations are valid for precipitation events between 0.03 cm (0.01 inch) to 2.54 cm (1 inch).

Flow (Q) Values

A total of 54 flow measurements were made from both paved (32) and unpaved (22) feedlots. Flow data from the paved surface ranged from 2 to 1614 ml per second. Flow data from the unpaved surface ranged from 1 to 364 ml per second. The following linear regression equations were developed for volumetric flow rates from paved lots:

$$\text{(Rain)} \quad Q = 0.388\ Pr + (-0.068) \qquad (18)$$

$$\text{(Snow)} \quad Q = 0.888\ Pr + (-0.063) \qquad (19)$$

where

Pr = precipitation/day (cm) and
Q = flow (cm/day).

The values of r^2 were 0.59 and 0.70 for rainfall and snowmelt, respectively. A graph of rainfall versus flow data for a paved facility is shown in Figure 29. Figure 30

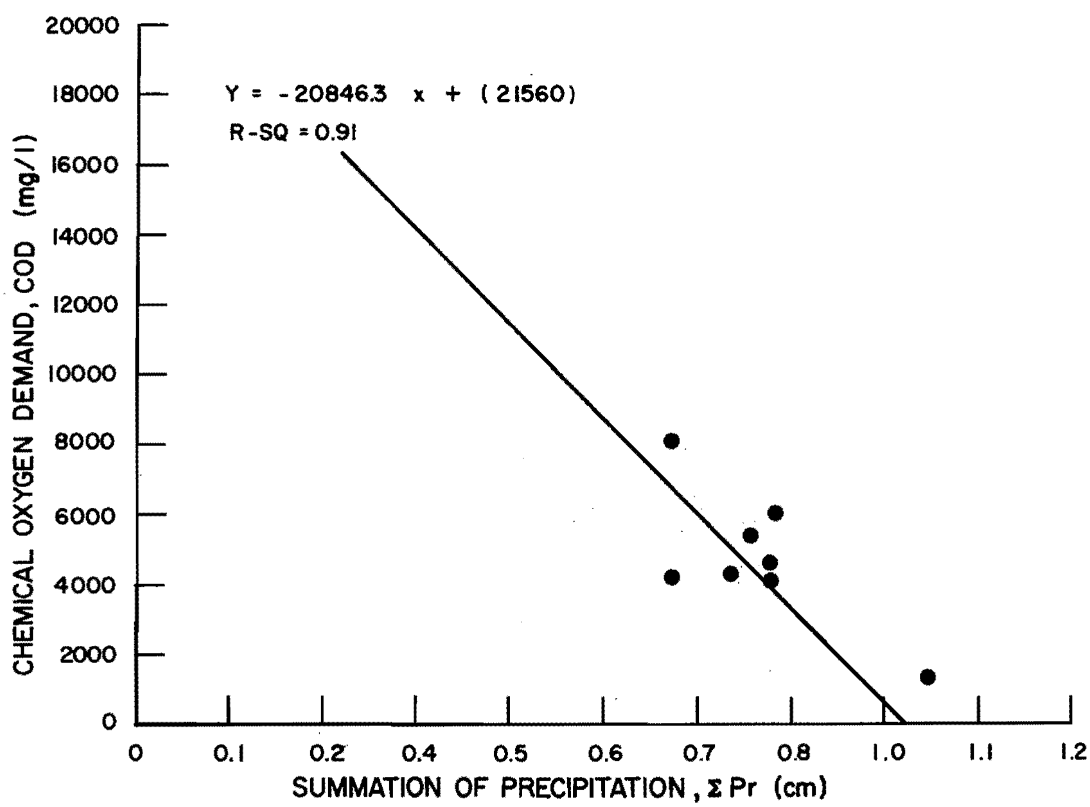


Figure 21. Relationship between COD and precipitation for unpaved lots during snowmelt.

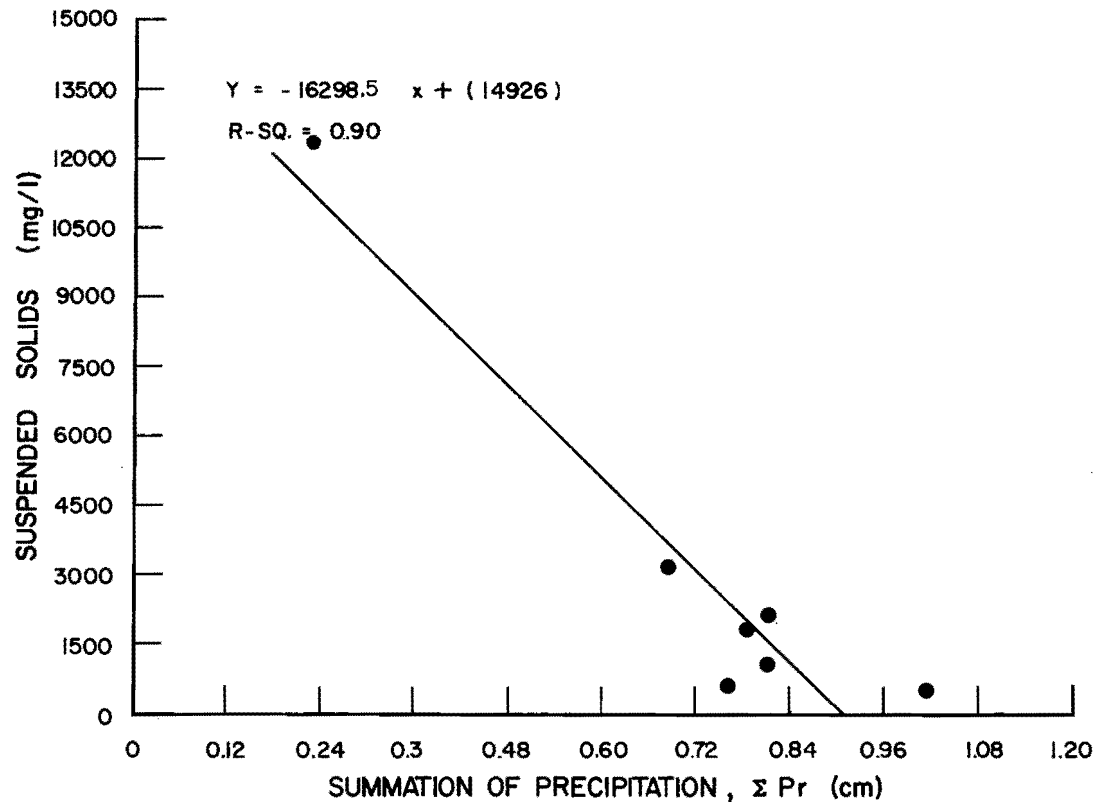


Figure 22. Relationship between SS and precipitation for unpaved lots during snowmelt.

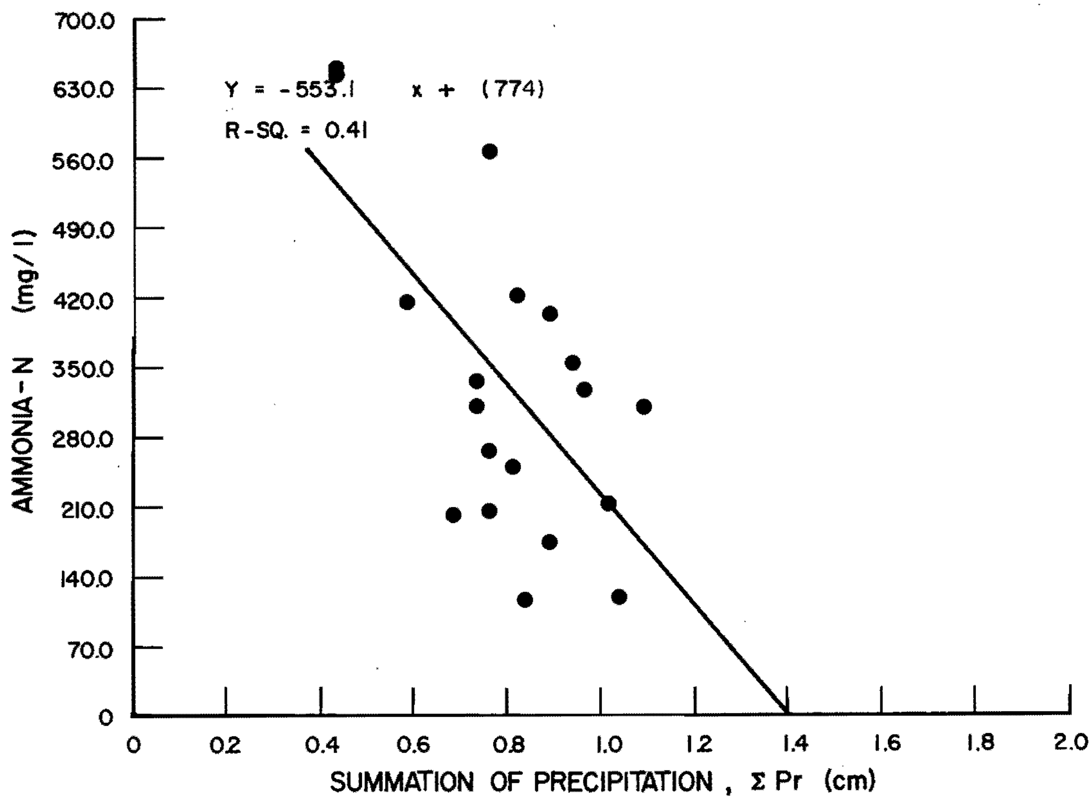


Figure 23. Relationship between NH_3-N and precipitation for paved lots during snowmelt.

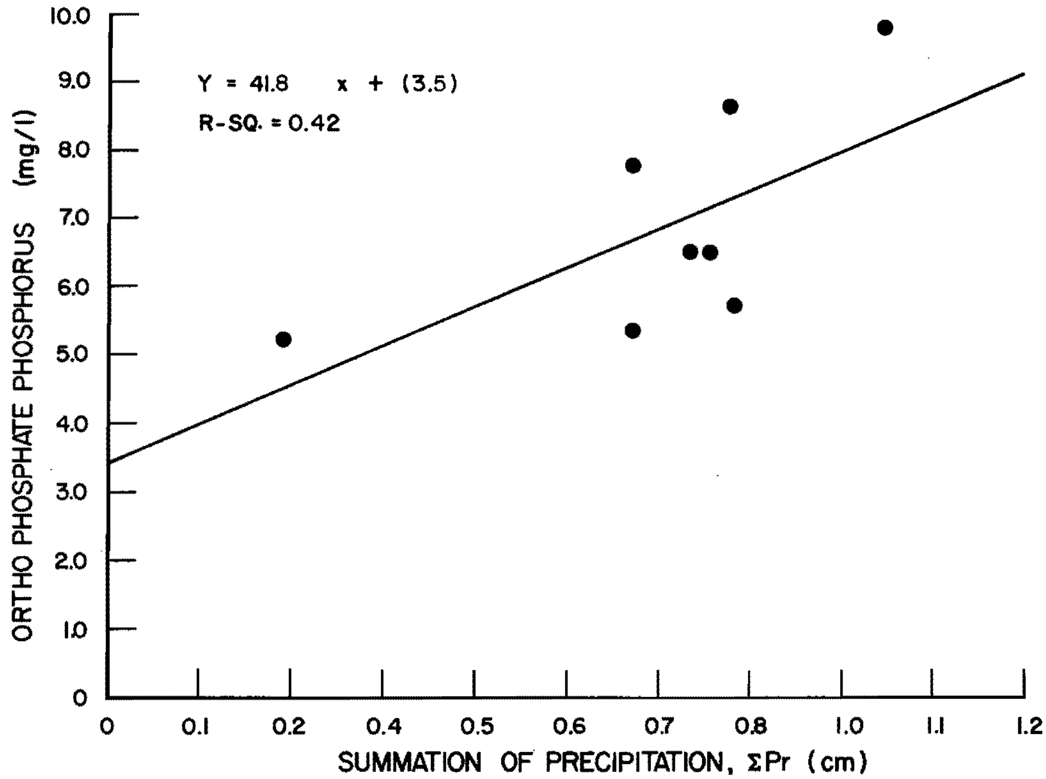


Figure 24. Relationship between orthophosphorus and precipitation for unpaved lots during snowmelt.

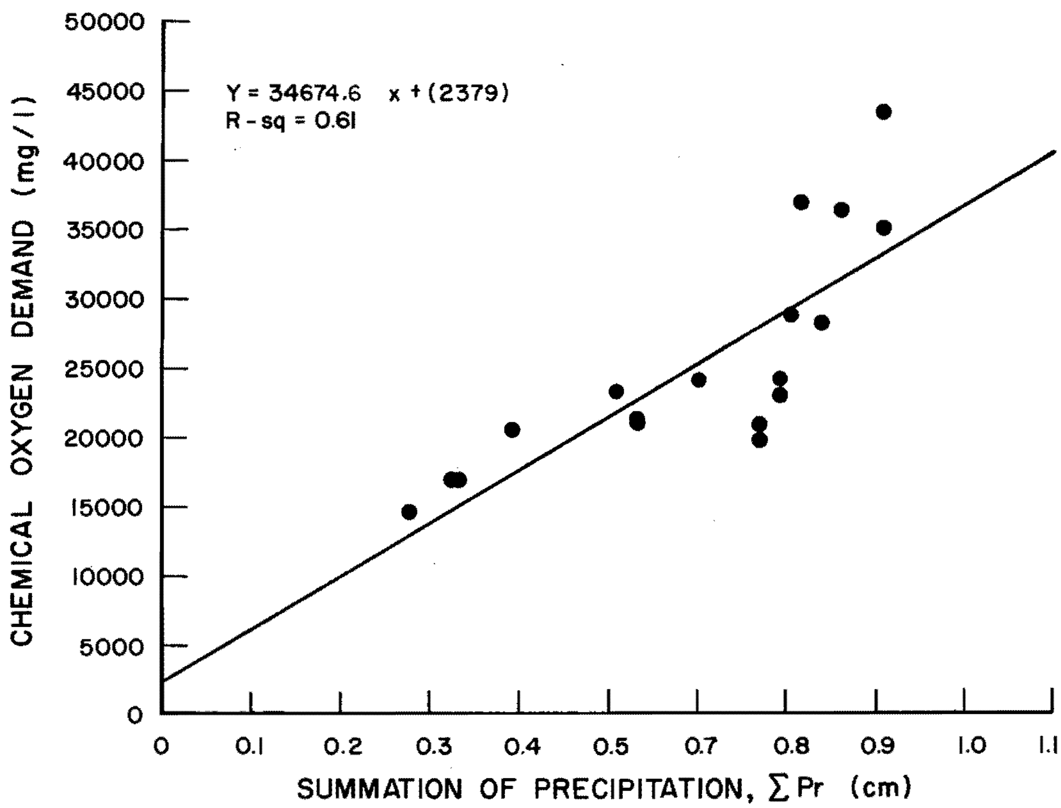


Figure 25. Relationship between COD and precipitation for paved lots during snowmelt.

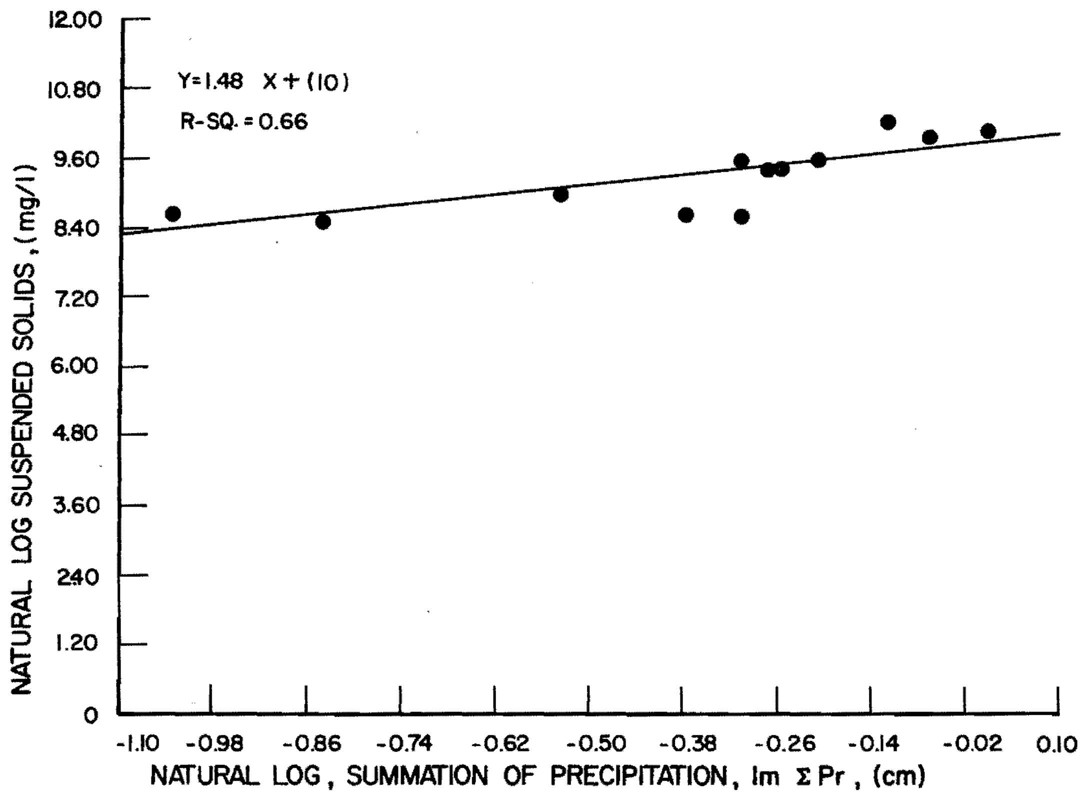


Figure 26. Relationship between natural log of SS and precipitation for paved lots during snowmelt.

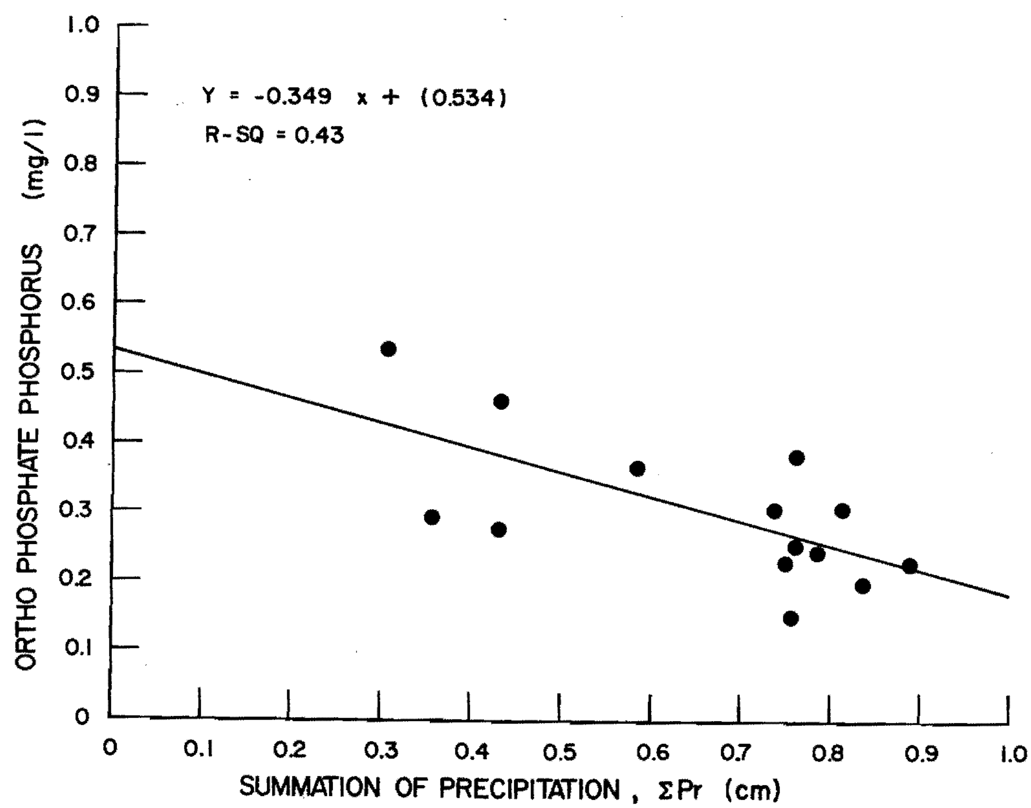


Figure 27. Relationship between orthophosphorus and precipitation for paved lots during snowmelt.

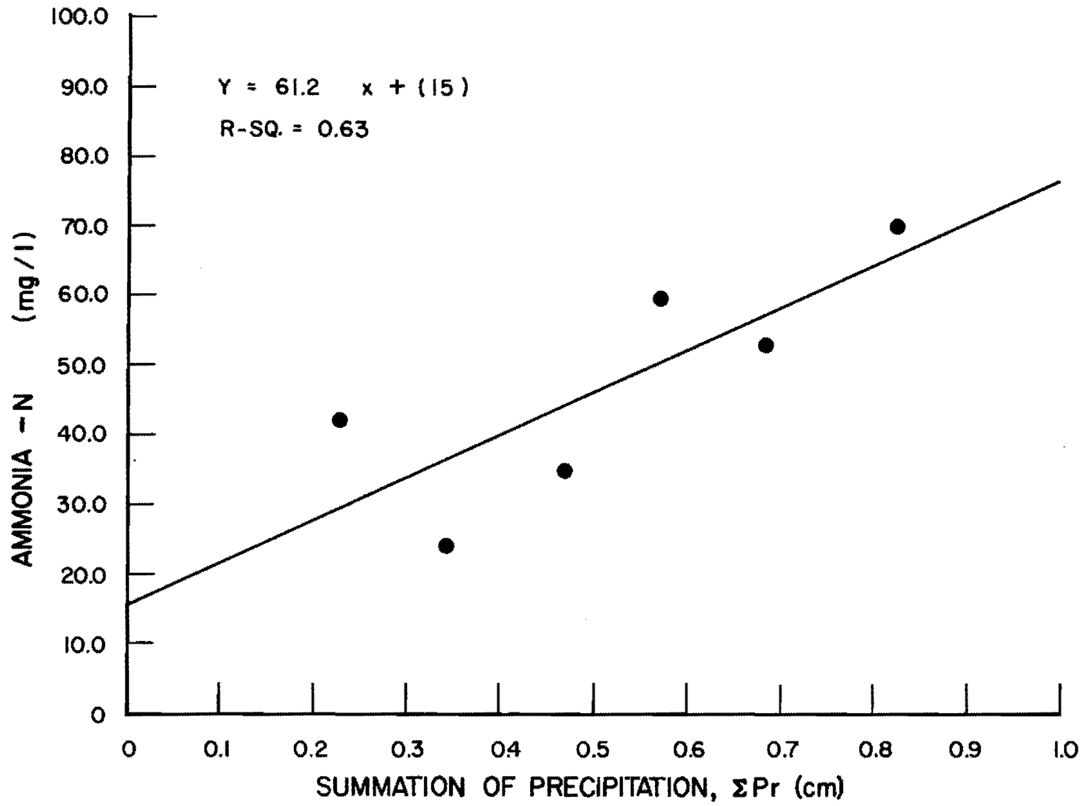


Figure 28. Relationship between NH_3-N and precipitation for unpaved lots during snowmelt.

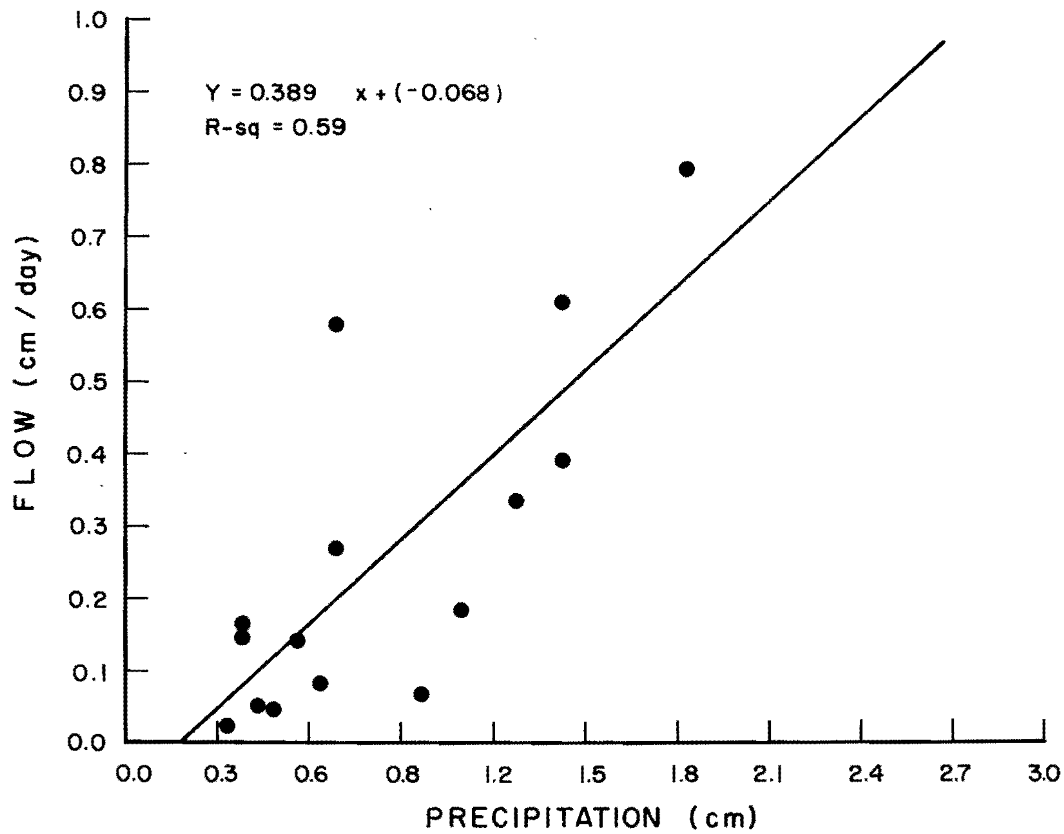


Figure 29. Relationship between flow and precipitation for paved lots during rainfall.

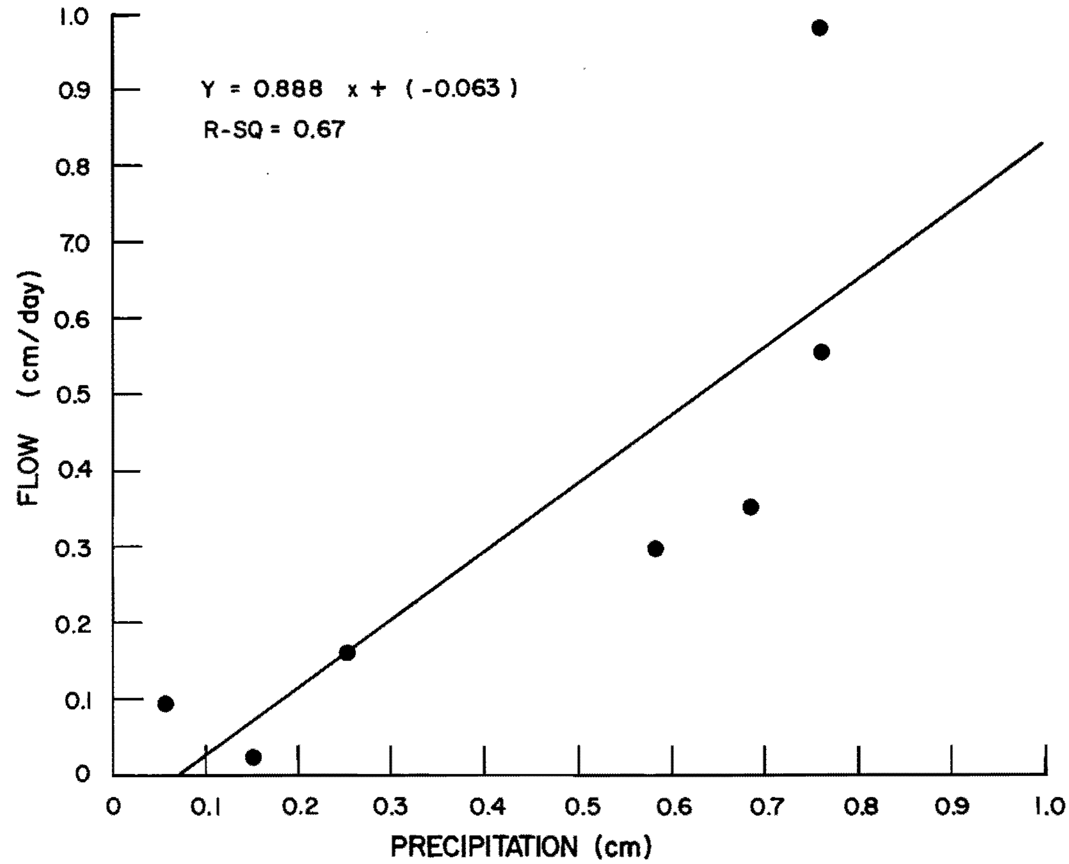


Figure 30. Relationship between flow and precipitation for paved lots during snowmelt.

presents snowfall versus flow for a paved facility. As indicated in Equations 18 and 19, higher flows occur during winter (snowmelt) precipitation events from paved lots than during summer (rainfall) events.

The relationship to define flow from an unpaved lot during a rainfall event was based upon the Soil Conservation Service Method for soil runoff (McElroy et al. 1976):

$$Q = \frac{(Pr - 0.2S)^2}{(Pr + 0.8S)} \quad . \quad . \quad . \quad . \quad . \quad . \quad (20)$$

where

S = infiltration/day (cm);
Q = flow (cm/day); and
Pr = precipitation/day (cm).

The potential infiltration quantity (S) was calculated from Equation 20 using field precipitation and flow data obtained from the monitored earthen feedlot described in the procedures (page 21).

Correlation of the calculated S values with the respective precipitation quantity produced the following equation:

$$S = \frac{Pr}{0.437 - 0.052\ Pr} \quad . \quad . \quad . \quad . \quad . \quad (21)$$

$(r^2 = 0.92)$

Predicted flow rates from unpaved feedlots (Equation 14) were equal to approximately 25 percent of the predicted flow from paved feedlots (Equation 18). Storage and ground infiltration on an unpaved facility would reduce the volume of feedlot runoff.

During a snowmelt event, when snow was falling, the resultant runoff from unpaved facilities was mathematically defined by the following equation:

$$Q = -1.798 \log Pr - \log 2.886 \quad . \quad . \quad (22)$$

$(r^2 = 0.98)$.

When no precipitation occurred, runoff was only a function of the previous snow.

The equation used to predict flow during this condition was:

$$Q = 0.402\ \Sigma(PPr - Q_{i-1}) + (-0.1) \quad . \quad . \ (23)$$

$$(r^2 = 0.77)$$

where

PPr = summation of previous snow event precipitation (cm), and
Q_{i-1} = previous day's runoff (cm).

Mass Transport

The mass loading leaving individual feedlots was a function of the flow, concentration of pollutant, and the area of the facility. The preceding mathematical relationships developed to predict runoff volumetric flow rates Q(j) and concentrations ($C(i,j)_{FL}$) of specific pollutants contained in the runoff were merely functions of the amount of daily precipitation or accumulated consecutive precipitation events.

Furthermore, the values of Q(j) and $C(i,j)_{FL}$ depended on surface conditions of the feedlot (i.e., paved or unpaved). Therefore, the predicted levels of Q(j) and C(i) for a particular precipitation event were the same for a 1 ha paved feedlot and a 0.1 ha paved feedlot. Other feedlot characteristics such as depth of manure, cattle density, and degree of slope have been found to be relatively insignificant when compared to the influence of precipitation on concentration of pollutant in runoff (Gilbertson et al. 1971, Gilbertson et al. 1969, AWMTC 1978, Miner 1967). The concentration of pollutants and quantity of feedlot runoff is influenced largely by the rainfall intensity, water content on the feedlot, and the type of feedlot surface (Gilbertson et al. 1971). As shown in the mass loading equation (page 9), the area of the feedlot was the variable which made the mass loading of a pollutant specific for that facility.

Since Q(i) and $C(i,j)_{FL}$ were uniformly applied to all the feedlots in a region, the contribution of pollutant mass entering the environmental sink was related to the total area of feedlots existing within the region. Once mass loadings were determined, the amount of mass that reaches the common sink (Cutler Reservoir) was dependent upon travel time of pollutants, changes in pollutant composition during transport, and the number of feedlots within the basin under study.

Feedlot Inventory and Categorization

Of the 220 facilities located and characterized within the study area, 206 facilities were used in the modeling phase. Fourteen feedlots were excluded because of their isolated locations on smaller waterways. The area encompassing the 206 feedlots was divided into regions. Regions are associated with streams that discharge at designated entrance points into Cutler Reservoir as shown in Table 17 and Figure 10.

Entrances to Cutler Reservoir were assigned as follows: 1) Bear River drainage area; 2) airport canals drainage area; 3) Little Bear River drainage area; 4) Newton City drainage area; and 5) Logan River drainage area.

Figure 31 shows 50 year monthly precipitation averages versus precipitation for four official weather stations located in the study area. The predicted BOD_5 mass loadings to Cutler Reservoir, based on monthly precipitation averages over a 50-year period, indicate that the highest BOD_5 mass loading was contributed by the Bear River (point 1) entrance (Table 18 and Figure 32). The Cub and Bear Rivers which enter Cutler Reservoir at location 1 transport pollutant mass from feedlot regions 1, 2, 3, 4, 5, 12, 14 and 15 (Figure 10). The Bear River entrance point drained an area containing the largest proportion of cattle (7,786) and largest total area of feedlots in the valley (23.7 ha) (Table 18). Nutrient and organic mass entering the sink at point 1 contributed approximately 60 percent of the total pollutants from feedlots in the valley (Figure 33). Region 3 (Lewiston), with a total feedlot area of 2.54 ha, contributed the highest pollutant levels during winter months (Table 19). Regions 4 and 14 (located from Benson to Cutler Reservoir on the Bear River), with feedlot areas of 5.98 ha and 3.69 ha, respectively, contributed the highest pollutant levels during summer months (Table 20). In the summer months, the greatest contribution of pollutants was by the four largest regions (2, 4, 9 and 14) in total area.

Table 17. Region and Culter entrance point of 206 feedlots.

Entrance	Region	Number of Feedlots	Total Area (ha)
1	1	4	2.222
	2	15	3.193
	3	16	2.540
	4	22	5.977
	5	13	2.705
	12	10	1.246
	14	20	3.689
	15	7	1.188
2	6	9	1.794
3	8	20	1.855
	9	24	3.618
	10	20	2.739
4	11	8	2.460
5	7	11	1.164
	13	7	1.412
	Total	206	37.802

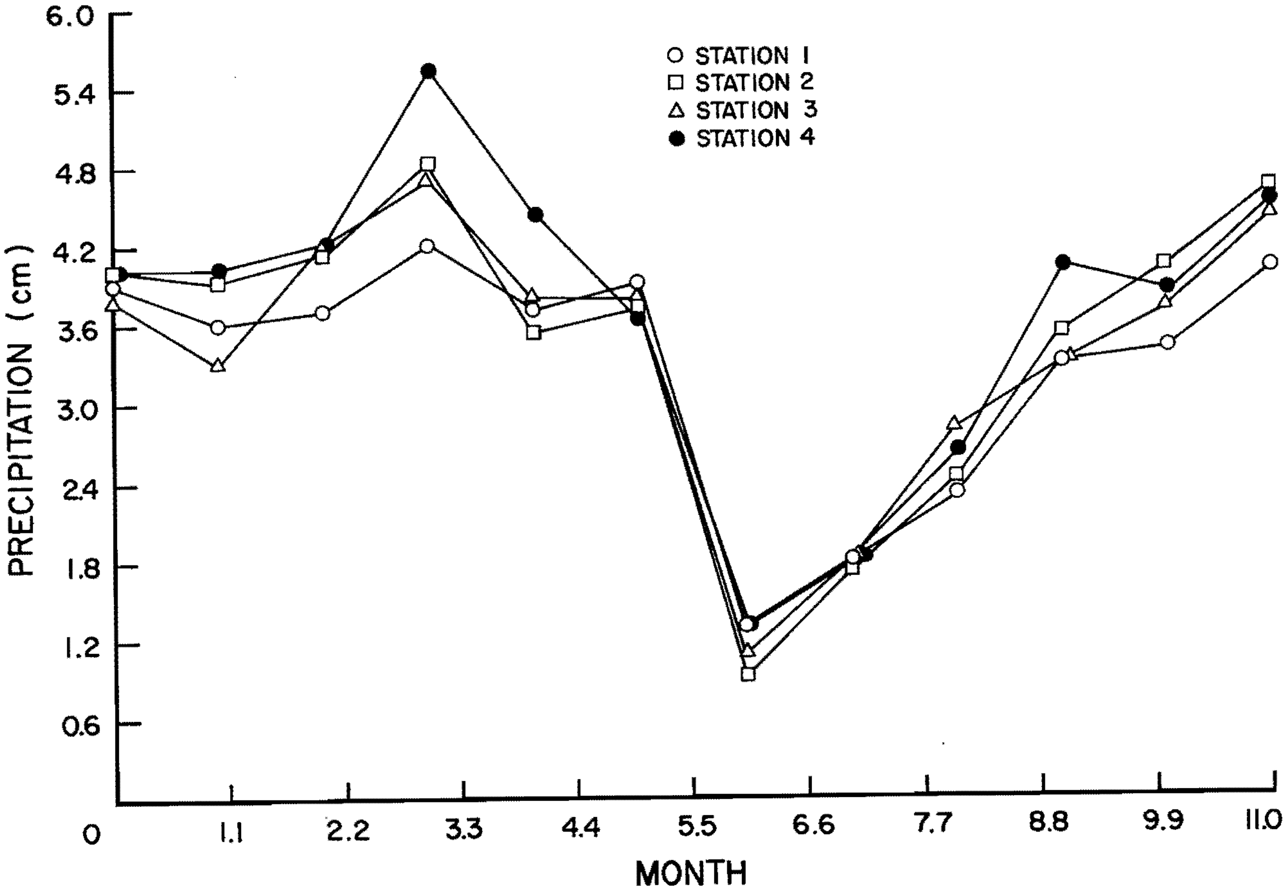


Figure 31. Fifty-year monthly average precipitation per station.

Table 18. Fifty-year monthly mass loading averages by entrance number for a winter (January) and a summer (May) month.

Entrance	COD (kg/Month)	BOD_5 (kg/Month)	SS (kg/Month)	VSS (kg/Month)	NH_3-N (kg/Month)	TP (kg/Month)	PO_4-P (kg/Month)
January							
1	94956.5	14631.7	62982.4	39491.7	598.1	399.0	42.4
2	6984.9	938.5	4516.1	2831.8	50.2	30.9	4.6
3	34956.0	5409.5	23130.7	14503.5	209.7	145.0	13.7
4	6834.0	978.8	4283.2	2685.7	48.7	29.2	3.2
5	14854.7	2707.0	9897.0	6205.6	94.4	58.1	3.4
May							
1	10348.1	2225.9	2403.8	1507.4	113.2	45.8	3.3
2	854.6	183.8	194.3	121.9	9.9	3.8	0.3
3	4350.8	935.9	926.8	581.2	45.7	19.4	1.4
4	841.3	181.0	179.4	112.5	10.0	3.7	0.2
5	1676.1	360.5	349.8	219.4	16.6	7.5	0.6

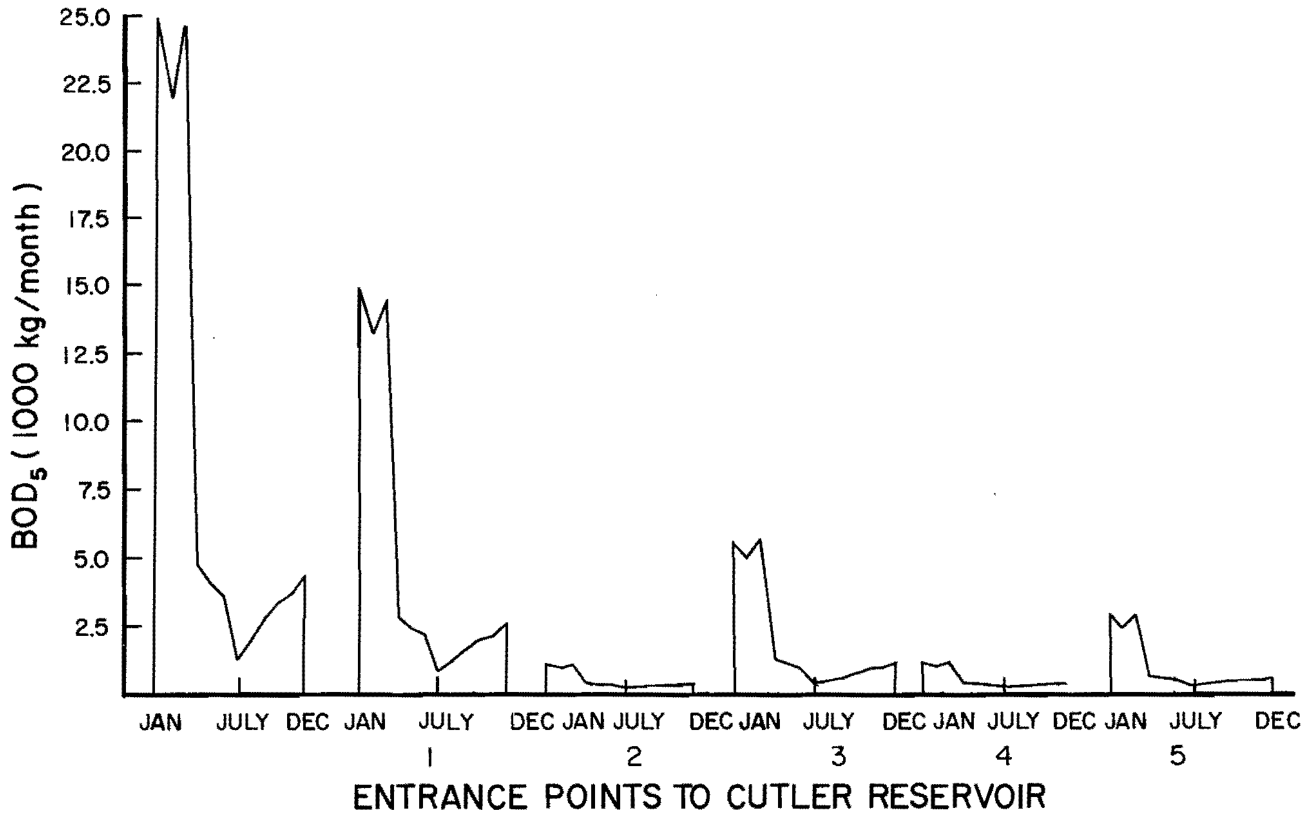


Figure 32. Predicted 50-year monthly BOD_5 average mass loadings from each entrance point to Cutler Reservoir.

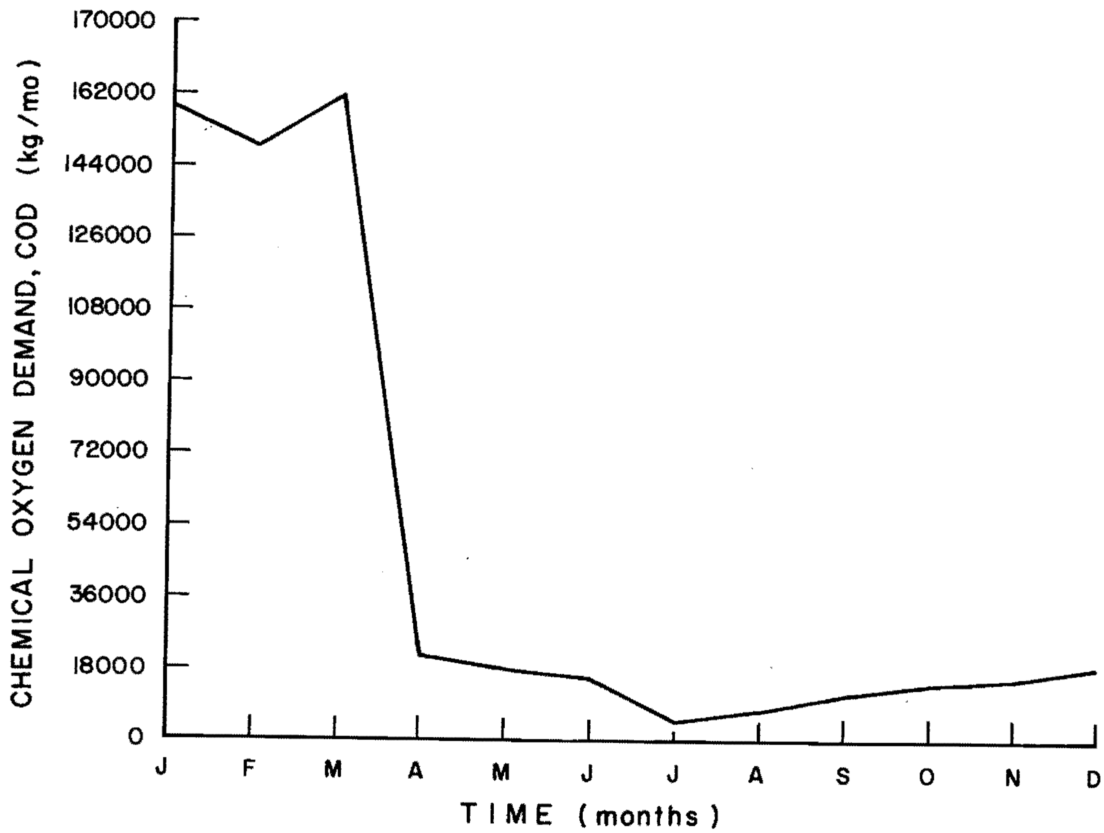


Figure 33. Predicted 50-year total monthly COD average mass loadings to the environmental sink.

Table 19. Fifty-year monthly mass loading averages by region number for a winter month (January).

Entrance	Region	COD (kg/Month)	BOD (kg/Month)	SS (kg/Month)	VSS (kg/Month)	NH_3 (kg/Month)	TP (kg/Month)	OP (kg/Month)
1	1	6937.8	1480.2	6862.5	4302.8	42.0	27.0	5.2
1	2	7555.7	1625.3	6417.3	4023.7	25.0	26.0	2.4
1	3	10106.2	2158.6	9603.2	6021.2	21.4	34.4	2.6
1	4	5759.4	1201.1	4657.0	2920.0	42.5	22.2	6.3
1	5	1899.0	167.1	1204.3	755.2	42.9	10.6	5.8
1	12	7969.9	1716.7	7565.1	4743.4	20.1	27.6	1.3
1	14	8802.0	1911.3	6898.2	4325.2	52.6	30.8	5.7
1	15	807.1	71.0	523.5	328.2	12.5	4.1	1.7
2	6	2281.5	468.0	1912.0	1198.8	41.8	9.9	5.8
3	8	6729.4	1463.7	5987.0	3753.9	23.5	23.1	2.2
3	9	6700.2	1377.6	6135.6	3847.1	31.1	24.5	4.2
3	10	3498.4	689.9	3004.3	1883.8	23.0	14.3	3.4
4	11	2720.5	546.6	2166.6	1358.5	21.5	10.9	3.2
5	7	4363.7	924.0	3825.9	2398.9	12.8	15.6	1.2
5	13	5505.9	1165.9	4948.6	3102.8	27.8	20.3	3.2

Table 20. Fifty-year monthly averages by region number for a summer month (May).

Entrance	Region	COD (kg/Month)	BOD (kg/Month)	SS (kg/Month)	VSS (kg/Month)	NH_3 (kg/Month)	TP (kg/Month)	OP (kg/Month)
1	1	571.0	122.8	196.4	123.2	5.9	2.5	0.3
1	2	763.9	164.3	216.4	135.7	7.1	3.4	0.4
1	3	707.1	152.1	177.9	111.6	6.3	3.2	0.4
1	4	1071.2	230.4	304.2	190.8	10.5	4.8	0.5
1	5	366.4	78.8	112.4	70.5	3.6	1.7	0.2
1	12	530.1	114.0	131.0	82.2	4.0	2.5	0.4
1	14	1084.1	233.2	258.0	161.8	8.7	4.9	0.5
1	15	197.3	42.4	74.7	46.8	2.1	0.9	0.1
2	6	394.7	84.9	116.9	73.3	3.8	1.8	0.2
3	8	620.4	133.5	143.4	89.9	4.5	2.9	0.4
3	9	799.3	171.9	209.8	131.5	7.0	3.7	0.4
3	10	544.5	117.1	151.4	94.9	4.9	2.5	0.4
4	11	434.9	93.5	123.2	77.2	3.8	2.0	0.2
5	7	389.5	83.8	89.8	56.3	3.1	1.8	0.3
5	13	480.7	103.4	120.4	75.5	3.6	2.2	0.3

Entrance points 3 and 5, which drain sub-basins containing a lesser area of feedlots (10.6 ha, 2.6 ha) contributed somewhat lower total mass loadings of all parameters for winter and summer seasons (Table 18). Entrance point 3 (regions 8, 9 and 10) was the second major contributor of pollutants to Cutler Reservoir (Figure 33). The Little Bear River enters Cutler Reservoir at position 3 (Figure 10). Regions 7 and 13 with fewer total feedlots contributed approximately 10 percent of the total pollutants in the drainage basin (Figure 32).

Entrance points 2 and 4 contributed a relatively low pollutant load to the system. Entrance point 2 drained region 6, which contained drainage canals that emptied into Cutler Reservoir from the east. Entrance point 4 drained region 11, which contained canals in and around Newton Creek. The BOD_5 mass loadings contributed by regions 6 and 11 were less than 10 percent of the total BOD_5 mass loadings contributed from the basin (Figure 32).

Total average monthly regional mass loading to Cutler Reservoir for one winter month (January) and one spring month (May) are presented in Tables 18 and 21. Monthly average mass loadings are presented in Appendix G. January and May were indicative of winter and summer monthly totals, respectively. Total COD mass loadings (158,586 kg/mo) and BOD_5 mass loadings (24,766 kg/mo) were eight times greater for winter months than summer months. The predicted 50-year monthly COD and BOD_5 averages are

Table 21. Fifty-year monthly mass loading averages from 206 Cache Valley feedlots for a winter (January) and a summer (May) month.

Month	COD (kg/Month)	BOD_5 (kg/Month)	SS (kg/Month)	VSS (kg/Month)	NH_3-N (kg/Month)	TP (kg/Month)	PO_4-P (kg/Month)
January	158586.	24766.	104809.	65718.	1001.	662.	67.
May	18071.	3887.	4054.	2542.	195.	80.	6.

shown in Figures 33 and 34, respectively. Predicted waste loading of VSS (Figure 35) and SS (Figure 36) followed a monthly pattern similar to COD and BOD_5 with winter totals exceeding summer totals by approximately 25 times. NH_3-N, TP and PO4-P show comparable patterns as illustrated in Figures 37, 38 and 39, respectively. The greater winter mass loadings are due to the larger predicted values for pollutant concentrations and runoff flow rates. As previously stated, winter pollutant concentrations during the sampling period exceeded summer pollutant concentration for both paved and unpaved facilities. Winter feedlot runoff flow rates, also, exceeded summer values. Paved facilities showed increases in predicted mass loadings for snowmelt runoff which far exceeded predicted concentrations from unpaved feedlots.

Predictive Loading Summary

The quantity and quality of feedlot runoff predicted by the mathematical model may have a significant effect on certain feedlot areas in Cache Valley, Utah. Potential organic and nutrient discharges caused by both beef and dairy cattle feedlot waste can be detrimental to receiving waters. Predicted total pollutant mass loading from

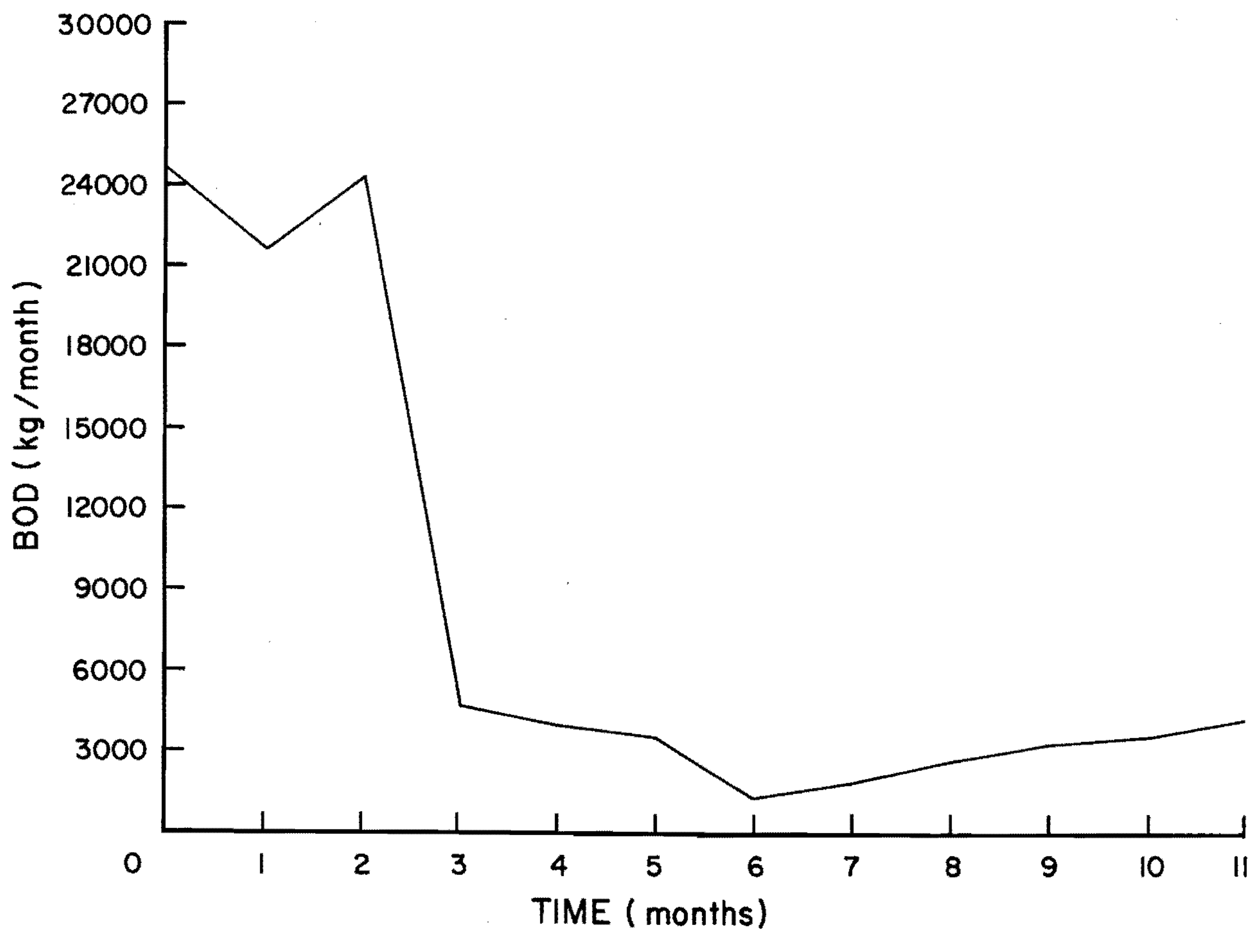


Figure 34. Predicted 50-year total monthly BOD_5 average mass loadings to the environmental sink.

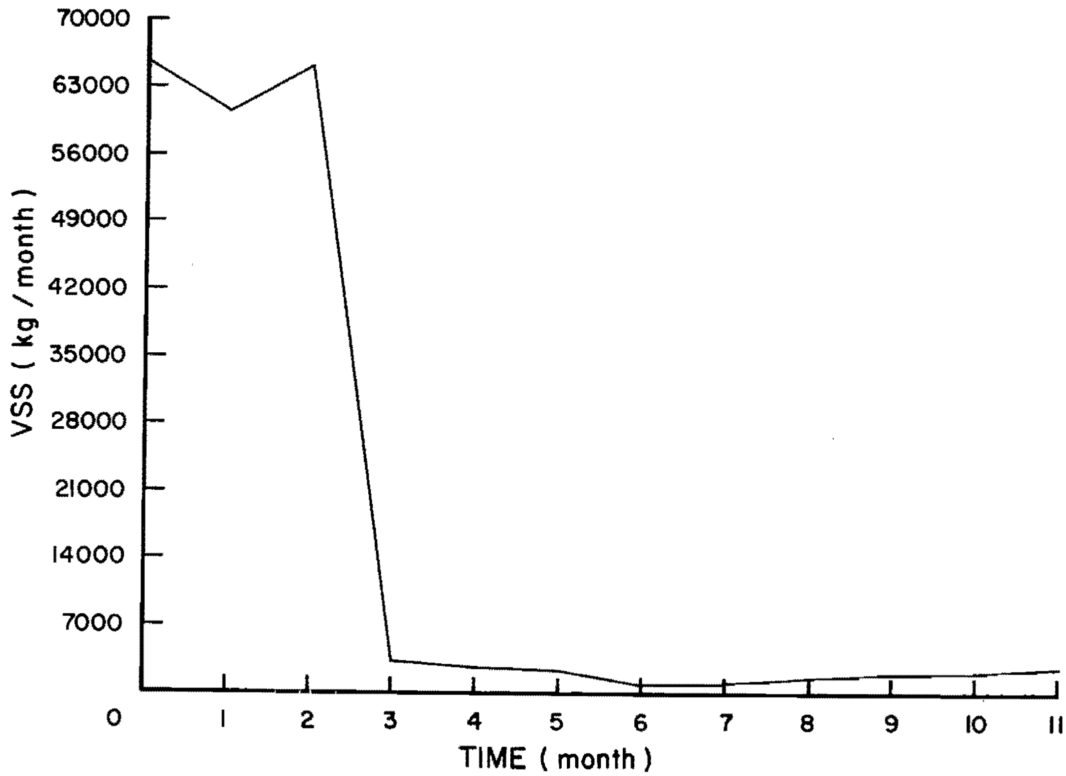


Figure 35. Predicted 50-year total volatile suspended solids (VSS) average mass loadings to the environmental sink.

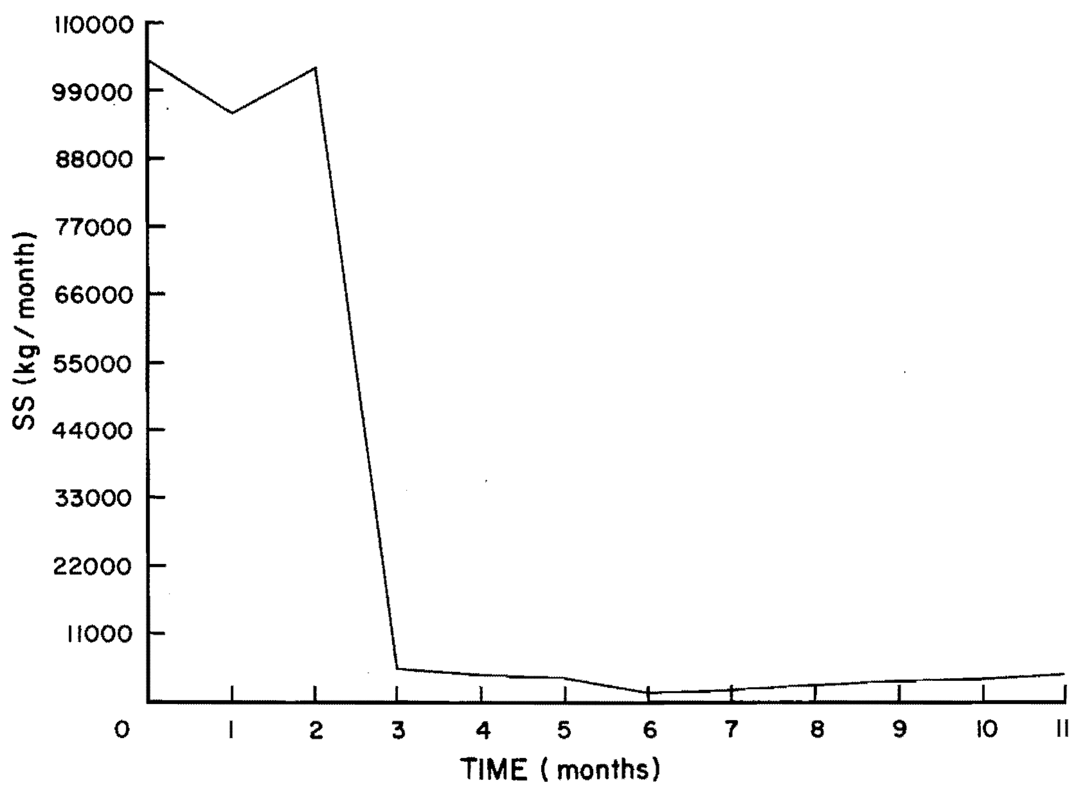


Figure 36. Predicted 50-year total monthly suspended solids (SS) mass loadings to the environmental sink.

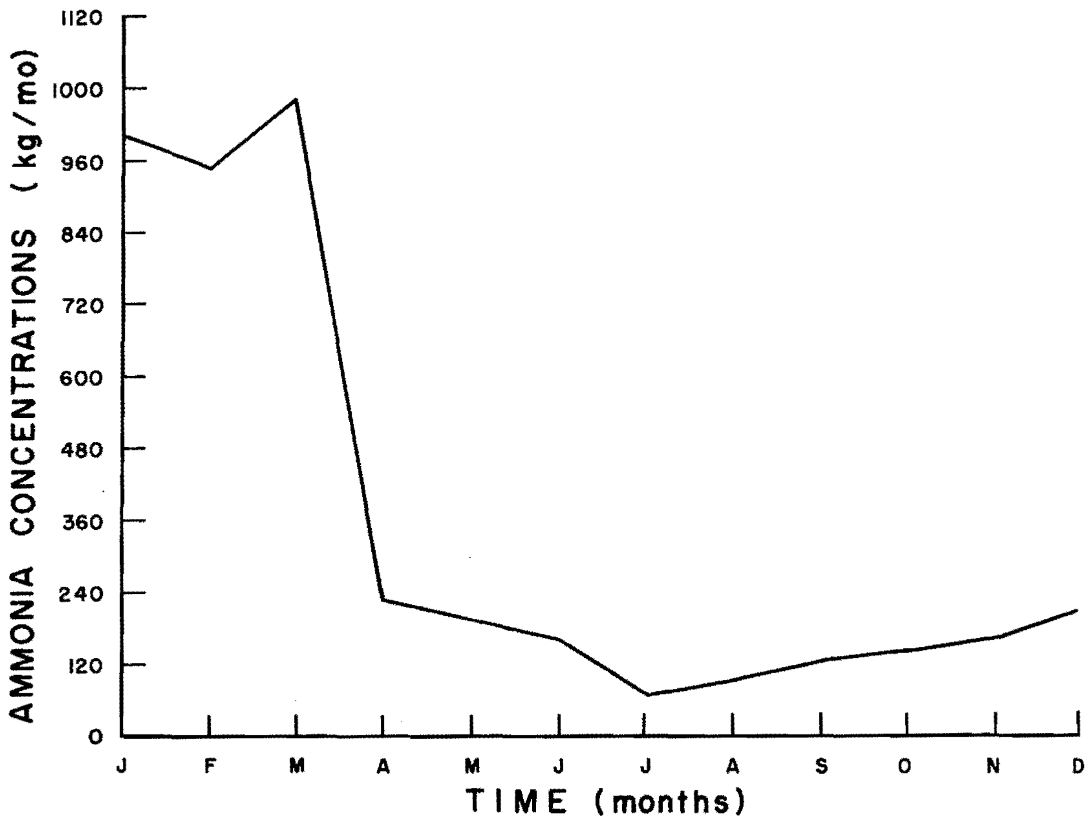


Figure 37. Predicted 50-year total monthly NH_3-N average mass loadings to the environmental sink.

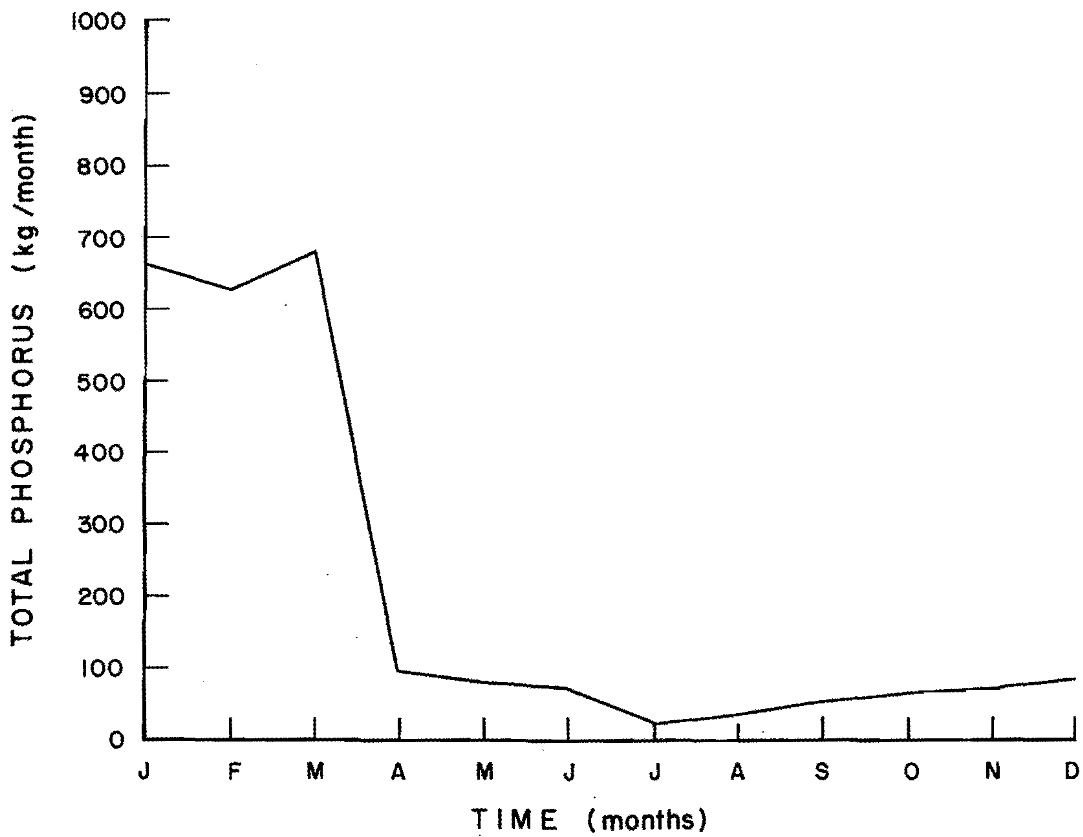


Figure 38. Predicted 50-year total monthly TP average mass loadings to the environmental sink.

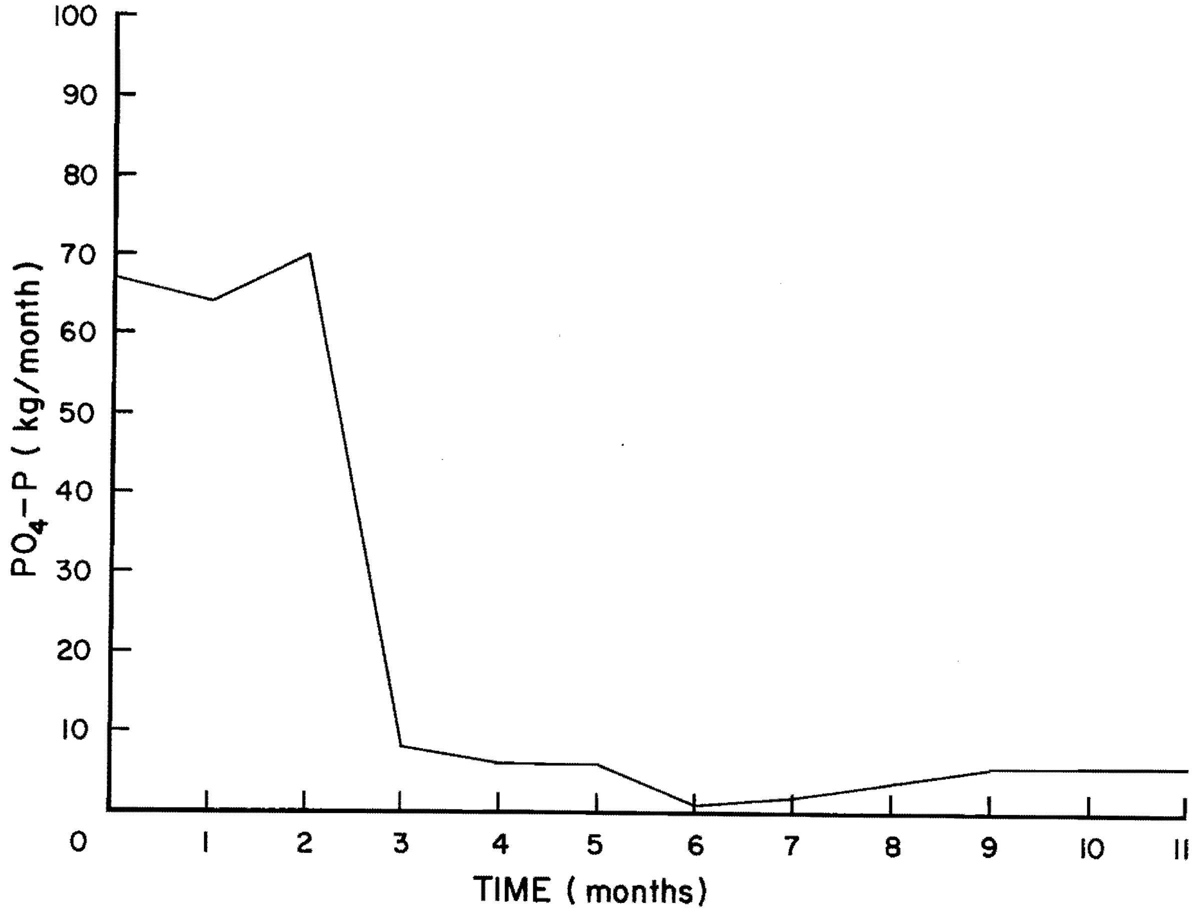


Figure 39. Predicted 50-year total monthly orthophosphorus (PO_4-P) average mass loadings to the environmental sink.

feedlot facilities were approximately eight times greater during the winter months (January through March) than the remaining portion of the year. Increased mass loadings to receiving streams were associated with continual freezing and thawing of manure slurries on the feedlots. Both paved and unpaved facilities discharge wastewater during the winter months. The predicted feedlot runoff mass loadings described on the preceding pages indicate that under worst case conditions the Bear River (Entrance 1) discharges the largest pollutional mass load into Cutler Reservoir. Whether this has a major impact on the area is yet to be determined. Excess organic matter and nutrients, however, can stimulate growth of aquatic organisms and associated depletion of dissolved oxygen. Septic conditions could result in the streams, and potential fish kills could occur. Feedlots adjacent to remaining rivers which discharge into Cutler Reservoir probably have little impact on the environmental sink. The reduced pollutional impact is due to the smaller number (area) of feedlots on these rivers.

The computer model only accounted for pollutant mass which migrated from the feedlot area to an environmental sink. The mass once having entered a receiving stream was treated as a conservative substance. Preliminary bioassays indicated little degradation of BOD_5 and ammonia-nitrogen within a period of 24 hours. Furthermore, river travel time from all feedlots to the environmental sink (Cutler Reservoir) was less than or equal to 24 hours. In addition, sedimentation of settleable solids contained in the runoff slurry was not accounted for in the model. The resulting model, therefore, predicted a worse case situation with regard to organic, nutrient, and suspended solids mass loadings.

Stream Monitoring Program

Sampling, Precipitation and Flows

Stream water quality data were obtained upstream and downstream from nine feedlots during the period of October 6, 1976, through July 21, 1977 (Figure 40). A control site was located on all streams and major tributaries contained in the stream monitoring area. Further sampling sites were located upstream and downstream from farmland to delineate the possible impact of farm areas.

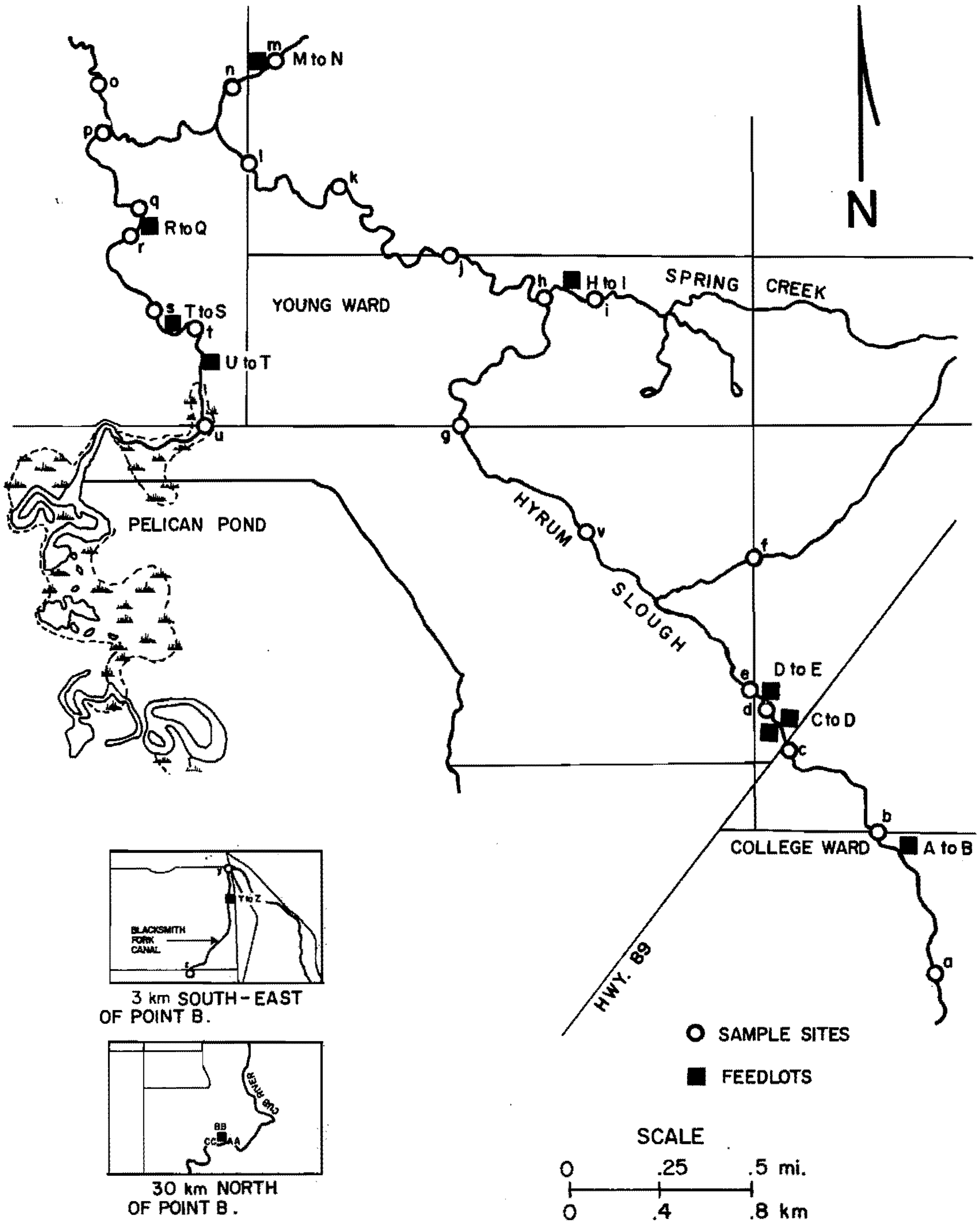


Figure 40. Stream monitoring sampling site locations.

Quantitative data were obtained on one northern facility from October 20, 1977, through April 17, 1978 (Figure 38). A total of 55 different samplings were conducted with 20 occurring during the snowfall months of January, February, and March. Samples were collected weekly from all sampling locations. Furthermore, stream samples were obtained during each precipitation event.

Total precipitation was 9.7 cm (3.8 inches) for January, February, and March 1976-77 (approximately half of normal precipitation for this time period). April through November 1977, precipitation was 38.5 cm (15.2 inches). Precipitation December 1977 through April 1978 was 10.6 cm (4.2 inches). The ambient air temperatures ranged from approximately -20°C to 15°C (-5°F to 60°F) during the winter months of 1976 and 1977. The high temperature for the year was approximately 38°C (100°F).

Flow rates were determined once a month for streams located within the sub-basin (Figure 38). For larger streams, such as the Cub River, USGS records were used. Feedlots A to B, C to D, D to E and control site V to G are located on the Hyrum Slough. Flows in the slough ranged from 0.06 m^3/sec (2.0 cfs) during the summer (1977) to 0.26 m^3/sec (9.4 cfs) during the fall (1977). The facilities between sampling stations T to S, R to Q, U to T and control point P (at the confluence of Spring River) were located on a stream between Pelican Pond and Spring River. The flows for this stream ranged from 0.01/m^3/sec (0.5 cfs) to 0.17 m^3/sec (6.0 cfs).

The feedlot facility between stations H and I, along with control stations J, L and O, were positioned on Spring River. Flow rates ranged from 0.89 m^3/sec (31.5 cfs) in the winter of 1977 to 1.56 m^3/sec (55.2 cfs) during spring (1977) runoff. The feedlot between sampling stations M to N was located on a drainage ditch that discharges into Spring River approximately 1.0 kilometer west of the Spring River-Pelican Pond stream confluence. The flow rate in the drainage ditch during the sampling period was between 0.03 m^3/sec to 0.21 m^3/sec (1.0 cfs to 7.4 cfs). Point K was positioned near a drainage ditch that flows into Spring River. Hydraulic flows of less than 0.06 m^3/sec (2.0 cfs) were measured in the drainage ditch. Flow rates at point F were between 0.03 m^3/sec and 6.54 m^3/sec (1.0 cfs and 18.9 cfs) depending upon the irrigation requirements of the area for that year.

Sampling stations Y and Z were located on the Nibley Canal which joins the Hyrum Slough 2 kilometers north of Hyrum, Utah. The Nibley Canal maintained flows between 0.61 m^3/sec and 1.25 m^3/sec (21.2 cfs and 44.1 cfs) during the year 1977. Sampling locations AA, BB, and CC were also positioned on the Cub River. The flow rates in the Cub River were between 0.41 m^3/sec and 12.59 m^3/sec (14.5 cfs and 444.6 cfs) for the same period.

<u>Pollutant Concentration Values for Nine South Cache Valley Feedlots</u>

Ranges of pollutant concentrations upstream and downstream from individual feedlots are presented in Appendix H.

Upstream pollutant concentrations exceed downstream concentrations at three feedlot locations approximately 50 percent of the sampling periods. Data obtained from the remaining six locations indicated that upstream pollutant concentrations exceeded downstream concentrations approximately 10 percent of the sampling periods. This phenomenon was mainly dependent upon the location of the sampling site and stream flow rate.

Concentrations of BOD_5 and COD within the stream system were greater from February (1977) to July (1977) than from October (1976) to February (1977). This phenomenon was true for all 20 sampling stations downstream and upstream from feedlot areas. This was believed due to increased agitation of the sediments by storm runoff which released stored organics within the system. An increase in agricultural runoff also may have contributed to the higher pollutant concentrations. Control site V to G also showed an increase in organic concentrations from February to July; however, increases were more sporadic and not as substantial. Stream data are presented in Appendix H.

Feedlots between stations M to N (Figure 41) and A to B (Figure 42) showed yearly BOD_5 concentration patterns that are typical of all feedlot sites. From October through February BOD_5 concentrations rarely exceeded 1.5 mg/l at both locations. The low concentrations from October through December can be partially attributed to low precipitation during that period ($\leq$ 0.75 cm). Precipitation for January and February increased appreciably to a total of 0.72 cm. The increase in precipitation did not produce an increase in BOD_5 concentration after feedlot A to B, but did for location M to N. Feedlot M to N instream BOD_5 concentrations were indicative of instream BOD_5 levels at the seven feedlot locations. The data for all sample stations are presented in Appendices H and I.

Increases in BOD_5 concentrations when precipitation did not occur were observed from February 23 through July 21 for sampling stations M to N and A to B (Figures 41 and 42). During this time period concentrations rarely were below 1.5 mg/l. Peaks for lot M to N on or about March 24, May 4, and June 8 correspond to precipitation events of 1.68 cm as snow, 0.64 cm as rain, and 1.02 cm as rain, respectively (Figure 41). Total precipitation for the months of March through July is presented in Table 22. The rise in BOD concentrations during rain events in May

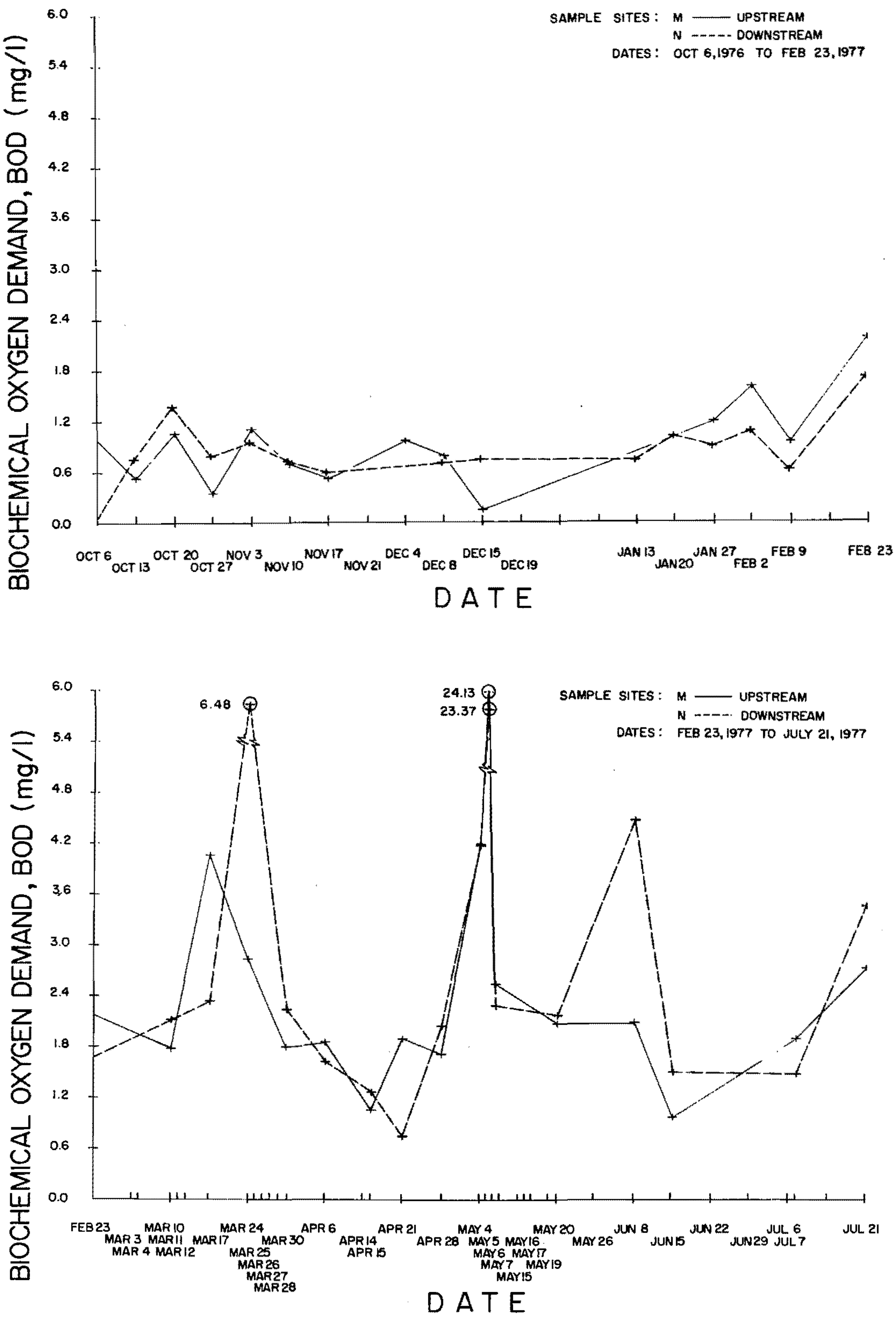
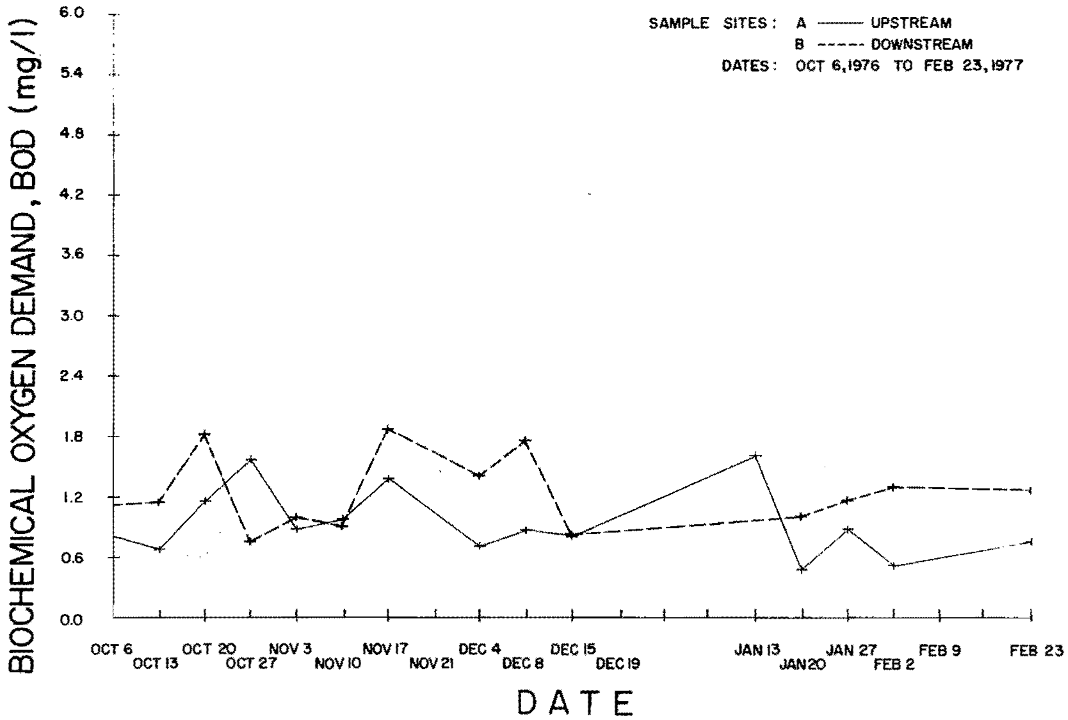


Figure 41. BOD_5 concentrations for sampling site locations M - N from October 6, 1976, to July 21, 1977.



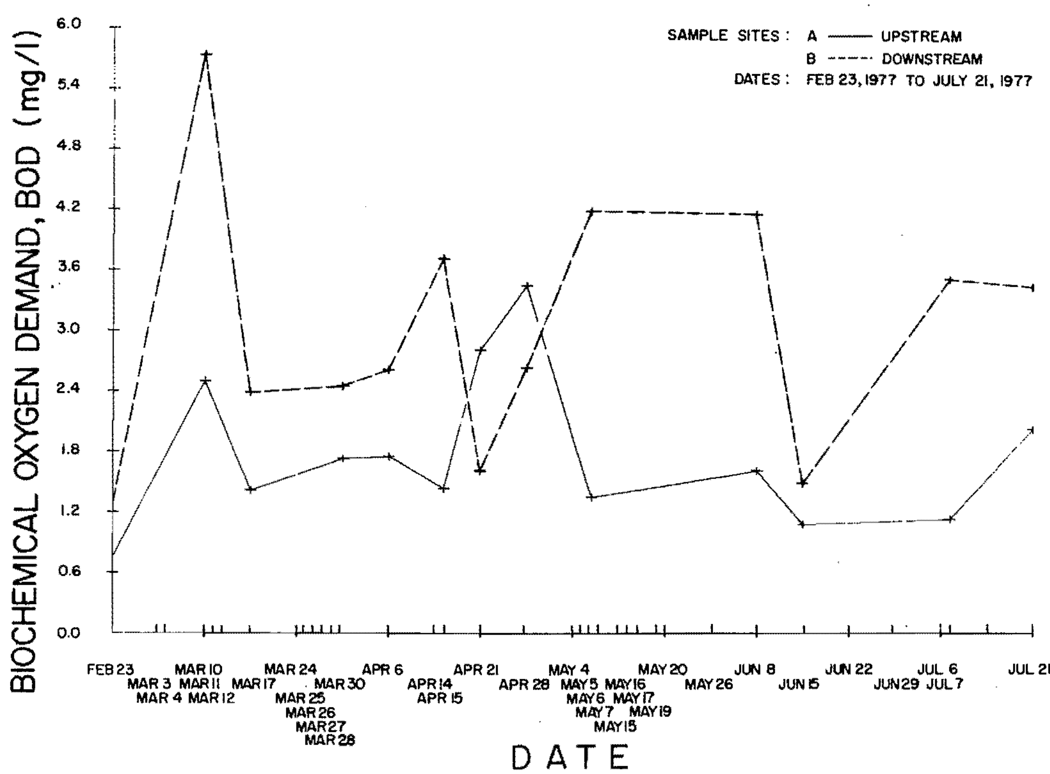


Figure 42. BOD_5 concentrations for sampling site locations A - B from October 6, 1976, to July 21, 1977.

Table 22. Precipitation data for the months of March 1977 to July 1977.

Month	Precipitation (cm)
March	1.28
April	0.38
May	2.38
June	2.30
July	0.87
Total	7.21

equalled or exceeded the extreme concentrations for BOD_5 (6.48) during snowmelt runoff (i.e., March 24) on a majority of occasions. This result was common for all feedlot sampling locations.

High background concentrations of pollutants contained within the stream sediments and agricultural runoff caused these fluctuations in BOD_5 levels. Organic contribution from sediments and nonpoint source runoff were substantially greater than the concentration contributed by feedlots. For example, during May 4, 1977 (rain event), at stream locations N - N, downstream BOD_5 concentrations exceeded upstream BOD_5 concentrations on that date by only 0.76 mg/l. The increase in BOD_5 concentration at site M - N during non-rain events, however, prior to May 4 was approximately 20 mg/l. An exception to the pattern was feedlot U to T (Figure 43) in which upstream concentrations rarely exceeded downstream concentrations.

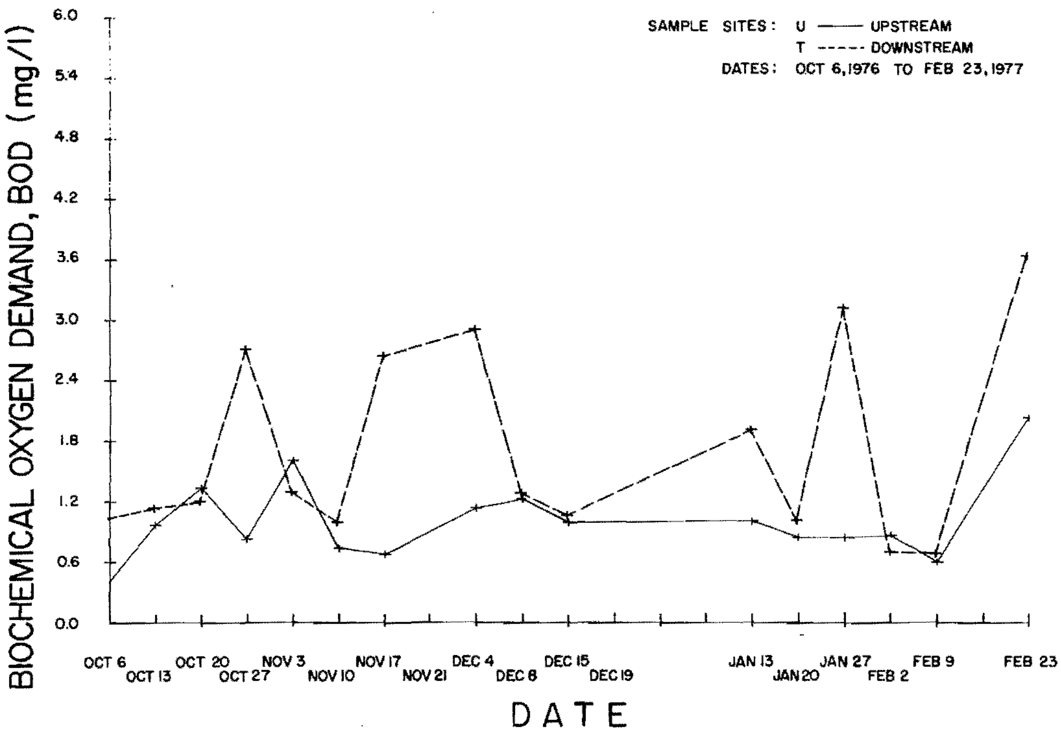
The location of sampling sites U and T was within 50 m of the feedlot area. At other locations sampling sites were over 50 m distance from the feedlot. The increased distances between sampling sites and the feedlot may cause error in determining pollutant concentration increases due to feedlots alone; diffuse or inchannel pollutant loadings may contribute to the increase in concentration. The sediments were considered to be a possible source for organic and nutrient loading resulting from mixing of the stream sediments with the overlying water after a precipitation event. The increase in turbulence would resuspend stored organics and nutrients contained in the sediments.

Concentrations of COD in the Hyrum Slough are shown in Figure 44 for sampling sites C to D between October 1976 and July 21, 1977. Peaks on or about the end of March 1977 and the middle of May were comparable to peaks for BOD_5 concentrations for the same periods. High COD concentrations (462.99 mg/l) observed after feedlot Y to Z (Figure 45) were obtained around March 30, 1977. Moderate increases occurred during the period of rainfall in May. Dairy cattle contained in the feeding operation at Y to Z had direct access to the stream. The high March COD concentration may have been attributed to sediment mixing by the cattle under low stream flow conditions. The May COD concentration (33.20 mg/l) under the same mixing conditions was diluted up to 10 times by increases in stream flow resulting from spring runoff.

Samples obtained November 17, 1976, at points H, I, R, Q, U and T along the Hyrum Slough may have been contaminated. Sample contamination may have been caused by industrial waste discharged into the slough on that date. The industry (animal rendering plant) is located on the Hyrum Slough upstream from sample location A.

Variations in SS and VSS concentrations within the stream system exhibited similar trends as BOD_5 and COD variation over the sampling period. Figures 46 and 47 show SS and VSS concentrations from the feedlot between sites D and E respectively. The SS and VSS concentrations for lot D to E are indicative of SS and VSS data obtained at all feedlot sampling site locations. The peak in SS and VSS concentrations (1681.4 mg/l) on or about February 23 at feedlot D to E was probably due to sampling error, since no precipitation occurred at that time. Furthermore, no increases in other parameter concentrations were measured on that date. Comparatively low concentrations of SS and VSS occurred October 1976 through February 1977. Increase in base concentrations and several extreme peaks were observed February through July 21, 1977 (Figures 46 and 47). This increase in concentration would correspond to the increase in rain event with precipitation over 0.25 cm February 1977 through July 1977. Increases in turbulence in the streams due to spring runoff would increase sediment mixing and thus increase SS and VSS background concentrations. Feedlots H to I (Figure 48) and M to N, however, exhibited little or no increases in SS and VSS concentrations during the sampling period. Feedlots M to N, H to I and A to B showed no increases in TP or PO_4-P over the testing period. Figure 49 shows feedlot H to I for TP from October 1976 through July 1977. Concentrations for feedlots U to T, D to E and C to D showed only limited increases in base levels for TP and PO_4-P from the October-February to February-July testing period (less than 50 percent). Figures 50 and 51 show TP and PO_4-P concentrations, respectively, for feedlot U to T October 1976 through July 1977.

The limited increase in TP and PO_4-P concentrations from October 1976 to July 1977, was caused by the low amounts discharged from the feedlots. Concentrations of TP rarely exceeded 1.0 mg/l at all sampling sites for the test period. For PO_4-P the concentrations rarely exceeded 0.5 mg/l. Since both TP and PO_4-P are converted rapidly into usable forms of phosphorus by stream aquatic organisms, little residue of phosphates would be available to mix into solution. In most cases, TP or PO_4-P concentration peaks within the stream were comparable during snowmelt or rainfall



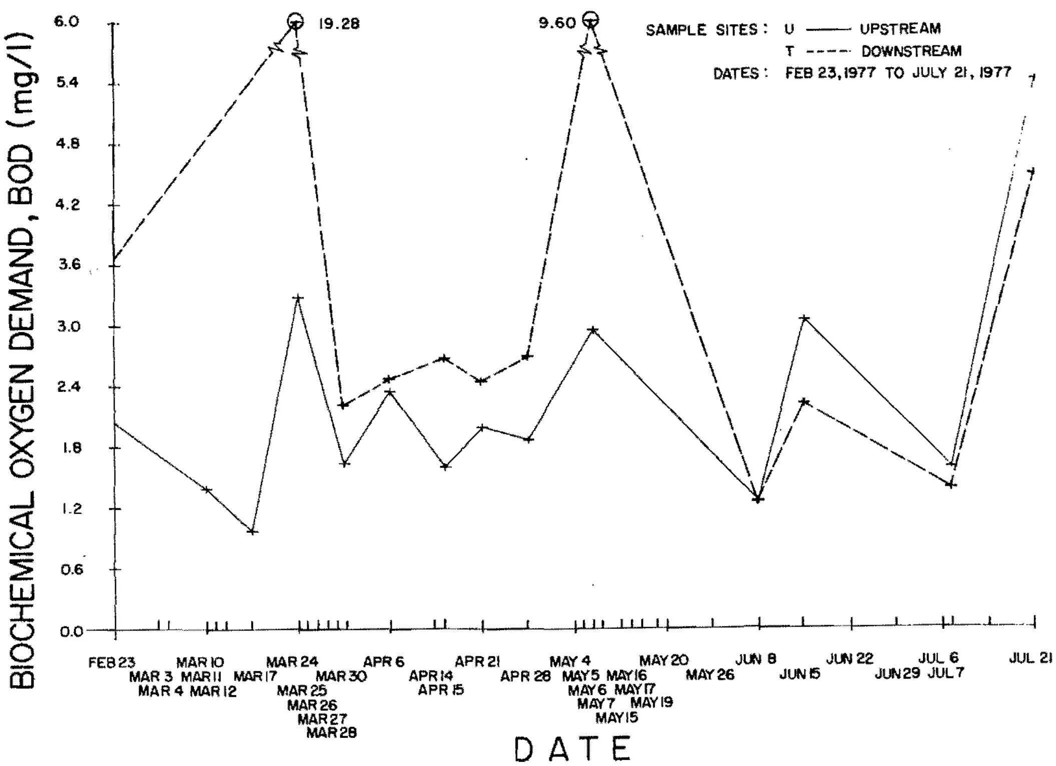


Figure 43. BOD_5 concentrations for sampling site locations U - T from October 6, 1976, to July 21, 1977.

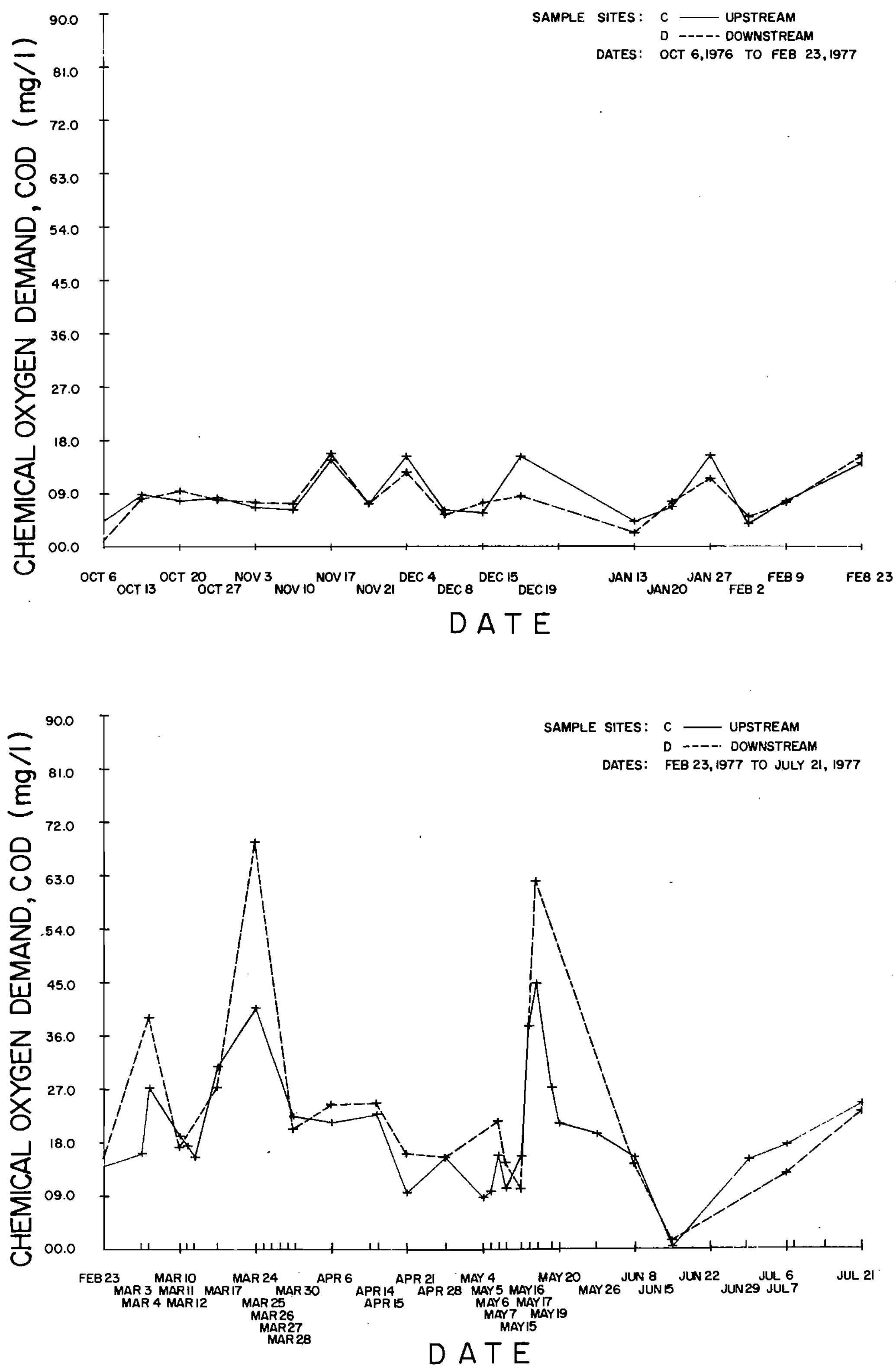


Figure 44. COD concentrations for sampling site locations C - D from October 6, 1976, to July 21, 1977.

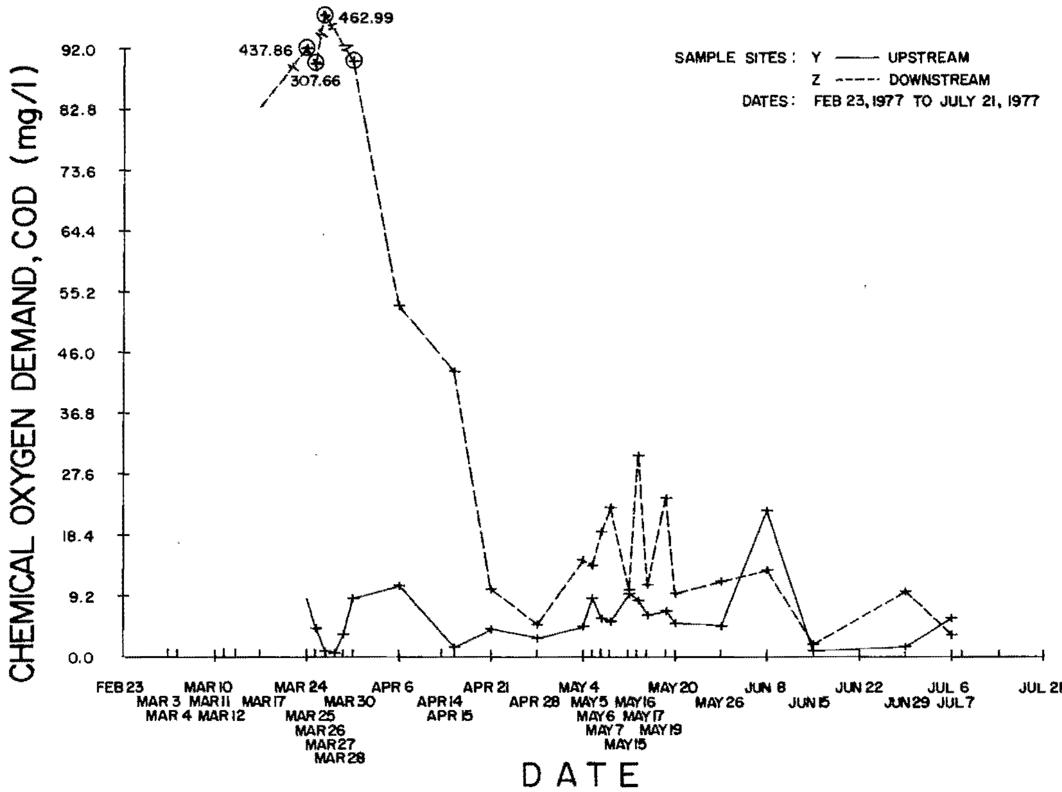
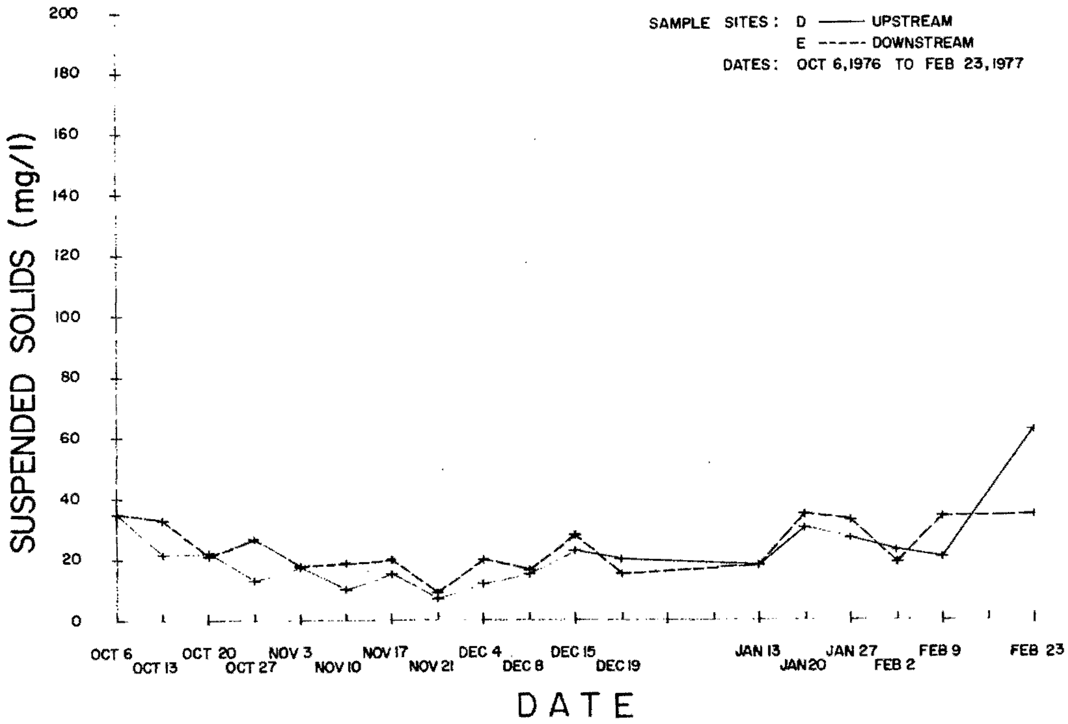


Figure 45. COD concentrations for sampling site locations Y - Z from February 23, 1977, to July 21, 1977.



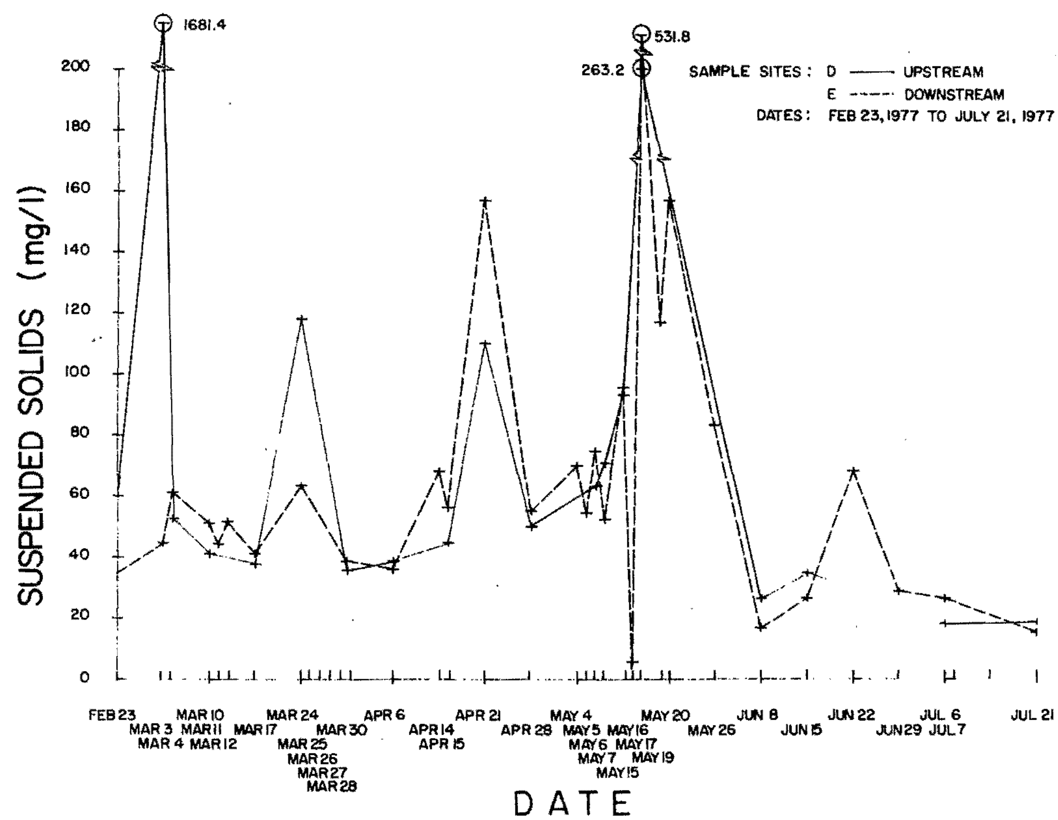
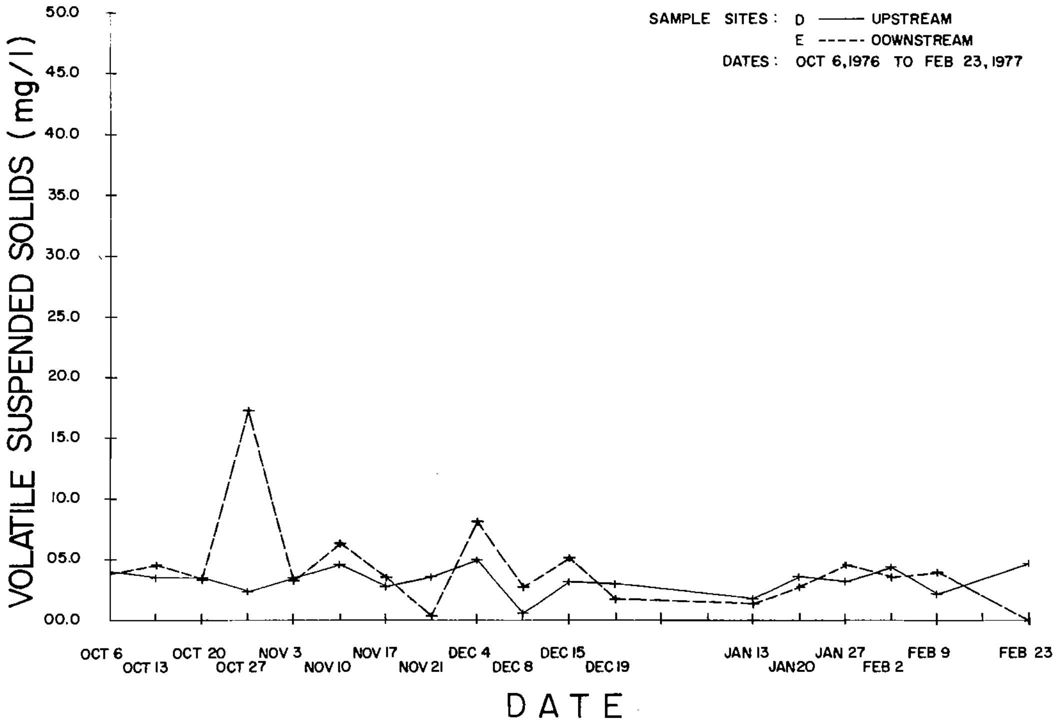


Figure 46. SS concentrations for sampling site locations D - E from October 6, 1976, to July 21, 1977.



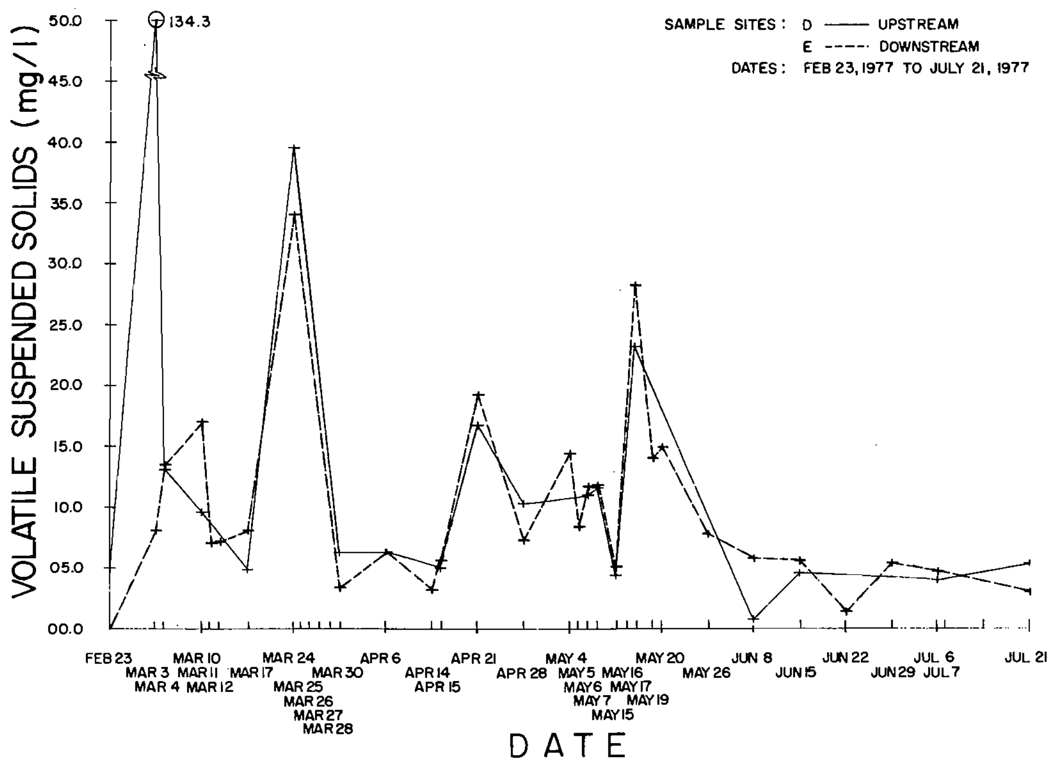
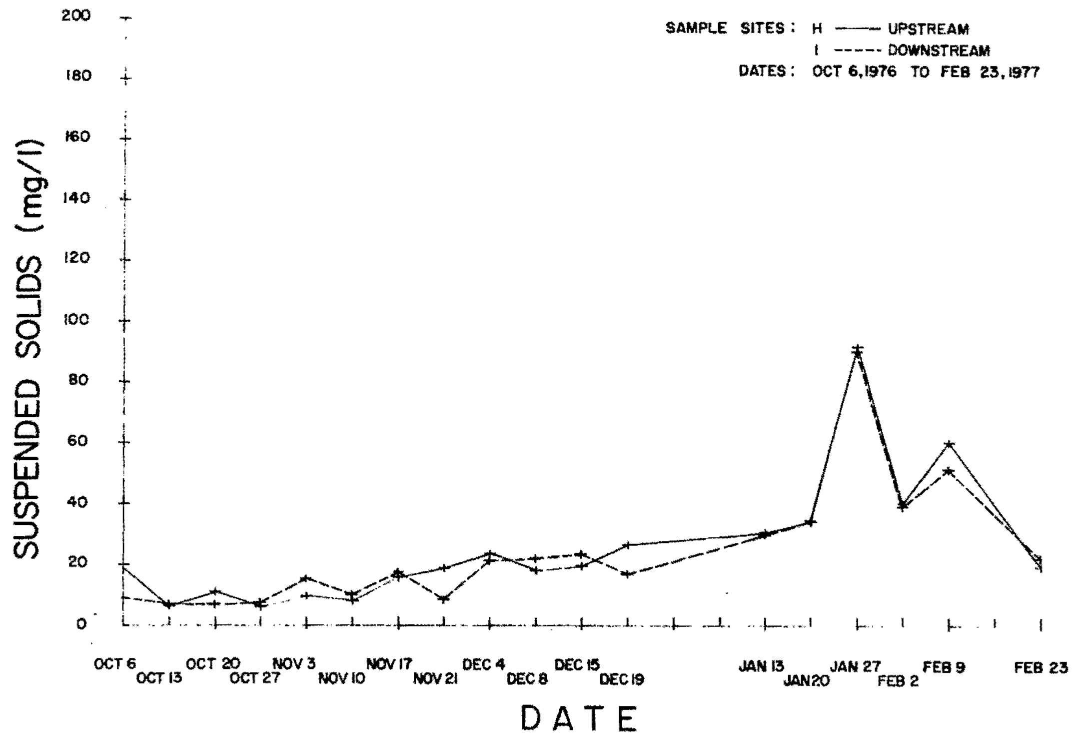


Figure 47. VSS concentrations for sampling site locations D - E from October 6, 1976, to July 21, 1977.



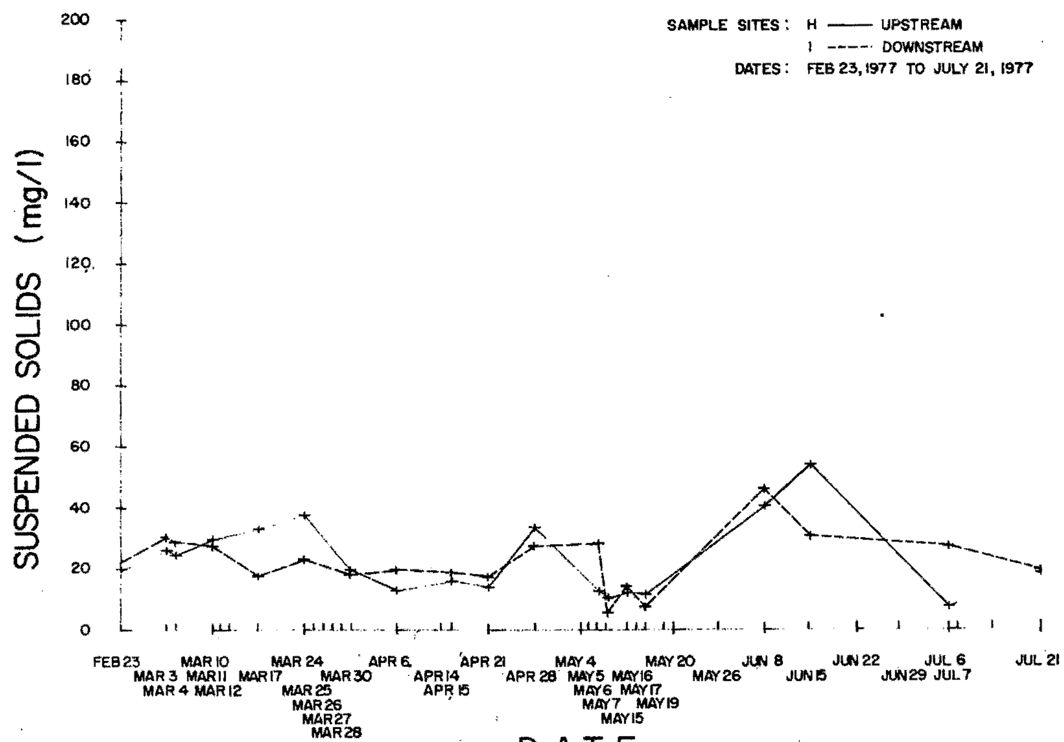


Figure 48. SS concentrations for sampling site locations H - I from October 6, 1976, to July 21, 1977.

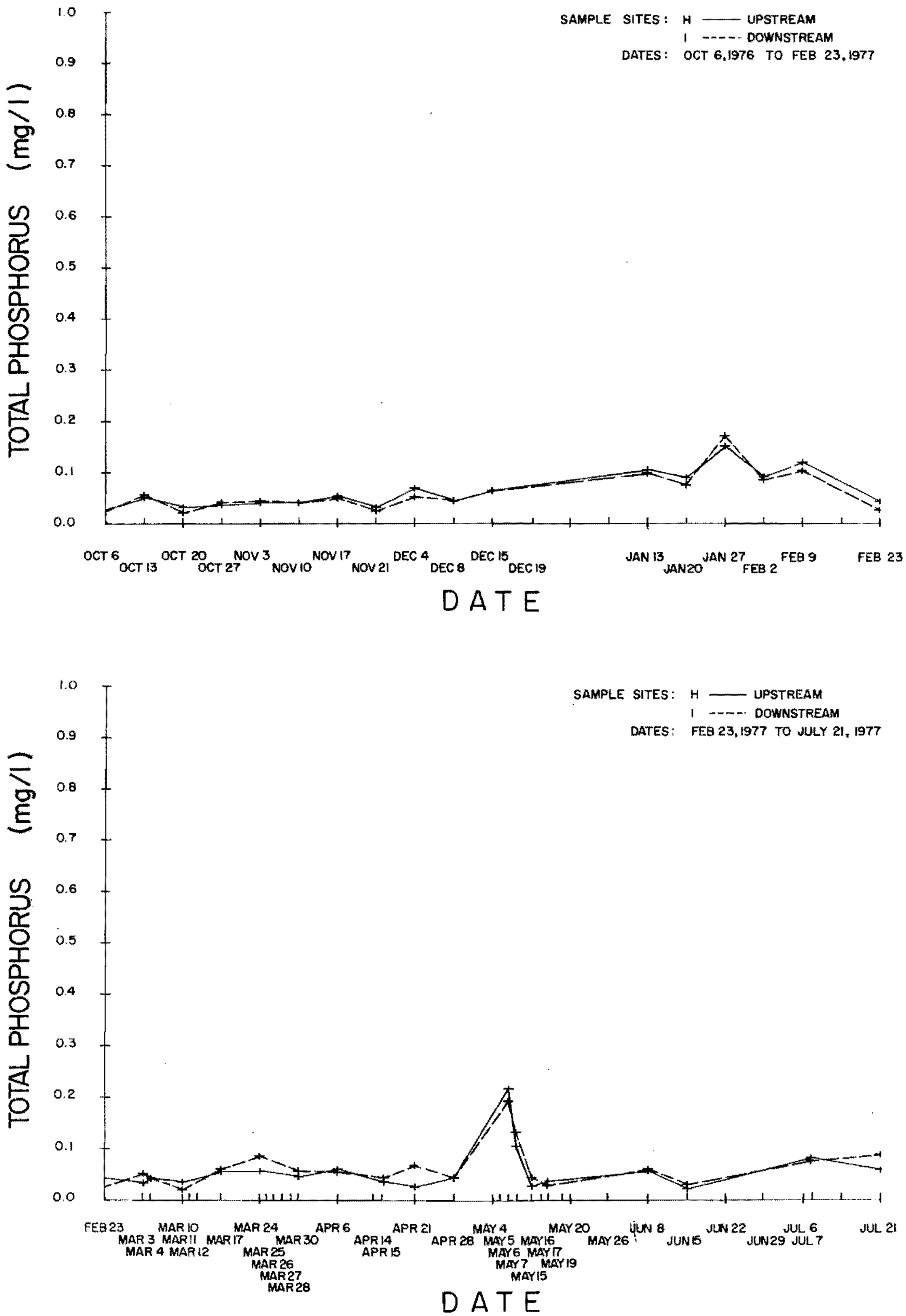
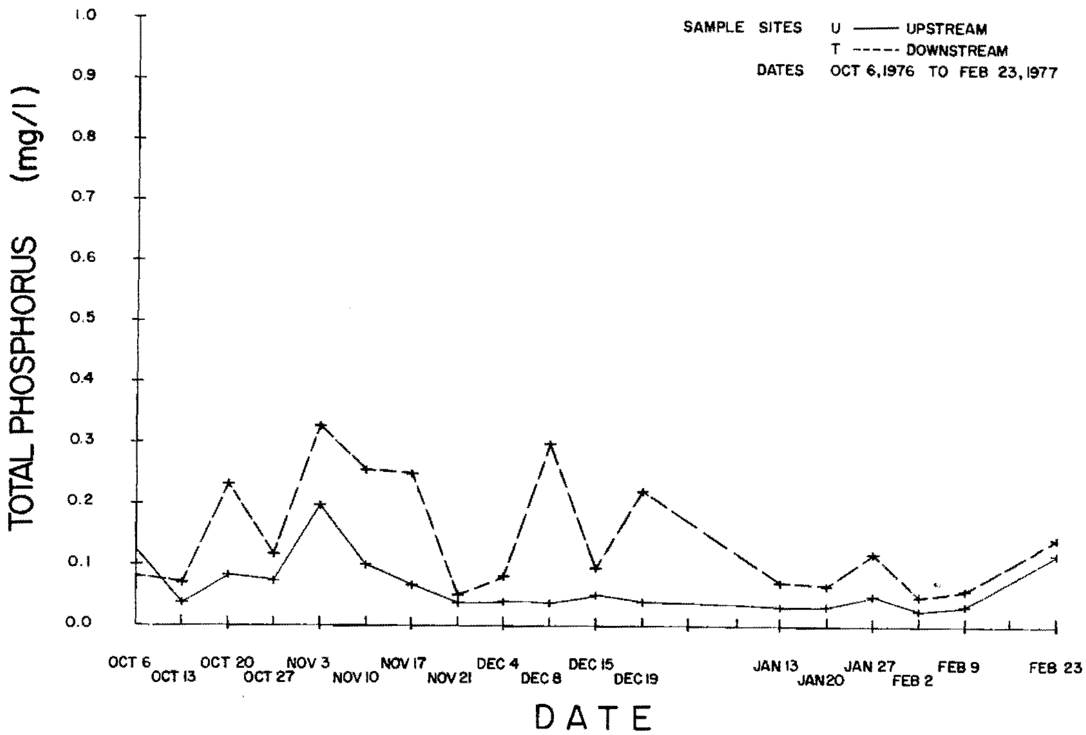


Figure 49. TP concentrations for sampling site locations H - I from October 6, 1976, to July 21, 1977.



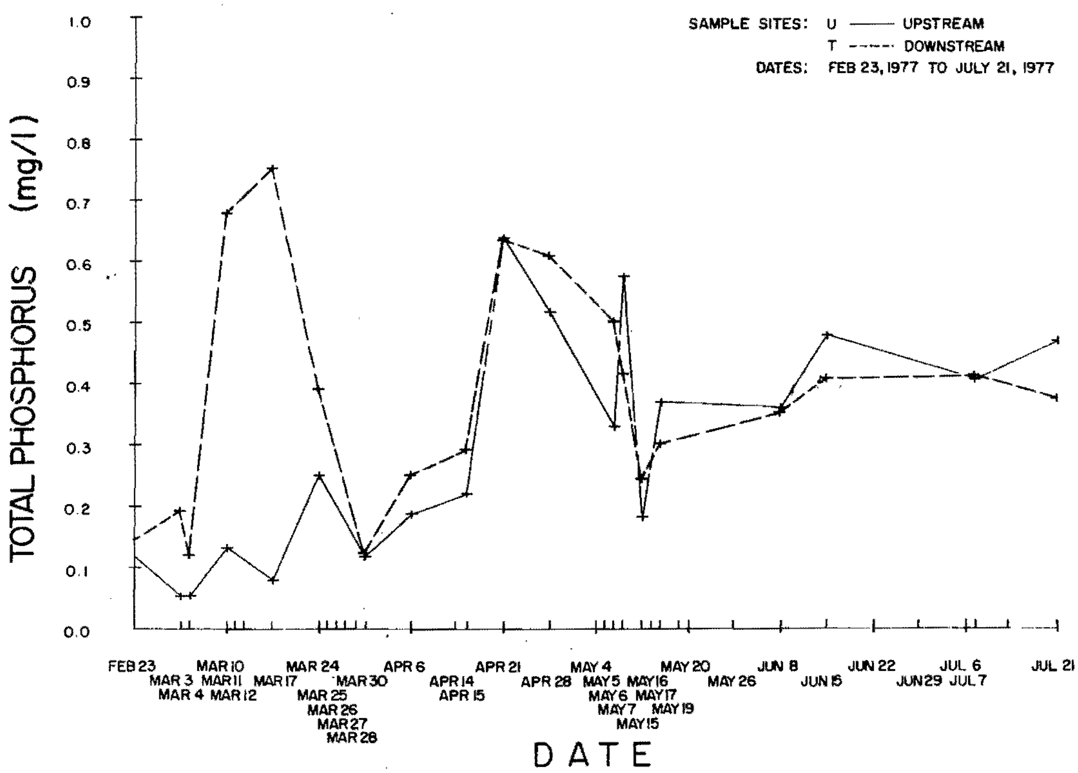
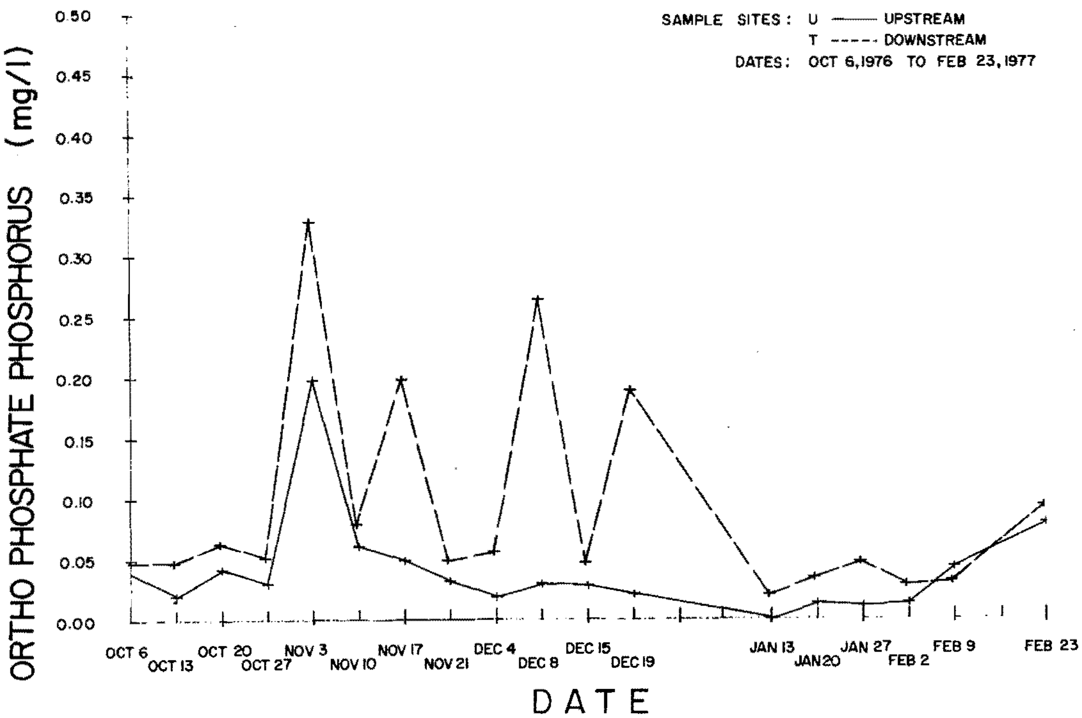


Figure 50. TP concentrations for sampling site locations U - T from October 6, 1976, to July 21, 1977.



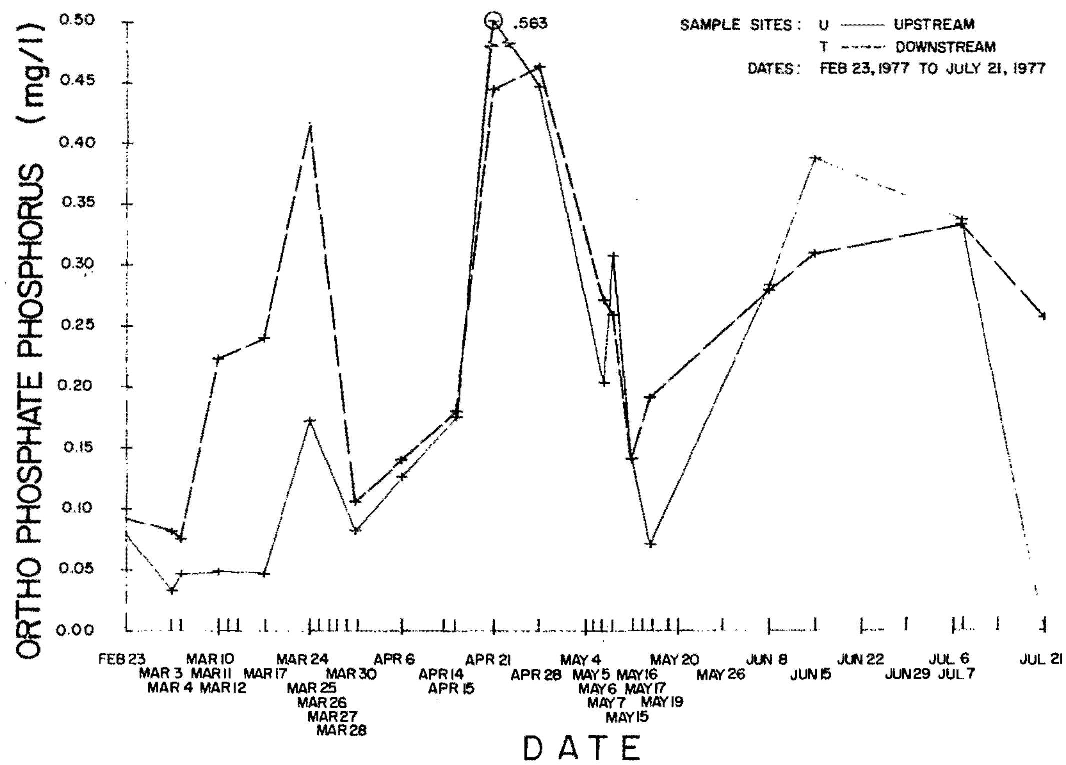


Figure 51. PO_4-P concentrations for sampling site locations U - T from October 6, 1976, to July 21, 1977.

events. The nature of the phosphorus within the stream sediment bottom and changes in phosphorus in pools on the feedlots may alter the input of phosphorus to the receiving streams. Changes in pH may occur in existing pools on the feedlot. Alteration of the pH can shift the concentration of phosphorus from one form of phosphate to another (i.e., from polyphosphate to orthophosphate).

During March 1977 ammonia-nitrogen concentrations for the test period were high (up to 4.9 mg/l) for feedlot R to Q. Figure 52 presents ammonia data from sampling sites R and Q from October 6, 1976, through July 21, 1977. The low March temperatures (0 to 40°F) coupled with increased ammonia-nitrogen mass loadings from feedlots may have resulted in an ammonia build-up within the system. During March 1977, below freezing temperatures limited microbial conversion of ammonia-nitrogen to other nitrogen forms (i.e., nitrite-nitrogen and nitrate-nitrogen).

Concentrations of ammonia-nitrogen, during May rain events, rarely exceeded 0.40 mg/l. Nitrate-nitrogen (Figure 53) and nitrite-nitrogen concentrations (Figure 54) were also correspondingly at their lowest level during this period. The increase in NO_2-N and NO_3-N concentrations April through July was caused by an increase in microbial activity in the sediments. Turbulence created by spring runoff would also increase the oxygen availability in the stream. Greater dissolved oxygen levels in conjunction with low organic concentration would increase the nitrification occurring in the seciments.

Pollutant Concentration Values for One Northern Cache Valley Feedlot

The northern feedlot facility was divided into two areas (Figure 9): 1) an area that did not allow cattle access to the stream and was covered with native vegetation (mostly native weeds), and 2) an area that did allow cattle access to the stream. The non-access area was developed as an experimental site or management scheme to control the discharge of pollutants into the stream.

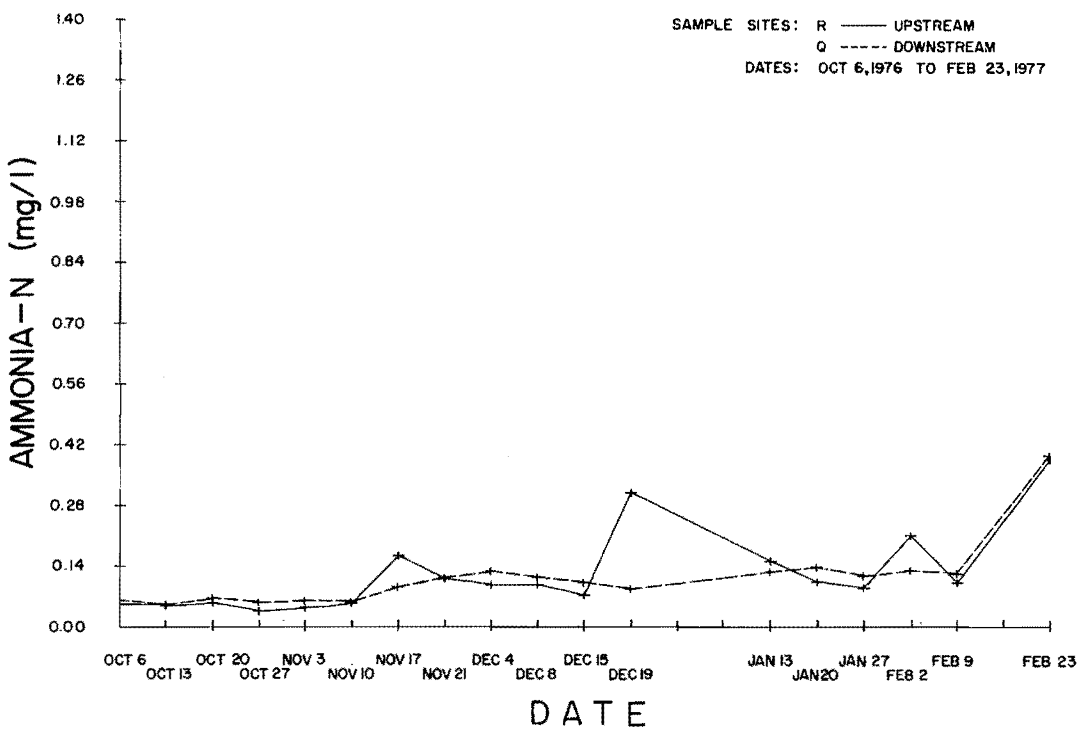
Ranges of concentrations of pollutants for the northern facility are shown in Appendix I. Figure 55 illustrates the fluctuation in BOD_5 concentrations during the sampling period of October 20, 1977, to April 17, 1978. Fluctuation in temperatures above and below freezing during the 1977-78 winter caused high BOD_5 concentration peaks in December 1977 for both rainfall (15.0 mg BOD_5/l) and snowmelt (22.5 mg BOD_5/l) events. These high organic loadings resulted from thawing of the snowfalls immediately after each precipitation event.

The proximity of sampling locations to the feedlot and continuous composite sampling of the stream at each station decreased the error that was present in grab sampling procedures. The decrease in error can be demonstrated by the infrequency of upstream concentrations exceeding downstream concentrations for all parameters under study. This was not the case with the southern facilities, where sampling conditions and cost prohibited the use of such automated techniques.

Concentrations of SS and VSS for the sampling locations upstream (AA), middle (BB) and downstream (CC) are shown in Figures 56 and 57. The quantity of rainfall (R) or snowfall (S) precipitation which occurred prior to sampling each event appears above the bars. Two background (zero precipitation) days were also monitored. On December 30, 1977, concentrations of SS increased from 19.6 mg/l to 110.7 mg/l. A precipitation event of 0.99 cm (0.39 inch) caused heavy runoff. The differences in stream pollutant concentrations between rainfall and snowmelt events (Figure 56) were not as prevalent as observed with southern feedlots. This phenomenon could be due to the fluctuation in temperatures in winter, previously noted, which resulted in primarily rain events. Other parameters such as BOD_5, COD, TKN, TP and TDS showed similar concentration variations during the sampling period (Appendix I).

Changes in concentrations for all parameters between upstream and middle lot locations where cattle were excluded from the stream were lower than between middle and downstream lot locations (control) where cattle had direct access to the stream. The higher pollutant concentrations between middle and downstream stations were attributed to their direct contribution of wastes to the stream and mixing of sediments by cattle in close proximity to a stream.

During high intensity rainfall events, channelization of feedlot runoff occurred in the vegetated area which was inaccessible to cattle. Runoff from the above feedlot would flow through pre-existing channels bypassing a large portion of lower soil area. Therefore, the pollutant removal efficiency of the vegetated non-access zone was somewhat limited. During one such event, which produced 0.69 cm of rain in 6 hours, COD in the river increased by 70 percent to a level of 17.2 mg/l COD below the non-access area. The water quality of the river was reduced drastically by the access area. The level of COD increased to 35.9 mg/l COD. Other parameters responded in a similar manner as shown in Figures 56, 57, 58, and 59. Baffles were added along the cattle pen, vegetated area interface, and throughout the vegetated area to correct the problem of channeling. The baffling had limited success in spreading the manure throughout the area. To minimize channeling through the green belt, a loose material such as rocks can be used to disperse the runoff at the interface. A sod-forming grass may also disperse the runoff flow.



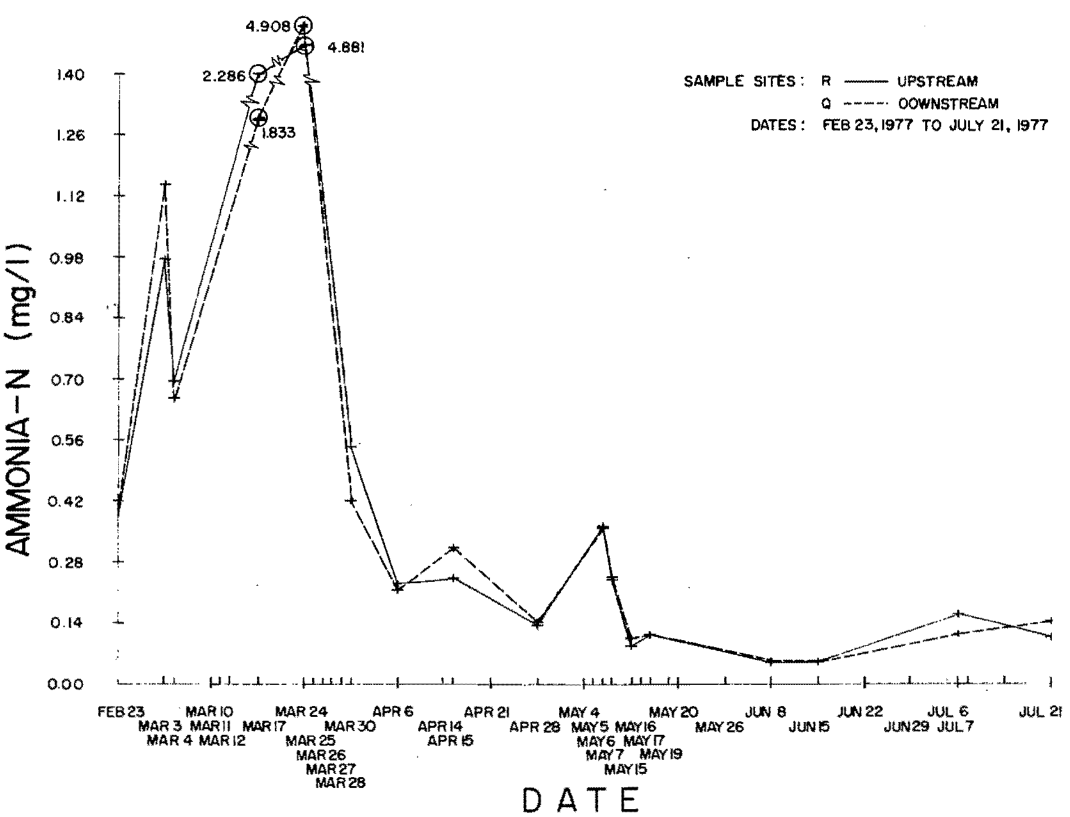
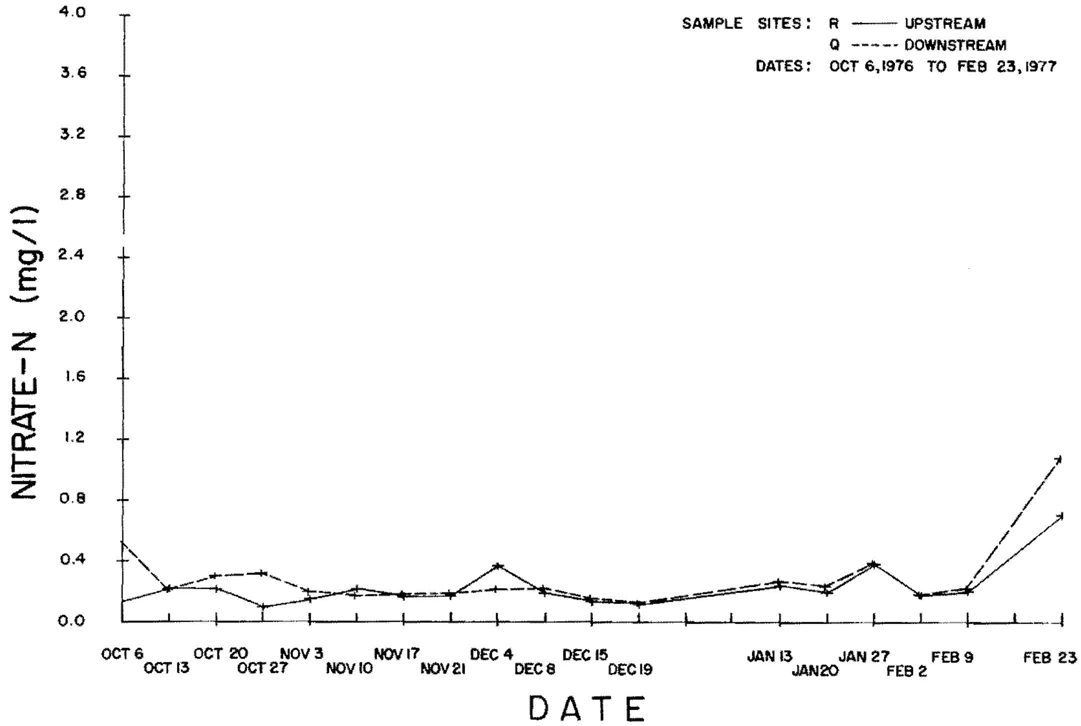


Figure 52. NH_3-N concentrations for sampling site locations R - Q from October 6, 1976, to July 21, 1977.



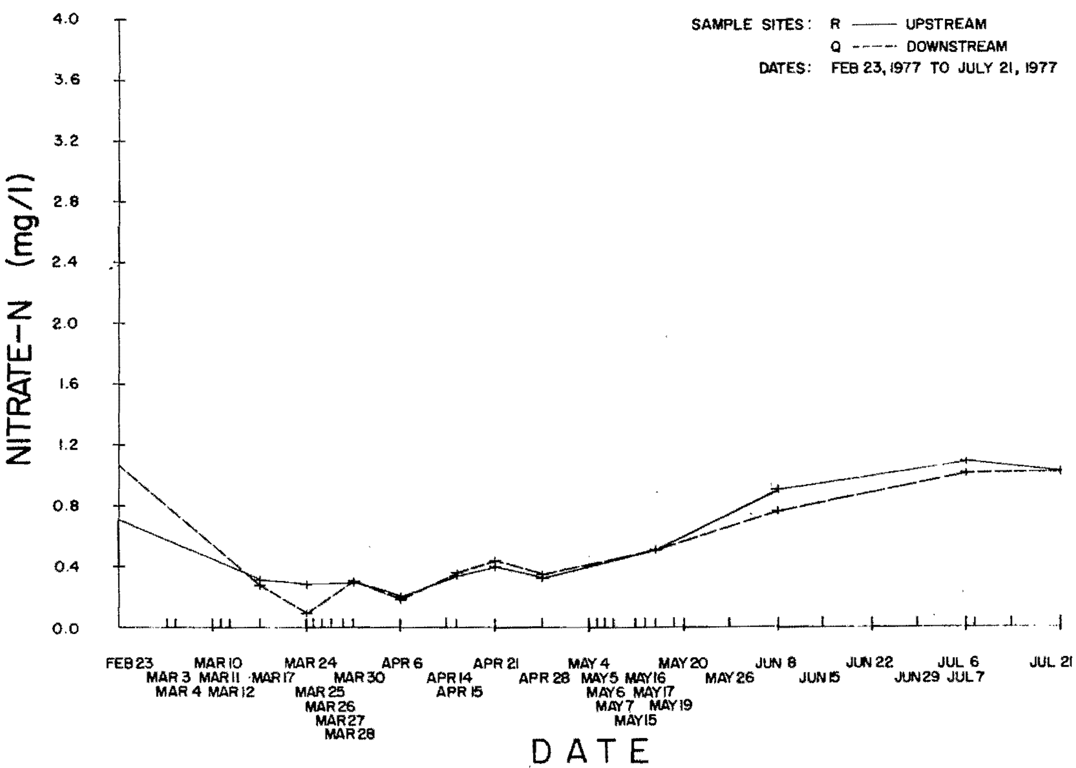
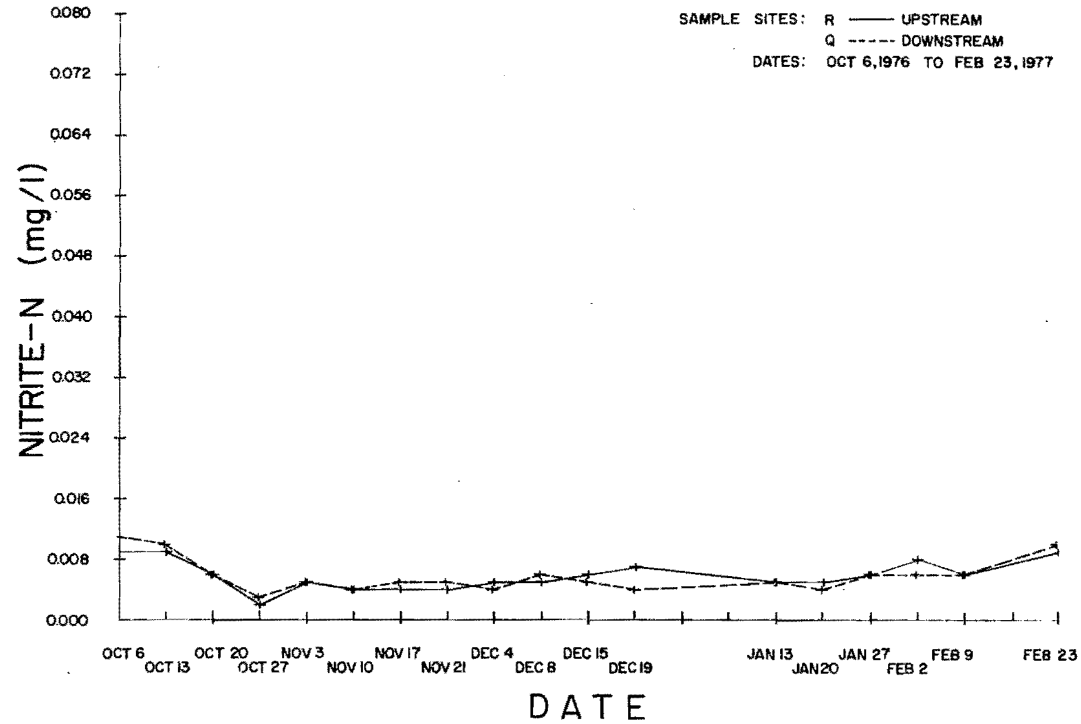


Figure 53. NO_3-N concentrations for sampling site locations R - Q from October 6, 1976, to July 21, 1977.



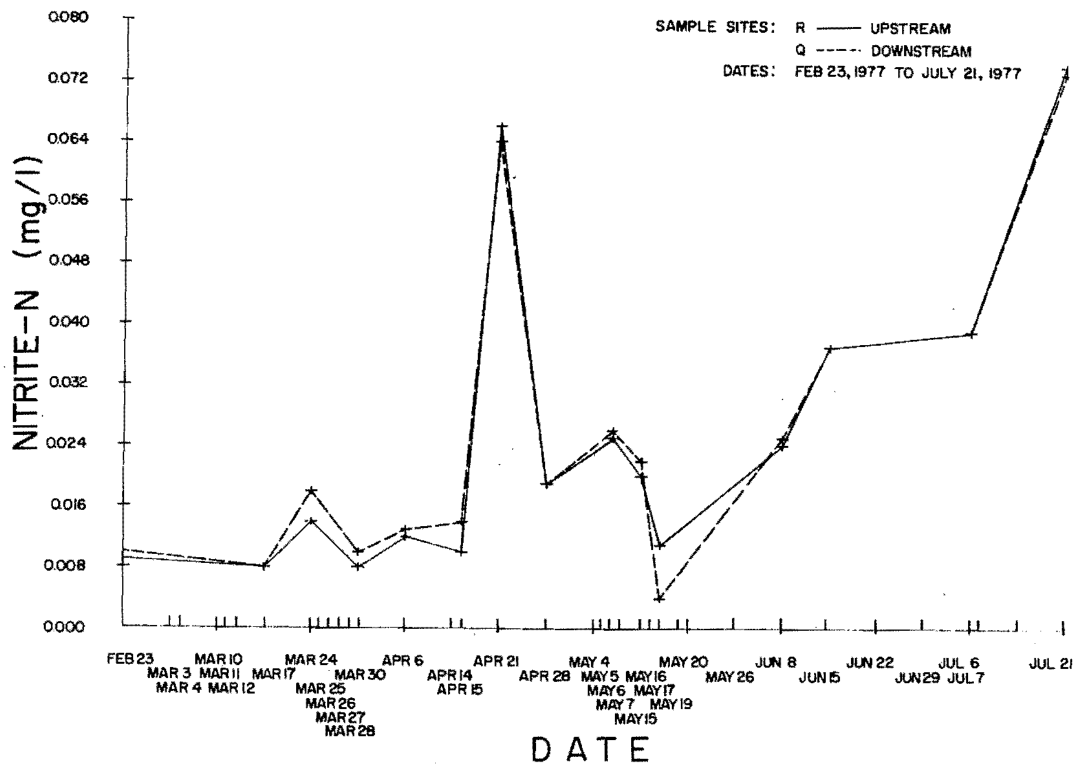


Figure 54. NO_2-N concentrations for sampling site locations R - Q from October 6, 1976, to July 21, 1977.

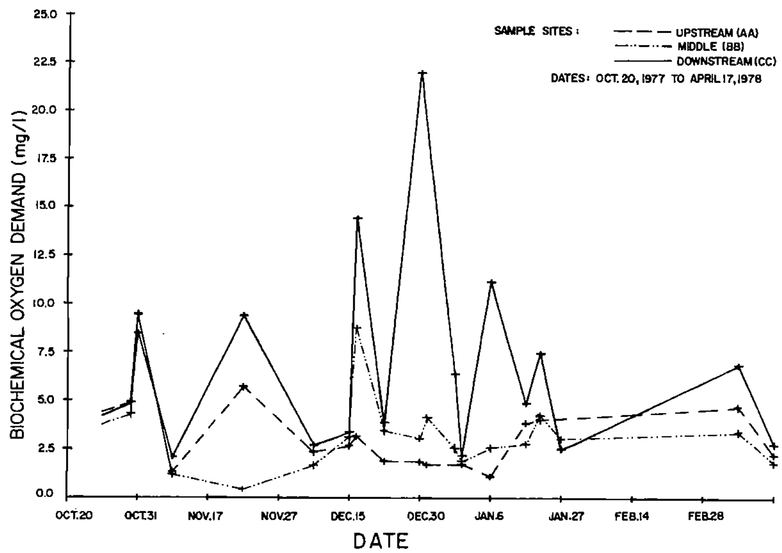


Figure 55. BOD_5 concentrations for sampling site locations AA, BB and CC.

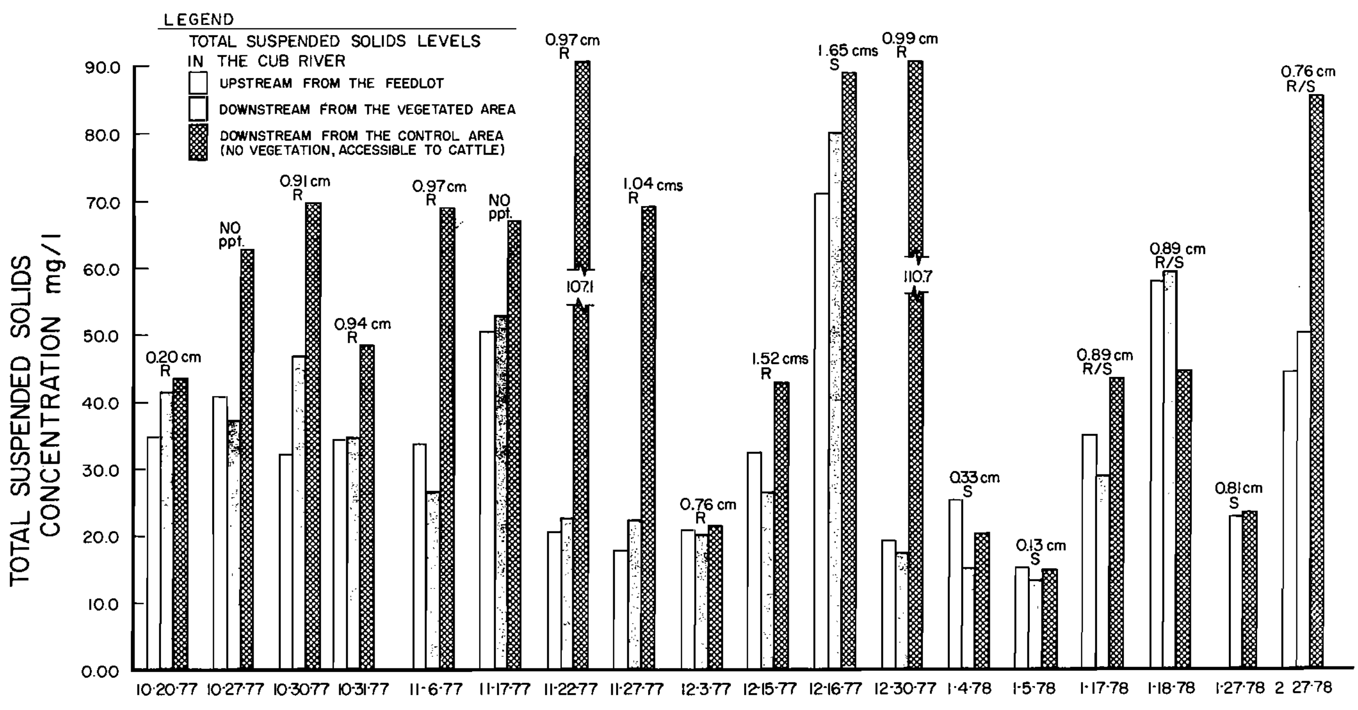


Figure 56. Total suspended solids concentration in the Cub River at various proximities to the feedlot and vegetated area.

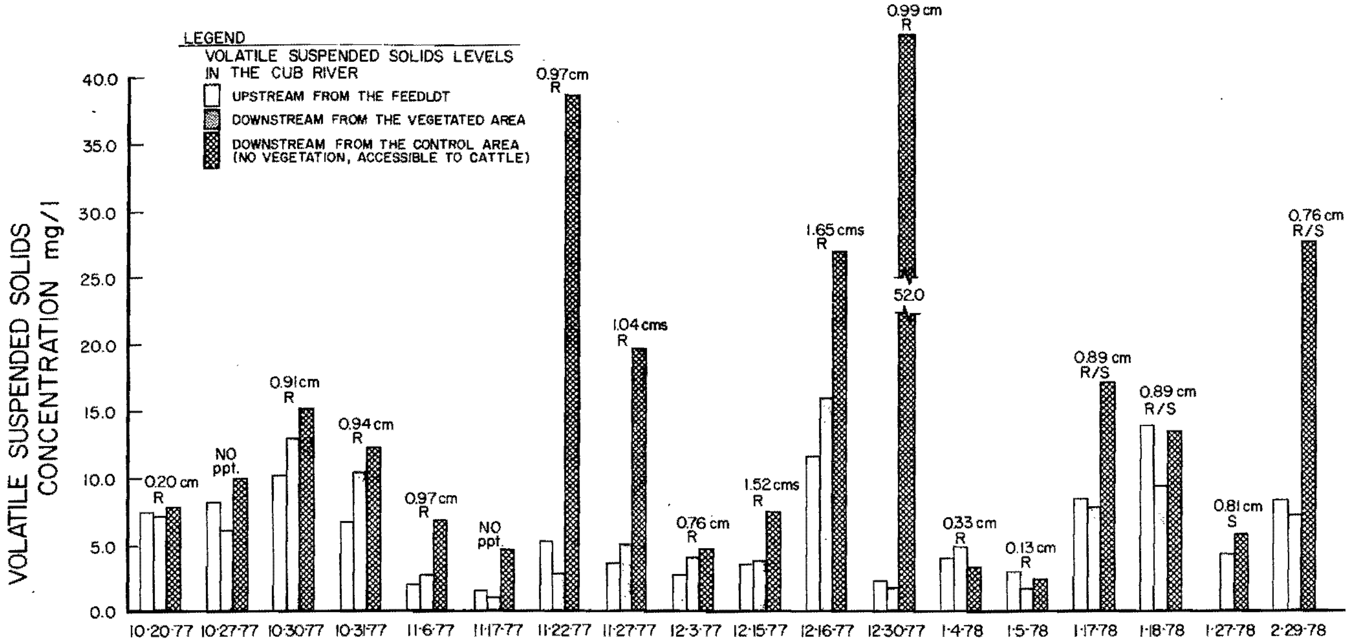


Figure 57. Volatile suspended solids concentration in the Cub River at various proximities to the feedlot and vegetated area.

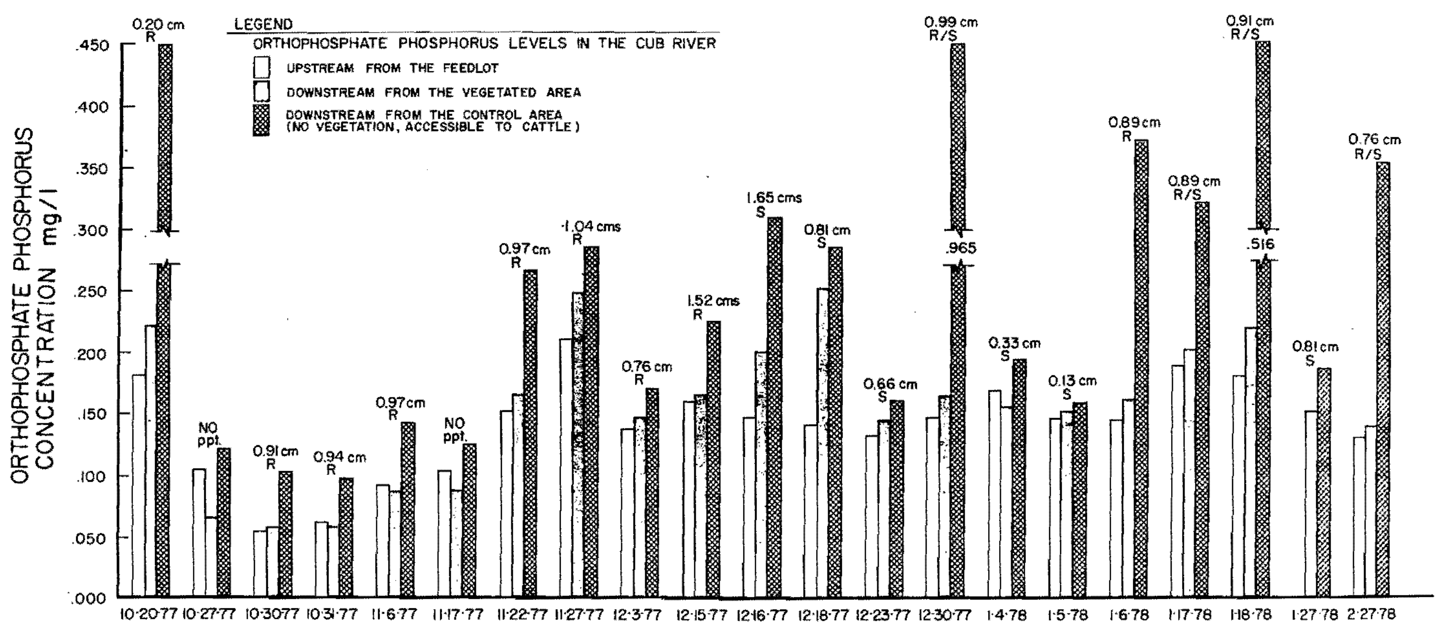


Figure 58. Orthophosphate phosphorus concentrations in the Cub River at various proximities in the feedlot and vegetated area.

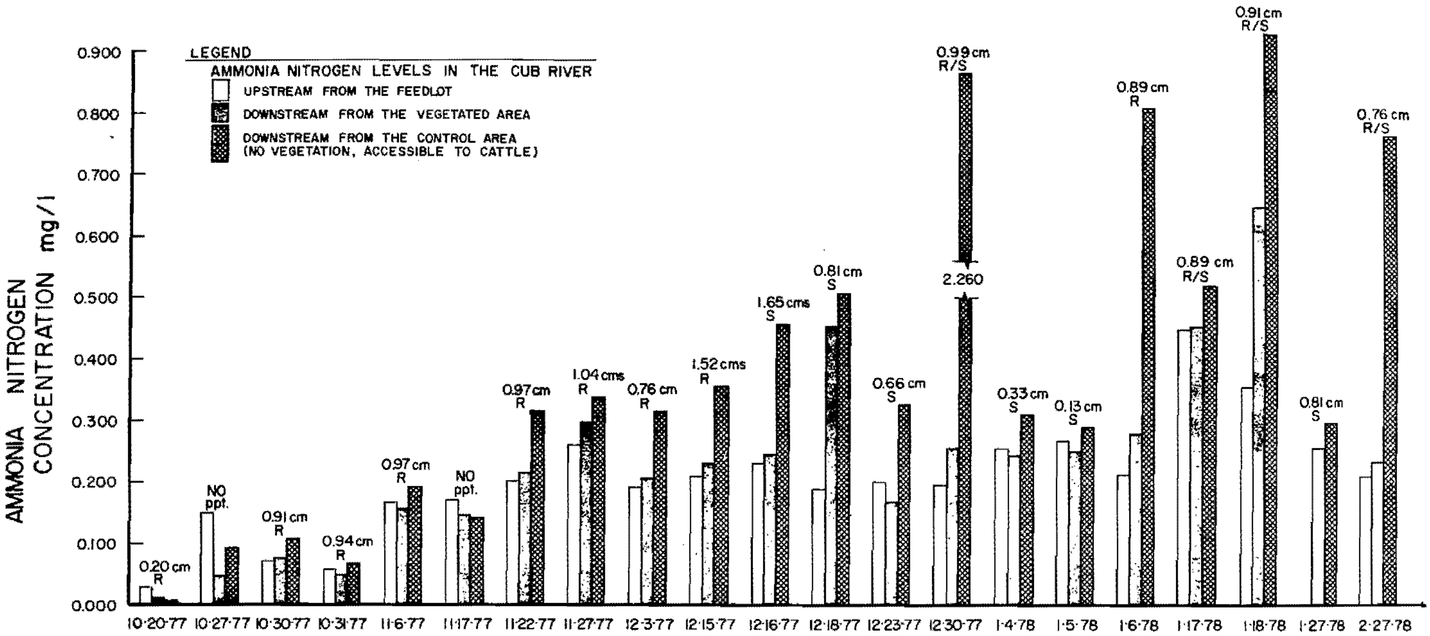


Figure 59. Ammonia nitrogen concentration in the Cub River at various proximities to the feedlot and vegetated area.

Evaluation of Stream Monitoring Conditions

Water quality within the sub-basin deteriorated after both snowmelt and rainfall precipitation events. The base concentrations (concentrations when no precipitation occurred within the system) increased from February to March and stayed high throughout May. This increase corresponded with an increase in precipitation for that period and was a result of scouring of inorganic and organic constituents from the surrounding area. Concentrations of pollutants measured at control points also increased for the same period, indicating that the increase in pollutant base concentrations were attributed to factors other than feedlot runoff. As mentioned previously, the proximity of the sampling site to the feedlot location was an important factor. Although great care was used in selecting sampling sites, it was necessary to select at least one sampling site as much as 300 m (1,000 feet) upstream or downstream from feedlot locations. The positioning of the sampling location upstream or downstream from the feedlot areas was compounded by the location of agricultural land immediately across or adjacent to feedlot facilities. Cattle during summer months were allowed to graze on the adjacent land, while during the winter months the cattle were confined to the feedlot area. Grab sampling from the bank of the waterway without disturbing the sediments was difficult and this introduced error. Furthermore, complete mixing of the feedlot runoff with the stream may not have occurred before samples were collected. A lack of good mixing was evident at the northern facility. After a rainfall, a plume of manure runoff was visible for a distance of 20 m down river. The plume passed beyond the west sample point. The sampling position for the west sampler (CC) was within the plumes range. The depth of the plume was unknown, so the effect on the samples was uncertain.

Increased pollutant concentrations released by the bottom sediment may have had a decided impact on stream quality. Snowmelt pollutant mass was discharged from the feedlots as a slurry or viscous mass. Suspended solids contained within runoff has the potential to settle in the stream. The settling characteristics of the slurry were observed visually during winter conditions at several sampling locations. The manure was noticed to settle in and around the stream area near the feedlot. The low winter temperatures caused a decrease in microbial activity which decreased the bioconversion of organic matter and nutrients. Increased turbulence due to spring runoff and increased precipitation in the form of rain, associated with higher temperatures and greater microbial activity, facilitated increases of instream pollutant concentrations. This could account for the nearly identical results upstream and downstream of feedlot locations as occurred on a number of occasions. Organic and nutrient mass loadings upstream of the sub-basin monitoring area on occasion may have overshadowed the impact of feedlot mass loadings contained within the monitoring area.

Comparisons of Actual and Predicted Mass Loadings

Mass loadings calculated from upstream and downstream measurements from nine southern and one northern Cache Valley, Utah, feedlots were compared with predicted mass loadings using the MLF equation (Equation 10). The mass loadings of individual parameters were determined from flow rates (5 year averages) and instream quality data collected over the sampling period as described in the preceding section.

Figure 60 illustrates the differences between observed and predicted values for BOD_5 mass loadings for six feedlots during a snow event. Comparison of observed and predicted mass loadings for unpaved and paved feedlots for snowmelt events (Figure 60) indicated: 1) upstream concentrations occasionally exceeded downstream concentrations for either paved or unpaved facilities (i.e., one paved (C to D) and one unpaved (D to E) facility); and 2) during snowmelt events either predicted or observed, values may be greater depending on the feedlot (i.e., C to D, obs. > pred.; D to E obs.< pred.). These phenomena were also obtained with values calculated for COD mass loadings for six southern feedlots under snowmelt conditions (Figure 61). Figure 62 is COD mass loadings under similar conditions, except on a different snowmelt runoff day.

Figure 63 illustrates the difference between observed and predicted values for SS mass loadings from feedlots U to T for four snow and three rain events. Predicted mass loadings exceeded observed mass loadings substantially (> 100 percent) for all snow events. For rain events, predicted and observed values correlated more closely.

Predicted COD mass loadings and observed stream COD mass loadings are compared for several locations in Figures 61, 62 and 64. Good agreement was obtained between observed and predicted mass loadings during rainfall events. Snowmelt runoff mass loadings, observed and predicted, however, exhibited significant fluctuations in the comparison between the two values. Tabulated results indicated streams with low flow (less than 10 cfs) will have higher predicted mass loadings than those observed in the field. Streams with greater flows will have higher observed mass loadings than predicted.

During winter months solids contained in manure slurries settle to the bed of the receiving stream. The sedimentation of solids occurs due to low flow and low turbulence conditions with the stream. Organic matter and nutrients accumulated within the stream. Low temperatures tend to reduce microbial activity which would degrade the

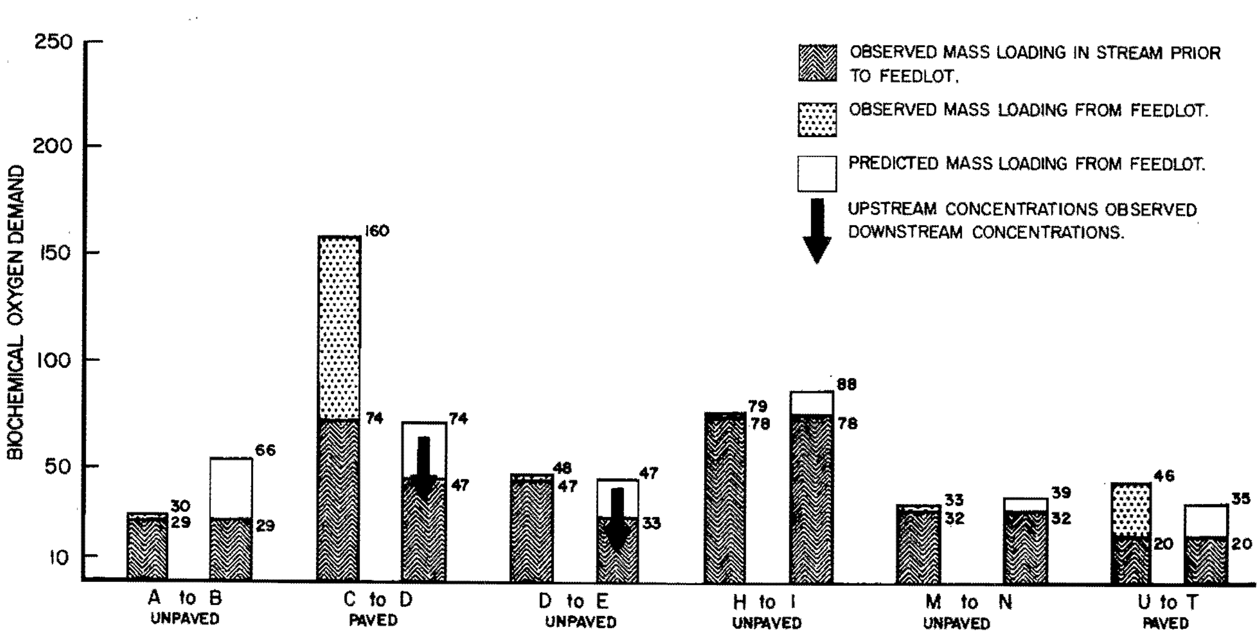


Figure 60. Observed and predicted BOD_5 mass loadings for six southern Cache Valley feedlots (snowmelt).

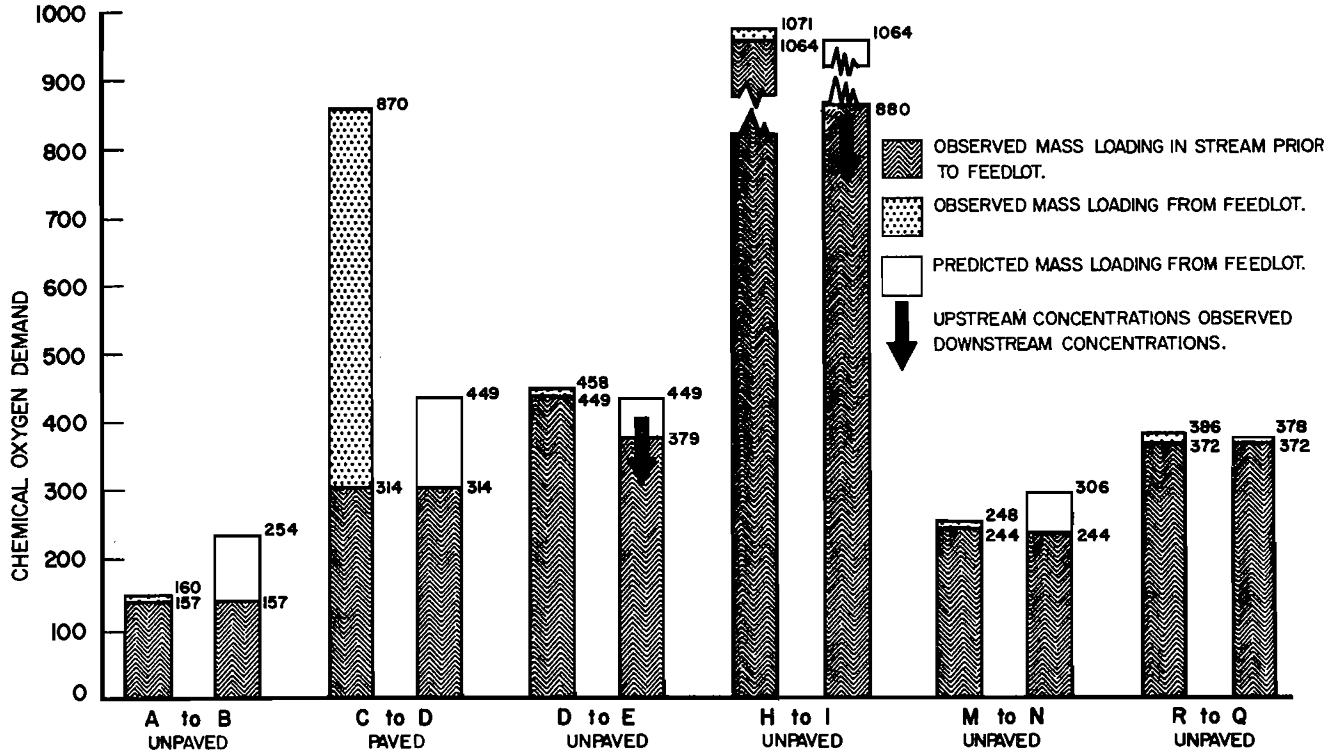


Figure 61. Observed and predicted COD mass loadings for six southern Cache Valley feedlots (snowmelt).

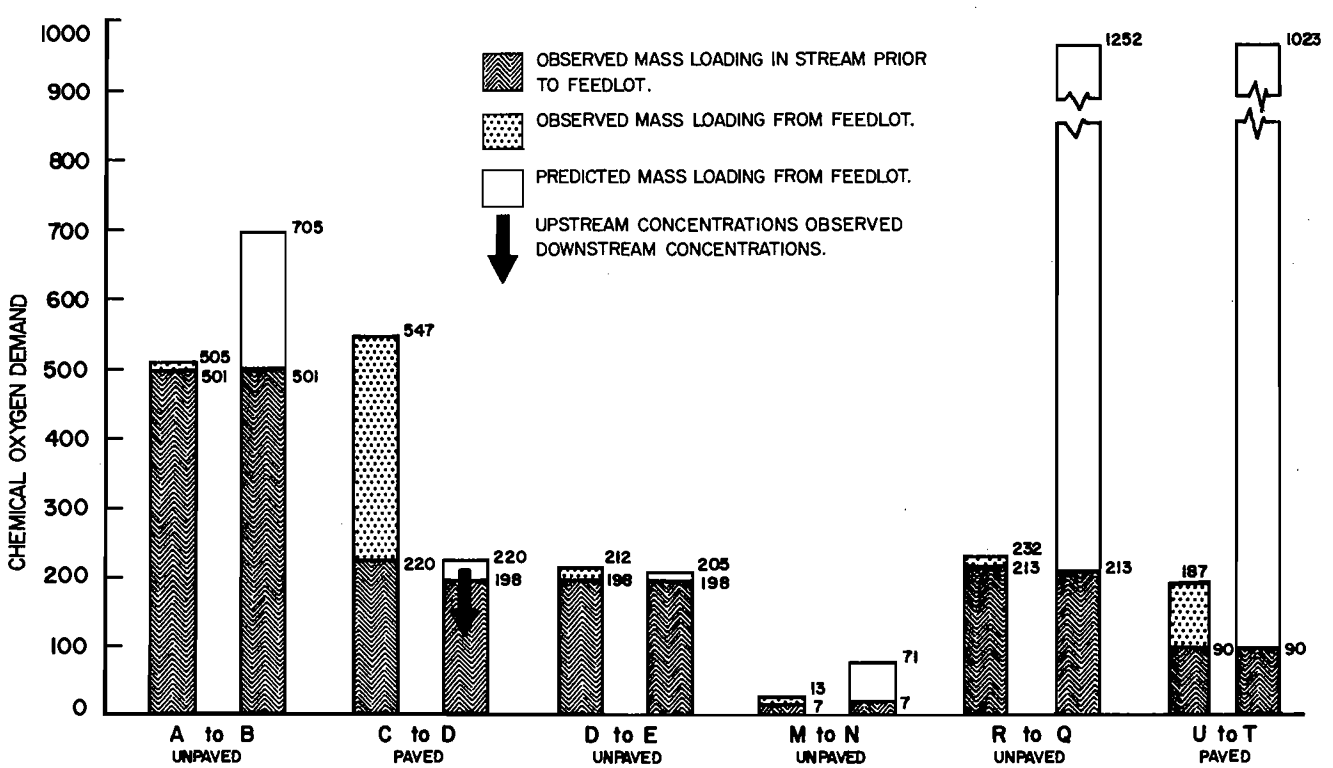


Figure 62. Observed and predicted COD mass loadings for six southern Cache Valley feedlots (snowmelt).

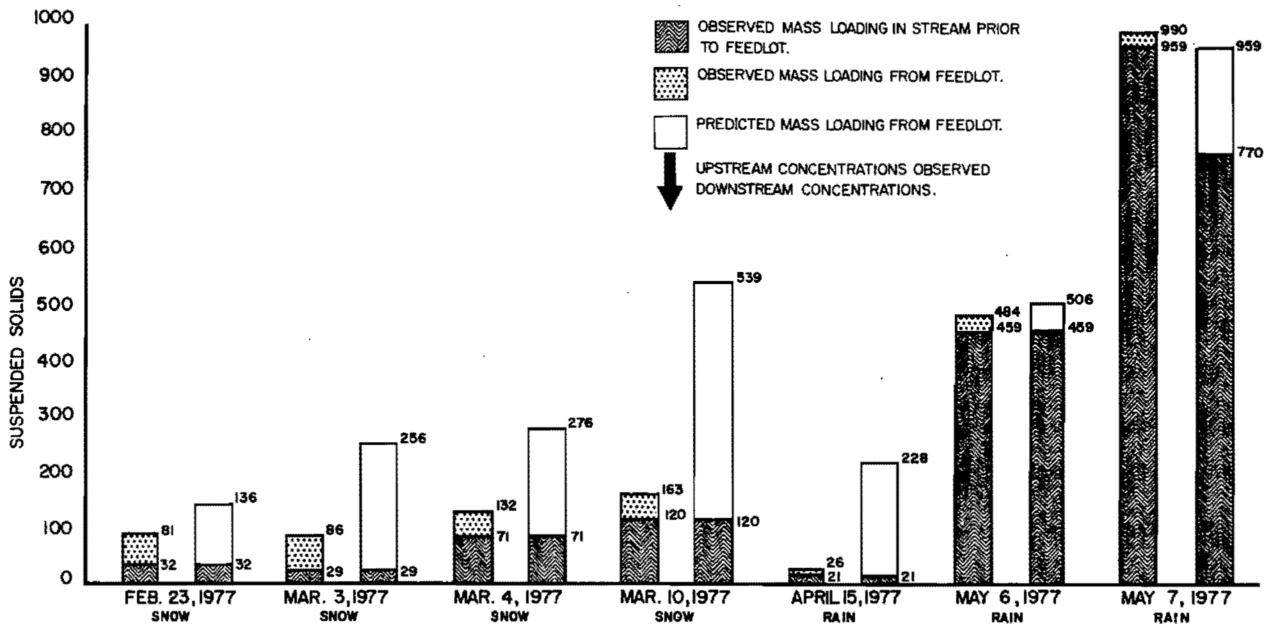


Figure 63. Observed and predicted SS mass loadings for feedlot U to T for four snow and three rain events.

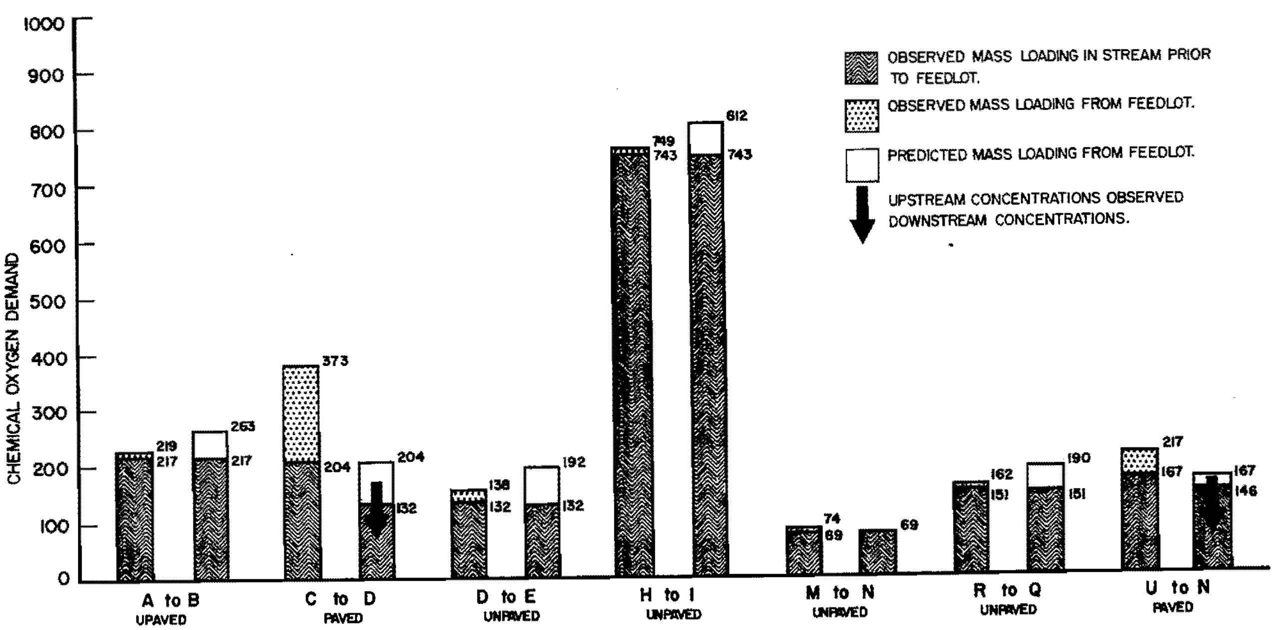


Figure 64. Observed and predicted COD mass loadings for six southern Cache Valley feedlots (rainfall).

organic matter and nutrients. Therefore, observed mass loading determined from measurements obtained upstream and downstream from the feedlot would be low. The model fails to account for sedimentation or biological degradation of organic matter and nutrients. Consequently, predicted mass loadings from feedlots will be greater than observed mass loadings. As shown in Figures 60, 61 and 62, predicted mass loadings generally exceeded observed mass loadings during snowmelt events. Furthermore, greater variation between predicted and observed mass loadings was obtained during winter conditions.

Calculations of predicted and observed mass loadings during rainfall events indicated closer comparisons (Figures 63 and 64). Increased flows in streams, increased turbulence, and less mass loadings were factors which contributed to the closer agreement between predicted and observed values.

Grab samples were taken at locations usually over 50 m from the feedlot site as discussed in a preceding section. The grab samples, therefore, may or may not have been representative of the stream as a whole. At one feedlot location a manure plume was noted extending downstream and away from the embankment. The mixing characteristics of each individual stream after every precipitation event was not ascertained. It can be assumed that after a high precipitation event (rain) that mixing of pollutants was more pronounced within the stream than after a low precipitation event (snow). Figures 60-64 seem to support this hypothesis. Observed and predictive mass loading values were closer during rain events.

SUMMARY AND CONCLUSIONS

Encroachment of urban areas on traditionally agricultural domains and associated increases in public awareness of environmental impacts of agricultural waste discharges has forced municipal, state and federal officials to implement stringent controls regulating agricultural waste discharges. This study evaluated the potential pollutant mass discharge from feedlot operations on a drainage system. The study area was the Bear River drainage system in Northern Utah. Over 220 beef and dairy cattle feedlot operations were isolated which had a potential discharge into the river system.

The potential mass loadings of pollutants to the drainage system was computed by a mathematical model which contained three sections: 1) loading functions, 2) precipitation model, and 3) transport model. The loading functions were based on concentration of pollutants, area of facility, and flow of runoff. Concentration of pollutants was dependent on the type of feedlot surface (i.e., paved or soil), type of precipitation event (i.e., snow or rain) and number of days of consecutive precipitation. Flow of runoff was also dependent on the type of feedlot surface and precipitation event.

Feedlot runoff was collected from two paved and two unpaved facilities. Samples were collected after precipitation events from the four facilities over an 8 month period. The data indicated the maximum mass loading of pollutants occurred during the winter (January through March). The data obtained from the control feedlots were used to formulate the regression equations used in the mass loading model.

The mass loading values generated by the computer model were compared with field data obtained on 10 feedlots located on a subdrainage basin of the Bear River drainage system. The model provided close approximation of pollutant mass loadings during rainfall events. Predictions of mass loadings during snowfall events varied substantially from mass loading derived from field measurements.

1. Concentrations of TSS, VSS, COD, BOD_5, TP, and NH_4-N in paved feedlot runoff during snowmelt events were two to four times higher than for rainfall runoff.

2. Concentrations of PO_4-P contained in snowmelt runoff from paved lots were lower than rainfall runoff.

3. A freely flowing liquid runoff occurred from paved lots during summer months. In winter months runoff consisted of a viscous mass which moves relatively slowly during intermittent freezing and thawing of the slurry.

4. The coefficient of determination (r^2) for linear relationships between COD to BOD_5, COD to TP, and SS to VSS, was equal to or greater than 0.84.

5. A low coefficient of determinations was obtained for the linear relationship between TP and PO_4-P concentration for paved and unpaved feedlots during winter. This was attributed to either/or both chemical and microbiological transformations which occur in the manure slurry.

6. Concentrations of pollutants in feedlot runoff for rainfall events were affected by prior precipitation. Concentrations of pollutants in runoff from a single rainfall event were substantially different than for concentrations in runoff occurring after more than one day's rain.

7. Depending on the parameter, snowmelt feedlot runoff pollutant concentrations were affected by up to four days prior precipitation. The parameters affected by previous snow events were COD, SS, NH_3-N and PO_4-P.

8. In the study area, 220 livestock operations with potential waste discharge into the drainage system were delineated.

9. Flow from unpaved feedlots during snow events was a function of either single snowmelt event, previous snowmelt events, or runoff when no snowmelt event was occurring.

10. Hydraulic transport time of pollutants to Cutler Reservoir, Cache Valley, Utah, from all feedlots located in the drainage system, was less than or equal to one day at low flow.

11. The predictive model computed mass loading of pollutants from feedlot facilities primarily as a function of available feedlot area. Reduction or enlargement of feedlot area was directly proportioned to mass loading of pollutants. This assumed the density of cattle per feedlot is essentially constant.

12. Using the predictive model under similar study conditions, concentrations of COD, BOD_5, NH_3-N, SS, VSS, and TP in winter or snowmelt runoff were six to eight times higher than in summer or rainfall runoff for paved and unpaved feedlots.

13. Physical separation of cattle approximately 61 m (200 feet) from a receiving stream in conjunction with providing a green belt buffer between the feedlot and stream showed tremendous potential for being a wastewater management scheme to prevent deterioration of stream water quality.

RECOMMENDATIONS FOR FURTHER RESEARCH

It is recommended that:

1. A study be conducted to determine the relative importance of pooling of liquid manure on feedlots after a precipitation event.

2. The separation of single and multiple precipitation events should be attempted to determine the influence previous precipitation events have on pollutant concentrations in runoff. This study should include a separate evaluation of both dairy and beef feedlots.

3. An extensive kinetic study be conducted on the decomposition of manure under natural stream conditions.

4. The importance of bottom sediments to stream pollutant concentrations downstream from feedlots be determined. The study should include an evaluation of the physical and biological mechanisms within the stream that effect the decomposition of feedlot runoff during winter and summer.

5. A study be conducted to determine the relative importance of slope and cattle density on the concentrations of pollutants in feedlot runoff.

6. The use of total feedlot area within a drainage system as a management scheme for control of feedlot runoff be evaluated.

7. An extensive study be conducted on the use of stream non-access areas for cattle as a management tool for controlling feedlot runoff. Also, the use of vegetation as a soil cover in conjunction with stream non-access areas should be evaluated.

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APPENDIX A

TRANSPORT AND PRECIPITATION MODEL PROGRAM

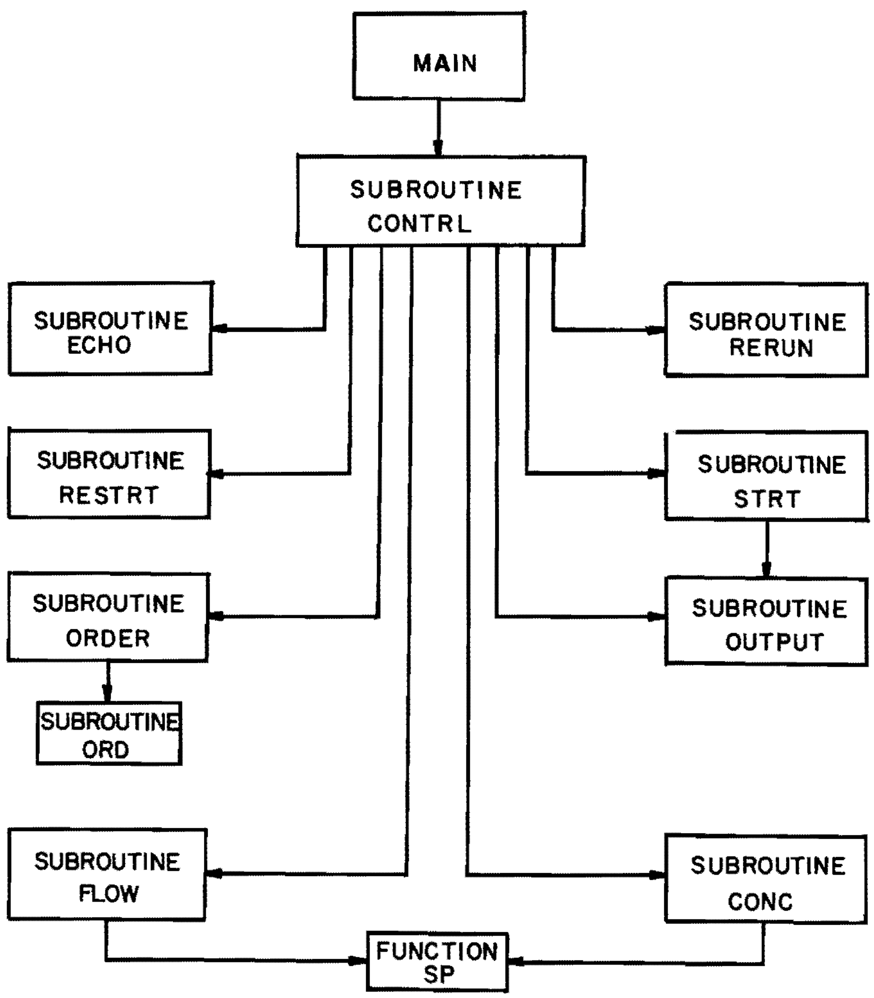

Figure A-1. Feedlot runoff transport model program structure.

Table A-1. Program unit, subroutine and function descriptions.

Program Unit, Subroutine or Function	Tasks Performed
MAIN	1. Initialize program variables 2. Read and write simulation run title
CONTRL	1. Read in program input data 2. Conducts internal checks on input data 3. Accumulates mass loading totals 4. Calls appropriate subroutines in the proper sequence
ECHO	1. Echos input data at user's option
RESTRT	1. Reads in program restart file and resets internal totals at user's option 2. Positions precipitation input file for program RESTART
ORDER	1. Sorts user input data into calculation and output order 2. Generates output sorting vectors 3. Calls subroutine ORD
ORD	1. Sorts a vector in ascending order
FLOW	1. Determines precipitation at each feedlot 2. Determines flow off of each feedlot
SP	1. Sums previous days precipitation at a feedlot
CONC	1. Determines concentration of each quality constituent leaving feedlot
OUTPUT	1. Manages and prints output summarizes in accordance with user options
STAT	1. Calculate average mass loadings and standard deviations of the loadings
RERUN	1. Writes to disk all internal totals necessary to restart program

APPENDIX B

COMPUTER PROGRAM

Table B-1. Description of feedlot runoff transport model variables.

Variable Name	Description
INF	Feedlot index
IRN	Region index
IEN	Entrance index
I	Quality constituent and dummy index
IY	Year index
IM	Month index
ID	Day index
IT	Treatment index
COMMON|A|	
NF	Number of feedlots
NR	Number of regions
NE	Number of entrances
NRF(6)	Read file numbers
NWF(7)	Write file numbers
IECHO(6)	Controls input data echo options
IOUTOP(10)	Controls output and execution options
NC	Number of quality constituents
ICON(I)	Quality constituent numbers
NS	Number of precipitation stations ≤ 4
NYEARS	Number of years of simulation
NT	Number of treatments
REM(I,IT)	Fraction of constituent I remaining after applying treatment IT
NTREG(IR,IT)	Identifies whether treatment IT is applied to region IR
IFN(INF)	Feedlot identification number
IELN(300)	Not used in this version of program
IP(INF)	Identifies whether a feedlot is paved or unpaved
PCOEF(I,INF)	Fraction of precipitation occurring at station I that falls at feedlot INF
IE(INF)	Entrance number associated with feedlot INF
IR(INF)	Region number associated with feedlot INF
AREA(INF)	Surface area of feedlot INF(HA)
RTITLE(40)	Title of simulation run
CTITLE(I)	Name of quality constituent I
MTITLE(IM)	Name of month IM
STA(5)	Output heading for precipitation tations
MONTH(IM)	Number of days in month (IM) (assumes February has 28 days)
NFMAX	Maximum number of feedlots (300)
NRMAX	Maximum number of regions (30)
NEMAX	Maximum number of entrances (10)
NCMAX	Maximum number of quality constituents (10)
NTMAX	Maximum number of treatments (10)
NPRMAX	Maximum number of previous days precipitation to be saved (5)
DATE(2)	Date of simulation run
ITIME(3)	Time of simulation run

Table B-1. Continued.

Variable Name	Description
IT(300,12)	Not used in this version of program
DECAY(10)	Not used in this version of program
PT(I)	Daily precipitation at station I (inches)
PQ(I,INF)	Previous (current day is I=1) flow off feedlot INF (cm)
PR(I,INF)	Previous (current day is I=1) precipitation at feedlot INF (cm)
C(I)	Concentration of quality constituent I (mg/l)
IREN(IRN)	Entrance number associated with region IRN
IEORD(IEN)	Entrance numbers in output order
IRORD(IRN)	Region numbers in output order
IEFN(INF)	Sorted entrance number associated with feedlot INF
IRFN(INF)	Sorted region number associated with feedlot INF
INRT(IRN)	Region identification number used to sort regional treatment input data
IOUTOR(IRN)	Region output order
PMT(I,IM)	Monthly total of daily precipitation at station I for current year (cm)
PTOT(I,IM)	Monthly total of daily precipitation at station I for entire simulation run (cm)
FMT1(I,IM,INF)	Total mass of constituent I leaving feedlot INF during month IM of current year (kg)
COMMON|B|	
FMT2(I,IM,INF)	Total mass of constituent I leaving feedlot INF during all months IM of simulation run (kg)
RMT1(I,IM,IRN)	Total mass of constituent I leaving feedlots in region IRN during month IM of current year (kg)
RMT2(I,IM,IRN)	Total mass of constituent I leaving feedlots in region IRN during all months IM of simulation run (kg)
RMR2SQ(I,IM,IRN)	The square of RMT1(I,IM,IRN) summed over simulation run (kg^2)
STDRMT(I,IM,IRN)	Standard deviation of RMT1(I,IM,IRN) (kg/month)
EMT1(I,IT,IM,IEN)	Total mass of constituent I leaving feedlots in region IEN receiving treatment IT during month IM of current year (kg)
COMMON|C|	
EMT2(I,IT,IM,IEN)	ETM1 (I,IT,IM,IEN) summed over simulation run (kg)

Table B-1. Continued.

Variable Name	Description
TOM1(I,IT,IM)	EMT1(I,IT,IM,IEN) summed over all entrances (kg)
TOM2(I,IT,IM)	EMT2(I,IT,IM,IEN) summed over all entrances (kg)
TOM2SQ(I,IT,IM)	The square of TOM1(I,IT,IM) summed over simulation run (kg^2)
STDTOM(I,IT,IM)	Standard deviation of the total mass of constituent I leaving feedlots during month IM under treatment IT (kg/month)

Table B-1. Continued.

Variable Name	Description
TOY1(I,IT)	Sum of constituent I leaving all feedlots during current year under treatment IT (kg)
TOY2(I,IT)	TOY1(I,IT) summed over simulation run (kg^2)
TOY2SQ(I,IT)	Square of TOY1(I,IT) summed over simulation run (kg^2)
STDTOY(I,IT)	Standard deviation of the total mass of constituent I leaving feedlots under treatment IT (kg/year)

Table B-2. Input data card format for computer program.

Data Segment	Card No. in Data Segment	Column	Format	Variable Name	Description
TITLE	1	1-80	20A4	RTITLE(I)	Run title
	2	1-80	20A4	RTITLE(I)	Run title
CONTROL	1		Unformatted	NF	Number of feedlots (Max = 300)
	1		Unformatted	NR	Number of regions (Max = 30)
	1		Unformatted	NE	Number of entrances (Max = 10)
	1		Unformatted	NRF(1)	Read file for feedlot description data
	1		Unformatted	NRF(2)	Read file for subroutine RESTRT
	1		Unformatted	NRF(3)	Read file for precipitation
	1		Unformatted	NWF(1)	Disk write file for array TOM1
	1		Unformatted	NWF(2)	Disk write file for array TOY1
	1		Unformatted	NWF(3)	Disk write file for average TOM1
	1		Unformatted	NWF(4)	Disk write file for average TOY1
	1		Unformatted	NWF(5)	Disk write file for array STDTOM
	1		Unformatted	NWF(6)	Disk write file for array STDTOY
	1		Unformatted	NWF(7)	Disk write file for program RESTART DATA
	1		Unformatted	IECHO(1)	Input data ECHO option = 1: ECHO treatment input data
	1		Unformatted	IECHO(2)	Input data ECHO option = 1: ECHO feedlot description input data
	1		Unformatted	IECHO(3)	Not used in this version of program
	1		Unformatted	IOUTOP(1)	Run option = 1: Simulation run is a RESTART of a previous run
	1		Unformatted	IOUTOP(2)	Run option: Number of previous days (including current day) precipitation to be saved (Max = 5)
	1		Unformatted	IOUTOP(3)	For years which are multiples of IOUTOP(3), output will be by month, treatment, and feedlot
	1		Unformatted	IOUTOP(4)	For years which are multiples of IOUTOP(4), output will be by month, treatment, and region
	1		Unformatted	IOUTOP(5)	For years which are multiples of IOUTOP(5), output will be by month, treatment, and entrance
	1		Unformatted	IOUTOP(6)	For years which are multiples of IOUTOP(6), output will be by month and treatment
	1		Unformatted	IOUTOP(7)	For years which are multiples of IOUTOP(7), output will be by month
	1		Unformatted	IOUTOP(8)	For years which are multiples of IOUTOP(8), output will include precipitation data
	1		Unformatted	IOUTOP(9)	For years which are multiples of IOUTOP(9), array TOM1 will be written to disk

Table B-2. Continued.

Data Segment	Card No. in Data Segment	Column	Format	Variable Name	Description
	1		Unformatted	IOUTOP(10)	For years which are multiples of IOUTOP(10), array TOY1 will be written to disk
	1		Unformatted	NC	Number of quality constituents (Max = 10)
	1		Unformatted	NS	Number of precipitation stations (Max = 4)
	1		Unformatted	NYEARS	Number of years in simulation run (Max = 9998)
	1		Unformatted	NT	Number of treatments (Min = 1, Max = 10) [If no treatment is desired set NT = 1 and set array NTREG (described below) = 0]
QUALITY CONSTITUENTS	1	1-2	I2	ICON(1)	Equation number in subroutine CONC associated with constituent 1
	1	5-8	A4	CTITLE(1)	Name of constituent 1
	1	9-80	18A4	DUM(J)	Description of constituent 1
	⋮	⋮	⋮	⋮	⋮
	NC	1-2	I2	ICON(NC)	Equation number in subroutine CONC associated with constituent NC
	NC	5-8	A4	CTITLE(NC)	Name of constituent NC
	NC	9-80	18A4	DUM(J)	Description of constituent NC
TREATMENT	1	1-2	I2	INRT(1)	Region number
	1	4	I1	NTREG(1,1)	If NTREG(1,1) = 1, treatment 1 is applied to region INRT(1)
	1	6	I1	NTREG(1,2)	If NTREG(1,2) = 1, treatment 2 is applied to region INRT(1)
	⋮	⋮	⋮	⋮	⋮
	2				Repeat card 1 for each remaining region
	3	1-5	F5.0	REM(1,1)	Fraction of constituent 1 remaining after treatment 1
	3	6-10	F5.0	REM(2,1)	Fraction of constituent 2 remaining after treatment 1
	⋮	⋮	⋮	⋮	⋮
	3	46-50	F5.0	REM(10,1)	Fraction of constituent 10 remaining after treatment 1
	4				Repeat card 3 for each remaining treatment
FEEDLOT DESCRIPTION	1	1-3	I3	IFN(1)	Number identifying feedlot 1
	1	5-7	I3	IELN(1)	Identifying element number in which feedlot 1 lies (not needed)
	1	9	I1	IP(1)	IP(1) = 0 if feedlot is paved = 1 if feedlot is unpaved
	1	48-51	F4.2	COEF(1,1)	Fraction of precipitation at station 1 occurring at feedlot 1
	1	52-55	F4.2	PCOEF(2,1)	Fraction of precipitation at station 2 occurring at feedlot 1
	1	56-59	F4.2	PCOEF(3,1)	Fraction of precipitation at station 3 occurring at feedlot 1
	1	60-63	F4.2	PCOEF(4,1)	Fraction of precipitation at station 4 occurring at feedlot 1
	1	64-65	I2	IE(1)	Entrance number associated with feedlot 1
	1	67-68	I2	IR(1)	Region number associated with feedlot 1
	1	70-74	F5.3	AREA(1)	Area of feedlot 1 (ha)
	2				Repeat card 1 for each remaining feedlot
PRECIPITATION	1		Unformatted	PT(1)	Daily precipitation at station 1 (in)
	⋮		⋮	⋮	
	1		Unformatted	PT(NS)	Daily precipitation at station NS (in)
	2				Repeat card 1 for each remaining day in simulation run

```
L
$ SET OWN
$ SET OWNARRAYS
FILE  23(KIND=DISK)
FILE  24(KIND=DISK)
FILE  31(KIND=DISK)
FILE  32(KIND=DISK)
FILE  33(KIND=DISK)
FILE  34(KIND=DISK)
FILE  35(KIND=DISK)
FILE  36(KIND=DISK)
FILE  37(KIND=DISK)
FILE  5(MAXRECSIZE=14)
FILE  6(MAXRECSIZE=22)
FILE  21(KIND=DISK,MAXRECSIZE=14,BLOCKSIZE=210,AREAS=1000,AREASIZE=450,
     *    SAVEFACTOR=999,BUFFERS=1,TITLE='SYSDAT')
FILE  22(KIND=TAPE,MAXRECSIZE=22,BLOCKSIZE=1100,SAVEFACTOR=999,
     *    BUFFERS=1,TITLE='SIMP2')
C*
C*     **********************************
C*     *                                *
C*     *  PROGRAMMED BY BRAD A. FINNEY  *
C*     *  UTAH STATE UNIVERSITY         *
C*     *  SEPTEMBER 1978                *
C*     *                                *
C*     **********************************
C*
       COMMON /A/ NF,NR,NE,NRF(6),NWF(7),IECHO(6),IOUTOP(10),NC,ICON(10),
     *        NS,NYEARS,NT,REM(10,10),NTREG(30,10),IFN(300),IELN(300),
     *        IP(300),PCOEF(5,300),IE(300),IR(300),AREA(300),RTITLE(40),
     *        CTITLE(10),MTITLE(12),STA(4),MONTH(12),NFMAX,NRMAX,
     *        NEMAX,NCMAX,NTMAX,NPRMAX,DATE(2),ITIME(3),TT(300,12),
     *        DECAY(10),PT(4),PQ(5,300),PP(5,300),C(10),IREN(30),
     *        IEORD(10),IRORD(30),IEFN(300),IRFN(300),INRT(30),
     *        IOUTOR(300),PMT(4,12),PTOT(4,12),FMT1(10,12,300)
       COMMON /B/ FMT2(10,12,300),RMT1(10,12,30),RMT2(10,12,30),
     *        RMT2SQ(10,12,30),STDRMT(10,12,30),EMT1(10,10,12,10)
       COMMON /C/ EMT2(10,10,12,10),TOM1(10,10,12),TOM2(10,10,12),
     *        TOM2SQ(10,10,12),STDTOM(10,10,12),TOY1(10,10),TOY2(10,10),
     *        TOY2SQ(10,10),STDTOY(10,10)
       DATA MONTH/31,28,31,30,31,30,31,31,30,31,30,31/,
     *     MTITLE/'JAN.','FEB.','MAR.','APR.','MAY','JUNE','JULY',
     *            'AUG.','SEP.','OCT.','NOV.','DEC.'/,
     *     STA/'STA.1','STA.2','STA.3','STA.4'/,
     *     NFMAX,NRMAX,NEMAX,NCMAX,NTMAX,NPRMAX/300,30,3*10,5/,
     *     PMT,PTOT,FMT1,FMT2,RMT1,RMT2,RMT2SQ,STDRMT/86496*0.0/,
     *     EMT1,EMT2,TOM1,TOM2,TOM2SQ,STDTOM/28800*0.0/,
     *     TOY1,TOY2,TOY2SQ,STDTOY/400*0.0/,
     *     DATE/'  /  /      '/
       READ(5,1100)RTITLE
 1100  FORMAT(20A4,/,20A4)
       DUM=TIME(15)
       DATE(1)=CONCAT(DATE(1),DUM,47,47,16)
       DATE(1)=CONCAT(DATE(1),DUM,23,31,16)
       DATE(2)=CONCAT(DATE(2),DUM,47,15,16)
       DUM=FLOAT(TIME(1))/60.
       ITIME(1)=DUM/3600.
       IDUM=ITIME(1)*3600
       ITIME(2)=(DUM-IDUM)/60
       ITIME(3)=DUM-IDUM-ITIME(2)*60
       WRITE(6,2100)RTITLE,DATE,ITIME
 2100  FORMAT(1H1,//////////,20X,88(1H*),/,20X,'*',86X,'*',/,20X,'*',
     *        28X,'FEEDLOT RUNOFF TRANSPORT MODEL',28X,'*',/,20X,'*',86X,
     *        '*',/,20X,'*',3X,20A4,3X,'*',/,20X,'*',3X,20A4,3X,'*',/,
     *        20X,'*',86X,'*',/,20X,'*',36X,'DATE: ',2A6,
     *        32X,'*',/,20X,'*',36X,'TIME: ',I2,':',I2,'.',I2,36X,'*',/,
     *        20X,'*',86X,'*',/,20X,88(1H*),/,1H1)
       CALL CONTRL
       END
```

```
      SUBROUTINE CONTRL
      COMMON /A/ NF,NR,NE,NRF(6),NWF(7),IECHO(6),IOUTOP(10),NC,ICON(10),
     *      NS,NYEARS,NT,REM(10,10),NTREG(30,10),IFN(300),IELN(300),
     *      IP(300),PCOEF(5,300),IE(300),IR(300),AREA(300),RTITLE(40),
     *      CTITLE(10),MTITLE(12),STA(4),MONTH(12),NFMAX,NRMAX,
     *      NEMAX,NCMAX,NTMAX,NPRMAX,DATE(2),ITIME(3),TT(300,12),
     *      DECAY(10),PT(4),PQ(5,300),PP(5,300),C(10),IREN(30),
     *      IEORD(10),IRORD(30),IEFN(300),IRFN(300),INRT(30),
     *      IOUTOR(300),PMT(4,12),PTOT(4,12),FMT1(10,12,300)
      COMMON /B/ FMT2(10,12,300),RMT1(10,12,30),RMT2(10,12,30),
     *      RMT2SQ(10,12,30),STDRMT(10,12,30),EMT1(10,10,12,10)
      COMMON /C/ EMT2(10,10,12,10),TOM1(10,10,12),TOM2(10,10,12),
     *      TOM2SQ(10,10,12),STDTOM(10,10,12),TOY1(10,10),TOY2(10,10),
     *      TOY2SQ(10,10),STDTOY(10,10)
      DIMENSION DUM(20)
C*
C*    READ CONTROL CARD
C*
      READ(5,/)NF,NR,NE,(NRF(I),I=1,3),(NWF(I),I=1,7),(IECHO(I),I=1,3),
     *         (IOUTOP(I),I=1,10),NC,NS,NYEARS,NT
      WRITE(6,2100)NF,NR,NE,(NRF(I),I=1,3),(NWF(I),I=1,7),
     *          (IECHO(I),I=1,3),(IOUTOP(I),I=1,10),NC
 2100 FORMAT(1X,'NF=',I3,3X,'NR=',I2,3X,'NE=',I2,/,1X,'VECTOR NRF ',
     *      3(I2,1X),3X,'VECTOR NWF ',7(I2,1X),3X,'VECTOR IECHO ',
     *      3(I1,1X),/,1X,'VECTOR IOUTOP ',10(I4,1X),/,1X,'NC=',I2)
      WRITE(6,2200)NS,NYEARS,NT
 2200 FORMAT(1X,'NS=',I1,3X,'NYEARS=',I4,3X,'NT=',I2)
      IF(NF.GT.0.AND.NR.GT.0.AND.NE.GT.0.AND.NC.GT.0.AND.NS.GT.0.AND.
     *   NYEARS.GT.0.AND.NT.GT.0.AND.IOUTOP(2).GT.0)GO TO 20
      WRITE(6,2300)
 2300 FORMAT(////,1X,'**** AT LEAST ONE OF THE FOLLOWING INPUT ',
     *        'VARIABLES IS LESS THAN OR EQUAL TO ZERO: ',
     *        'NF,NR,NE,NC,NS,NYEARS,NT,IOUTOP(2) (LESS THAN 1)')
       STOP
 20    CONTINUE
       IF(NF.LE.NFMAX.AND.NR.LE.NRMAX.AND.NE.LE.NEMAX.AND.NC.LE.NCMAX.
     *    AND.NT.LE.NTMAX.AND.IOUTOP(2).LE.NPRMAX)GO TO 40
       WRITE(6,2400)
 2400  FORMAT(////,1X,'**** INPUT LIMITS EXCEEDED. MAXIMUM VALUES FOR ',
     *        'INPUT VARIABLES ARE AS FOLLOWS: NF=',I3,3X,'NR=',I2,3X,
     *        'NE=',I2,3X,'NC=',I2,3X,'NT=',I2,3X,'IOUTOP(2)=',I2)
       STOP
 40    CONTINUE
C*
C*     READ CONSTITUENT CARDS
C*
       WRITE(6,2500)NC
 2500  FORMAT(1H1,///,1X,I2,' CONSTITUENTS MODELED IN THIS RUN',/)
       DO 60 I=1,NC
       READ(5,1200)ICON(I),CTITLE(I),(DUM(J),J=1,18)
 1200  FORMAT(I2,2X,A4,18A4)
       WRITE(6,2600)ICON(I),CTITLE(I),(DUM(J),J=1,18)
 2600  FORMAT(1X,'CONSTITUENT ',I2,2X,A4,2X,18A4)
 60    CONTINUE
C*
C*     READ TREATMENT CARDS
C*
       DO 80 IRN=1,NR
       READ(5,1300)INRT(IRN),(NTREG(IRN,IT),IT=1,NT)
 1300  FORMAT(I2,10(1X,I1))
 80    CONTINUE
       DO 100 IT=1,NT
       READ(5,1400)(REM(I,IT),I=1,NC)
 1400  FORMAT(10F5.0)
 100   CONTINUE
       IF(IECHO(1).EQ.1)CALL ECHO(1)
C*
C*     READ FEEDLOT DESCRIPTION CARDS
C*
       IRF=NRF(1)
       DO 120 I=1,NF
       READ(IRF,1500)IFN(I),IELN(I),IP(I),(PCOEF(J,I),J=1,4),IE(I),
```

```
     *                IR(I),AREA(I)
1500  FORMAT(I3,1X,I3,1X,I1,38X,4F4.2,1X,I1,1X,I2,1X,F5.3)
120   CONTINUE
      CLOSE IRF
      IF(IRF.NE.5)CLOSE 5
      IF(IECHO(2).EQ.1)CALL ECHO(2)
C*
      CALL RESTRT(IYST)
      CALL ORDER
C*
C*    BEGIN TIME LOOPS
C*
      IRF=NRF(3)
      DO 540 IY=IYST,NYEARS
      DO 260 IM=1,12
      ND=MONTH(IM)
      DO 240 ID=1,ND
      READ(IRF,/)(PT(I),I=1,NS)
      DO 180 I=1,NS
      PT(I)=PT(I)*2.54
      PMT(I,IM)=PMT(I,IM)+PT(I)
180   CONTINUE
      DO 220 INF=1,NF
      CALL FLOW(INF,IM,ID,Q)
      Q=Q*0.1*AREA(INF)
      CALL CONC(INF,IM,ID)
      DO 200 I=1,NC
      C(I)=C(I)*Q
      FMT1(I,IM,INF)=FMT1(I,IM,INF)+C(I)
200   CONTINUE
220   CONTINUE
240   CONTINUE
260   CONTINUE
C*    ACCUMULATE TOTALS
C*
      DO 280 IM=1,12
      DO 280 I=1,NS
      PTOT(I,IM)=PTOT(I,IM)+PMT(I,IM)
280   CONTINUE
      DO 340 INF=1,NF
      IRN=IR(INF)
      DO 320 IM=1,12
      DO 300 I=1,NC
      FMT2(I,IM,INF)=FMT2(I,IM,INF)+FMT1(I,IM,INF)
      RMT1(I,IM,IRN)=RMT1(I,IM,IRN)+FMT1(I,IM,INF)
300   CONTINUE
320   CONTINUE
340   CONTINUE
      DO 460 IRN=1,NR
      IEN=IREN(IRN)
      DO 440 IM=1,12
      DO 420 I=1,NC
      RMT2(I,IM,IRN)=RMT2(I,IM,IRN)+RMT1(I,IM,IRN)
      RMT2SQ(I,IM,IRN)=RMT2SQ(I,IM,IRN)+RMT1(I,IM,IRN)*RMT1(I,IM,IRN)
      DO 400 IT=1,NT
      IF(NTREG(IRN,IT).NE.1)GO TO 360
      DUM(1)=RMT1(I,IM,IRN)*REM(I,IT)
      GO TO 380
360   CONTINUE
      DUM(1)=RMT1(I,IM,IRN)
380   CONTINUE
      EMT1(I,IT,IM,IEN)=EMT1(I,IT,IM,IEN)+DUM(1)
400   CONTINUE
420   CONTINUE
440   CONTINUE
460   CONTINUE
      DO 480 IEN=1,NE
      DO 480 IM=1,12
      DO 480 IT=1,NT
      DO 480 I=1,NC
      EMT2(I,IT,IM,IEN)=EMT2(I,IT,IM,IEN)+EMT1(I,IT,IM,IEN)
      TOM1(I,IT,IM)=TOM1(I,IT,IM)+EMT1(I,IT,IM,IEN)
```

```
480   CONTINUE
      DO 500 IM=1,12
      DO 500 IT=1,NT
      DO 500 I=1,NC
      TOM2(I,IT,IM)=TOM2(I,IT,IM)+TOM1(I,IT,IM)
      TOM2SQ(I,IT,IM)=TOM2SQ(I,IT,IM)+TOM1(I,IT,IM)*TOM1(I,IT,IM)
      TOY1(I,IT)=TOY1(I,IT)+TOM1(I,IT,IM)
500   CONTINUE
      DO 520 IT=1,NT
      DO 520 I=1,NC
      TOY2(I,IT)=TOY2(I,IT)+TOY1(I,IT)
      TOY2SQ(I,IT)=TOY2SQ(I,IT)+TOY1(I,IT)*TOY1(I,IT)
520   CONTINUE
      CALL OUTPUT(IY)
540   CONTINUE
      LOCK IRF
      LOCK NWF(1)
      LOCK NWF(2)
      IF(NYEARS.NE.1)CALL STAT
      CALL RERUN
      RETURN
      END
      SUBROUTINE ECHO(N)
      COMMON /A/ NF,NR,NE,NRF(6),NWF(7),IECHO(6),IOUTOP(10),NC,ICON(10),
     *       NS,NYEARS,NT,REM(10,10),NTREG(30,10),IFN(300),IELN(300),
     *       IP(300),PCOEF(5,300),IE(300),IR(300),AREA(300),RTITLE(40),
     *       CTITLE(10),MTITLE(12),STA(4),MONTH(12),NFMAX,NRMAX,
     *       NEMAX,NCMAX,NTMAX,NPRMAX,DATE(2),ITIME(3),TT(300,12),
     *       DECAY(10),PT(4),PQ(5,300),PP(5,300),C(10),IREN(30),
     *       IEORD(10),IRORD(30),IEFN(300),IRFN(300),INRT(30),
     *       IOUTOR(300),PMT(4,12),PTOT(4,12),FMT1(10,12,300)
      COMMON /B/ FMT2(10,12,300),RMT1(10,12,30),RMT2(10,12,30),
     *       RMT2SQ(10,12,30),STDRMT(10,12,30),EMT1(10,10,12,10)
      COMMON /C/ EMT2(10,10,12,10),TOM1(10,10,12),TOM2(10,10,12),
     *       TOM2SQ(10,10,12),STDTOM(10,10,12),TOY1(10,10),TOY2(10,10),
     *       TOY2SQ(10,10),STDTOY(10,10)
      REAL NUM(10)
      DATA NUM/' 1',' 2',' 3',' 4',' 5',' 6',' 7',' 8',' 9','10'/
      GO TO (20,80),N
20    CONTINUE
      WRITE(6,2100)(NUM(I),I=1,NT)
2100  FORMAT(1H1,//,1X,'TREATMENT DATA',//,1X,'ARRAY NTREG',/,1X,
     *       'THE ENTRY "1" INDICATES THE TREATMENT IS TO BE APPLIED ',
     *       'IN THE REGION',//,14X,'TREATMENT',/,1X,'REGION',4X,
     *       10(A2,1X))
      DO 40 I=1,NR
      WRITE(6,2200)INRT(I),(NTREG(I,J),J=1,NT)
2200  FORMAT(3X,I2,7X,10(I1,2X))
40    CONTINUE
      WRITE(6,2300)(NUM(I),I=1,NT)
2300  FORMAT(///,1X,'ARRAY REM',/,1X,'FRACTION OF QUALITY CONSTITUENT',
     *       ' REMAINING AFTER TREATMENT',//,20X,'TREATMENT',/,1X,
     *       'CONSTITUENT',1X,10(A2,4X))
      DO 60 I=1,NC
      WRITE(6,2400)I,(REM(I,J),J=1,NT)
2400  FORMAT(5X,I2,5X,10(F4.2,2X))
60    CONTINUE
      RETURN
80    CONTINUE
      WRITE(6,2500)
2500  FORMAT(1H1,///,53X,'FEEDLOT DESCRIPTION DATA',//,85X,
     *       'PRECIPITATION',/,30X,'FEEDLOT  ELEMENT  PAVED   REGION  ',
     *       'ENTRANCE  AREA',8X,'COEFFICIENT',/,47X,'(YES=0)',20X,
     *       '(HA)      A      B      C      D',/)
      DO 100 I=1,NF
      WRITE(6,2600)IFN(I),IELN(I),IP(I),IR(I),IE(I),AREA(I),
     *            (PCOEF(J,I),J=1,4)
2600  FORMAT(32X,I3,6X,I3,6X,I1,7X,I2,7X,I2,5X,F5.3,4(2X,F4.2))
100   CONTINUE
      RETURN
      END
      SUBROUTINE RESTRT(IYST)
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      COMMON /A/ NF,NR,NE,NRF(6),NWF(7),IECHO(6),IOUTOP(10),NC,ICON(10),
     *        NS,NYEARS,NT,REM(10,10),NTREG(30,10),IFN(300),IELN(300),
     *        IP(300),PCOEF(5,300),IE(300),IR(300),AREA(300),RTITLE(40),
     *        CTITLE(10),MTITLE(12),STA(4),MONTH(12),NFMAX,NRMAX,
     *        NEMAX,NCMAX,NTMAX,NPRMAX,DATE(2),ITIME(3),TT(300,12),
     *        DECAY(10),PT(4),PQ(5,300),PP(5,300),C(10),IREN(30),
     *        IEORD(10),IRORD(30),IEFN(300),IRFN(300),INRT(30),
     *        IOUTOR(300),PMT(4,12),PTOT(4,12),FMT1(10,12,300)
      COMMON /B/ FMT2(10,12,300),RMT1(10,12,30),RMT2(10,12,30),
     *        RMT2SQ(10,12,30),STDRMT(10,12,30),EMT1(10,10,12,10)
      COMMON /C/ EMT2(10,10,12,10),TOM1(10,10,12),TOM2(10,10,12),
     *        TOM2SQ(10,10,12),STDTOM(10,10,12),TOY1(10,10),TOY2(10,10),
     *        TOY2SQ(10,10),STDTOY(10,10)
      IF(IOUTOP(1).EQ.1)GO TO 20
      IYST=1
      RETURN
20    CONTINUE
      IRF=NRF(2)
      READ(IRF,/)J1,J2,J3,J4,J5,J6,J7
      IYST=J1+1
      NYEARS=NYEARS+J1
      IF(J2.EQ.NS.AND.J3.EQ.NF.AND.J4.EQ.NR.AND.J5.EQ.NE.AND.J6.EQ.NT
     *          .AND.J7.EQ.NC)GO TO 40
      WRITE(6,2000)J2,J3,J4,J5,J6,J7
2000  FORMAT(///,1X,'**** ERROR: RESTART DATA IS NOT COMPATIBLE WITH ',
     *        'USER INPUT DATA',/,10X,'INPUT FILE SHOWS THAT NS=',I2,3X,
     *        'NF=',I3,3X,'NR=',I2,3X,'NE=',I2,3X,'NT=',I2,3X,'NC=',I2)
      STOP
40    CONTINUE
      DO 60 IM=1,12
      READ(IRF,/) (PTOT(I,IM),I=1,NS)
60    CONTINUE
      DO 80 INF=1,NF
      DO 80 IM=1,12
      READ(IRF,/) (FMT2(I,IM,INF),I=1,NC)
80    CONTINUE
      DO 100 IRN=1,NR
      DO 100 IM=1,12
      READ(IRF,/) (RMT2(I,IM,IRN),I=1,NC)
      READ(IRF,/) (RMT2SQ(I,IM,IRN),I=1,NC)
100   CONTINUE
      DO 120 IEN=1,NE
      DO 120 IM=1,12
      DO 120 IT=1,NT
      READ(IRF,/) (EMT2(I,IT,IM,IEN),I=1,NC)
120   CONTINUE
      DO 140 IM=1,12
      DO 140 IT=1,NT
      READ(IRF,/) (TOM2(I,IT,IM),I=1,NC)
      READ(IRF,/) (TOM2SQ(I,IT,IM),I=1,NC)
140   CONTINUE
      DO 160 IT=1,NT
      READ(IRF,/) (TOY2(I,IT),I=1,NC)
      READ(IRF,/) (TOY2SQ(I,IT),I=1,NC)
160   CONTINUE
      CLOSE IRF
C*
C*    POSITION PRECIPITATION FILE
C*
      IRF=NRF(3)
      J1=J1*365
      DO 180 I=1,J1
      READ(IRF,2100)
2100  FORMAT(/)
180   CONTINUE
      RETURN
      END
      SUBROUTINE ORDER
      COMMON /A/ NF,NR,NE,NRF(6),NWF(7),IECHO(6),IOUTOP(10),NC,ICON(10),
     *        NS,NYEARS,NT,REM(10,10),NTREG(30,10),IFN(300),IELN(300),
     *        IP(300),PCOEF(5,300),IE(300),IR(300),AREA(300),RTITLE(40),
     *        CTITLE(10),MTITLE(12),STA(4),MONTH(12),NFMAX,NRMAX,
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      *       NEMAX,NCMAX,NTMAX,NPRMAX,DATE(2),ITIME(3),TT(300,12),
      *       DECAY(10),PT(4),PQ(5,300),PP(5,300),C(10),IREN(30),
      *       IEORD(10),IRORD(30),IEFN(300),IRFN(300),INRT(30),
      *       IOUTOR(300),PMT(4,12),PTOT(4,12),FMT1(10,12,300)
       COMMON /B/ FMT2(10,12,300),RMT1(10,12,30),RMT2(10,12,30),
      *       RMT2SQ(10,12,30),STDRMT(10,12,30),EMT1(10,10,12,10)
       COMMON /C/ EMT2(10,10,12,10),TOM1(10,10,12),TOM2(10,10,12),
      *       TOM2SQ(10,10,12),STDTOM(10,10,12),TOY1(10,10),TOY2(10,10),
      *       TOY2SQ(10,10),STDTOY(10,10)
       DIMENSION N(300),DUM1(300),DUM2(5,300),IDUM1(300),IDUM2(300),
      *          IDUM3(30,10),IFORD(300)
       DO 20 INF=1,NF
       J=IFN(INF)
       IFORD(J)=INF
       N(INF)=IE(INF)*100000+IR(INF)*1000+J
20     CONTINUE
       CALL ORD(N,NF)
       DO 60 INF=1,NF
       I=N(INF)-(N(INF)/1000)*1000
       J=IFORD(I)
       IFN(INF)=I
       IEFN(INF)=IE(J)
       IRFN(INF)=IR(J)
       DUM1(INF)=AREA(J)
       IDUM1(INF)=IP(J)
       DO 40 IS=1,NS
       DUM2(IS,INF)=PCOEF(IS,J)
40     CONTINUE
60     CONTINUE
       DO 100 INF=1,NF
       AREA(INF)=DUM1(INF)
       IP(INF)=IDUM1(INF)
       DO 80 IS=1,NS
       PCOEF(IS,INF)=DUM2(IS,INF)
80     CONTINUE
100    CONTINUE
       K=1
       L=1
       IEORD(1)=IEFN(1)
       IRORD(1)=IRFN(1)
       DO 140 INF=2,NF
       J=IEFN(INF)
       IF(J.EQ.IEORD(K)) GO TO 120
       K=K+1
       IEORD(K)=J
120    CONTINUE
       J=IRFN(INF)
       IF(J.EQ.IRORD(L))GO TO 140
       L=L+1
       IRORD(L)=J
140    CONTINUE
       DO 160 IEN=1,NE
       I=IEORD(IEN)
       IDUM1(I)=IEN
160    CONTINUE
       DO 180 IRN=1,NR
       I=IRORD(IRN)
       IDUM2(I)=IRN
180    CONTINUE
       DO 200 INF=1,NF
       IEN=IEFN(INF)
       I=IDUM1(IEN)
       IE(INF)=I
       IRN=IRFN(INF)
       J=IDUM2(IRN)
       IR(INF)=J
       IOUTOR(J)=IEN
       IREN(J)=I
200    CONTINUE
       DO 280 IRN=1,NR
       JRN=IRORD(IRN)
       DO 220 J=1,NR
```

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      K=J
      IF(INRT(J).EQ.JRN)GO TO 240
220   CONTINUE
      WRITE(6,2000)(INRT(L),L=1,NR)
2000  FORMAT(///, ' *** ERROR   REGION NUMBERS ON TREATMENT CARDS DO ',
     *       'NOT MATCH REGION NUMBERS ON FEEDLOT IDENTIFICATION ',
     *       'CARDS',/,1X,'REGIONS ON TREATMENT CARDS = ',30(I2,1X))
      WRITE(6,2100)(IRORD(L),L=1,NR)
2100  FORMAT(1X,'REGION NUMBERS ON FEEDLOT ID CARDS = ',30(I2,1X))
      STOP
240   CONTINUE
      DO 260 IT=1,NT
      IDUM3(IRN,IT)=NTREG(K,IT)
260   CONTINUE
280   CONTINUE
      DO 300 IT=1,NT
      DO 300 IRN=1,NR
      NTREG(IRN,IT)=IDUM3(IRN,IT)
300   CONTINUE
      RETURN
      END
      SUBROUTINE ORD(V,NOV)
      INTEGER V(300),V1
      L=NOV
10    CONTINUE
      L=L/2
      IF(L.LE.0)RETURN
      M=NOV-L
      DO 30 I=1,M
      J=I
20    CONTINUE
      JJ=J+L
      IF((V(J)-V(JJ)).LE.0)GO TO 30
      V1=V(J)
      V(J)=V(JJ)
      V(JJ)=V1
      J=J-L
      IF(J.GT.0)GO TO 20
30    CONTINUE
      GO TO 10
      END
      SUBROUTINE FLOW(INF,IM,ID,Q)
      COMMON /A/ NF,NR,NE,NRF(6),NWF(7),IECHO(6),IOUTOP(10),NC,ICON(10),
     *       NS,NYEARS,NT,REM(10,10),NTREG(30,10),IFN(300),IELN(300),
     *       IP(300),PCOEF(5,300),IE(300),IR(300),AREA(300),RTITLE(40),
     *       CTITLE(10),MTITLE(12),STA(4),MONTH(12),NFMAX,NRMAX,
     *       NEMAX,NCMAX,NTMAX,NPRMAX,DATE(2),ITIME(3),TT(300,12),
     *       DECAY(10),PT(4),PQ(5,300),PP(5,300),C(10),IREN(30),
     *       IEORD(10),IRORD(30),IEFN(300),IRFN(300),INRT(30),
     *       IOUTOR(300),PMT(4,12),PTOT(4,12),FMT1(10,12,300)
      COMMON /B/ FMT2(10,12,300),RMT1(10,12,30),RMT2(10,12,30),
     *       RMT2SQ(10,12,30),STDRMT(10,12,30),EMT1(10,10,12,10)
      COMMON /C/ EMT2(10,10,12,10),TOM1(10,10,12),TOM2(10,10,12),
     *       TOM2SQ(10,10,12),STDTOM(10,10,12),TOY1(10,10),TOY2(10,10),
     *       TOY2SQ(10,10),STDTOY(10,10)
      IF(IM.LE.3)GO TO 60
C*
C*    RAIN
C*
      P=0.
      DO 20 I=1,NS
      P=P+PT(I)*PCOEF(I,INF)
20    CONTINUE
      PP(1,INF)=P
      IF(IP(INF).EQ.1)GO TO 40
C*    PAVED LOT
      Q=P*0.388-0.068
      IF(Q.LT.0.)Q=0.
      RETURN
40    CONTINUE
C*    UNPAVED LOT
```

```
      IF(P.EQ.0.)GO TO 50
      S=P/(0.437-0.05*P)
      Q=(P-0.2*S)**2/(P+0.8*S)
      IF(Q.LT.0.)Q=0.
      RETURN
50    CONTINUE
      Q=0.
      RETURN
60    CONTINUE
C*
C*    SNOW
C*
      IDUM=IOUTOP(2)+1
80    CONTINUE
      IDUM=IDUM-1
      IDUMP1=IDUM+1
      PP(IDUMP1,INF)=PP(IDUM,INF)
      PQ(IDUMP1,INF)=PQ(IDUM,INF)
      IF(IDUM.NE.1)GO TO 80
      IDUM=IOUTOP(2)
      PP(1,INF)=0.
      DO 100 I=1,NS
      PP(1,INF)=PP(1,INF)+PT(I)*PCOEF(I,INF)
100   CONTINUE
      IF(IP(INF).EQ.1)GO TO 120
C*    PAVED LOT
      Q=PP(1,INF)*0.888-0.063
      IF(Q.LT.0.)Q=0.
      RETURN
120   CONTINUE
C*    UNPAVED LOT
      IF(PP(1,INF).LE.1.E-3)GO TO 140
C*    MEASURABLE EVENT
      Q=10.**(-1.798*ALOG10(PP(1,INF))-2.886)
      IF(Q.GT.0.3)Q=0.3
      GO TO 220
140   CONTINUE
C*    NO EVENT
      S=SP(5,1.,1.,1.,1.,1.,INF,IM,ID)
      IF(IM.EQ.1.AND.ID.LT.IDUM)IDUM=ID
      DO 160 I=1,IDUM
      J=I
      IF(PP(I,INF).LE.1.E-3.AND.PQ(I,INF).GT.0.)GO TO 180
160   CONTINUE
      GO TO 200
180   CONTINUE
      S=S-PQ(J,INF)
200   CONTINUE
      Q=S*0.402-0.101
220   CONTINUE
      IF(Q.LT.0.)Q=0.
      PQ(1,INF)=Q
      RETURN
      END
      SUBROUTINE CONC(INF,IM,ID)
      COMMON /A/ NF,NR,NE,NRF(6),NWF(7),IECHO(6),IOUTOP(10),NC,ICON(10),
     *       NS,NYEARS,NT,REM(10,10),NTREG(30,10),IFN(300),IELN(300),
     *       IP(300),PCOEF(5,300),IE(300),IR(300),AREA(300),RTITLE(40),
     *       CTITLE(10),MTITLE(12),STA(4),MONTH(12),NFMAX,NRMAX,
     *       NEMAX,NCMAX,NTMAX,NPRMAX,DATE(2),ITIME(3),TT(300,12),
     *       DECAY(10),PT(4),PQ(5,300),PP(5,300),C(10),IREN(30),
     *       IEORD(10),IRORD(30),IEFN(300),IRFN(300),INRT(30),
     *       IOUTOR(300),PMT(4,12),PTOT(4,12),FMT1(10,12,300)
      COMMON /B/ FMT2(10,12,300),RMT1(10,12,30),RMT2(10,12,30),
     *       RMT2SQ(10,12,30),STDRMT(10,12,30),EMT1(10,10,12,10)
      COMMON /C/ EMT2(10,10,12,10),TOM1(10,10,12),TOM2(10,10,12),
     *       TOM2SQ(10,10,12),STDTOM(10,10,12),TOY1(10,10),TOY2(10,10),
     *       TOY2SQ(10,10),STDTOY(10,10)
C*
C*    ALTHOUGH ALL CONSTITUENTS NEED NOT BE INCLUDED, THEY MUST BE
C*    IN THE FOLLOWING ORDER:  COD BOD SS VSS NH3 TP OP .
C*    COD MUST BE INCLUDED IF BOD AND TP ARE INCLUDED.
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C*     SS MUST BE INCLUDED IF VSS IS INCLUDED.
C*
       P=PP(1,INF)
       DO 420 I=1,NC
       GO TO(20,100,140,220,240,320,340),ICON(I)
 20    CONTINUE
C*
C*     COD
C*
       IF(IM.LE.3)GO TO 60
C*     RAIN
       IF(PP(2,INF).GT.1.E-4)GO TO 40
C*     SINGLE EVENT
       C(I)=-2287.78*P+12612.81
       GO TO 400
 40    CONTINUE
C*     MULTIPLE EVENT
       C(I)=-5003.79*SP(5,1.,1.,1.,1.,1.,INF,IM,ID)+21405.67
       GO TO 400
 60    CONTINUE
C*     SNOW
       IF(IP(INF).EQ.1)GO TO 80
C*     PAVED LOT
       C(I)=34674.59*SP(3,1.,1.,1.,1.,1.,INF,IM,ID)+2379.47
       GO TO 420
 80    CONTINUE
C*     UNPAVED LOT
       C(I)=-20840.*SP(4,1.,1.,1.,1.,1.,INF,IM,ID)+21560.
       GO TO 400
 100   CONTINUE
C*
C*     BOD
C*
       IF(IP(INF).EQ.1.AND.IM.LE.3)GO TO 120
C*     PAVED RAIN AND SNOW, UNPAVED RAIN
       C(I)=0.215*C(1)+1.182
       GO TO 420
 120   CONTINUE
C*     UNPAVED SNOW
       C(I)=0.088*C(1)+0.089
       GO TO 420
 140   CONTINUE
C*
C*     SS
C*
       IF(IM.LE.3)GO TO 180
C*     RAIN
       IF(PP(2,INF).GT.1.E-4)GO TO 160
C*     SINGLE EVENT
       C(I)=865.68*P+687.78
       GO TO 420
 160   CONTINUE
C*     MULTIPLE EVENT
       C(I)=-6639.69*SP(5,1.,1.,1.,1.,1.,INF,IM,ID)+14088.
       GO TO 400
 180   CONTINUE
C*     SNOW
       IF(IP(INF).EQ.1)GO TO 200
C*     PAVED LOT
       DUM=SP(3,1.,1.,1.,1.,1.,INF,IM,ID)
       IF(DUM.EQ.0.)DUM=1.E-6
       C(I)=EXP(1.479*ALOG(DUM)+9.919)
       GO TO 400
 200   CONTINUE
C*     UNPAVED
       C(I)=-16298.46*SP(4,1.,1.,1.,1.,1.,INF,IM,ID)+14926.65
       GO TO 400
 220   CONTINUE
C*
C*     VSS
C*
       C(I)=0.627*C(I-1)+0.272
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      GO TO 420
240   CONTINUE
C*
C*    NH3
C*
      IF(IM.LE.3)GO TO 280
C*    RAIN
      IF(PP(2,INF).GT.1.E-4)GO TO 260
C*    SINGLE EVENT
      C(I)=-211.34*P+265.26
      GO TO 400
260   CONTINUE
C*    MULTIPLE EVENT
      C(I)=-127.23*SP(5,1.,1.,1.,1.,1.,INF,IM,ID)+346.23
      GO TO 400
280   CONTINUE
C*    SNOW
      IF(IP(INF).EQ.1)GO TO 300
C*    PAVED LOT
      C(I)=-553.68*SP(4,1.,1.,1.,1.,1.,INF,IM,ID)+773.81
      GO TO 400
300   CONTINUE
C*    UNPAVED LOT
      C(I)=61.21*SP(5,1.,.5,.5,.5,.5,INF,IM,ID)+15.44
      GO TO 420
320   CONTINUE
C*
C*    TP
C*
      C(I)=0.003283*C(1)+13.624
      GO TO 420
340   CONTINUE
C*
C*    OP
C*
      IF(IM.LE.3)GO TO 360
C*    RAIN
      IF(PP(2,INF).GT.1.E-4)P=SP(5,1.,1.,1.,1.,1.,INF,IM,ID)
      C(I)=3.381*P-0.016
      GO TO 400
360   CONTINUE
C*    SNOW
      IF(IP(INF).EQ.1)GO TO 380
C*    PAVED
      C(I)=-0.349*SP(3,1.,1.,1.,1.,1.,INF,IM,ID)+0.534
      GO TO 400
380   CONTINUE
C*    UNPAVED
      C(I)=4.775*SP(4,1.,1.,1.,1.,1.,INF,IM,ID)+3.436
400   CONTINUE
      IF(C(I).LT.0.)C(I)=0.
420   CONTINUE
      RETURN
      END
      FUNCTION SP(N,F1,F2,F3,F4,F5,INF,IM,ID)
      COMMON /A/ NF,NR,NE,NRF(6),NWF(7),IECHO(6),IOUTOP(10),NC,ICON(10),
     *       NS,NYEARS,NT,REM(10,10),NTREG(30,10),IFN(300),IELN(300),
     *       IP(300),PCOEF(5,300),IE(300),IR(300),AREA(300),RTITLE(40),
     *       CTITLE(10),MTITLE(12),STA(4),MONTH(12),NFMAX,NRMAX,
     *       NEMAX,NCMAX,NTMAX,NPRMAX,DATE(2),ITIME(3),TT(300,12),
     *       DECAY(10),PT(4),PQ(5,300),PP(5,300),C(10),IREN(30),
     *       IEORD(10),IRORD(30),IEFN(300),IRFN(300),INRT(30),
     *       IOUTOR(300),PMT(4,12),PTOT(4,12),FMT1(10,12,300)
      COMMON /B/ FMT2(10,12,300),RMT1(10,12,30),RMT2(10,12,30),
     *       RMT2SQ(10,12,30),STDRMT(10,12,30),EMT1(10,10,12,10)
      COMMON /C/ EMT2(10,10,12,10),TOM1(10,10,12),TOM2(10,10,12),
     *       TOM2SQ(10,10,12),STDTOM(10,10,12),TOY1(10,10),TOY2(10,10),
     *       TOY2SQ(10,10),STDTOY(10,10)
      DIMENSION FRAC(5)
      FRAC(1)=F1
      FRAC(2)=F2
      FRAC(3)=F3
```

```
      FRAC(4)=F4
      FRAC(5)=F5
      X=0.
      IF(IM.NE.1.AND.IM.NE.4)GO TO 20
      IF(ID.LT.N)N=ID
20    CONTINUE
      DO 40 I=1,N
      X=X+PP(I,INF)*FRAC(I)
40    CONTINUE
      SP=X
      RETURN
      END
      SUBROUTINE OUTPUT(IY)
      COMMON /A/ NF,NR,NE,NRF(6),NWF(7),IECHO(6),IOUTOP(10),NC,ICON(10),
     *       NS,NYEARS,NT,REM(10,10),NTREG(30,10),IFN(300),IELN(300),
     *       IP(300),PCOEF(5,300),IE(300),IR(300),AREA(300),RTITLE(40),
     *       CTITLE(10),MTITLE(12),STA(4),MONTH(12),NFMAX,NRMAX,
     *       NEMAX,NCMAX,NTMAX,NPRMAX,DATE(2),ITIME(3),TT(300,12),
     *       DECAY(10),PT(4),PQ(5,300),PP(5,300),C(10),IREN(30),
     *       IEORD(10),IRORD(30),IEFN(300),IRFN(300),INRT(30),
     *       IOUTOR(300),PMT(4,12),PTOT(4,12),FMT1(10,12,300)
      COMMON /B/ FMT2(10,12,300),RMT1(10,12,30),RMT2(10,12,30),
     *       RMT2SQ(10,12,30),STDRMT(10,12,30),EMT1(10,10,12,10)
      COMMON /C/ EMT2(10,10,12,10),TOM1(10,10,12),TOM2(10,10,12),
     *       TOM2SQ(10,10,12),STDTOM(10,10,12),TOY1(10,10),TOY2(10,10),
     *       TOY2SQ(10,10),STDTOY(10,10)
      DIMENSION UNITS1(10),DUM(10)
      DATA UNITS1/10*'(KG/'/
      IDUM=(IY/IOUTOP(3))*IOUTOP(3)
      IF(IDUM.NE.IY)GO TO 200
      IF(IY.EQ.9999)GO TO 20
      WRITE(6,2000)IY
2000  FORMAT(1H1,//,18X,58(1H*),/,18X,'*',56X,'*',/,18X,'*',2X,
     *        'TOTALS FOR YEAR ',I4,' BY MONTH, TREATMENT AND FEEDLOT',
     *       2X,'*',/,18X,'*',56X,'*',/,18X,58(1H*))
      GO TO 40
20    CONTINUE
      WRITE(6,2100)
2100  FORMAT(1H1,//,18X,58(1H*),/,18X,'*',56X,'*',/,18X,'*',2X,
     *        'AVERAGE LAKE LOADING BY MONTH, TREATMENT AND FEEDLOT  *',
     *       /,18X,'*',56X,'*',/,18X,58(1H*))
40    CONTINUE
      DO 180 IM=1,12
      X=MTITLE(IM)
      DO 160 IT=1,NT
      WRITE(6,2200)IT,X
2200  FORMAT(//,40X,'TREATMENT ',I2,4X,A4,/,40X,20(1H-),//,2X,'EN-')
      WRITE(6,2300)
2300  FORMAT('+',7X,'REGION')
      WRITE(6,2400)
2400  FORMAT('+',14X,'FEED-')
      WRITE(6,2500)(CTITLE(I),I=1,NC)
2500  FORMAT('+',16X,10(7X,A4))
      WRITE(6,2600)
2600  FORMAT(1X,'TRANCE')
      WRITE(6,2700)
2700  FORMAT('+',15X,'LOT')
      WRITE(6,2800)(UNITS1(I),I=1,NC)
2800  FORMAT('+',19X,10(1X,A4,'MONTH)'))
      WRITE(6,2900)
2900  FORMAT(' ')
      DO 140 INF=1,NF
      IRN=IR(INF)
      IEN=IE(INF)
      IF(NTREG(IRN,IT).NE.1)GO TO 80
      DO 60 I=1,NC
      DUM(I)=FMT1(I,IM,INF)*REM(I,IT)
60    CONTINUE
      GO TO 120
80    CONTINUE
      DO 100 I=1,NC
      DUM(I)=FMT1(I,IM,INF)
```

```
100   CONTINUE
120   CONTINUE
      WRITE(6,3000)IEFN(INF),IRFN(INF),IFN(INF),(DUM(I),I=1,NC)
3000  FORMAT(2X,I2,6X,I2,4X,I3,10(2X,F9.1))
140   CONTINUE
160   CONTINUE
180   CONTINUE
200   CONTINUE
      IDUM=(IY/IOUTOP(4))*IOUTOP(4)
      IF(IDUM.NE.IY)GO TO 400
      IF(IY.EQ.9999)GO TO 220
      WRITE(6,3100)IY
3100  FORMAT(1H1,//,18X,57(1H*),/,18X,'*',55X,'*',/,18X,'*',2X,
     *        'TOTALS FOR YEAR ',I4,' BY MONTH, TREATMENT AND REGION',
     *        2X,'*',/,18X,'*',55X,'*',/,18X,57(1H*))
      GO TO 240
220   CONTINUE
      WRITE(6,3200)
3200  FORMAT(1H1,//,18X,57(1H*),/,18X,'*',55X,'*',/,18X,'*',2X,
     *       'AVERAGE LAKE LOADING BY MONTH, TREATMENT AND REGION  *',
     *     /,18X,'*',55X,'*',/,18X,57(1H*))
240   CONTINUE
      DO 380 IM=1,12
      X=MTITLE(IM)
      DO 360 IT=1,NT
      WRITE(6,2200)IT,X
      WRITE(6,2300)
      WRITE(6,2500)(CTITLE(I),I=1,NC)
      WRITE(6,2600)
      WRITE(6,2800)(UNITS1(I),I=1,NC)
      WRITE(6,2900)
      DO 340 IRN=1,NR
      IDUM=IOUTOR(IRN)
      IF(NTREG(IRN,IT).NE.1)GO TO 280
      DO 260 I=1,NC
      DUM(I)=RMT1(I,IM,IRN)*REM(I,IT)
260   CONTINUE
      GO TO 320
280   CONTINUE
      DO 300 I=1,NC
      DUM(I)=RMT1(I,IM,IRN)
300   CONTINUE
320   CONTINUE
      WRITE(6,3300)IDUM,IRORD(IRN),(DUM(I),I=1,NC)
3300  FORMAT(2X,I2,6X,I2,7X,10(2X,F9.1))
340   CONTINUE
360   CONTINUE
380   CONTINUE
400   CONTINUE
      IDUM=(IY/IOUTOP(5))*IOUTOP(5)
      IF(IDUM.NE.IY)GO TO 540
      IF(IY.EQ.9999)GO TO 420
      WRITE(6,3400)IY
3400  FORMAT(1H1,//,18X,59(1H*),/,18X,'*',57X,'*',/,18X,'*',2X,
     *        'TOTALS FOR YEAR ',I4,' BY MONTH, TREATMENT AND ENTRANCE',
     *        2X,'*',/,18X,'*',57X,'*',/,18X,59(1H*))
      GO TO 440
420   CONTINUE
      WRITE(6,3500)
3500  FORMAT(1H1,//,18X,59(1H*),/,18X,'*',57X,'*',/,18X,'*',2X,
     *        'AVERAGE LAKE LOADING BY MONTH, TREATMENT AND ENTRANCE  *',
     *        /,18X,'*',57X,'*',/,18X,59(1H*))
440   CONTINUE
      DO 520 IM=1,12
      X=MTITLE(IM)
      DO 500 IT=1,NT
      WRITE(6,3600)IT,X
3600  FORMAT(//,41X,'TREATMENT ',I2,4X,A4,/,41X,20(1H-),//,1X,
     *        'ENTRANCE')
      WRITE(6,2500)(CTITLE(I),I=1,NC)
      WRITE(6,2900)
      WRITE(6,2800)(UNITS1(I),I=1,NC)
```

```
      WRITE(6,2900)
      DO 480 IEN=1,NE
      DO 460 I=1,NC
      DUM(I)=EMT1(I,IT,IM,IEN)
460   CONTINUE
      WRITE(6,3700)IEORD(IEN),(DUM(I),I=1,NC)
3700  FORMAT(4X,I2,13X,10(2X,F9.1))
480   CONTINUE
500   CONTINUE
520   CONTINUE
540   CONTINUE
      IDUM=(IY/IOUTOP(6))*IOUTOP(6)
      IF(IDUM.NE.IY)GO TO 640
      IF(IY.EQ.9999)GO TO 560
      WRITE(6,3800)IY
3800  FORMAT(1H1,//,22X,49(1H*),/,22X,'*',47X,'*',/,22X,'*',2X,
     *        'TOTALS FOR YEAR ',I4,' BY MONTH AND TREATMENT  *',
     *        /,22X,'*',47X,'*',/,22X,49(1H*))
      GO TO 580
560   CONTINUE
      WRITE(6,3900)
3900  FORMAT(1H1,//,22X,49(1H*),/,22X,'*',47X,'*',/,22X,'*',2X,
     *        'AVERAGE LAKE LOADING BY MONTH AND TREATMENT  *',
     *        /,22X,'*',47X,'*',/,22X,49(1H*))
580   CONTINUE
      DO 620 IM=1,12
      X=MTITLE(IM)
      WRITE(6,4000)X
4000  FORMAT(//,46X,A4,/,46X,4(1H-),//,1X,'TREATMENT')
      WRITE(6,2500)(CTITLE(I),I=1,NC)
      WRITE(6,2900)
      WRITE(6,2800)(UNITS1(I),I=1,NC)
      WRITE(6,2900)
      DO 600 IT=1,NT
      WRITE(6,4100)IT,(TOM1(I,IT,IM),I=1,NC)
4100  FORMAT(4X,I2,13X,10(2X,F9.0))
600   CONTINUE
620   CONTINUE
640   CONTINUE
      IDUM=(IY/IOUTOP(7))*IOUTOP(7)
      IF(IDUM.NE.IY)GO TO 720
      IF(IY.EQ.9999)GO TO 660
      WRITE(6,4200)IY
4200  FORMAT(1H1,//,27X,39(1H*),/,27X,'*',37X,'*',/,27X,'*',2X,
     *        'TOTALS FOR YEAR ',I4,' BY TREATMENT',2X,'*',/,27X,'*',37X,
     *        '*',/,27X,39(1H*),//)
      GO TO 680
660   CONTINUE
      WRITE(6,4300)
4300  FORMAT(1H1,//,27X,39(1H*),/,27X,'*',37X,'*',/,27X,'*',2X,
     *        'AVERAGE LAKE LOADING BY TREATMENT  *',/,27X,'*',37X,'*',
     *        /,27X,39(1H*),//)
680   CONTINUE
      WRITE(6,4400)(CTITLE(I),I=1,NC)
4400  FORMAT(1X,'TREATMENT',10(6X,A4,2X))
      WRITE(6,2900)
      WRITE(6,4500)(UNITS1(I),I=1,NC)
4500  FORMAT(10X,10(3X,A4,'YEAR)'))
      WRITE(6,2900)
      DO 700 IT=1,NT
      WRITE(6,4600)IT,(TOY1(I,IT),I=1,NC)
4600  FORMAT(4X,I2,4X,10(1X,F11.0))
700   CONTINUE
720   CONTINUE
      IDUM=(IY/IOUTOP(8))*IOUTOP(8)
      IF(IDUM.NE.IY)GO TO 780
      IF(IY.EQ.9999)GO TO 740
      WRITE(6,4700)IY
4700  FORMAT(1H1,//,40X,52(1H*),/,40X,'*',50X,'*',/,40X,'*',2X,
     *        'MONTHLY PRECIPITATION FOR YEAR ',I4,' BY STATION  *',
     *        /,40X,'*',50X,'*',/,40X,52(1H*),//)
      GO TO 750
```

```
740   CONTINUE
      WRITE(6,4800)
4800  FORMAT(1H1,//,43X,46(1H*),/,43X,'*',44X,'*',/,43X,'*',2X,
     *       'AVERAGE MONTHLY PRECIPITATION BY STATION  *',/,43X,'*',
     *       44X,'*',/,43X,46(1H*),//)
750   CONTINUE
      WRITE(6,4900)(MTITLE(I),I=1,12)
4900  FORMAT(1X,'STATION',12(5X,A4,1X),/,7X,12(6X,'(CM)'),/)
      DO 760 I=1,NS
      WRITE(6,5000)I,(PMT(I,IM),IM=1,12)
5000  FORMAT(3X,I1,3X,12(5X,F5.1))
760   CONTINUE
780   CONTINUE
      IDUM=(IY/IOUTOP(9))*IOUTOP(9)
      IF(IDUM.NE.IY)GO TO 820
      IWF=NWF(1)
      DO 800 IM=1,12
      DO 800 IT=1,NT
      WRITE(IWF,/)(TOM1(I,IT,IM),I=1,NC)
800   CONTINUE
820   CONTINUE
      IDUM=(IY/IOUTOP(10))*IOUTOP(10)
      IF(IDUM.NE.IY)GO TO 860
      IWF=NWF(2)
      DO 840 IT=1,NT
      WRITE(IWF,/)(TOY1(I,IT),I=1,NC)
840   CONTINUE
860   CONTINUE
      IF(IY.EQ.9999)GO TO 1000
C*
C*    ZERO OUT CURRENT YEAR TOTALS
      DO 880 IM=1,12
      DO 880 I=1,NS
      PMT(I,IM)=0.
880   CONTINUE
      DO 900 INF=1,NF
      DO 900 IM=1,12
      DO 900 I=1,NC
      FMT1(I,IM,INF)=0.
900   CONTINUE
      DO 920 IRN=1,NR
      DO 920 IM=1,12
      DO 920 I=1,NC
      RMT1(I,IM,IRN)=0.
920   CONTINUE
      DO 940 IEN=1,NE
      DO 940 IM=1,12
      DO 940 IT=1,NT
      DO 940 I=1,NC
      EMT1(I,IT,IM,IEN)=0.
940   CONTINUE
      DO 960 IM=1,12
      DO 960 IT=1,NT
      DO 960 I=1,NC
      TOM1(I,IT,IM)=0.
960   CONTINUE
      DO 980 IT=1,NT
      DO 980 I=1,NC
      TOY1(I,IT)=0.
980   CONTINUE
      RETURN
1000  CONTINUE
      LOCK NWF(1)
      LOCK NWF(2)
C*
C*    WRITE STANDARD DEVIATIONS TO PRINTER AND DISK
C*
       WRITE(6,5100)
5100   FORMAT(1H1,//,11X,71(1H*),/,11X,'*',69X,'*',/,11X,'*',2X,
     *       'STANDARD DEVIATION OF LAKE LOADING BY MONTH, TREATMENT ',
     *       'AND REGION  *',/,11X,'*',69X,'*',/,11X,71(1H*))
       DO 1140 IM=1,12
```

```
      X=MTITLE(IM)
      DO 1120 IT=1,NT
      WRITE(6,2200)IT,X
      WRITE(6,2300)
      WRITE(6,2500)(CTITLE(I),I=1,NC)
      WRITE(6,2600)
      WRITE(6,2800)(UNITS1(I),I=1,NC)
      WRITE(6,2900)
      DO 1100 IRN=1,NR
      IDUM=IOUTOR(IRN)
      IF(NTREG(IRN,IT).NE.1)GO TO 1040
      DO 1020 I=1,NC
      DUM(I)=STDRMT(I,IM,IRN)*REM(I,IT)
 1020 CONTINUE
      GO TO 1080
 1040 CONTINUE
      DO 1060 I=1,NC
      DUM(I)=STDRMT(I,IM,IRN)
 1060 CONTINUE
 1080 CONTINUE
      WRITE(6,3300)IDUM,IRORD(IRN),(DUM(I),I=1,NC)
 1100 CONTINUE
 1120 CONTINUE
 1140 CONTINUE
      IWF=NWF(5)
      WRITE(6,5200)
 5200 FORMAT(1H1,//,14X,63(1H*),/,14X,'*',61X,'*',/,14X,'*',2X,
     *        'STANDARD DEVIATION OF LAKE LOADING BY MONTH AND TREATMENT'
     *        ,2X,'*',/,14X,'*',61X,'*',/,14X,63(1H*))
      DO 1180 IM=1,12
      X=MTITLE(IM)
      WRITE(6,4000)X
      WRITE(6,2500)(CTITLE(I),I=1,NC)
      WRITE(6,2900)
      WRITE(6,2800)(UNITS1(I),I=1,NC)
      WRITE(6,2900)
      DO 1160 IT=1,NT
      WRITE(6,4100)IT,(STDTOM(I,IT,IM),I=1,NC)
      WRITE(IWF,/)(STDTOM(I,IT,IM),I=1,NC)
 1160 CONTINUE
 1180 CONTINUE
      LOCK IWF
      IWF=NWF(6)
      WRITE(6,5300)
 5300 FORMAT(1H1,//,20X,53(1H*),/,20X,'*',51X,'*',/,20X,'*',2X,
     *        'STANDARD DEVIATION OF LAKE LOADING BY TREATMENT  *',/,
     *        20X,'*',51X,'*',/,20X,53(1H*),//)
      WRITE(6,4400)(CTITLE(I),I=1,NC)
      WRITE(6,2900)
      WRITE(6,4500)(UNITS1(I),I=1,NC)
      WRITE(6,2900)
      DO 1200 IT=1,NT
      WRITE(6,4600)IT,(STDTOY(I,IT),I=1,NC)
      WRITE(IWF,/)(STDTOY(I,IT),I=1,NC)
 1200 CONTINUE
      LOCK IWF
      RETURN
      END
      SUBROUTINE STAT
      COMMON /A/ NF,NR,NE,NRF(6),NWF(7),IECHO(6),IOUTOP(10),NC,ICON(10),
     *        NS,NYEARS,NT,REM(10,10),NTREG(30,10),IFN(300),IELN(300),
     *        IP(300),PCOEF(5,300),IE(300),IR(300),AREA(300),RTITLE(40),
     *        CTITLE(10),MTITLE(12),STA(4),MONTH(12),NFMAX,NRMAX,
     *        NEMAX,NCMAX,NTMAX,NPRMAX,DATE(2),ITIME(3),TT(300,12),
     *        DECAY(10),PT(4),PQ(5,300),PP(5,300),C(10),IREN(30),
     *        IEORD(10),IRORD(30),IEFN(300),IRFN(300),INRT(30),
     *        IOUTOR(300),PMT(4,12),PTOT(4,12),FMT1(10,12,300)
      COMMON /B/ FMT2(10,12,300),RMT1(10,12,30),RMT2(10,12,30),
     *        RMT2SQ(10,12,30),STDRMT(10,12,30),EMT1(10,10,12,10)
      COMMON /C/ EMT2(10,10,12,10),TOM1(10,10,12),TOM2(10,10,12),
     *        TOM2SQ(10,10,12),STDTOM(10,10,12),TOY1(10,10),TOY2(10,10),
     *        TOY2SQ(10,10),STDTOY(10,10)
```

```
C*
C*    CALCULATE AVERAGES
C*
      DIV=NYEARS
      DIVM1=DIV-1.
      DO 20 IM=1,12
      DO 20 I=1,NS
      PMT(I,IM)=PTOT(I,IM)/DIV
   20 CONTINUE
      DO 40 INF=1,NF
      DO 40 IM=1,12
      DO 40 I=1,NC
      FMT1(I,IM,INF)=FMT2(I,IM,INF)/DIV
   40 CONTINUE
      DO 60 IRN=1,NR
      DO 60 IM=1,12
      DO 60 I=1,NC
      RMT1(I,IM,IRN)=RMT2(I,IM,IRN)/DIV
      STDRMT(I,IM,IRN)=SQRT((RMT2SQ(I,IM,IRN)-RMT2(I,IM,IRN)**2/DIV)
     *                      /(DIVM1))
   60 CONTINUE
      DO 80 IEN=1,NE
      DO 80 IM=1,12
      DO 80 IT=1,NT
      DO 80 I=1,NC
      EMT1(I,IT,IM,IEN)=EMT2(I,IT,IM,IEN)/DIV
   80 CONTINUE
      DO 100 IM=1,12
      DO 100 IT=1,NT
      DO 100 I=1,NC
      TOM1(I,IT,IM)=TOM2(I,IT,IM)/DIV
      STDTOM(I,IT,IM)=SQRT((TOM2SQ(I,IT,IM)-TOM2(I,IT,IM)**2/DIV)
     *                     /DIVM1)
  100 CONTINUE
      DO 120 IT=1,NT
      DO 120 I=1,NC
      TOY1(I,IT)=TOY2(I,IT)/DIV
      STDTOY(I,IT)=SQRT((TOY2SQ(I,IT)-TOY2(I,IT)**2/DIV)/DIVM1)
  120 CONTINUE
      DO 140 I=1,10
      IOUTOP(I)=9999
  140 CONTINUE
      NWF(1)=NWF(3)
      NWF(2)=NWF(4)
      IY=9999
      CALL OUTPUT(IY)
      CONTINUE
      RETURN
      END
      SUBROUTINE RERUN
      COMMON /A/ NF,NR,NE,NRF(6),NWF(7),IECHO(6),IOUTOP(10),NC,ICON(10),
     *       NS,NYEARS,NT,REM(10,10),NTREG(30,10),IFN(300),IELN(300),
     *       IP(300),PCOEF(5,300),IE(300),IR(300),AREA(300),RTITLE(40),
     *       CTITLE(10),MTITLE(12),STA(4),MONTH(12),NFMAX,NRMAX,
     *       NEMAX,NCMAX,NTMAX,NPRMAX,DATE(2),ITIME(3),TT(300,12),
     *       DECAY(10),PT(4),PQ(5,300),PP(5,300),C(10),IREN(30),
     *       IEORD(10),IRORD(30),IEFN(300),IRFN(300),INRT(30),
     *       IOUTOR(300),PMT(4,12),PTOT(4,12),FMT1(10,12,300)
      COMMON /B/ FMT2(10,12,300),RMT1(10,12,30),RMT2(10,12,30),
     *       RMT2SQ(10,12,30),STDRMT(10,12,30),EMT1(10,10,12,10)
      COMMON /C/ EMT2(10,10,12,10),TOM1(10,10,12),TOM2(10,10,12),
     *       TOM2SQ(10,10,12),STDTOM(10,10,12),TOY1(10,10),TOY2(10,10),
     *       TOY2SQ(10,10),STDTOY(10,10)
      IWF=NWF(7)
      WRITE(IWF,/)NYEARS,NS,NF,NR,NE,NT,NC
      DO 20 IM=1,12
      WRITE(IWF,/)(PTOT(I,IM),I=1,NS)
   20 CONTINUE
      DO 40 INF=1,NF
      DO 40 IM=1,12
      WRITE(IWF,/)(FMT2(I,IM,INF),I=1,NC)
   40 CONTINUE
```

```
      DO 60 IRN=1,NR
      DO 60 IM=1,12
      WRITE(IWF,/)(RMT2(I,IM,IRN),I=1,NC)
      WRITE(IWF,/)(RMT2SQ(I,IM,IRN),I=1,NC)
60    CONTINUE
      DO 80 IEN=1,NE
      DO 80 IM=1,12
      DO 80 IT=1,NT
      WRITE(IWF,/)(EMT2(I,IT,IM,IEN),I=1,NC)
80    CONTINUE
      DO 100 IM=1,12
      DO 100 IT=1,NT
      WRITE(IWF,/)(TOM2(I,IT,IM),I=1,NC)
      WRITE(IWF,/)(TOM2SQ(I,IT,IM),I=1,NC)
100   CONTINUE
      DO 120 IT=1,NT
      WRITE(IWF,/)(TOY2(I,IT),I=1,NC)
      WRITE(IWF,/)(TOY2SQ(I,IT),I=1,NC)
120   CONTINUE
      LOCK IWF
      RETURN
      END
#
```

APPENDIX C

SITE DESCRIPTIONS OF EXPERIMENTAL FEEDLOTS USED TO DETERMINE MASS LOADING FUNCTIONS

KEY TO FIGURES C-I — C-4

COVERED FEEDING AREAS

OPEN AREAS

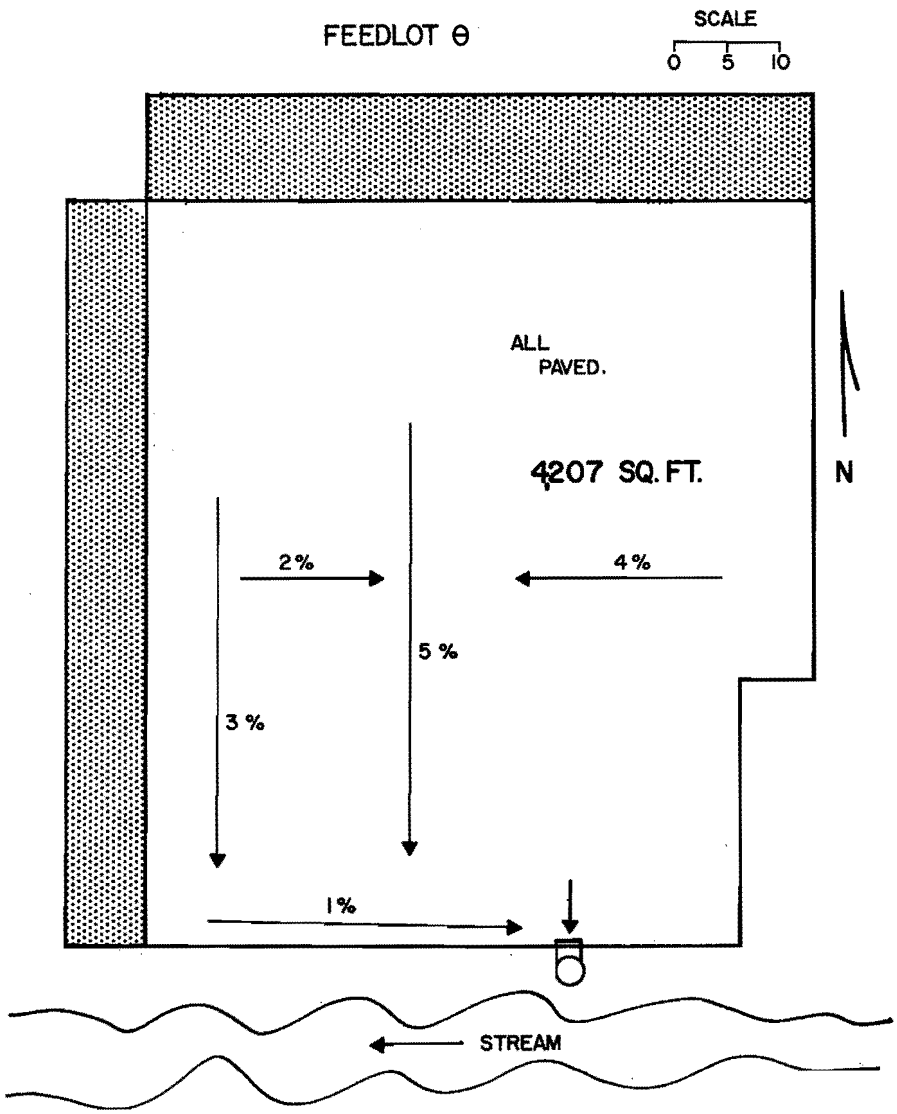


Figure C-1. Dimensions and slope of feedlot θ.

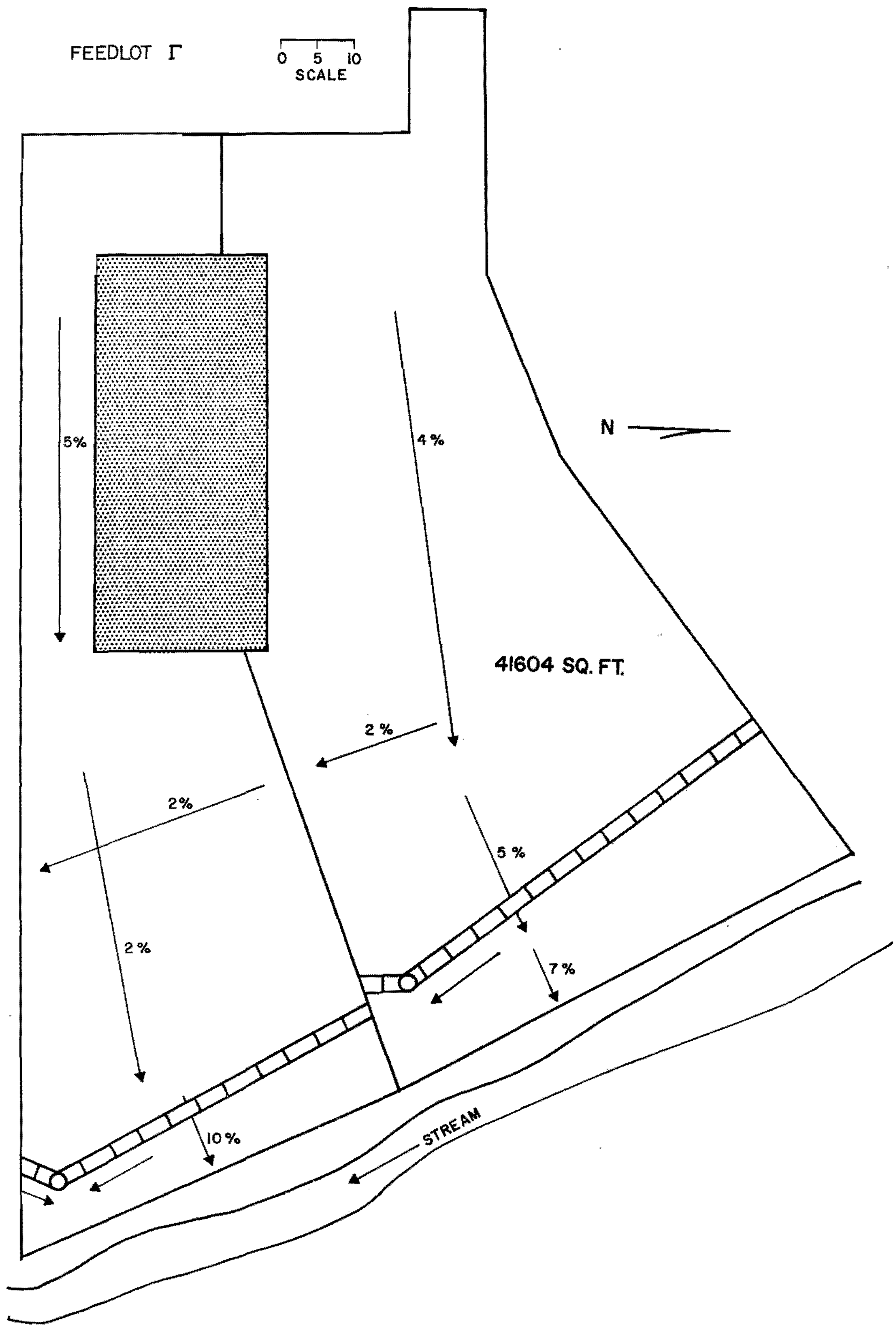


Figure C-2. Dimensions and slope of feedlot Γ.

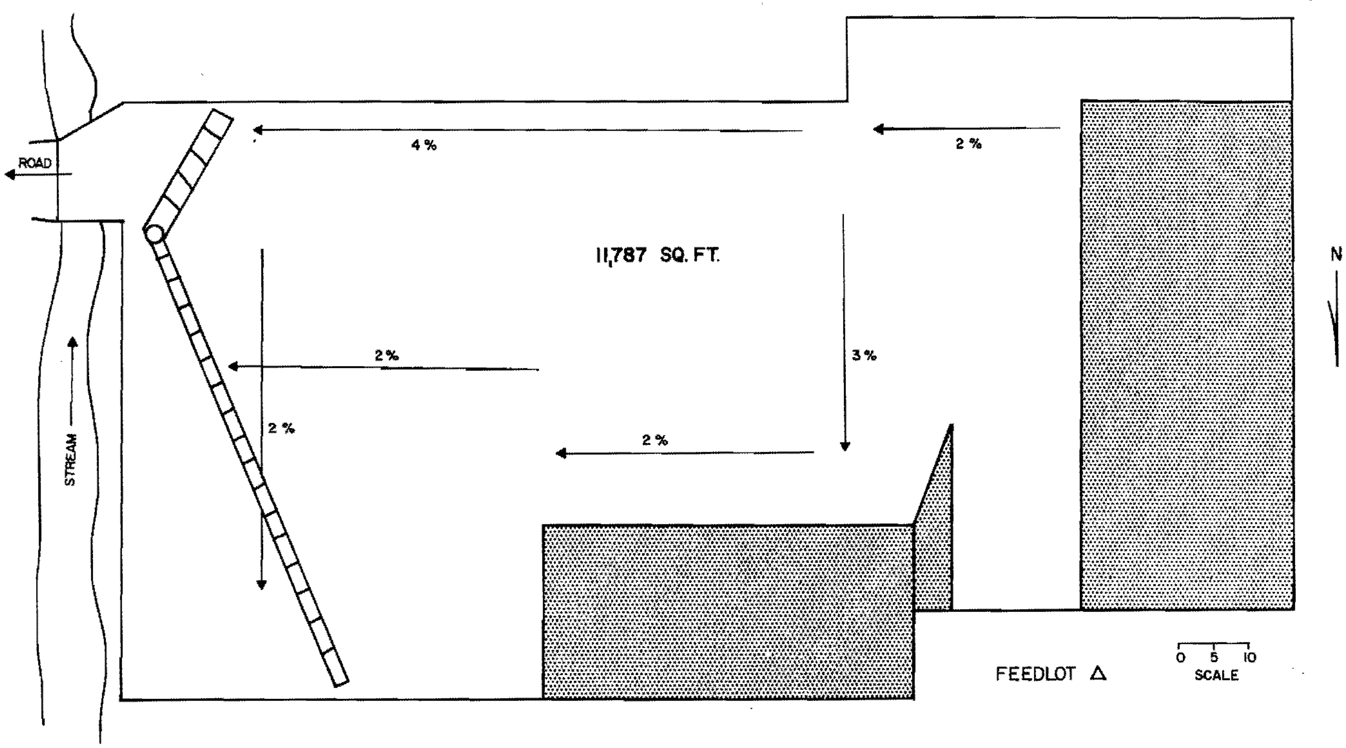


Figure C-3. Dimensions and slope of feedlot Δ.

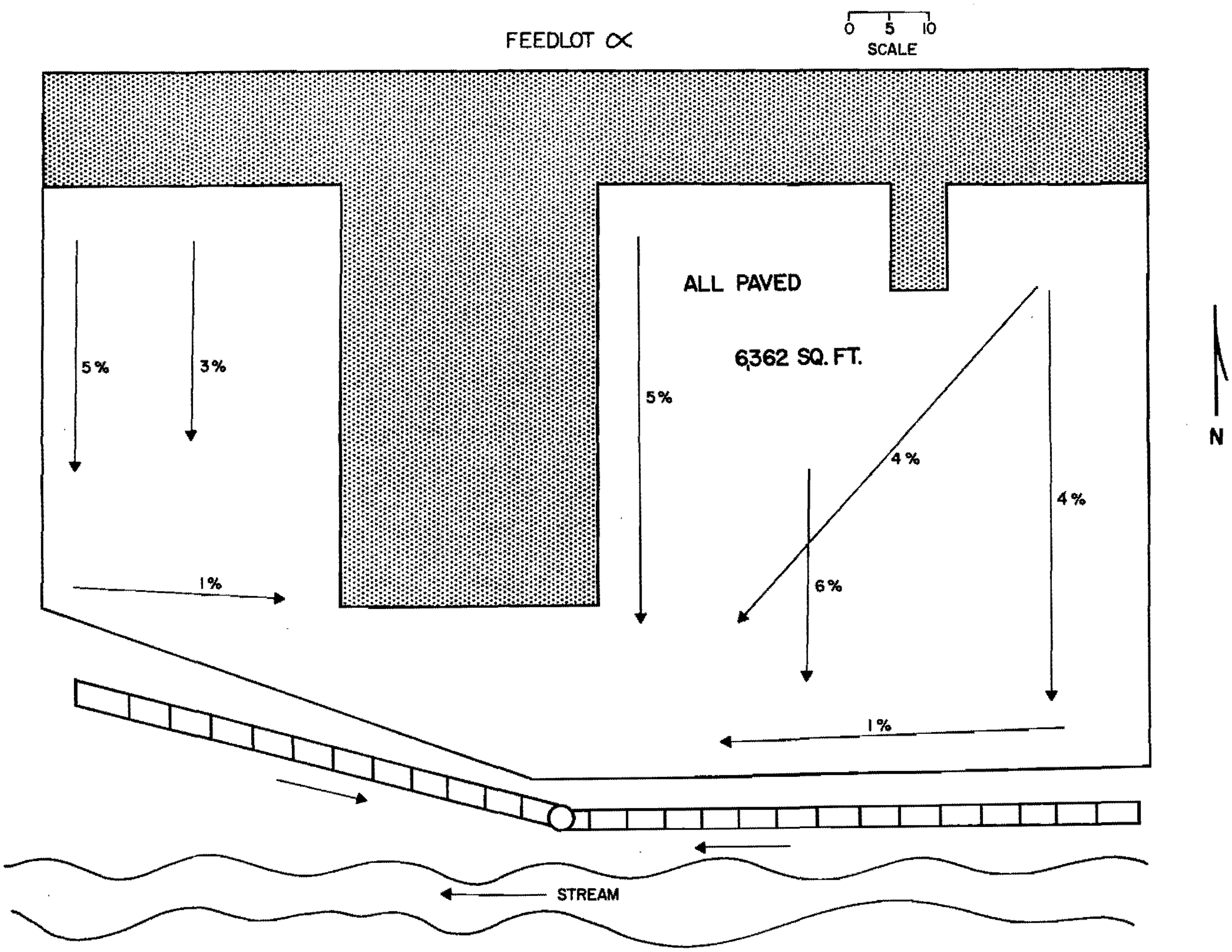


Figure C-4. Dimensions and slope of feedlot α.

APPENDIX D

SITE DESCRIPTIONS OF FEEDLOTS MONITORED DURING

STREAM MONITORING PHASE OF THE STUDY

KEY TO FIGURES D-1 — D-8

COVERED FEEDING AREAS **OPEN AREAS**

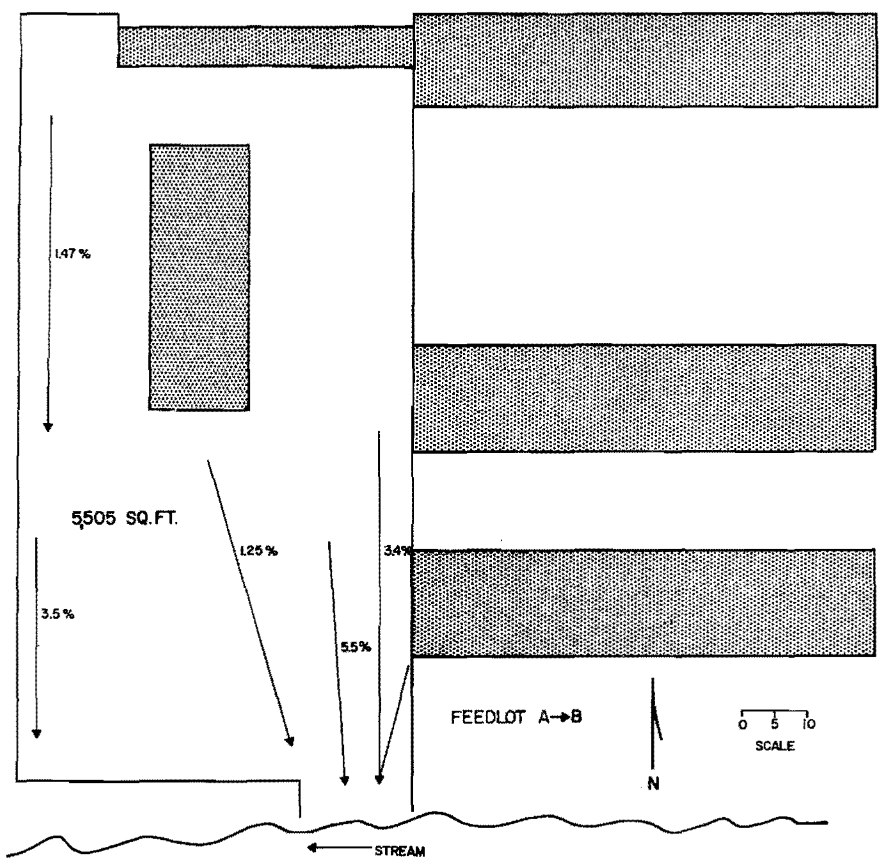


Figure D-1. Dimensions and slope of feedlots A-B.

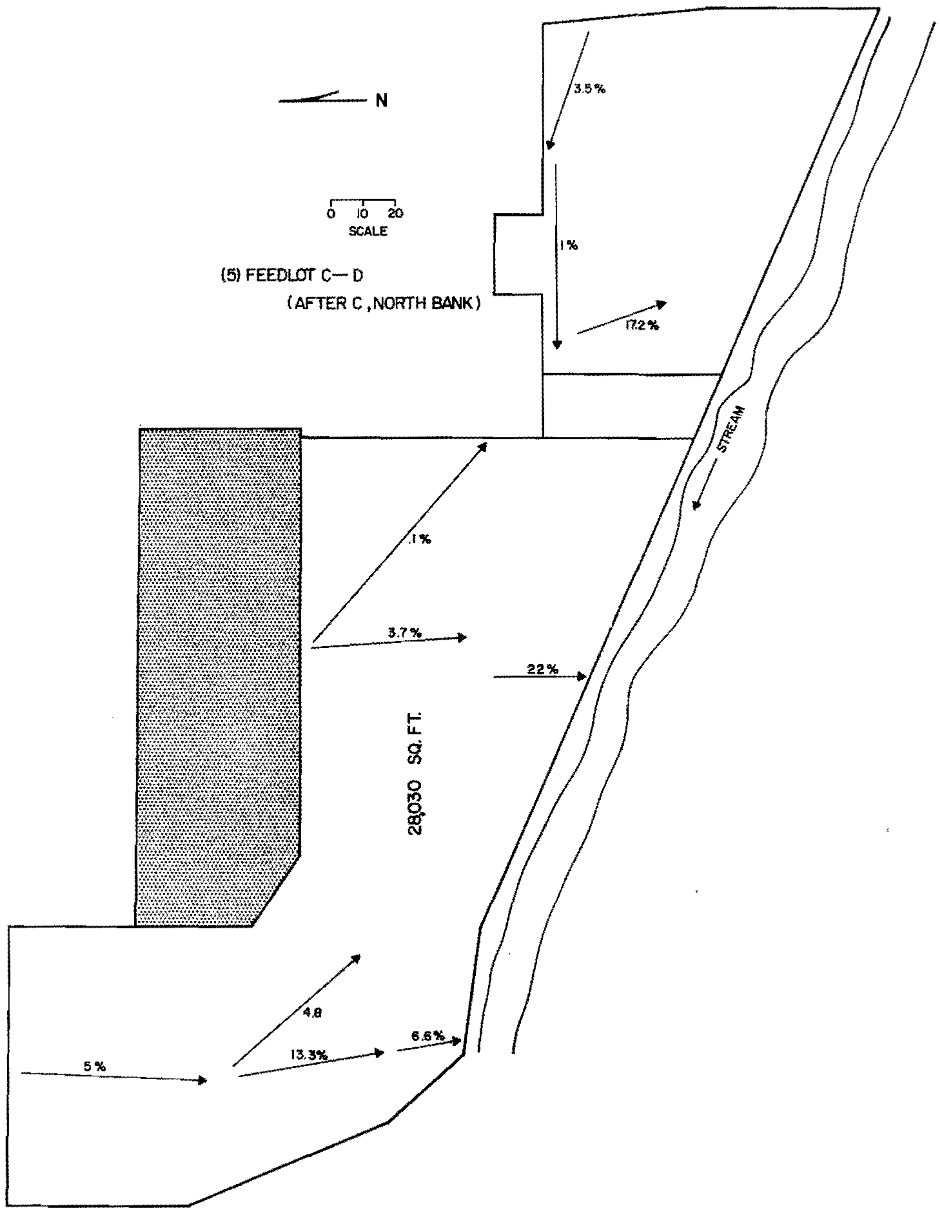


Figure D-2. Dimensions and slope of feedlots C-D (after C, North Bank).

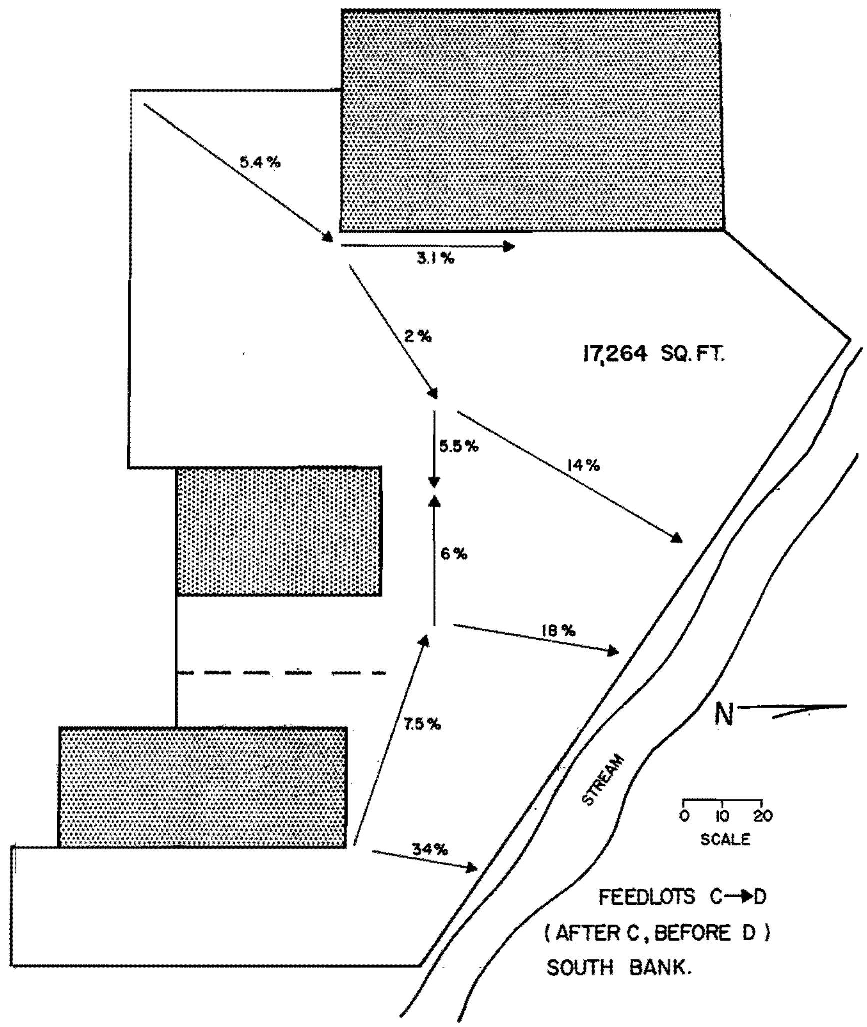


Figure D-3. Dimensions and slope of feedlots C-D (after C, before D, South Bank).

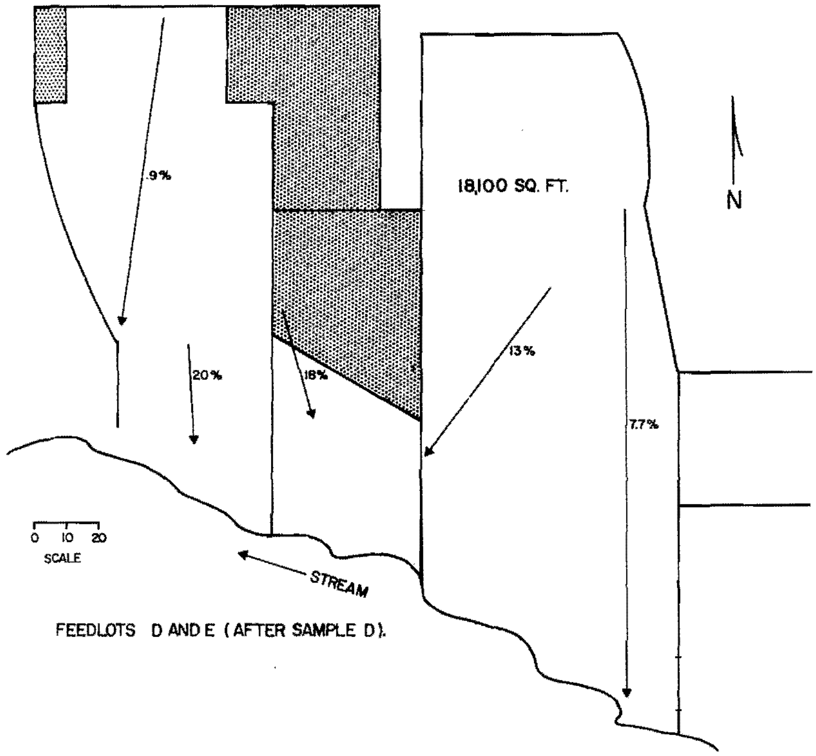


Figure D-4. Dimensions and slope of feedlots D-E.

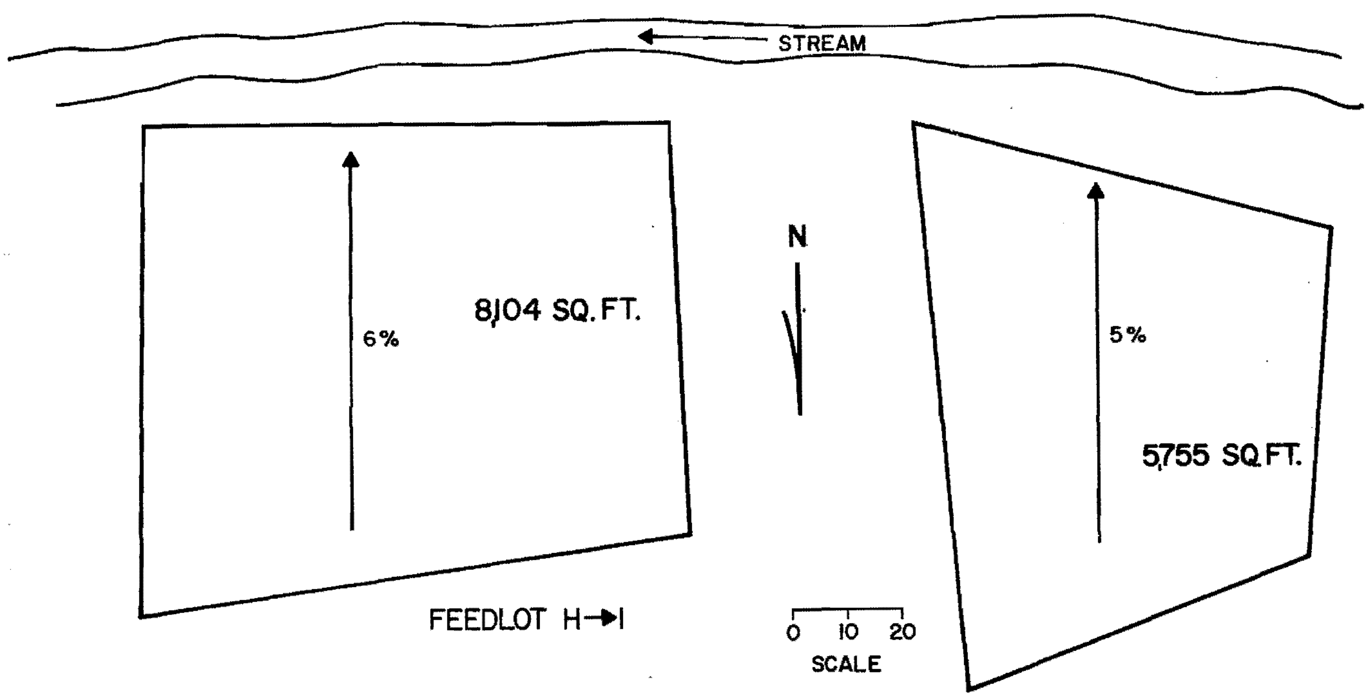


Figure D-5. Dimensions and slope of feedlots H-I.

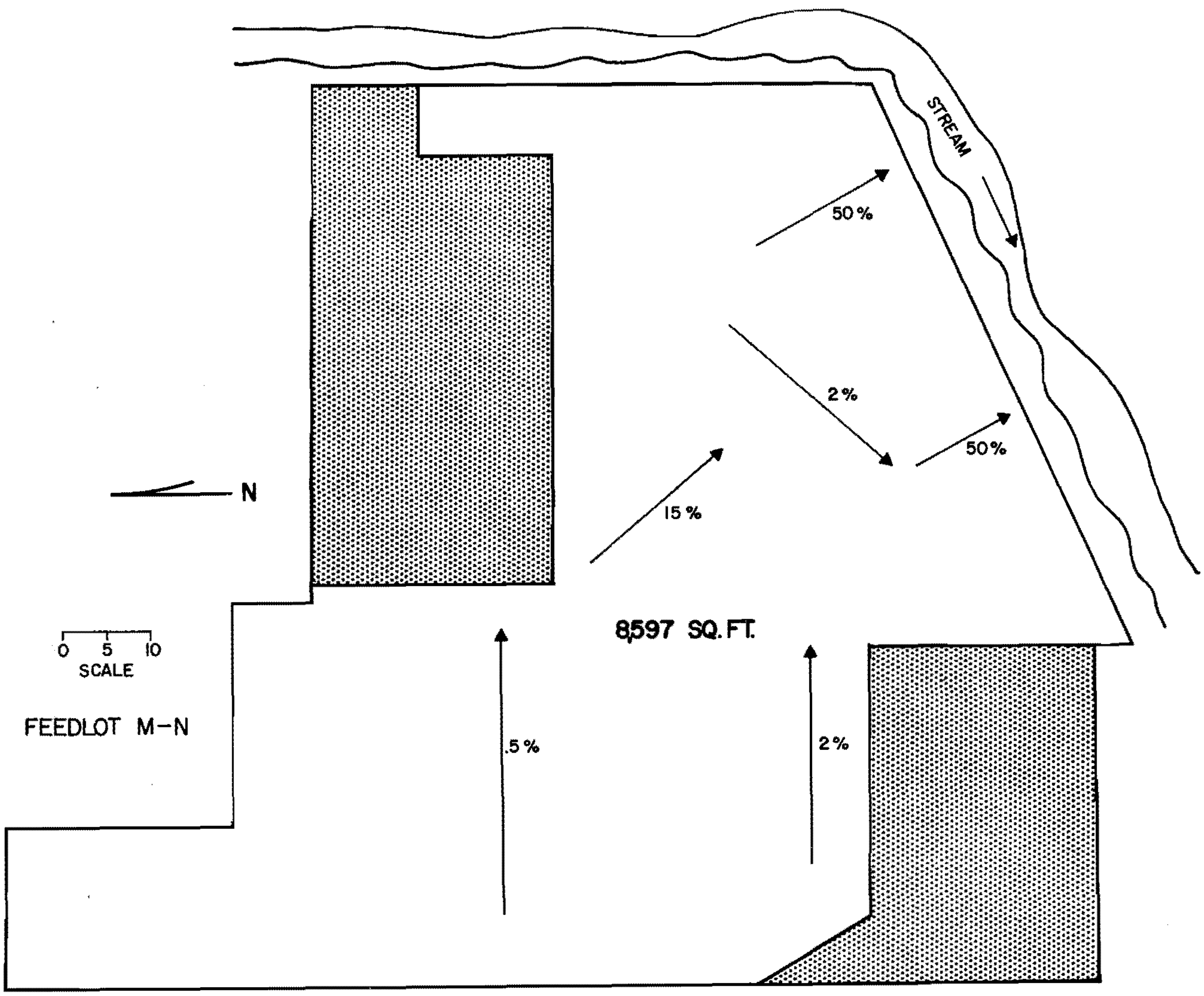


Figure D-6. Dimensions and slope of feedlots M-N.

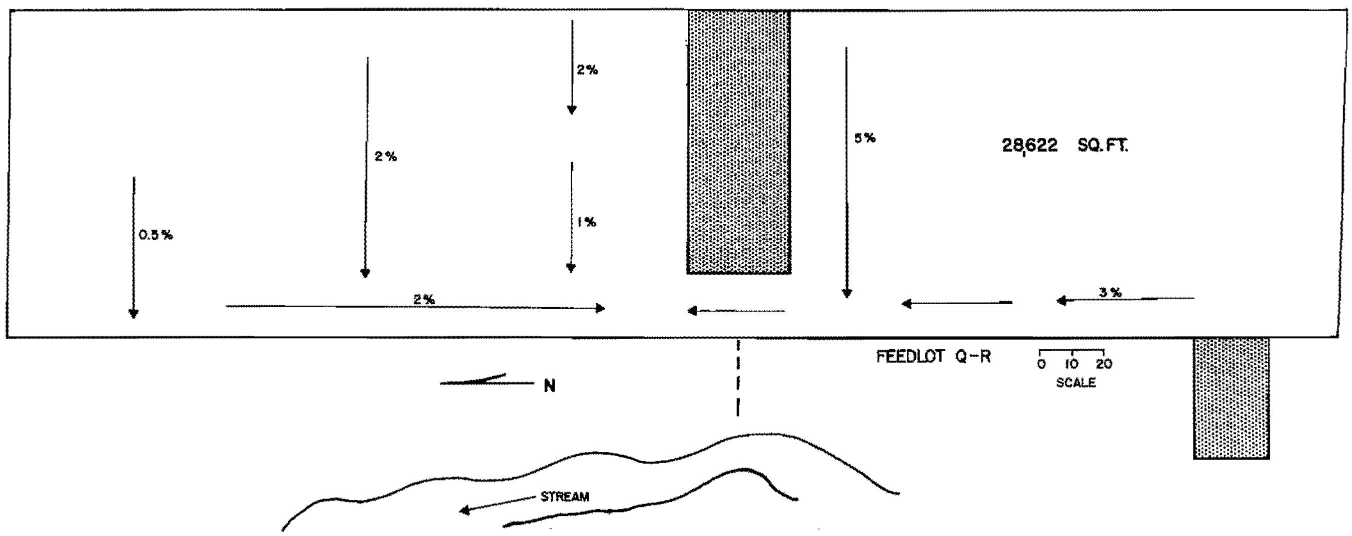


Figure D-7. Dimensions and slope of feedlots Q-R.

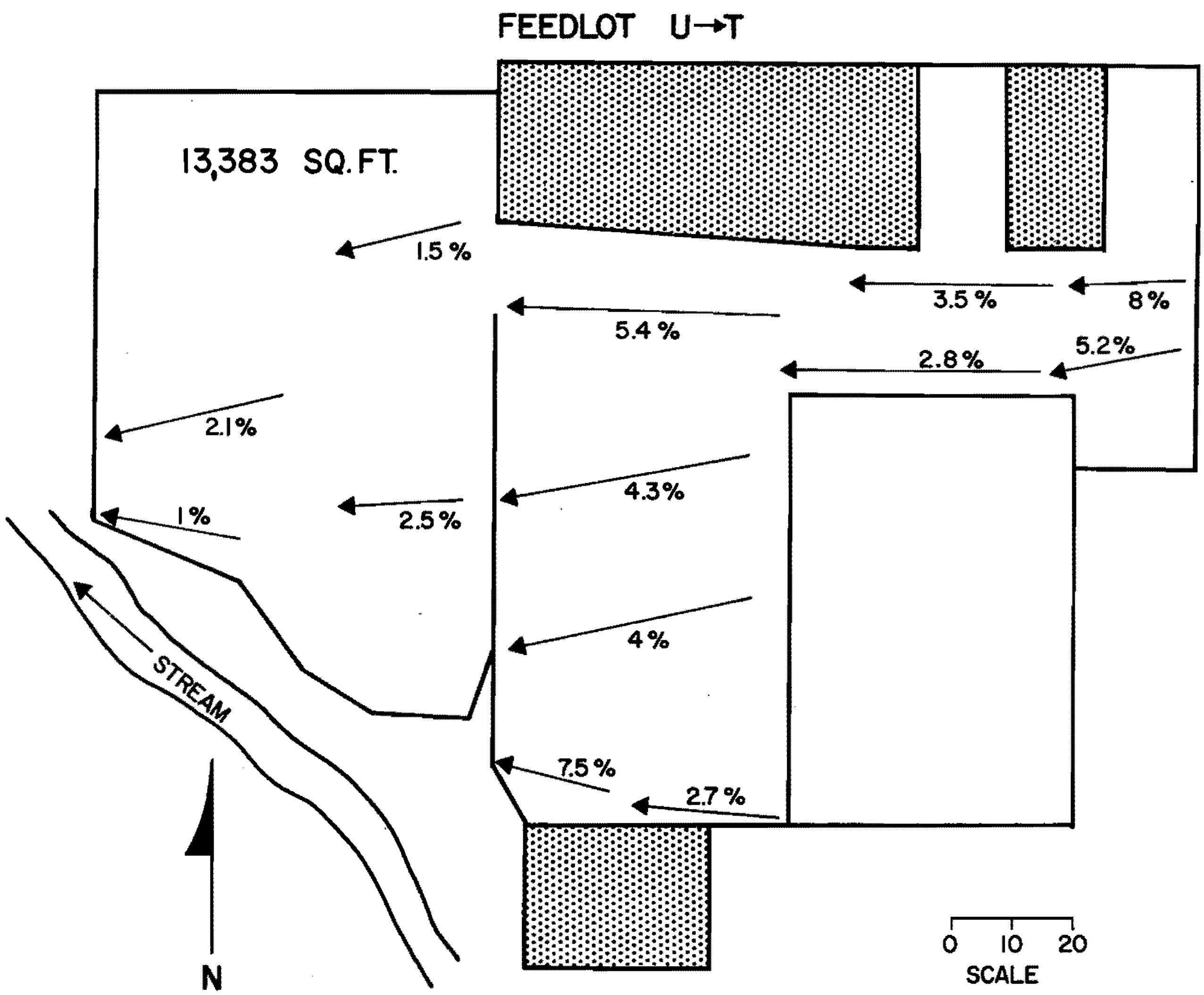


Figure D-8. Dimensions and slope of feedlots U-T.

APPENDIX E

FEEDLOT RECORDS OF CACHE VALLEY, UTAH

Table E-1. Feedlot records of Cache Valley.

Lot Number	Location	Cattle Number	Slope (%)	Surface	Area (ha)	Potential Discharge	Cattle Type	Density (# head/ ha)	Region Number	Entrance Point
1	Clarkston T14 N R2 W S26	50+	2.3	S	0.139	M	Beef	359.7	NR	NR
2	Clarkston T14 N R2 W S26	23	4.0	S	0.084	M	Dairy	273.8	NR	NR
3	Clarkston T14 N R2 W S26	9	2.7	S	0.023	M	Dairy	391.3	NR	NR
4	Clarkston T14 N R2 W S27	7	6.4	S	0.039	L	Beef	179.5	NR	NR
5	Outside Cornish T14 N R1 W S17	90	8.1	P	0.297	L	NR	303.0	11	1
6	Cornish T14 N R1 W S16	6	3.7	P	0.028	L	Beef	214.3	3	1
7	Cornish T14 N R1 W S4	100+	4.2	S/P	0.409	H	Dairy	244.5	3	1
8	Cornish T14 N R1 W S10	33	1.6	S	0.074	L	Beef	445.9	3	1
9	Young Ward T11 N R1 W S21	50	2.0	S/P	0.116	M	Dairy	431.0	8	3
10	Young Ward T11 N R1 W S11	100	2.5	P	0.209	L	NR	478.5	8	3
11	Young Ward T11 N R1 W S14	50+	2.6	P	0.102	M	NR	490.2	8	3
12	Benson T12 N R1 W S11	100	1.4	P/S	0.158	M	Dairy	632.9	14	1
13	Benson T12 N R1 W S3	50+	8.1	S	0.084	L	Dairy	595.2	14	1
14	Benson T12 N R1 W S2	45	7.7	S	0.321	H	Dairy	140.2	14	1
15	Benson T12 N R1 W S2	19	14.3	S	0.260	H	Dairy	73.1	14	1
16	Benson T12 N R1 W S1	100+	3.6	P	0.112	H	Dairy	892.9	14	1
17	Benson T12 N R1 W S11	175	1.0	P	0.093	L	Dairy	1881.7	14	1

Table E-1. Continued.

Lot Number	Location	Cattle Number	Slope (%)	Surface	Area (ha)	Potential Discharge	Cattle Type	Density (# head/ ha)	Region Number	Entrance Point
18	Benson T12 N R1 W S2	140	5.6	S	0.697	H	Dairy	200.9	14	1
19	Benson T12 N R1 W S1	37	9.3	S	0.465	H	Beef	79.6	4	1
20	Benson T12 N R1 W S12	60	2.6	P	0.093	H	Dairy	645.2	14	1
21	Benson T12 N R1 W S12	80	2.8	P	0.163	L	Dairy	490.8	14	1
22	Benson T12 N R1 W S	150	3.5	P	0.121	H	Dairy	1239.7	14	1
23	Benson T12 N R1 W S14	8	5.6	S	0.121	H	Beef	66.1	14	1
24	Benson T12 N R1 W S14	100	1.6	P	0.074	H	Dairy	1351.4	14	1
25	Benson T12 N R1 W S11	100+	3.3	P	0.059	H	Dairy	1694.9	14	1
26	College Ward T11 N R1 W S13	68	4.6	S	0.135	L	Dairy	503.7	8	3
27	Cornish T14 R1 W S10	30	3.0	S	0.028	L	Dairy	1071.4	3	1
28	Cornish T14 R1 W S15	65	1.3	P	0.245	M	Dairy	265.3	3	1
29	Cornish T14 R1 W S22	35	1.0	S	0.186	M	Dairy	188.2	3	1
30	Benson T12 N R1 E S6	190	3.5	S/P	0.465	H	Dairy	408.6	14	1
31	Wellsville T10 N R1 W S10	65	3.6	S	0.595	H	Dairy	109.2	10	3
32	College Ward T11 N R1 E S19	100+	3.6	P	0.067	M	NR	1492.5	8	3
33	College Ward T11 N R1 E S17	35	3.6	P	0.039	H	NR	897.4	8	3
34	Providence T11 N R6 E S9	55	3.6	P	0.084	H	Dairy	654.8	7	5
35	College Ward T11 N R1 E S19	25	4.3	S	0.335	H	Dairy	74.6	8	3
36	College Ward T11 N R1 E S19	15	6.6	P	0.195	M	Dairy	76.9	8	3
37	College Ward T11 N R1 E S19	25	4.3	S	0.093	M	Beef	268.8	8	3
38	College Ward T11 N R1 E S19	30	3.6	P	0.046	L	Dairy	652.2	8	3

Table E-1. Continued.

Lot Number	Location	Cattle Number	Slope (%)	Surface	Area (ha)	Potential Discharge	Cattle Type	Density (# head/ ha)	Region Number	Entrance Point
39	Nibley T11 N R1 E S21	55	2.6	S/P	0.186	H	Dairy/ Beef	295.7	7	5
40	Nibley T11 N R1 E S33	145	17.0	S/P	0.297	H	Dairy	488.2	9	3
41	Wellsville T10 N R1 W S3	52	4.6	S	0.056	H	Beef	928.6	10	3
42	College Ward T11 N R1 E S17	115	2.6	P	0.074	H	Dairy	1554.1	8	3
43	Wellsville T11 N R1 W S35	9	2.0	S	0.018	L	Beef	500	10	3
44	Wellsville T10 N R1 W S3	65	3.3	S	0.372	M	NR	174.7	10	3
45	Benson T12 R1E S7	100	1.6	P	0.046	L	NR	2173.9	14	1
46	Benson T12 R1E S6	220	3.6	P	0.128	H	NR	1718.8	14	1
47	Benson T12 R1E S6	30	11.3	S	0.074	H	NR	405.4	14	1
48	Benson T12 R1E S7	170	4.2	P	0.056	M	NR	3035.7	14	1
49	Benson T12 R1 E S7	15	12.3	S	0.046	M	NR	326.1	14	1
50	Cornish T14 N R1 W S2	80	1.6	P	0.051	L	NR	1568.6	3	1
51	Cornish T14 N R1 W S2	50 winter	5.3	S	0.097	M	NR	515.5	3	1
52	Lewiston T15 R1 W S36	250	1.3	S/P	0.557	L	NR	448.8	3	1
53	Lewiston T14 R1 W S12	100+	1.6	S	0.084	L	NR	1190.5	3	1
54	Lewiston T14 R1 W S12	40	2.7	S	0.056	L	NR	714.3	3	1
55	Lewiston T14 R1 W S18	40	1.0	P	0.037	L	NR	1081.1	NR	NR
56	Lewiston T14 R1 W S18	100+	1.3	P	0.056	L	NR	1785.7	NR	NR
57	Lewiston T14 R1 W S13	50	4.3	P/S	0.069	L	NR	724.6	NR	NR
58	Lewiston T14 R1 W S13	200+	2.8	S	0.074	L	NR	2702.7	NR	NR
59	Lewiston T14 R1 E S15	100+	0.7	S	1.394	M	NR	71.7	2	1

Table E-1. Continued.

Lot Number	Location	Cattle Number	Slope (%)	Surface	Area (ha)	Potential Discharge	Cattle Type	Density (# head/ ha)	Region Number	Entrance Point
60	Trenton T14 R1 W S25	40	1.3	P	0.037	L	NR	1081.1	3	1
61	Trenton T14 R1 W S35	45	4.2	S	0.112	M	NR	401.8	3	1
62	Trenton T14 R1 W S27	30	3.6	P	0.023	L	NR	1304.3	3	7
63	Trenton T14 R1 W S27	35	8.0	S/P	0.098	H	NR	357.1	3	1
64	Trenton T14 R1 W S27	30	14.6	S	0.132	H	NR	227.3	3	1
65	Trenton T13 R1 W S3	50+	4.6	P	0.116	L	NR	431.0	NR	NR
66	Trenton T14 R1 W S36	250+	3.1	P	0.323	L	NR	774.0	3	1
67	Richmond T13 R1 E S10	50	3.2	P	0.060	M	NR	833.3	12	1
68	Richmond T14 R1 E S34	17	5.1	S	0.186	H	NR	91.4	12	1
69	Newton T13 R1 W S18	110	9.9	S	0.204	H	NR	539.2	11	4
70	T13 R1 W S18	5	11.9	S	0.139	M	NR	36.0	11	4
71	Newton T13 R1 W S18	40	8.6	S	0.104	L	NR	384.6	11	4
72	Newton T13 R1 W S18	87	0.0	S	0.104	L	NR	836.5	11	4
73	Newton T13 R1 W S17	125	0.5	S/P	0.285	L	NR	438.6	11	4
74	Newton T13 R1 W S19	60	0.8	P	0.307	L	NR	195.4	11	4
75	Newton T13 R1 W S20	30	16.1	S	0.511	H	NR	58.7	11	4
76	Newton T13 R1 W S20	40	11.4	S	0.325	H	NR	123.1	11	4
77	Amalga T13 R1 W S27	100	5.5	P	0.084	H	NR	1190.5	11	1
78	Benson T13 R1 W S34	200+	1.4	P/S	0.418	M	NR	478.5	14	1
79	Benson T13 R1 W S36	300	4.2	P/S	0.353	H	NR	849.9	4	1
80	Benson T13 R1 W S35	60	2.7	S	0.046	L	NR	1304.3	4	1

Table E-1. Continued.

Lot Number	Location	Cattle Number	Slope (%)	Surface	Area (ha)	Potential Discharge	Cattle Type	Density (# head/ ha)	Region Number	Entrance Point
81	Benson T13 R1 W S26	160+	4.5	S/P	0.511	M	NR	313.1	4	1
82	Benson T13 R1 W S25	20	2.8	S	0.093	L	NR	215.1	4	1
83	Benson T13 R1 W S36	170	5.0	P	0.163	H	NR	1042.9	4	1
84	Benson T13 R1 E S19	80	5.4	S/P	0.725	M	NR	110.3	4	1
85	Benson T13 R1 E S30	300+	2.4	P	0.195	H	NR	1538.5	4	1
86	Benson T13 R1 W S36	35	3.9	S	0.069	M	NR	507.2	4	1
87	Benson T13 R1 W S36	15	6.1	S	0.056	M	NR	267.9	4	1
88	Benson T13 R1 E S31	70	3.1	S	0.186	L	Dairy	376.3	4	1
89	Benson T13 N R1 E S31	10	2.7	S	0.102	M	NR	98.0	4	1
90	Benson T13 N R1 W S25	300	6.1	S	1.208	H	NR	248.3	4	1
91	Benson T13 N R1 W S25	30	2.4	S	0.036	M	NR	833.3	4	1
92	Benson T13 N R1 W S25	47	1.1	P	0.033	M	Dairy	1424.2	4	1
93	Benson T13 N R1 E S30	150	4.1	S/P	0.325	H	Dairy	461.5	4	1
94	Benson T13 N R1 E S30	25	11.0	S	0.465	H	NR	53.8	4	1
95	Amalga T13 N R1 E S30	20	24.0	S	0.167	H	NR	119.8	4	1
96	Amalga T13 N R1 W S24	90	3.2	P/S	0.149	H	Dairy	604.0	4	1
97	Amalga T13 N R1 W S24	75	11.1	S	0.372	H	Dairy	201.6	4	1
98	Amalga T13 N R1 W S13	40	6.1	S	0.074	M	NR	540.5	4	1
99	Amalga T13 N R1 W S13	35	10.2	S	0.037	M	NR	946.0	4	1
100	Logan T11 N R1 E S7	12	4.1	S/P	0.056	H	Dairy	214.3	7	5
* 101	Young Ward T11 N R1 W S12	30	3.6	S/P	0.084	H	Beef (Mix)	357.1	8	3

Table E-1. Continued.

Lot Number	Location	Cattle Number	Slope (%)	Surface	Area (ha)	Potential Discharge	Cattle Type	Density (# head/ ha)	Region Number	Entrance Point
102	Young Ward T11 N R1 W S13	45	4.0	S	0.084	H	NR	535.7	8	3
103	Young Ward T11 N R1 W S14	24	2.6	P/S	0.037	L	NR	648.6	8	3
104	Young Ward T11 N R1 W S14	30	2.9	S	0.093	M	Beef	322.6	8	3
105	Young Ward T11 N R1 W S14	15	1.3	S	0.033	L	NR	454.5	8	3
106	Logan T12 N R1 E S31	200	1.0	S	0.651	H	NR	307.2	13	5
107	Logan T12 N R1 E S31	19	1.1	S	0.019	M	NR	1000	13	5
108	Young Ward T11 N R1 W S12	75	3.6	S	0.020	L	NR	3750	8	3
109	Young Ward T11 N R1 W S2	15	2.1	S	0.014	L	NR	1071.4	8	3
110	College Ward T11 N R1 E S18	50	6.0	P	0.014	L	NR	3571.4	8	3
111	Avon T9 N R1 E S3	45	15.3	S	0.186	L	Dairy	241.9	9	3
112	Avon T9 N R1 E S10	50	3.1	S/P	0.279	H	Dairy	179.2	9	3
113	Avon T9 N R1 E S10	60	5.5	S	0.139	H	NR	431.7	9	3
114	Avon T9 N R1 E S10	30	2.9	S	0.093	L	Dairy	322.6	9	3
115	Avon T9 N R1 E S10	100+	3.3	S	0.465	H	Beef	215.1	9	3
116	Avon T9 N R1 E S11	21	1.0	S	0.037	H	Beef	567.6	9	3
117	Avon T10 N R1 E S28	45	1.5	P	0.037	H	Beef	1216.2	9	3
118	Avon T10 N R1 E S28	100	12.0	S	0.204	L	Beef	490.2	NR	NR
119	Avon T10 N R1 E S28	60	8.4	S/P	0.260	H	Dairy	230.8	9	3
120	Hyrum T10 N R1 E S16	23	10.5	P	0.242	L	Dairy	95.0	NR	NR
121	Hyrum T10 N R1 E S16	30	1.2	P	0.023	L	Dairy	1304.3	9	3
122	Hyrum T10 N R1 E S15	30	3.9	S/P	0.093	H	Dairy	322.6	9	3

Table E-1. Continued.

Lot Number	Location	Cattle Number	Slope (%)	Surface	Area (ha)	Potential Discharge	Cattle Type	Density (# head/ ha)	Region Number	Entrance Point
123	Hyrum T10 N R1 E S21	85	4.2	P	0.069	H	Beef	1231.9	9	3
124	Hyrum T10 N R1 E S9	65	2.6	P	0.069	M	Dairy	942.0	9	3
125	Hyrum T11 N R1 E S31	310	3.6	P	0.245	H	Dairy	1265.3	9	3
126	Mt. Sterling T10 N R1 W S11	40	8.3	S	0.093	L	Beef	430.1	10	3
127	Mt. Sterling T10 N R1 W S14	80	4.0	P	0.084	L	Dairy	952.4	10	3
128	Wellsville T11 N R1 E S36	37	3.0	P	0.074	M	NR	500	10	3
129	Wellsville/Hyrum T10 N R1 W S6	58	1.0	S	0.093	M	NR	623.7	9	3
130	Wellsville T10 N R1 W S3	46	3.3	S	0.093	H	NR	494.6	10	3
131	Wellsville T10 N R1 W S2	20	3.6	S	0.046	M	NR	434.8	10	3
132	Logan T11 N R1 E S9	200	2.6	P	0.121	H	NR	1652.9	7	5
133	Logan T11 N R1 E S9	12	2.6	S	0.112	H	Beef	107.1	7	5
134	Millville T11 N R1 E S15	24	3.1	S	0.112	H	NR	214.3	7	5
135	Logan T11 N R1 E S9	90	2.9	P	0.195	H	Dairy	461.5	7	5
136	Wellsville T11 N R1 W S34	25	4.0	S	0.074	M	Dairy	337.8	10	3
137	Wellsville T11 N R1 W S34	15	12.0	S	0.069	M	Beef	217.4	10	3
138	Wellsville T10 N R1 W S3	10	8.6	S	0.139	L	Beef	71.9	10	3
139	Smithfield T13 N R1 E S33	170	0.9	S/P	0.688	M	Dairy	247.1	5	1
140	Mendon T11 N R1 W S21	11	3.4	S	0.186	L	NR	59.1	10	3
141	Wellsville T10 N R1 W S10	14	4.6	S	0.069	M	NR	202.9	10	3
142	Wellsville T10 N R1 W S3	14	6.3	S	0.158	H	NR	88.6	10	3
143	Mendon T11 N R1 W S5	25	3.8	S	0.056	M	Beef	446.4	10	3

Table E-1. Continued.

Lot Number	Location	Cattle Number	Slope (%)	Surface	Area (ha)	Potential Discharge	Cattle Type	Density (# head/ ha)	Region Number	Entrance Point
144	Mendon T12 N R1 W S32	41	1.0	P	0.065	H	Dairy	630.8	10	3
145	Millville T11 N R1 E S22	7	0.0	S	0.037	H	Beef	189.2	7	5
146	Millville T11 N R1 E S22	70	0.0	S	0.149	H	NR	469.8	7	5
147	Millville T11 N R1 E S22	25	1.0	S	0.093	H	Beef	268.8	7	5
148	Millville T11 N R1 E S22	12	2.0	S	0.019	H	Beef	631.6	7	5
149	Logan T12 N R1 E S22	91	2.0	S	0.639	H	Dairy	142.4	6	1
150	Hyrum T10 N R1 E S5	30	6.6	S	0.139	M	NR	215.8	9	3
151	Hyrum T10 N R1 E S9	40	7.0	S	0.144	L	NR	277.8	9	3
152	Hyrum T10 N R1 E S4	18	45.0	S	0.186	M	NR	96.8	9	3
153	Hyrum T10 N R1 E S4	30	2.0	S	0.093	L	NR	322.6	9	3
154	Hyrum T10 N R1 E S5	30	6.0	S	0.046	L	NR	652.2	9	3
155	Richmond T14 N R1 E S35	15	7.1	S	0.279	L	Beef	53.8	12	1
156	Richmond T13 N R1 E S2	70	2.9	P/S	0.167	M	Dairy	419.2	12	1
157	Richmond T13 N R1 E S2	75	4.4	P	0.069	M	Beef	1087.0	12	1
158	Logan T12 N R1 E S30	15	2.5	S	0.511	L	Beef	29.4	6	2
159	Logan T12 R1 E S29	40	3.8	S	0.140	H	NR	285.7	6	2
160	Logan T12 R1 E S29	40	5.4	S	0.180	H	NR	222.2	6	2
161	Hyde Park T12 R1 E S10	10	3.8	S	0.230	H	Beef	43.5	15	1
162	Hyde Park T12 R1 E S10	100	1.5	S	0.280	L	Dairy	357.1	15	1
163	Hyde Park T12 N R1 E S10	50	8.3	S	0.204	H	Dairy and Beef	245.1	15	1
164	Logan T12 N R1 E S28	25	1.1	P	0.076	L	Beef	328.9	6	2

Table E-1. Continued.

Lot Number	Location	Cattle Number	Slope (%)	Surface	Area (ha)	Potential Discharge	Cattle Type	Density (# head/ ha)	Region Number	Entrance Point
165	Logan T12 N R1 E S21	65	0.9	P/S	0.081	M	Dairy	802.5	6	2
166	Logan T12 N R1 E S21	60	0.7	S	0.176	M	Dairy	340.9	6	2
167	Logan T12 N R1 E S16	150	0.5	P/S	0.139	M	Beef	1079.1	6	2
168	Hyde Park T12 N R1 E S10	10	7.6	S	0.186	H	NR	53.8	15	1
169	Smithfield T13 N R1 E S32	5	7.7	S	0.167	H	Dairy	29.9	5	1
170	Smithfield T13 N R1 E S28	8	0.2	S	0.093	L	Beef	86.0	5	1
171	Smithfield T13 N R1 E S34	9	1.8	S	0.149	L	Beef	60.4	5	1
172	North Logan T12 N R1 E S11	20	6.4	S	0.177	H	Beef	113.0	15	1
173	Hyde Park T12 N R1 E S11	10	6.7	S	0.074	M	NR	135.1	15	1
174	North Logan T12 N R1 E S24	15	3.7	S	0.084	H	Beef	178.6	5	1
175	North Logan T12 N R1 E S14	10	3.5	S	0.037	H	Beef	270.3	15	1
176	Logan	30	1.6	S/P	0.139	L	Beef	215.8	13	5
177	Smithfield	25	2.8	S	0.288	L	Dairy	86.8	5	1
178	Smithfield	16	0.9	S	0.223	L	Dairy	71.7	5	1
179	Smithfield	60	1.7	S	0.172	L	NR	348.8	5	1
180	Smithfield	15	1.5	S	0.042	L	Beef	357.1	5	1
181	Smithfield	57	2.7	S	0.362	L	Dairy	157.5	5	1
182	Smithfield T13 N R1 E S25	9	1.0	S	0.065	L	Dairy	138.5	5	1
183	Smithfield	30	10.4	S	0.260	H	Dairy	115.4	5	1
184	Smithfield	75	3.1	P	0.218	H	Dairy	344.0	12	1
185	Smithfield T13 R1 E S22	60	1.7	P	0.084	H	Beef	714.3	12	1

Table E-1. Continued.

Lot Number	Location	Cattle Number	Slope (%)	Surface	Area (ha)	Potential Discharge	Cattle Type	Density (# head/ ha)	Region Number	Entrance Point
186	Smithfield	59	1.3	S	0.112	L	Beef	526.8	5	1
187	Logan	120	1.7	P	0.297	L	Dairy	404.0	13	5
188	Logan T12 N R1 E S29	10	1.7	S	0.028	L	NR	357.1	6	2
189	Logan T12 N R1 E S31	5	4.8	S	0.004	L	Beef	1250	13	5
190	Logan T11 N R1 E S5	11	0.6	P	0.023	L	Dairy	478.3	13	5
191	Logan T11 N R1 E S5	100	2.1	P/S	0.279	H	Dairy	358.4	13	5
192	Young Ward T11 N R1 E S17	14	1.6	S	0.065	M	Dairy	215.4	8	3
193	Mendon T11 N R1 W S8	15	4.1	S	0.223	H	Dairy	67.3	10	3
194	Mendon T11 N R1 W S8	40	2.2	P	0.102	M	Beef	392.2	10	3
195	Hyrum T10 N R1 E S5	45	0.3	P/S	0.098	H	NR	459.2	9	3
196	Hyrum T11 N R1 E S32	25	8.0	S	0.056	M	NR	446.4	9	3
197	Hyrum T10 N R1 E S5	40	2.0	S	0.093	L	Dairy	430.1	9	3
198	Hyrum T10 N R1 E S5	15	12.0	S	0.116	L	NR	129.3	9	3
199	Cove T14 N R1 E S13	25	NR	S	0.204	H	Dairy	122.5	2	1
200	Cove T14 N R1 E S12	15	NR	S	0.033	H	Dairy	454.5	2	1
201	Cove T14 N R1 E S13	50	NR	P	0.056	M	Dairy	892.9	2	1
202	Cove T14 N R1 E S13	30	NR	S	0.139	M	Dairy	215.8	2	1
203	Wellsville T11 N R1 W S27	35	8.5	S	0.232	M	NR	150.9	10	3
204	Cove T14 R1 E S12	25	13.8	S	0.186	H	Beef	134.4	2	1
205	Cove T14 R1 E S1	25	9.3	S/P	0.204	H	Dairy	122.5	2	1
206	Cove T15 R2 E S31	30	5.3	S/P	0.093	H	Dairy	322.9	2	1

Table E-1. Continued.

Lot Number	Location	Cattle Number	Slope (%)	Surface	Area (ha)	Potential Discharge	Cattle Type	Density (# head/ ha)	Region Number	Entrance Point
207	Cove T15 R2 E S31	5	7.0	S/P	0.084	H	Dairy	59.5	2	1
208	Cove T15 R2 E S31	15	20.2	S	0.084	H	Dairy	178.6	2	1
209	Cove T14 R1 E S11	30	6.8	P	0.060	L	Dairy	500.0	2	1
210	Cove T14 R1 E S14	60	3.6	P	0.186	H	Dairy	322.6	2	1
211	Lewiston T14 R1 E S21	80	0.7	P	0.112	L	Dairy	714.3	1	1
212	Lewiston T14 R1 E S15	25	1.7	P	0.186	H	Dairy	134.4	1	1
213	Lewiston T14 R1 E S10	400	31.6	S	1.812	H	NR	220.8	1	1
214	Lewiston T15 R1 E S33	40	0.7	S	0.121	L	Dairy	330.6	2	1
215	Lewiston T14 R1 E S5	70	1.0	P	0.042	L	Dairy	1666.7	2	1
216	Lewiston T15 R1 E S32	240	2.0	S/P	0.307	M	Dairy	781.8	2	1
217	Lewiston T14 N R1 E S22	100	0.4	P	0.112	L	Dairy	892.9	1	1
218	Richmond T14 N R1 E S34	60	8.4	S	0.084	M	Dairy	714.3	12	1
219	Richmond T14 N R1 E S35	5	4.0	S	0.074	H	Beef	67.6	12	1
220	Richmond T14 N R1 E S35	5	0.1	S	0.025	L	Beef	200	12	1

APPENDIX F

CONTAINED FEEDLOT RUNOFF DATA

Table F-1. Feedlot runoff data, lot alpha (α), paved feedlot.

Sample Date	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l
2-23	4,790	16,878	5,700	3,850	61.8	0.294	
2-24		28,207	14,960	8,600	114.6	0.309	251.1
2-25	9,240	36,336	22,267	13,333	137.4	0.201	311.4
2-26					176.4	0.232	
2-28					113.0		327.7
3-02	6,187	23,281			95.1	0.278	650.6
3-03	5,050	20,889	14,850			0.308	336.5
3-04		43,386	29,000				404.1
3-10	6,000	21,076	8,150		81.0	0.369	415.5
3-11		21,263			91.7		
3-17	3,528				50.5		267.5
3-18	6,668		24,672		129.4		422.5
3-24	4,230	9,453	2,080	1,400	23.9		
3-25		10,743			32.9		
3-26							
4-14			1,378	856		1.62	183.8
5-04		13,313	2,250	1,717			141.0
5-06		6,652					30.5
5-07		9,760					48.6
5-14							
5-26							
7-21		11,417	864	764		0.70	171.0
8-26	2,500		1,400	1,057			66.3
9-17							
9-22	1,500						
10-29							
11-23	6,300	17,711	9,767	7,333		4.03	178.1
12-15	4,700	12,430	4,826	3,933		1.93	
12-23							
12-31							

Table F-2. Feedlot runoff data, lot theta (θ), paved feedlot.

Sample Date	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l
2-23	3,880	14,628	4,762	3,048	49.5	0.535	
2-24	6,340	24,172	12,600	8,800	119.5	0.386	566.1
2-25		28,828	12,950	9,650	117.2	0.248	120.7
2-26	5,340				48.8	0.154	118.4
2-28	7,160	24,075			80.7		354.6
3-02	5,400	20,478	5,075		52.0	0.463	642.1
3-03		19,731	5,680		68.6		312.4
3-04	7,380	35,052	28,600			0.231	175.9
3-10	4,510		5,743		47.5		202.9
3-11							
3-17	5,330	22,934			90.1	0.256	207.0
3-18	3,743				10.9		214.9
3-24	2,384	9,241			38.9	8.14	25.7
3-25							
3-26		10,782					
4-14			968	720		2.96	93.9
5-04		8,970	1,749	1,273			91.2
5-06							107.8
5-07		11,130					35.1
5-14							
5-26			1,400	1,130		4.66	
7-21		11,892	1,038	850		0.65	182.0
8-26							
9-17	6,500	17,904					244.0
9-22	2,700						
10-29							
11-23	5,200	15,835	6,057	4,600		4.89	210.3
12-15	11,200						104.1
12-23	4,317	15,475	7,714			4.14	
12-31		15,400				2.59	202.5

Table F-3. Feedlot runoff data, lot gamma (γ), unpaved feedlot.

Sample Date	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l
2-25	392	1,397	544	331	27.5	9.85	53.0
2-28	629	5,432	1,853	825	34.7	6.53	70.1
3-02		17,732	12,374		66.6	5.23	42.1
3-03	907	8,128	3,174		52.9	5.37	59.7
3-04	486	4,696	1,082		18.5	8.67	34.8
3-07	209	4,135	2,161				
3-10	323	4,253	3,190		51.7		24.1
3-11	25					7.80	
3-17	522	4,360	634		37.1	6.53	
3-18	634	6,072			36.2	5.75	
3-24	1,194						
3-25		10,474			53.6		
3-26							
5-04							
8-26	1,300	4,056					
9-22	1,000	4,271					

APPENDIX G

PREDICTED AVERAGE MONTHLY MASS LOADINGS

Table G-1. Totals for year 50 by month, treatment and region.

TREATMENT 1 JAN.

EN-TRANCE	REGION	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	1	3990.1	393.5	2559.6	1604.9	18.3	16.2	0.9
1	2	5348.2	629.1	3187.7	1998.8	66.4	26.0	4.5
1	3	4619.8	476.4	2793.5	1751.7	54.5	23.4	4.7
1	4	17216.1	1964.0	10476.9	6569.4	131.5	75.4	8.3
1	5	9217.5	811.3	5954.2	3733.7	102.5	49.8	14.3
1	12	2501.7	342.3	1281.9	803.8	43.0	10.9	0.8
1	14	14546.9	2237.3	8001.2	5017.0	128.5	61.9	5.0
1	15	3429.0	301.8	2218.6	1391.2	20.1	16.8	3.1
2	6	5904.2	694.5	3662.6	2296.6	41.4	25.4	2.5
3	8	9158.2	1510.9	5557.9	3485.0	103.8	39.4	6.5
3	9	8351.8	869.0	5194.2	3256.9	48.8	36.3	3.6
3	10	7751.6	873.9	4754.9	2981.5	48.7	35.3	4.8
5	11	7051.6	821.7	4200.1	2633.7	77.0	33.9	5.9
6	7	2679.4	324.5	1551.9	973.1	25.8	11.7	1.1
6	13	5609.6	960.9	2943.9	1845.9	61.2	23.4	1.5

TREATMENT 1 FEB.

EN-TRANCE	REGION	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	1	11992.9	1631.4	7895.9	4951.0	61.3	52.2	6.7
1	2	8286.2	1417.4	4531.2	2841.2	74.7	33.1	1.5
1	3	16118.1	2506.3	10947.7	6864.4	50.7	65.0	5.0
1	4	19392.1	2291.3	12193.1	7645.5	125.9	86.2	11.4
1	5	9817.1	864.0	6461.0	4051.3	45.6	45.2	6.8
1	12	6821.0	1334.9	4014.5	2517.2	86.2	28.9	3.9
1	14	16466.2	2509.2	10098.5	6332.0	105.0	65.3	2.9
1	15	2600.0	228.8	1512.2	948.3	26.6	15.4	3.9
2	6	7868.5	931.5	5045.6	3163.7	43.2	34.3	3.9
3	8	9369.0	1489.9	5484.7	3439.1	75.4	38.0	2.9
3	9	10158.6	1479.4	5885.2	3690.4	191.5	51.5	20.3
3	10	7612.8	948.8	4560.0	2859.2	44.9	32.8	3.1
5	11	8540.7	1080.7	5355.9	3358.4	62.8	39.5	6.8
6	7	4982.4	900.8	2962.5	1857.6	45.3	21.5	2.7
6	13	7345.0	1138.5	4313.9	2704.9	47.6	28.8	1.0

TREATMENT 1 MAR.

EN-TRANCE	REGION	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	1	11613.3	1765.5	7667.5	4807.8	86.5	54.6	9.8
1	2	14156.5	2443.9	8271.6	5186.5	84.6	56.2	3.1
1	3	14907.9	2372.6	9395.8	5891.4	80.7	61.5	5.3
1	4	22016.3	3175.3	13779.4	8640.1	100.9	89.8	6.3
1	5	7781.6	684.9	5048.3	3165.6	80.8	42.3	11.4

Table G-1. Continued.

1	12	12941.0	2505.6	8115.5	5088.6	53.8	49.7	2.1
1	14	24756.4	4445.0	15727.6	9861.5	133.7	95.5	3.9
1	15	4169.8	367.0	2685.1	1683.7	15.3	18.9	2.4
2	6	9526.7	1368.8	6015.4	3771.9	60.8	44.7	6.7
3	8	15036.1	2836.4	9743.6	6109.4	75.4	57.1	1.9
3	9	18325.9	2678.4	11778.0	7385.2	149.3	80.5	16.8
3	10	12605.0	1707.6	8059.9	5053.8	55.2	52.9	4.9
5	11	10187.1	1479.9	6264.0	3927.7	42.7	41.4	2.7
6	7	10315.0	1928.2	7395.5	4637.1	44.7	41.6	4.1
6	13	11454.1	2270.3	7669.2	4808.7	57.1	43.9	2.0

TREATMENT 1 APR.

EN-TRANCE	REGION	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	1	1236.3	265.9	245.2	153.8	14.4	5.5	0.3
1	2	1713.3	368.6	453.5	284.4	15.6	8.6	1.9
1	3	1551.2	333.7	311.1	195.1	17.3	6.9	0.3
1	4	1808.7	389.0	454.7	285.1	26.7	7.8	0.3
1	5	928.0	199.6	195.7	122.7	14.1	4.1	0.2
1	12	1517.8	326.5	422.3	264.8	13.8	7.4	1.3
1	14	1444.7	310.7	355.7	223.1	20.6	6.2	0.3
1	15	626.8	134.8	160.1	100.4	7.9	2.8	0.2
2	6	868.8	186.9	207.8	130.3	11.7	3.8	0.2
3	8	1155.2	248.5	368.3	231.0	15.4	5.0	0.3
3	9	2668.0	573.9	907.2	568.9	30.1	12.2	1.7
3	10	1673.5	360.0	465.0	291.6	21.0	7.5	0.7
5	11	867.5	186.6	353.4	221.6	12.5	3.6	0.1
6	7	1152.8	248.0	317.5	199.1	11.4	5.5	0.8
6	13	784.9	168.8	234.2	146.9	10.3	3.3	0.2

TREATMENT 1 MAY

EN-TRANCE	REGION	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	1	425.2	91.5	70.6	44.3	6.7	1.9	0.1
1	2	870.6	187.3	181.7	113.9	10.1	3.9	0.3
1	3	517.6	111.3	108.9	68.3	8.1	2.2	0.1
1	4	1088.1	234.0	246.9	154.8	15.9	4.7	0.2
1	5	563.2	121.1	104.5	65.6	8.7	2.5	0.1
1	12	720.2	154.9	162.6	101.9	9.5	3.1	0.2
1	14	873.4	187.9	196.6	123.3	12.3	3.8	0.2
1	15	422.7	90.9	96.6	60.6	6.2	1.8	0.1
2	6	543.4	116.9	104.9	65.8	7.9	2.4	0.1
3	8	663.6	142.7	207.8	130.3	9.1	2.8	0.1
3	9	1582.4	340.3	555.5	348.3	21.8	6.7	0.4
3	10	1075.1	231.2	299.8	188.0	15.4	4.6	0.2
5	11	524.0	112.7	204.6	128.3	7.5	2.2	0.1
6	7	563.4	121.2	134.5	84.3	7.6	2.4	0.1
6	13	465.1	100.0	121.8	76.3	5.9	2.0	0.1

TREATMENT 1 JUNE

EN-TRANCE	REGION	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	1	619.2	133.2	133.8	83.9	4.0	2.8	0.3
1	2	1032.3	222.1	161.9	101.5	6.3	4.9	0.7
1	3	805.9	173.4	160.4	100.6	4.2	3.7	0.3
1	4	1484.1	319.3	304.6	191.0	11.3	6.7	0.6
1	5	594.2	127.8	109.8	68.8	5.6	2.7	0.2

Table G-1. Continued.

1	12	1003.5	215.9	178.8	112.1	7.1	4.5	0.4
1	14	1525.0	328.0	266.2	166.9	11.8	6.9	0.7
1	15	365.6	78.6	72.7	45.6	3.1	1.6	0.1
2	6	634.5	136.5	102.0	64.0	4.8	2.9	0.3
3	8	1025.5	220.6	236.3	148.2	8.8	4.6	0.5
3	9	1619.2	348.3	424.2	266.0	15.4	7.2	0.7
3	10	1087.9	234.0	244.5	153.3	9.4	4.9	0.4
5	11	693.4	149.1	186.9	117.2	6.2	3.1	0.3
6	7	750.5	161.4	168.2	105.5	6.4	3.3	0.3
6	13	666.7	143.4	109.6	68.7	3.7	3.1	0.4

TREATMENT 1 JULY

EN- TRANCE	REGION	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	1	1261.8	271.4	238.9	149.8	11.3	5.8	0.5
1	2	995.3	214.1	209.7	131.5	6.1	4.8	0.8
1	3	1641.6	353.1	355.6	223.0	12.4	7.5	0.6
1	4	1342.7	288.8	263.6	165.3	11.9	6.0	0.4
1	5	529.9	114.0	99.7	62.5	5.1	2.4	0.2
1	12	821.5	176.7	151.5	95.0	3.4	3.8	0.5
1	14	1414.2	304.2	294.7	184.8	13.2	6.3	0.5
1	15	323.6	69.6	65.4	41.0	2.6	1.5	0.1
2	6	579.7	124.7	99.1	62.1	4.8	2.6	0.2
3	8	934.9	201.1	229.0	143.6	8.1	4.1	0.4
3	9	1376.3	296.0	337.5	211.6	10.9	6.2	0.8
3	10	949.4	204.2	212.1	133.0	7.5	4.3	0.4
5	11	631.6	135.9	169.8	106.5	6.3	2.8	0.2
6	7	621.1	133.6	110.4	69.3	3.8	2.8	0.3
6	13	623.6	134.1	69.9	43.9	4.0	2.8	0.3

TREATMENT 1 AUG.

EN- TRANCE	REGION	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	1	190.3	40.9	37.4	23.5	2.7	0.8	0.0
1	2	144.4	31.1	36.9	23.1	1.8	0.6	0.0
1	3	235.5	50.7	46.4	29.1	3.3	1.0	0.0
1	4	339.5	73.0	81.5	51.1	5.3	1.5	0.0
1	5	172.3	37.1	33.8	21.2	2.8	0.7	0.0
1	12	93.0	20.0	21.4	13.4	1.4	0.4	0.0
1	14	240.1	51.6	51.8	32.5	3.7	1.0	0.0
1	15	62.7	13.5	17.4	10.9	0.9	0.3	0.0
2	6	127.2	27.3	30.9	19.4	1.9	0.5	0.0
3	8	188.4	40.5	58.4	36.6	2.8	0.8	0.0
3	9	198.9	42.8	71.8	45.0	2.9	0.8	0.0
3	10	178.0	38.3	44.2	27.7	2.8	0.8	0.0
5	11	164.4	35.4	70.3	44.1	2.5	0.7	0.0
6	7	74.9	16.1	18.5	11.6	1.1	0.3	0.0
6	13	142.6	30.7	42.5	26.7	2.0	0.6	0.0

TREATMENT 1 SEP.

EN- TRANCE	REGION	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	1	625.6	134.6	114.7	71.9	8.8	2.7	0.1
1	2	678.5	146.0	167.9	105.3	5.5	3.3	0.6
1	3	771.4	165.9	156.7	98.3	10.7	3.4	0.1
1	4	1340.9	288.4	291.6	182.9	17.4	5.9	0.3
1	5	608.0	130.8	118.4	74.2	8.4	2.7	0.1
1	12	591.2	127.2	116.8	73.3	3.7	2.8	0.3

Table G-1. Continued.

1	14	1178.4	253.5	259.9	163.0	14.7	5.2	0.3
1	15	288.0	61.9	69.7	43.7	3.2	1.3	0.1
2	6	542.6	116.7	115.3	72.3	6.4	2.4	0.2
3	8	827.5	178.0	224.1	140.5	9.8	3.6	0.2
3	9	1080.4	232.4	290.5	182.1	10.3	4.9	0.6
3	10	821.0	176.6	192.0	120.4	9.2	3.7	0.3
5	11	641.4	138.0	227.6	142.7	8.4	2.7	0.1
6	7	458.2	98.6	74.9	47.0	3.5	2.1	0.2
6	13	587.6	126.4	125.2	78.5	6.3	2.6	0.2

TREATMENT 1 OCT.

EN-TRANCE	REGION	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	1	681.3	146.5	142.7	89.5	8.8	3.0	0.1
1	2	1142.6	245.8	217.8	136.6	9.9	5.3	0.7
1	3	849.5	182.7	163.3	102.4	11.2	3.7	0.1
1	4	2687.3	578.1	515.7	323.4	15.2	12.3	1.1
1	5	938.3	201.8	169.1	106.0	6.9	4.3	0.4
1	12	1037.1	223.1	204.1	128.0	9.6	4.6	0.4
1	14	3030.7	651.9	541.2	339.4	20.6	13.7	1.4
1	15	481.4	103.6	95.0	59.6	5.4	2.1	0.1
2	6	1060.2	228.1	148.0	92.8	7.9	4.8	0.5
3	8	1857.9	399.6	401.5	251.8	12.9	8.4	0.9
3	9	1883.8	405.2	564.7	354.1	21.3	8.2	0.7
3	10	1519.6	326.9	381.1	239.0	13.7	6.8	0.5
5	11	1245.6	267.9	279.4	175.2	9.2	5.6	0.5
6	7	794.1	170.8	179.7	112.7	8.1	3.5	0.3
6	13	1265.1	272.1	147.6	92.6	4.8	5.9	0.8

TREATMENT 1 NOV.

EN-TRANCE	REGION	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	1	311.5	67.0	54.7	34.3	4.5	1.4	0.0
1	2	1214.8	261.3	202.9	127.3	8.6	5.8	0.8
1	3	382.7	82.3	78.6	49.3	5.5	1.7	0.1
1	4	1222.8	263.0	260.0	163.0	13.3	5.4	0.3
1	5	577.7	124.3	106.9	67.0	7.0	2.6	0.1
1	12	1227.4	264.0	234.9	147.3	9.6	5.5	0.5
1	14	1139.4	245.1	234.7	147.2	12.0	5.0	0.4
1	15	490.2	105.4	100.7	63.1	5.1	2.2	0.1
2	6	631.0	135.7	110.9	69.6	6.4	2.8	0.2
3	8	852.9	183.5	235.4	147.6	8.9	3.7	0.3
3	9	2143.8	461.1	612.9	384.4	22.2	9.4	0.9
3	10	1315.8	283.0	317.9	199.3	13.5	5.8	0.4
5	11	580.5	124.9	188.0	117.9	6.7	2.5	0.1
6	7	923.6	198.7	203.3	127.5	8.5	4.1	0.3
6	13	539.5	116.0	94.5	59.3	4.5	2.4	0.2

TREATMENT 1 DEC.

EN-TRANCE	REGION	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	1	1402.0	301.6	283.0	177.5	11.9	6.3	0.5
1	2	1297.3	279.1	277.7	174.2	11.8	5.9	0.7
1	3	1790.5	385.1	362.0	227.0	13.0	8.1	0.5
1	4	2977.7	640.5	603.9	378.7	33.5	13.2	0.8
1	5	1217.2	261.8	230.5	144.5	15.0	5.4	0.3

Table G-1. Continued.

1	12	993.4	213.7	202.1	126.8	9.1	4.4	0.3
1	14	2938.3	632.0	653.5	409.8	32.8	12.9	0.9
1	15	562.2	120.9	130.5	81.8	6.9	2.4	0.1
2	6	1181.3	254.1	222.6	139.6	13.2	5.2	0.4
3	8	1921.1	413.2	527.5	330.8	20.5	8.3	0.6
3	9	1992.9	428.6	620.6	389.2	23.2	8.6	0.7
3	10	1672.2	359.7	423.1	265.3	19.1	7.3	0.4
5	11	1413.4	304.0	435.8	273.3	16.7	6.1	0.4
6	7	779.2	167.6	169.4	106.2	8.1	3.4	0.2
6	13	1374.9	295.7	228.9	143.5	12.5	6.1	0.5

Table G-2. Totals for year 50 by month, treatment and entrance.

TREATMENT 1 JAN.

ENTRANCE	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	60869.3	7155.6	36473.5	22870.5	564.9	280.5	41.6
2	5904.2	694.5	3662.6	2296.6	41.4	25.4	2.5
3	25261.6	3253.8	15507.1	9723.5	201.2	111.0	14.9
5	7051.6	821.7	4200.1	2633.7	77.0	33.9	5.9
6	8289.0	1285.4	4495.8	2819.0	87.0	35.0	2.6

TREATMENT 1 FEB.

ENTRANCE	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	91493.6	12783.3	57654.0	36150.9	576.1	391.3	42.1
2	7868.5	931.5	5045.6	3163.7	43.2	34.3	3.9
3	27140.4	3918.1	15929.9	9988.7	311.8	122.3	26.3
5	8540.7	1080.7	5355.9	3358.4	62.8	39.5	6.8
6	12327.4	2039.3	7276.4	4562.5	92.9	50.3	3.7

TREATMENT 1 MAR.

ENTRANCE	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	112342.9	17759.8	70690.8	44325.1	636.4	468.5	44.3
2	9526.7	1368.8	6015.4	3771.9	60.8	44.7	6.7
3	45966.9	7222.4	29581.5	18548.4	279.8	190.5	23.6
5	10187.1	1479.9	6264.0	3927.7	42.7	41.4	2.7
6	21769.1	4198.4	15064.7	9445.8	101.8	85.6	6.1

TREATMENT 1 APR.

ENTRANCE	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	10826.8	2328.9	2598.3	1629.4	130.5	49.2	4.7
2	868.8	186.9	207.8	130.3	11.7	3.8	0.2
3	5496.8	1182.4	1740.5	1091.4	66.5	24.7	2.7
5	867.5	186.6	353.4	221.6	12.5	3.6	0.1
6	1937.8	416.8	551.8	346.0	21.7	8.8	1.0

Table G-2. Continued.

TREATMENT 1 MAY

ENTRANCE	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	5481.1	1178.9	1168.3	732.7	77.6	23.9	1.1
2	543.4	116.9	104.9	65.8	7.9	2.4	0.1
3	3321.1	714.3	1063.1	666.6	46.2	14.1	0.7
5	524.0	112.7	204.6	128.3	7.5	2.2	0.1
6	1028.5	221.2	256.3	160.7	13.5	4.4	0.2

TREATMENT 1 JUNE

ENTRANCE	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	7429.8	1598.2	1388.1	870.5	53.3	33.9	3.3
2	634.5	136.5	102.0	64.0	4.8	2.9	0.3
3	3732.6	802.9	904.9	567.5	33.6	16.6	1.6
5	693.4	149.1	186.9	117.2	6.2	3.1	0.3
6	1417.3	304.9	277.8	174.2	10.2	6.4	0.7

TREATMENT 1 JULY

ENTRANCE	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	8330.7	1792.0	1679.1	1053.0	65.9	38.1	3.7
2	579.7	124.7	99.1	62.1	4.8	2.6	0.2
3	3260.6	701.4	778.6	488.3	26.4	14.6	1.5
5	631.6	135.9	169.8	106.5	6.3	2.8	0.2
6	1244.7	267.7	180.4	113.1	7.8	5.7	0.6

TREATMENT 1 AUG.

ENTRANCE	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	1478.1	317.9	326.6	204.8	21.9	6.4	0.2
2	127.2	27.3	30.9	19.4	1.9	0.5	0.0
3	565.4	121.6	174.4	109.3	8.4	2.4	0.1
5	164.4	35.4	70.3	44.1	2.5	0.7	0.0
6	217.5	46.8	61.0	38.3	3.1	0.9	0.0

TREATMENT 1 SEP.

ENTRANCE	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	6082.0	1308.3	1295.7	812.5	72.3	27.2	1.9
2	542.6	116.7	115.3	72.3	6.4	2.4	0.2
3	2729.0	587.0	706.6	443.1	29.3	12.1	1.1
5	641.4	138.0	227.6	142.7	8.4	2.7	0.1
6	1045.8	224.9	200.1	125.5	9.9	4.7	0.4

Table G-2. Continued.

TREATMENT 1 OCT.

ENTRANCE	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	10848.2	2333.5	2048.9	1284.9	87.7	49.1	4.4
2	1060.2	228.1	148.0	92.8	7.9	4.8	0.5
3	5261.3	1131.7	1347.4	845.0	47.9	23.3	2.1
5	1245.6	267.9	279.4	175.2	9.2	5.6	0.5
6	2059.1	442.9	327.3	205.2	12.9	9.4	1.1

TREATMENT 1 NOV.

ENTRANCE	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	6566.5	1412.5	1273.4	798.6	65.7	29.5	2.4
2	631.0	135.7	110.9	69.6	6.4	2.8	0.2
3	4312.6	927.6	1166.2	731.3	44.6	18.9	1.6
5	580.5	124.9	188.0	117.9	6.7	2.5	0.1
6	1463.1	314.7	297.9	186.8	13.1	6.5	0.5

TREATMENT 1 DEC.

ENTRANCE	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	13178.6	2834.7	2743.3	1720.4	134.1	58.7	4.1
2	1181.3	254.1	222.6	139.6	13.2	5.2	0.4
3	5586.2	1201.5	1571.2	985.3	62.7	24.3	1.7
5	1413.4	304.0	435.8	273.3	16.7	6.1	0.4
6	2154.1	463.4	398.2	249.7	20.6	9.6	0.8

Table G-3. Totals for year 50 by month and treatment.

JAN.

TREATMENT	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	107376.	13211.	64339.	40343.	972.	486.	68.

FEB.

TREATMENT	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	147371.	20753.	91262.	57224.	1087.	638.	83.

MAR.

TREATMENT	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	199793.	32029.	127616.	80019.	1121.	831.	83.

Table G-3. Continued.

APR.

TREATMENT	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	19998.	4302.	5452.	3419.	243.	90.	9.

MAY

TREATMENT	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	10898.	2344.	2797.	1754.	153.	47.	2.

JUNE

TREATMENT	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	13908.	2992.	2860.	1793.	108.	63.	6.

JULY

TREATMENT	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	14047.	3022.	2907.	1823.	111.	64.	6.

AUG.

TREATMENT	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	2553.	549.	663.	416.	38.	11.	0.

SEP.

TREATMENT	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	11041.	2375.	2545.	1596.	126.	49.	4.

OCT.

TREATMENT	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	20474.	4404.	4151.	2603.	166.	92.	9.

NOV.

TREATMENT	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	13554.	2915.	3036.	1904.	137.	60.	5.

Table G-3. Continued.

DEC.

TREATMENT	COD (KG/MONTH)	BOD (KG/MONTH)	SS (KG/MONTH)	VSS (KG/MONTH)	NH3 (KG/MONTH)	TP (KG/MONTH)	OP (KG/MONTH)
1	23514.	5058.	5371.	3368.	247.	104.	7.

Table G-4. Totals for year 50 by treatment.

TREATMENT	COD (KG/YEAR)	BOD (KG/YEAR)	SS (KG/YEAR)	VSS (KG/YEAR)	NH3 (KG/YEAR)	TP (KG/YEAR)	OP (KG/YEAR)
1	584524.	93953.	312999.	196263.	4509.	2534.	282.

Table G-5. Monthly precipitation for year 50 by station.

STATION	JAN. (CM)	FEB. (CM)	MAR. (CM)	APR. (CM)	MAY (CM)	JUNE (CM)	JULY (CM)	AUG. (CM)
1	0.9	3.6	4.4	4.0	1.4	2.1	4.8	0.6
2	0.8	4.0	5.9	3.0	1.1	1.5	2.6	0.2
3	3.6	3.4	5.2	3.4	2.0	3.1	2.6	0.7
4	1.8	3.7	5.1	7.7	3.1	3.6	3.5	0.4

STATION	SEP. (CM)	OCT. (CM)	NOV. (CM)	DEC. (CM)
1	2.1	2.1	1.0	4.8
2	2.9	2.7	2.1	5.1
3	2.5	5.6	2.4	5.6
4	2.8	4.0	4.7	4.3

APPENDIX H

STREAM MONITORING DATA FOR NINE CACHE VALLEY FEEDLOTS

Table H-1. Stream monitoring data, sampling sites A to V, October 6.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A	0.81	4.50	27.5	3.2	0.055	0.017	0.045	0.006	0.840	8.35
B	1.13	9.38	40.9	4.8	0.064	0.022	0.058	0.007	0.814	8.35
C	0.95	4.50	38.5	4.5	0.098	0.027	0.070	0.007	0.902	8.38
D	1.18	1.29	35.0	4.0	0.088	0.015	0.059	0.008	0.826	8.38
E	0.87	9.75	34.7	3.9	0.084	0.025	0.054	0.008	0.869	8.40
F	0.75		8.5	1.3	0.038	0.013	0.063	0.007	0.581	8.30
G	0.78	6.48	26.4	3.3	0.094	0.052	0.074	0.015	0.793	8.20
H	1.02	5.25	18.8	3.1	0.028	0.010	0.061	0.006	0.435	8.12
I	1.30	5.59	9.1	1.8	0.025	0.008	0.059	0.007	0.465	8.00
J	2.09	2.32	49.1	5.0	0.111	0.040	0.053	0.010	0.714	8.30
K	0.66	1.84	18.5	2.2	0.048	0.005	0.044	0.004	0.453	8.30
L	1.26	5.23	53.2	4.2	0.094	0.028	0.056	0.010	0.675	8.20
M	0.98	5.23	35.7	4.3	0.028	0.003	0.039	0.003	0.275	8.30
N	0.00	2.13	7.8	1.4	0.031	0.008	0.040	0.003	0.217	8.35
O	0.36	5.47	26.1	3.5	0.068	0.027	0.049	0.009	0.622	8.34
P	0.93	8.54	4.7	1.3	0.078	0.052	0.100	0.011	0.358	8.28
Q	1.04	12.92	5.7	1.6	0.127	0.085	0.061	0.011	0.509	8.48
R	0.87	11.78	4.8	1.4	0.078	0.055	0.053	0.009	0.136	8.51
S	1.04	13.43	15.9	2.6	0.124	0.075	0.056	0.007	0.406	8.35
T	1.05	12.59	7.3	1.8	0.081	0.047	0.058	0.005	0.434	8.31
U	0.42	31.01	7.2	1.7	0.124	0.039	0.057	0.002	0.355	8.28
V	0.49	4.71	30.4	3.5	0.088	0.045	0.060	0.007	0.687	8.39

Table H-2. Stream monitoring data, sampling sites A to V, October 13.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A	0.68	7.93	8.3	2.0	0.083	0.043	0.072	0.022	2.336	8.40
B	1.15	7.03	33.0	4.2	0.152	0.057	0.172	0.026	1.872	8.35
C	0.57	8.87	26.5	3.1	0.133	0.047	0.130	0.030	2.713	8.30
D	1.07	8.23	21.6	3.5	0.136	0.068	0.152	0.032	1.738	8.29
E	0.88	11.47	32.6	4.6	0.171	0.078	0.139	0.032	2.247	8.30
F	0.61	7.33	29.6	5.4	0.140	0.043	0.115	0.012	0.742	8.29
G	4.16	13.56	19.2	3.1	0.152	0.096	0.071	0.030	2.462	8.21
H	0.87	1.62	6.6	1.7	0.051	0.015	0.051	0.009	0.611	8.18
I	0.92	3.05	7.1	2.0	0.057	0.026	0.045	0.009	0.651	8.20
J	0.86	4.85	11.0	1.9	0.076	0.038	0.082	0.017	0.865	8.33
K	0.46	2.11	11.6	1.8	0.032	0.007	0.044	0.004	0.475	8.49
L	0.83	2.56	11.7	2.3	0.067	0.026	0.059	0.013	0.767	8.30
M	0.53	3.53	6.6	2.1	0.022	0.000	0.036	0.001	0.282	8.20
N	0.74	3.01	7.1	1.6	0.067	0.001	0.039	0.002	0.286	8.35
O	1.67	16.24	9.3	3.0	0.181	0.110	0.128	0.012	0.212	8.26
P	0.38	4.96	13.3	2.2	0.060	0.028	0.047	0.010	0.725	8.39
Q	1.05	18.65	6.6	2.2	0.200	0.153	0.051	0.010	0.194	8.58
R	1.30	14.14	14.7	4.1	0.197	0.155	0.050	0.009	0.221	8.60
S	0.89	13.95	20.1	3.6	0.111	0.046	0.064	0.006	0.226	8.40
T	1.15	16.24	9.2	2.4	0.070	0.046	0.075	0.006	0.326	8.28
U	0.97	17.71	7.5	2.2	0.038	0.020	0.044	0.000	0.079	8.20
V	0.41	8.76	13.4	1.8	0.086	0.051	0.080	0.026	1.578	8.30

Table H-3. Stream monitoring data, sampling sites A to V, October 20.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A	1.16	5.60	6.9	1.8	0.094	0.057	0.114	0.014	1.804	8.60
B	1.82	7.26	30.4	5.0	0.174	0.066	0.119	0.016	1.250	8.58
C	2.30	7.78	35.7	4.8	0.167	0.074	0.158	0.013	1.592	8.50
D	2.04	9.51	22.1	3.5	0.070	0.076	0.128	0.015	1.215	8.50
E	1.89	7.78	20.7	3.4	0.159	0.078	0.094	0.015	1.599	8.50
F	1.11	10.15	63.0	8.2	0.174	0.020	0.056	0.006	0.710	8.39
G	1.10	5.49	12.1	2.3	0.094	0.046	0.046	0.012	1.222	8.40
H	1.07	0.34	11.2	2.3	0.033	0.010	0.093	0.006	0.691	8.40
I	0.72	2.52	7.04	1.6	0.022	0.014	0.057	0.007	0.713	8.33
J	1.07	2.93	9.5	1.9	0.047	0.022	0.076	0.009	0.853	8.40
K	0.86	4.66	22.1	3.2	0.043	0.014	0.040	0.004	0.486	8.50
L	0.86	3.38	9.8	1.9	0.047	0.018	0.045	0.008	0.781	8.42
M	1.06	6.66	15.2	3.3	0.058	0.007	0.027	0.001	0.047	8.50
N	1.36	4.81	13.3	1.8	0.040	0.009	0.060	0.003	0.055	8.50
O	1.11	4.32	9.3	1.6	0.043	0.018	0.048	0.008	0.708	8.49
P	1.64	15.34	10.4	2.7	0.148	0.079	0.136	0.008	0.258	8.46
Q	1.17	10.79	6.3	1.8	0.127	0.066	0.066	0.006	0.282	8.50
R	1.16		6.5	1.9	0.087	0.047	0.056	0.006	0.217	8.50
S	1.84	14.55	9.0	2.3	0.301	0.065	0.061	0.005	0.255	8.45
T	1.22	16.06	5.7	1.7	0.232	0.062	0.056	0.004	0.248	8.60
U	1.34	17.78	7.4	2.1	0.083	0.042	0.054	0.003	0.179	8.40
V	0.90	7.03	10.7	2.1	0.080	0.042	0.061	0.011	0.831	8.50

Table H-4. Stream monitoring data, sampling sites A to V, October 27.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A	1.57	11.88	36.8	6.2	0.172	0.055	0.130	0.013	1.306	8.23
B	0.76	9.58	9.3	0.8	0.069	0.037	0.067	0.014	0.447	8.30
C	0.87	8.33	16.2	6.5	0.105	0.041	0.066	0.014	1.055	8.30
D	0.87	7.94	13.0	2.4	0.113	0.037	0.071	0.013	0.416	8.29
E	0.88	7.94	26.5	17.3	0.094	0.041	0.086	0.014	2.030	8.30
F	1.50	30.38	141.9	22.2	0.654	0.018	0.073	0.004	0.964	8.20
G	1.06	5.00	19.3	7.6	0.168	0.100	0.042	0.015	0.972	8.21
H	0.56	0.27	6.3	1.6	0.037	01006	0.057	0.006	0.516	8.15
I	0.84	0.59	7.7	1.9	0.042	0.005	0.057	0.006	0.919	8.11
J	1.15	2.39	10.1	1.8	0.060	0.024	0.056	0.010	0.416	8.20
K	0.62	5.90	12.6	2.5	0.030	0.001	0.037	0.003	0.591	8.31
L	0.82	3.87	7.8	1.6	0.062	0.025	0.054	0.010	0.427	8.20
M	0.35	2.54	8.2	1.1	0.021	0.000	0.029	0.000	0.406	8.28
N	0.78	2.74	8.9	1.5	0.040	0.003	0.052	0.002	0.102	8.25
O	0.60	9.50	10.2	1.8	0.069	0.024	0.046	0.009	0.255	8.20
P	2.37	16.97	4.5	3.9	0.127	0.064	0.094	0.005	0.401	8.19
Q	0.89	12.63	6.2	1.8	0.106	0.045	0.056	0.003	0.302	8.20
R	1.15	15.95	8.2	3.4	0.092	0.034	0.037	0.002	0.099	8.20
S	1.83	21.62	5.9	1.6	0.092	0.041	0.048	0.002	0.338	8.17
T	2.72	19.20	4.8	2.4	0.117	0.050	0.051	0.002	0.164	8.12
U	0.83	15.09	3.4	1.0	0.074	0.030	0.037	0.000	0.142	8.40
V	0.30	5.55	16.7	6.4	0.079	0.031	0.046	0.012	0.948	8.48

Table H-5. Stream monitoring data, sampling sites A to V, November 3.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A	0.88	5.58	14.6	3.1	0.014	0.045	0.073	0.013	1.242	8.31
B	1.00	5.43	41.5	4.8	0.190	0.053	0.074	0.014	1.100	8.35
C	1.24	6.58	16.8	3.0	0.153	0.051	0.064	0.012	1.199	8.32
D	0.85	7.51	17.4	3.5	0.108	0.040	0.157	0.014	1.159	8.32
E	1.02	7.20	17.5	3.3	0.100	0.041	0.072	0.014	1.205	8.35
F	1.49	22.41	166.8	21.1	0.575	0.028	0.083	0.006	0.710	8.32
G	0.82	4.43	14.3	2.6	0.112	0.045	0.062	0.012	0.914	8.32
H	0.90	1.19	9.8	1.8	0.041	0.003	0.079	0.007	0.676	8.40
I	0.91	0.00	15.5	3.0	0.045	0.013	0.072	0.008	0.708	8.25
J	0.64	2.27	10.4	2.4	0.074	0.028	0.066	0.013	0.772	8.29
K	0.86	2.85	12.2	1.8	0.054	0.002	0.038	0.005	0.388	8.55
L	0.94	0.81	7.1	2.8	0.073	0.025	0.059	0.010	0.673	8.40
M	1.11	1.54	13.8	2.2	0.025	0.060	0.029	0.001	0.015	8.40
N	0.94	2.16	15.8	3.2	0.065	0.007	0.043	0.003	0.029	8.38
O	0.91	5.31	10.5	2.3	0.076	0.028	0.062	0.010	0.749	8.30
P	1.23	11.97	8.5	2.6	0.155	0.079	0.094	0.008	0.164	8.30
Q	1.19	14.86	9.0	1.9	0.194	0.083	0.060	0.005	0.198	8.32
R	1.53	17.86	8.5	2.1	0.127	0.063	0.045	0.005	0.151	8.33
S	1.69	17.79	8.6	2.1	0.512	0.357	0.049	0.004	0.188	8.29
T	1.31	13.54	5.5	2.0	0.327	0.236	0.045	0.004	0.163	8.30
U	1.61	19.83	33.6	6.6	0.198	0.073	0.044	0.002	0.117	8.22
V	0.64	5.55	21.9	3.8	0.116	0.035	0.048	0.011	0.862	8.39

Table H-6. Stream monitoring data, sampling sites A to V, November 10.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A	0.98	5.60	2.5	0.0	0.058	0.028	0.089	0.017	1.618	7.94
B	0.91	12.47	66.2	8.3	0.206	0.061	0.153	0.022	0.951	8.05
C	1.01	6.21	6.6	4.0	0.255	0.039	0.052	0.016	1.567	8.09
D	0.67	7.26	10.2	4.6	0.202	0.042	0.085	0.016	1.436	8.09
E	0.91	8.03	18.5	6.4	0.140	0.052	0.078	0.016	1.642	8.15
F	1.76	7.80	25.4	8.8	0.110	0.028	0.057	0.006	0.662	8.09
G	0.65	4.86	8.1	5.4	0.081	0.042	0.041	0.012	1.139	8.13
H	0.69	1.70	8.2	5.0	0.041	0.014	0.070	0.007	0.692	8.08
I	0.68	2.47	10.2	5.2	0.041	0.013	0.058	0.007	0.724	8.04
J	0.62	4.40	9.5	4.8	0.058	0.025	0.050	0.009	0.771	8.13
K	0.54	4.48	8.5	4.2	0.002	0.003	0.025	0.005	0.381	8.32
L	0.52	4.59	11.9	11.2	0.048	0.031	0.060	0.009	0.809	8.20
M	0.69	5.75	18.1	5.6	0.025	0.014	0.027	0.002	0.019	8.29
N	0.71	3.86	15.2	3.2	0.035	0.023	0.045	0.003	0.034	8.30
O	0.74	7.33	12.2	3.4	0.054	0.028	0.065	0.009	0.711	8.21
P	1.46	15.71	10.5	6.6	0.140	0.094	0.094	0.006	0.186	8.22
Q	0.98	14.20	6.9	5.0	0.123	0.080	0.057	0.004	0.152	8.22
R	1.00	13.20	4.4	4.8	0.107	0.073	0.055	0.004	0.218	8.23
S	1.24	17.06	6.8	5.0	0.209	0.067	0.039	0.003	0.229	8.17
T	1.01	15.19	4.3	4.2	0.255	0.078	0.041	0.003	0.166	8.25
U	0.74	14.63	3.8	4.4	0.100	0.061	0.036	0.002	0.144	8.14
V	0.23	5.10	12.1	6.4	0.071	0.031	0.047	0.011	1.069	8.29

Table H-7. Stream monitoring data, sampling sites A to V, November 17.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	$o\text{-}PO_4$ mg/l	$NH_3\text{-}N$ mg/l	$NO_2\text{-}N$ mg/l	$NO_3\text{-}N$ mg/l	pH
A	1.38	191.77	11.0	4.4	0.756	0.577	0.571	0.029	1.590	8.36
B	1.87	11.41	33.4	7.6	0.730	0.492	8.24	0.034	1.421	8.35
C	1.36	14.62	10.0	4.6	0.568	0.423	6.91	0.044	1.445	8.30
D	1.54	15.77	15.2	2.8	0.484	0.364	5.77	0.048	1.645	8.25
E	1.38	14.89	19.6	3.6	0.471	0.344	5.24	0.048	1.514	8.29
F	1.00	168.12	22.8	4.8	0.091	0.052	0.546	0.009	0.622	8.31
G	1.61	153.86	9.2	1.4	0.266	0.184	2.23	0.033	1.329	8.30
H	0.29	1.25	16.0	4.2	0.054	0.016	0.97	0.008	0.720	8.17
I	0.88	251.50	17.6	3.4	0.050	0.020	0.157	0.021	0.674	8.12
J	0.56	6.03	13.6	5.2	0.094	0.051	0.367	0.019	0.945	8.30
K	0.41	3.41	18.0	2.6	0.050	0.005	0.074	0.014	0.893	8.41
L	0.57	5.08	16.6	3.0	0.094	0.051	0.402	0.009	0.916	8.20
M	0.52	8.22	13.4	0.6	0.027	0.003	0.036	0.001	0.022	8.38
N	0.58	5.76	15.0	2.8	0.044	0.009	0.124	0.003	0.038	8.33
O	0.93	284.25	14.4	1.0	0.101	0.046	0.773	0.019	0.853	8.29
P	0.76	10.12	7.8	0.2	0.101	0.064	0.160	0.006	0.182	8.30
Q	1.30	209.66	9.8	1.4	0.124	0.080	0.091	0.005	0.163	8.30
R	1.13	14.78	12.8	1.8	0.104	0.059	0.164	0.004	0.168	8.30
S	2.61	15.92	7.6	3.2	0.108	0.064	0.097	0.004	0.162	8.20
T	2.66	16.45	6.2	4.4	0.249	0.197	0.064	0.004	0.168	8.20
U	0.68	102.94	4.4	0.8	0.067	0.049	0.078	0.003	0.127	8.25
V	0.68	8.49	10.6	2.4	0.101	0.061	0.402	0.022	1.046	8.40

Table H-8. Stream monitoring data, sampling sites A to V, November 21.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	$o\text{-}PO_4$ mg/l	$NH_3\text{-}N$ mg/l	$NO_2\text{-}N$ mg/l	$NO_3\text{-}N$ mg/l	pH
A		3.61	4.6	1.6	0.047	0.032	0.370	0.014	1.850	8.45
B		7.92	38.6	5.9	0.130	0.043	0.410	0.017	1.634	8.40
C		7.22	7.4	3.4	0.060	0.043	1.40	0.017	1.540	8.39
D		7.25	7.0	3.6	0.095	0.056	0.287	0.016	1.776	8.32
E		10.56	8.8	0.4	0.085	0.057	0.451	0.016	1.588	8.32
F		10.60	112.7	14.7	0.095	0.020	0.130	0.005	0.792	8.21
G		9.11	8.4	3.4	0.139	0.109	0.431	0.018	1.374	8.28
H		3.57	19.0	4.0	0.032	0.013	0.072	0.007	0.828	8.10
I		5.21	8.6	1.4	0.025	0.020	0.078	0.007	0.809	8.15
J		6.47	11.0	4.2	0.063	0.045	0.082	0.010	1.050	8.20
K		4.69	7.8	2.2	0.019	0.002	0.030	0.010	1.022	8.48
L		6.96	10.2	2.0	0.063	0.046	0.077	0.010	0.975	8.23
M		5.39	7.0	6.6	0.000	0.002	0.029	0.001	0.025	8.39
N		7.44	36.2	5.0	0.060	0.012	0.059	0.003	0.044	8.36
O		7.37	12.0	6.4	0.108	0.048	0.033	0.010	0.890	8.28
P		34.45	131.6	55.0	0.579	0.078	0.295	0.008	0.238	8.18
Q		11.87	17.0	6.6	0.294	0.234	0.113	0.005	0.169	8.23
R		14.58	17.2	2.0	0.250	0.187	0.111	0.004	0.173	8.22
S		15.18	6.4	1.6	0.066	0.057	0.067	0.003	0.170	8.12
T		8.48	3.2	1.0	0.063	0.048	0.066	0.003	0.138	8.20
U		11.20	4.2	1.2	0.038	0.032	0.054	0.001	0.093	8.01
V		3.09	14.2	3.4	0.051	0.034	0.086	0.014	1.116	8.22

Table H-9. Stream monitoring data, sampling sites A to V, December 2.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	$o\text{-}PO_4$ mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A	0.71	1.69	5.6	2.6	0.066	0.043	0.169	0.016	1.889	8.30
B	1.41	8.53	39.6	7.4	0.137	0.047	0.251	0.015	1.718	8.31
C	1.15	15.24	11.4	5.6	0.089	0.044	0.188	0.015	1.707	8.31
D	0.33	12.61	12.0	5.0	0.089	0.043	0.215	0.017	1.638	8.31
E	1.12	8.69	19.6	8.2	0.095	0.047	0.217	0.018	1.667	8.30
F	1.74	25.25	88.6	14.8	0.408	0.020	0.092	0.012	0.730	8.25
G	1.06	15.86	15.0	5.8	0.121	0.070	0.190	0.016	1.486	8.28
H	0.93	0.99	23.8	6.4	0.069	0.015	0.108	0.009	0.737	8.16
I	0.72	2.64	21.4	3.6	0.053	0.012	0.112	0.007	0.806	8.20
J	1.05	7.58	23.8	7.6	0.095	0.033	0.166	0.009	0.951	8.20
K	0.66	1.65	21.0	3.6	0.056	0.009	0.086	0.010	1.082	8.35
L	1.39	4.33	21.0	5.2	0.073	0.031	0.149	0.009		8.21
M				Sample Spot Frozen Over						
N	0.97	8.17	38.4	6.2	0.073	0.012	0.081	0.003	0.094	8.24
O	0.81	2.88	15.4	3.2	0.066	0.035	0.194	0.011	0.926	8.25
P	2.94	14.17	37.0	8.4	0.169	0.067	0.208	0.006	0.173	8.23
Q	1.90	17.92	7.8	4.0	0.108	0.047	0.127	0.004	0.198	8.23
R	1.31	11.29	9.2	3.8	0.079	0.033	0.097	0.005	0.372	8.21
S	1.71	9.68	18.0	4.0	0.066	0.043	0.086	0.006	0.124	8.20
T	2.92	14.58	6.4	4.8	0.081	0.055	0.115	0.003	0.215	8.22
U	1.14	12.52	5.8	5.8	0.040	0.019	0.066	0.002	0.098	8.18
V	1.01	6.47	32.6	6.0	0.095	0.030	0.175	0.012	1.299	8.35

Table H-10. Stream monitoring data, sampling sites A to V, December 8.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	$o\text{-}PO_4$ mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A	0.87	10.52	12.8	3.0	0.062	0.040	0.204	0.020	1.490	8.42
B	1.76	21.66	110.8	19.7	0.435	0.072	0.207	0.018	1.975	8.40
C	0.80	6.12	16.0	1.8	0.092	0.063	0.187	0.021	1.652	8.38
D	1.17	5.41	15.2	0.6	0.088	0.046	0.199	0.022	1.550	8.40
E	0.66	6.33	16.2	2.8	0.095	0.053	0.211	0.022	1.541	8.37
F	1.98	22.42	71.3	7.3	0.192	0.025	0.132	0.006	0.747	8.26
G	1.01	11.86	19.8	2.1	0.225	0.165	0.216	0.019	1.217	8.30
H	0.94	2.47	18.2	0.2	0.045	0.016	0.125	0.008	0.777	8.20
I	0.74	2.89	22.2	4.6	0.045	0.016	0.115	0.008	0.774	8.25
J	1.44	5.91	20.6	2.8	0.128	0.086	0.190	0.011	0.867	8.21
K	0.28	9.89	20.6	5.2	0.042	0.012	0.096	0.010	1.037	8.42
L	0.64	5.66	26.4	1.6	0.088	0.054	0.142	0.011	0.942	8.28
M	0.79	19.73	20.4	3.4	0.028	0.003	0.064	0.002	0.094	8.32
N	0.69	3.81	17.0	2.6	0.032	0.007	0.083	0.003	0.096	8.30
O	1.11	7.46	20.6	2.8	0.085	0.049	0.150	0.012	0.901	8.28
P	1.96	11.86	24.2	3.4	0.255	0.102	0.174	0.007	0.183	8.35
Q	1.01	15.63	10.6	2.4	0.102	0.061	0.114	0.006	0.203	8.29
R	0.99	10.52	7.2	2.6	0.055	0.040	0.097	0.005	0.190	8.27
S	1.98	12.78	8.0	4.6	0.338	0.309	0.100	0.007	0.170	8.22
T	1.30	11.56	6.8	2.2	0.298	0.263	0.088	0.006	0.176	8.23
U	1.23	11.94	4.2	0.8	0.038	0.030	0.058	0.003	0.115	8.10
V	1.03	10.98	38.2	5.2	0.135	0.046	0.172	0.017	1.182	8.38

Table H-11. Stream monitoring data, sampling sites A to V, December 15.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A	0.81	7.23	15.2	1.0	0.078	0.049	0.180	0.017	2.122	8.1
B	0.83	7.47	35.6	5.4	0.111	0.043	0.153	0.014	1.520	8.1
C	1.19	5.66	21.2	5.0	0.115	0.052	0.166	0.017	1.627	8.2
D	0.85	7.47	22.8	3.2	0.101	0.054	0.185	0.017	1.968	8.1
E	0.79	10.30	27.8	5.2	0.115	0.059	0.166	0.016	1.561	8.2
F	1.66	26.30	138.3	24.6	0.334	0.016	0.097	0.006	0.778	8.1
G	0.99	10.22	18.8	3.4	0.184	0.164	0.225	0.012	1.533	8.1
H	1.17	11.47	19.8	2.8	0.065	0.023	0.139	0.006	0.811	8.0
I	0.56	6.18	23.6	2.8	0.065	0.025	0.112	0.006	0.770	8.1
J	0.80	9.62	20.8	4.0	0.121	0.067	0.121	0.008	0.965	8.2
K	0.45	6.18	25.6	4.4	0.061	0.021	0.093	0.008	1.099	8.3
L	0.57	41.17	23.4	4.0	0.108	0.056	0.127	0.008	0.877	7.9
M	0.15	8.28	88.6	13.3	0.224	0.007	0.031	0.001	0.081	8.0
N	0.73	6.50	37.0	11.7	0.061	0.013	0.065	0.003	0.083	8.0
O	1.48	10.42	19.6	1.8	0.078	0.049	0.117	0.008	0.839	8.0
P	1.59	11.23	22.6	5.0	0.091	0.048	0.151	0.004	0.154	8.0
Q	0.80	11.11	10.8	2.0	0.520	0.067	0.101	0.005	0.137	8.0
R	1.43	11.39	11.0	2.0	0.071	0.034	0.073	0.006	0.137	8.0
S	2.06	15.03	6.2	3.8	0.065	0.033	0.063	0.003	0.163	7.7
T	1.08	21.01	7.8	3.2	0.095	0.046	0.068	0.004	0.138	7.7
U	1.00	10.67	4.4	4.0	0.051	0.028	0.047	0.003	0.100	7.7
V		29.17	26.6	5.0	0.118	0.033	0.104	0.012	1.364	8.0

Table H-12. Stream monitoring data, sampling sites A to V, December 19.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A		7:89	6.4	0.8	0.256	0.193	18.288	0.013	1.387	8.06
B		9.12	29.4	3.0	0.327	0.175	7.252	0.014	1.574	8.15
C		15.21	17.4	0.2	0.224	0.142	5.631	0.014	1.483	8.16
D		8.59	20.0	3.0	0.215	0.147	3.423	0.014	1.465	8.19
E		6.46	15.0	1.8	0.202	0.138	4.775	0.014	1.428	8.19
F		17.71	45.5	6.0	0.095	0.019	0.145	0.006	0.825	8.19
G		7.48	12.0	0.2	0.185	0.147	1.269	0.011	1.061	8.11
H		3.27	26.8	2.0		0.025	0.101	0.005	0.716	8.04
I		2.93	17.0	1.8		0.019	0.092	0.006	0.735	8.02
J		2.93	15.8	0.2	0.092	0.060	0.236	0.007	0.788	8.09
K		3.72	28.4	1.2	0.050	0.016	0.096	0.006	0.733	8.22
L		5.15	23.2	2.8	0.089	0.058	0.187	0.008	0.857	8.13
M			298.5	24.4	0.482	0.109	0.161	0.009	0.136	8.20
N		8.10	39.2	3.6	0.082	0.016	0.067	0.003	0.082	8.15
O		6.67	18.8	1.8	0.092	0.052	0.123	0.008	0.816	8.18
P		12.84	16.2	4.0	0.147	0.066	0.148	0.005	0.137	8.00
Q		11.86	9.0	1.6	0.085	0.074	0.087	0.004	0.108	7.97
R		45.15	108.6	22.9	0.423	0.058	0.309	0.007	0.121	7.98
S		10.39	20.6	2.6	0.371	0.345	0.074	0.004	0.127	7.90
T		10.88	6.2	0.6	0.221	0.188	0.071	0.004	0.095	7.92
U		11.62	3.0	1.6	0.040	0.021	0.067	0.003	0.084	7.82
V		5.24	14.6	0.8	0.131	0.077	1.674	0.010	0.986	8.19

Table H-13. Stream monitoring data, sampling sites A to V, January 13.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A	1.61	2.78	3.2	0.0	0.067	0.018	0.146	0.008	2.046	7.76
B										
C	1.33	4.29	21.0	2.6	0.127	0.042	0.179	0.009	2.148	7.83
D	1.10	2.38	18.0	1.8	0.117	0.042	0.176	0.009	1.858	7.83
E	1.42	4.96	18.0	1.4	0.124	0.048	0.163	0.009	1.931	7.90
F	3.83	18.66	58.8	9.9	0.290	0.055	0.165	0.007	1.304	7.89
G	0.83	3.93	16.4	1.6		0.051	0.124	0.007	1.745	7.90
H	0.90	4.33	30.8	3.4	0.106	0.005	0.095	0.005	1.190	7.88
I	0.65	4.51	30.0	2.6	0.099	0.009	0.108	0.005	1.373	7.89
J	0.79	5.96	33.2	3.6	0.106	0.021	0.096	0.006	1.402	7.90
K	0.70	6.43	65.7	4.2	0.170	0.014	0.141	0.008	1.552	8.08
L	1.09	3.18	33.0	3.2	0.106	0.019	0.107	0.006	1.136	8.00
M										
N	0.72	5.88	25.0	1.2	0.064	0.000	0.073	0.003	0.147	8.01
O	0.86	4.76	29.2	3.2	0.096	0.025	0.092	0.006	1.453	7.97
P	1.07	5.52	10.6	1.4	0.103	0.039	0.207	0.005	0.252	7.89
Q	4.67	10.32	11.8	6.4	0.117	0.050	0.127	0.005	0.252	7.81
R	5.95	31.28	47.0	12.2	0.241	0.051	0.152	0.005	0.242	7.95
S	1.95	11.91	11.8	1.6	0.088	0.028	0.136	0.004	0.311	7.80
T	1.93	4.72	9.4	2.0	0.071	0.019	0.103	0.004	0.285	7.78
U	1.01	6.75	5.0	1.4	0.032	0.000	0.065	0.003	0.123	7.62
V	1.01	4.17	18.2	1.2	0.103	0.030	0.127	0.007	1.866	8.00

Table H-14. Stream monitoring data, sampling sites A to V, January 20.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A	0.48	2.04	10.2	0.6	0.090	0.054	0.116	0.010	1.187	8.10
B	1.01	5.96	47.0	5.2	0.179	0.056	0.180	0.010	1.277	8.20
C	0.97	6.74	28.4	2.4	0.136	0.061	0.231	0.012	1.418	8.25
D	1.51	7.60	30.6	3.6	0.123	0.072	0.161	0.013	1.205	8.30
E	0.84	5.37	34.6	2.8	0.136	0.059	0.186	0.013	1.202	8.32
F	1.27	33.16	161.2	21.6	0.475	0.024	0.109	0.011	0.843	8.26
G	0.81	7.13	21.6	4.0	0.153	0.104	0.139	0.009	1.188	8.35
H	0.91	4.98	34.4	3.4	0.090	0.024	0.093	0.006	0.790	8.30
I	0.52	4.31	34.6	4.8	0.076	0.025	0.084	0.006	0.749	8.35
J	0.69	6.12	33.2	3.6	0.133	0.062	0.125	0.007	0.911	8.11
K	0.29	5.10	35.0	4.8	0.076	0.027	0.176	0.008	1.170	8.28
L	0.87	11.76	36.8	3.6	0.149	0.075	0.114	0.007	0.860	8.28
M										
N	1.00	9.80	51.8	8.5	0.100	0.016	0.079	0.005	0.090	8.30
O	0.89	7.41	29.2	4.0	0.159	0.092	0.122	0.007	1.211	8.30
P	1.26	10.74	26.8	4.4	0.143	0.062	0.251	0.006	0.299	8.30
Q	1.07	8.19	23.0	4.8	0.116	0.048	0.137	0.004	0.217	8.29
R	1.19	7.25	30.2	6.4	0.110	0.040	0.104	0.005	0.197	8.30
S	0.96	11.29	23.2	4.8	0.116	0.035	0.107	0.006	0.259	8.24
T	1.03	7.55	9.6	1.6	0.066	0.033	0.129	0.006	0.242	8.29
U	0.85	5.57	8.4	2.4	0.033	0.013	0.075	0.004	0.099	8.30
V	0.69	6.74	29.4	3.4	0.116	0.046	0.165	0.010	1.183	8.38

Table H-15. Stream monitoring data, sampling sites A to V, January 27.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A	0.88	4.74	4.8	0.8	0.079	0.064	0.125	0.011	1.602	7.90
B	1.17	5.69	28.6	3.2	0.132	0.066	0.155	0.012	1.998	8.05
C	0.12	15.39	31.0	4.2	0.152	0.075	0.184	0.013	1.883	8.10
D	0.94	11.57	27.0	3.2	0.149	0.072	0.143	0.012	1.470	8.18
E	0.72	16.54	32.7	4.6	0.169	0.077	0.171	0.012	1.880	8.12
F	1.92	12.95	80.0	13.7	0.172	0.023	0.089	0.006	0.866	8.10
G	0.98	5.58	23.2	4.4	0.132	0.087	0.167	0.012	1.470	8.09
H	1.27	11.12	91.8	15.1	0.152	0.016	0.091	0.005	0.778	8.02
I	1.27	10.16	90.2	9.8	0.172	0.016	0.079	0.004	0.756	8.18
J	1.25	7.75	41.7	6.4	0.129	0.059	0.088	0.006	0.835	8.10
K	1.11	6.26	74.7	10.9	0.145	0.023	0.104	0.007	1.600	8.30
L	1.30	8.14	58.8	5.3	0.129	0.048	0.097	0.007	0.830	8.24
M	1.19	6.38	11.2	2.4	0.040	0.007	0.055	0.003	0.116	8.18
N	0.88	7.14	11.8	3.6	0.083	0.011	0.055	0.004	0.107	8.15
O	1.34	8.67	44.0	4.2	0.155	0.049	0.110	0.007	0.812	8.17
P	2.82	18.44	57.4	8.0	0.126	0.061	0.156	0.007	0.209	8.10
Q	1.66	10.08	12.0	3.2	0.102	0.048	0.117	0.006	0.370	8.09
R	1.18	6.26	11.8	3.4	0.066	0.028	0.090	0.006	0.383	8.02
S	1.84	10.16	12.4	4.4	0.093	0.038	0.065	0.006	0.192	7.96
T	3.14	11.54	11.0	3.0	0.119	0.046	0.073	0.006	0.300	7.90
U	0.85	4.81	9.0	2.6	0.050	0.011	0.052	0.004	0.111	7.80
V	0.94	13.29	27.4	1.8	0.109	0.496	0.121	0.008	1.606	8.28

Table H-16. Stream monitoring data, sampling sites A to V, February 2.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A	0.52	2.33	11.6	2.6	0.058	0.035	0.179	0.010	0.990	8.30
B	1.30	6.98	49.4	5.8	0.120	0.009	0.321	0.010	0.926	8.30
C	0.86	3.88	24.0	4.8	0.120	0.060	0.289	0.011	1.043	8.31
D	1.07	5.08	23.0	4.4	0.117	0.066	0.288	0.011	1.024	8.23
E	1.39	4.15	18.8	3.6	0.120	0.071	0.297	0.010	1.011	8.15
F	1.20	14.67	66.5	9.8	0.198	0.021	0.137	0.007	0.847	8.00
G	1.10	4.46	20.4	2.8	0.114	0.060	0.226	0.010	1.111	7.78
H	0.66	5.24	40.4	4.6	0.092	0.013	0.079	0.005	0.720	7.93
I	0.82	1.55	39.2	4.2	0.086	0.013	0.087	0.006	0.755	7.93
J	0.93	4.19	48.0	5.6	0.120	0.029	0.133	0.007	0.816	8.07
K	0.83	7.76	100.4	14.0	0.216	0.029	0.210	0.008	1.056	8.15
L	0.76	7.41	57.4	7.0	0.132	0.029	0.138	0.007	0.787	7.93
M	1.60	3.18	29.4	3.0	0.058	0.002	0.064	0.003	0.074	8.10
N	1.06	1.94	24.0	4.2	0.058	0.004	0.070	0.003	0.091	8.09
O	0.97	7.60	45.4	5.0	0.120	0.027	0.138	0.007	0.775	7.91
P	1.56	6.71	16.4	4.8	0.095	0.041	0.203	0.007	0.173	7.65
Q	1.32	3.49	8.6	2.6	0.058	0.032	0.129	0.006	0.164	7.85
R	5.00	5.01	24.4	8.2	0.123	0.044	0.211	0.008	0.178	7.61
S	0.91	5.43	16.4	5.4	0.067	0.030	0.085	0.006	0.158	7.85
T	0.72	4.46	4.4	0.2	0.048	0.027	0.080	0.006	0.080	7.99
U	0.87	3.57	2.3	2.0	0.026	0.013	0.066	0.004	0.080	7.60
V	1.39	8.50	45.0	5.8	0.145	0.049	0.250	0.009	0.444	7.90

Table H-17. Stream monitoring data, sampling sites A to V, February 9.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A		5.18	8.0	2.2	0.130	0.104	0.406	0.021	2.043	8.31
B		11.74	36.4	4.0	0.230	0.129	0.596	0.019	1.624	8.38
C		7.77	28.0	4.4	0.191	0.112	0.573	0.018	1.402	8.33
D		7.47	20.8	2.2	0.220	0.145	0.608	0.017	1.419	8.31
E		10.43	34.0	4.0	0.432	0.153	0.579	0.018	1.909	8.30
F	0.94	16.73	96.0	10.8	0.223	0.016	0.100	0.006	0.752	8.33
G	0.65	4.85	27.6	4.0	0.140	0.075	0.270	0.010	1.001	8.25
H	0.47	6.00	60.3	6.0	0.120	0.014	0.075	0.005	0.725	8.25
I	0.43	9.58	51.5	8.0	0.104	0.014	0.065	0.005	0.731	8.35
J	0.53	5.02	37.6	2.2	0.117	0.030	0.125	0.007	0.804	8.37
K	0.03	5.25	82.1	7.2	0.169	0.027	0.177	0.007	1.030	8.52
L	0.63	6.33	51.9	5.0	0.111	0.029	0.130	0.007	0.811	8.30
M	0.95	5.02	21.6	2.2	0.050	0.006	0.061	0.003	0.009	8.45
N	0.60	5.28	31.0	3.4	0.066	0.013	0.063	0.003	0.107	8.44
O	0.48	8.36	48.4	4.5	0.111	0.038	0.146	0.009	0.745	8.38
P	0.60	4.85	11.6	2.6	0.079	0.046	0.181	0.007	0.207	8.36
Q	1.73	6.86	16.6	4.0	0.182	0.056	0.122	0.006	0.205	8.30
R	1.32	12.40	43.0	6.6	0.182		0.102	0.006	0.205	8.40
S			408.2	48.1		0.030	0.074	0.006	0.231	8.06
T	0.70	3.41	14.0	3.4	0.059	0.030	0.080	0.007	0.208	8.03
U	0.60	8.95	7.2	3.0	0.034	0.043	0.068	0.004	0.095	7.92
V	0.98	13.71	43.8	6.4	0.162	0.059	0.275	0.009	1.035	8.41

Table H-18. Stream monitoring data, sampling sites A to V, February 23.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A	0.76	8.24	3.4	1.4	0.125	0.089	0.520	0.017	1.254	8.44
B	1.27	11.34	12.5	2.4	0.151	0.098	0.536	0.015	1.188	8.50
C	2.00	14.13	29.6	2.7	0.148	0.102	0.632	0.014	1.206	8.52
D	1.86	15.40	62.6	4.7	0.226	0.123	0.644	0.018	1.114	8.41
E	1.78	15.48	34.6	0.0	0.207	0.118	0.690	0.017	1.189	8.40
F	2.91	26.83	85.1	7.9	0.062	0.031	0.771	0.006	0.803	8.30
G	1.69	9.83	20.8	1.8	0.154	0.108	0.451	0.016	1.061	8.28
H	0.58	1.00	19.4	1.0	0.043	0.015	0.063	0.005	0.811	8.22
I	0.62	3.26	22.2	1.8	0.026	0.013	0.072	0.005	0.753	8.20
J	0.84	7.24	24.2	2.4	0.089	0.044	0.165	0.008	0.842	8.32
K	1.27	7.44	36.7	1.3	0.072	0.019	0.169	0.009	0.939	8.52
L	0.94	6.61	53.8	3.6	0.108	0.040	0.155	0.008	1.625	8.28
M	2.17	10.03	53.9	4.2	0.098	0.015	0.106	0.004	0.076	8.40
N	1.69	10.07	56.6	4.5	0.154	0.016	0.107	0.006	0.077	8.40
O	1.44	5.77	11.4	1.2	0.085	0.045	0.162	0.009	0.837	8.31
P	2.42	9.07	19.6	1.2	0.174	0.124	0.416	0.010	0.223	8.25
Q	3.38	17.79	9.6	1.0	0.170	0.118	0.393	0.010	1.065	8.21
R	3.57	27.02	11.2	1.0	0.151	0.097	0.385	0.009	0.708	8.20
S	3.55	18.19	11.0	1.6	0.141	0.094	0.389	0.009	0.146	8.18
T	3.66	18.59	11.8	2.2	0.144	0.092	0.312	0.009	0.214	8.09
U	2.04	15.00	2.8	0.0	0.118	0.079	0.153	0.007	0.083	7.92
V	2.56	13.61	40.0	6.2	0.125	0.082		0.011	1.176	8.34

Table H-19. Stream monitoring data, sampling sites A to X, March 3.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A		15.68	10.0	1.6		0.087	0.304			8.60
B		31.16	186.9	18.29	0.320	0.105	0.521			8.58
C		16.28	145.6	18.1	0.126	0.112	0.579			8.35
D			1681.4	134.3	0.528	0.115	0.729			8.50
E		23.92	44.5	8.1	0.228	0.102	0.687			8.50
F		27.54	66.3	10.9	0.123	0.031	0.294			8.30
G		30.35	77.4	12.8	0.262	0.133	0.896			8.40
H		6.43	26.2	4.6	0.034	0.015	0.070			8.35
I		8.00	30.6	4.4	0.051	0.000	0.068			8.30
J		12.98	33.6	5.0	0.092	0.063	0.226			8.30
K		14.87	75.3	11.6	0.283	0.025	0.202			8.60
L		9.25	35.2	6.6	0.078	0.036	0.196			8.30
M		18.69	92.7	12.3	0.153	0.005	0.125			8.63
N		10.45	80.7	10.2	0.106	0.033	0.131			8.60
O		11.42	42.8	6.0	0.123	0.041	0.179			8.30
P		27.62	18.8	6.2	0.184	0.091	0.646			8.25
Q		50.57	25.3	13.8	0.409	0.161	1.146			8.25
R		41.41	25.0	10.6	0.357	0.142	0.975			8.20
S		31.36	19.6	6.6	0.231	0.099	0.620			8.20
T		23.72	17.4	6.0	0.191	0.082	0.554			8.15
U		15.36	2.0	2.6	0.054	0.033	0.116			8.00
V		35.78	61.4	13.2	0.218	0.084	0.424			8.40
X			228.1	60.3	0.252	0.155	0.858			5.90

Table H-20. Stream monitoring data, sampling sites A to V, March 4.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A		13.67	10.0	2.4	0.132	0.116	0.556			
B		22.11	66.5	13.0	0.164	0.139	0.585			
C		27.26	34.0	9.0	0.215	0.165	1.207			
D		39.07	52.7	13.1	0.299	0.211	1.319			
E		32.96	61.0	13.5	0.273	0.198	1.107			
F		26.13	97.0	15.5	0.177	0.076	0.197			
G		22.71	46.6	9.4	0.228	0.129	0.578			
H		10.45	24.6	3.4	0.042	0.032	0.063			
I		8.64	28.9	5.2	0.042	0.031	0.071			
J		14.47	39.3	5.8	0.087	0.016	0.178			
K		18.49	58.0	1.2	0.080	0.060	0.155			
L		11.66	41.0	6.7	0.074	0.076	0.146			
M		13.47	55.1	5.2	0.061	0.018	0.105			
N		16.88	53.7	8.7	0.080	0.031	0.099			
O		11.26	47.7	7.7	0.087	0.055	0.144			
P		29.35	21.6	8.8	0.151	0.116	0.611			
Q		25.73	20.5	7.2	0.151	0.124	0.656			
R		25.33	29.2	7.8	0.151	0.108	0.696			
S		30.15	62.5	10.1	0.145	0.071	0.607			
T		24.52	18.8	4.8	0.119	0.076	0.619			
U		14.87	4.8	2.0	0.055	0.047	0.092			
V		26.53	39.2	11.6	0.215	0.163	0.652			

Table H-21. Stream monitoring data, sampling sites A to V, March 10.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO4 mg/l	NH3-N mg/l	NO2-N mg/l	NO3-N mg/l	pH
A	2.50	12.13	48.9	11.4	0.218	0.110	0.390	0.017	1.345	7.75
B	5.73	21.20	44.2	4.2	0.218	0.110	0.454	0.013	0.812	7.70
C	6.39	19.12	38.3	8.8	0.270	0.136	0.625	0.014	1.124	7.60
D	4.12	17.24	41.2	9.6	0.270	0.141	0.578	0.013	1.209	7.60
E	2.89	17.82	50.9	17.0	0.257	0.144	0.604	0.013	1.141	7.50
F	1.80	11.10	96.0	16.0	0.127	0.023	0.016	0.006	2.255	7.40
G	2.26	14.67	52.1	10.5	0.312	0.120	0.248	0.013	1.098	7.52
H	0.84		29.8	2.6	0.036	0.014	0.046	0.004	0.747	7.50
I	0.95		27.6	3.6	0.020	0.015	0.046	0.004	0.138	7.61
J	1.49				0.088	0.044	0.097	0.007	0.715	7.40
K	1.66		102.9	6.8	0.159	0.030	0.145	0.008	0.738	7.65
L	1.34	14.52	42.6	5.8	0.319	0.046	0.096	0.008	0.781	7.44
M	1.78	0.38	87.6	18.4	0.107	0.015	0.088	0.003	0.036	7.70
N	2.13	3.92	58.5	2.9	0.059	0.020	0.088	0.003	0.060	7.55
O	1.77	1.50	34.5	10.0	0.127	0.046	0.139	0.008	0.696	7.61
P	4.47	12.13	30.1	2.3	0.263	0.149	0.458	0.008	0.680	7.42
Q	4.64	14.48	42.9	5.8	0.286	0.023	0.373	0.008	0.209	7.40
R	depleated	85.25	91.0	25.8	0.380	0.294	1.906	0.008	0.198	7.50
S	depleated	95.54	50.7	24.4	0.380	0.255	2.126	0.008	0.232	7.40
T	depleated	79.49	36.7	17.2	0.676	0.223	1.701	0.007	0.224	7.30
U	1.39	6.14	8.2	4.4	0.133	0.049	0.096	0.001	0.078	7.50
V	2.38	12.48	73.8	8.4	0.166	0.088	0.335	0.014	0.904	7.55

Table H-22. Stream monitoring data, sampling sites A to E, March 10.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO4 mg/l	NH3-N mg/l	NO2-N mg/l	NO3-N mg/l	pH
A0		11.92	30.3	6.9	0.189	0.107	0.278			
A1		12.13	48.9	11.4	0.218	0.110	0.390			
A2		11.06	30.0	5.5	0.189	0.099	0.092			
A3		8.99	28.2	6.6	0.189	0.108	0.549			
B0		18.09	61.6	8.2	0.240	0.117	0.291			
B1		21.20	44.2	4.2	0.218	0.110	0.454			
B2		18.05	95.7	8.6	0.234	0.120	0.092			
B3		13.98	36.0	7.6	0.250	0.124	0.522			
C0		16.09	84.6	0.0	0.288	0.128	0.104			
C1		19.12	38.3	8.8	0.270	0.136	0.625			
C2		21.12	40.0	8.0	0.208	0.112	0.108			
C3		12.25	44.5	0.0	0.208	0.124	0.424			
E0		15.55	19.0	12.5	0.266	0.152	0.116			
E1		17.82	50.9	17.0	0.257	0.144	0.604			
E2		15.82	31.9	6.4	0.262	0.131	0.108			
E3		14.63	42.6	0.0	0.240	0.137	0.447			

Table H-23. Stream monitoring data, sampling sites A to E, March 11.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/	pH
A4		19.57	30.0	6.27	0.161	0.119	0.581			
A5		14.13	29.2	5.2	0.082	0.112	0.325			
A6		26.11	48.4	8.2	0.208	0.115	0.496			
B4		21.66	66.1	7.8	0.297	0.153	0.589			
B5		20.31	97.3	10.1	0.224	0.108	0.459			
B6		14.94	52.9	2.9	0.253	0.108	0.462			
C4		17.55	40.7	4.07	0.223	0.125	0.649			
C5		9.37	46.3	3.2	0.250	0.129	0.533			
C6		11.10	42.5	9.0	0.166	0.120	0.572			
E4		14.39	44.1	7.1	0.280	0.142	0.675			
E5		15.63	46.0	8.1	0.304	0.160	0.667			
E6		15.32	32.2	8.1	0.250	0.136	0.716			

Table H-24. Stream monitoring data, sampling sites A to E, March 12.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A7		25.12	25.9	2.3	0.850	0.978	14.536			
A8		26.92	23.2	4.6	1.123	0.932	14.309			
B7		24.54	51.5	8.7	0.770	0.749	11.279			
B8		22.23	51.1	7.1	1.123	0.876	12.866			
C7		15.61	39.9	7.9	0.770	0.689	10.268			
C8		11.29	40.9	4.8	1.097	0.803	12.165			
E7		17.40	51.4	7.2	0.617	0.451	9.361			
E8		15.63	68.7	5.5	0.929	0.803	11.505			

Table H-25. Stream monitoring data, sampling sites A to V, 1 to 3, and Z, March 17.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A	1.42	26.60	11.4	3.2	0.186	0.174	0.674	0.020	2.503	8.35
B	2.38	22.15	38.0	0.0	0.289	0.177	0.791	0.018	1.587	8.40
C	4.83	30.85	40.3	8.3	0.364	0.189	1.079	0.018	2.056	8.50
D	3.93	27.26	37.7	4.9	0.368	0.219	1.061	0.025	2.005	8.45
E	3.18	20.55	41.0	8.1	0.374	0.211	0.935	0.019	1.514	8.40
F	2.66	26.99	80.0	12.9	0.159	0.059	0.155	0.006	1.633	8.25
G	2.40	14.39	48.3	8.3	0.285	0.191	0.881	0.021	1.258	8.30
H	0.80	4.76	33.2	3.4	0.056	0.014	0.041	0.004	0.885	8.19
I	3.00	2.69	17.8	2.4	0.060	0.015	0.093	0.004	1.161	8.20
J	1.13	5.42	36.6	4.2	0.142	0.059	0.204	0.010	1.287	8.28
K	2.50	23.87	102.4	10.6	0.207	0.064	0.181	0.010	0.852	8.53
L	1.25	5.77	35.4	4.4	0.108	0.057	0.159	0.010	1.448	8.35
M	4.06	8.15	58.7	5.0	0.145	0.014	0.095	0.002	0.033	8.48
N	2.35	17.67	42.3	3.0	0.125	0.019	0.116	0.003	0.168	8.43
O	1.11	5.46	47.0	7.6	0.156	0.052	0.171	0.013	0.957	8.32
P	3.21	27.72	103.0	13.0	0.480	0.105	0.476	0.008	0.142	8.30
Q	depleted	77.61	93.3	32.6	0.846	0.260	1.833	0.008	0.279	8.25
R	depleted	72.29	70.0	20.8	0.754	0.243	2.286	0.008	0.316	8.20
S	depleted	68.64	33.9	18.6	0.740	0.250	1.791	0.006	0.199	8.21
T	depleted	71.20	32.5	20.0	0.750	0.240	1.836	0.006	0.225	8.20
U	0.97	8.07	3.0	2.8	0.080	0.047	0.095	0.006	0.088	8.05
V	2.86	21.92	66.3	12.2	0.330	0.113	0.378	0.014	0.548	8.35
1	2.12	17.47	13.2	5.0	0.179	0.132	0.422	0.044		8.42
2	3.06	19.85	10.0	3.8	0.227	0.143	0.629	0.053		8.40
3	1.32	12.99	3.4	2.4	0.193	0.122	0.228	0.018		8.19
Z	depleted	83.30	215.0	33.8	0.443	0.201	1.088	0.027		7.95

Table H-26. Stream monitoring data, sampling sites A to V, 1, 2, Z, and Y, March 24.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A	depleted	61.31	65.7	31.3	0.510	0.207	1.265	0.034	1.004	8.30
B	depleted	43.59	59.6	29.2	0.319	0.189	1.110	0.019	0.962	8.40
C	depleted	40.70	67.6	28.0	0.336	0.195	0.895	0.020	0.890	8.45
D	depleted	68.57	118.0	39.5	0.722	0.229	1.127	0.023	0.924	8.40
E	depleted	46.52	63.2	34.0	0.488	0.240	1.222	0.025	1.136	8.35
F	depleted	48.56	55.7	28.0	0.273	0.105	0.504	0.038	2.556	8.10
G	5.72	33.20	60.9	28.9	0.634	0.486	1.497	0.027	0.953	8.20
H	1.13	11.27	37.6	14.6	0.057	0.016	0.076	0.007	0.655	8.20
I	1.34	11.23	23.2	12.4	0.085	0.017	0.102	0.007	0.617	8.20
J	2.52	20.93	33.6	13.6	0.404	0.310	0.559	0.017	0.804	8.15
K	3.72	31.36	86.4	29.2	0.251	0.060	0.194	0.012	0.535	8.40
L	2.08	11.67	55.3	20.5	0.262	0.114	0.578	0.018	0.784	8.20
M	2.84	19.25	114.0	32.4	0.251	0.017	0.183	0.005	0.095	8.30
N	6.48	27.75	82.9	24.8	0.216	0.034	0.398	0.007	0.101	8.30
O	3.81	16.76	56.3	19.4	0.265	0.121	0.586	0.019	0.424	8.20
P	depleted	336.96	288.0	228.0	1.798	1.681	9.022	0.020	0.222	8.10
Q	depleted		174.7	145.3	1.352	1.353	4.908	0.018	0.094	8.00
R	depleted		108.8	84.8	0.857	0.776	4.881	0.014	0.285	8.00
S				No	Sample					
T	19.28	68.53	48.0	36.7	0.389	0.414	2.187	0.012	0.198	8.15
U	3.28	25.10			0.251	0.172	0.309	0.009	0.116	8.12
V		33.84	101.1	35.1	0.428	0.140	0.858	0.020	1.408	8.17
1	18.44	82.33	58.0	31.7	0.772	0.348	1.477	0.073	0.916	8.21
2	17.76		38.5	22.8	0.850	0.409	1.660	0.086	0.688	8.18
Z	24.36	499.09	467.7	314.3	1.671	0.991	7.515	0.057	0.868	8.20
Y	3.24	1.12	16.6	16.0	0.032	0.014	0.062	0.013	1.248	8.75

Table H-27. Stream monitoring data, sampling sites Z and Y, March 25.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
Z					1.310	0.307	2.790			
Y		3.58			0.025	0.003	0.053			

Table H-28. Stream monitoring data, sampling sites Z and Y, March 26.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
Z		462.99			1.077	0.345	2.995			
Y		1.22			0.016	0.017	0.051			

Table H-29. Stream monitoring data, sampling sites Z and Y, March 27.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
Z					0.907	0.229	1.926			
Y		0.610			0.032	0.002	0.053			

Table H-30. Stream monitoring data, sampling sites Z and Y, March 28.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
Z					0.518	0.145	0.533			
Y		3.50			0.029	0.005	0.073			

Table H-31. Stream monitoring data, sampling sites A to V, 1, 2, Z and Y, March 10.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A	1.73	21.16	21.4	1.2	0.234	0.154	0.630	0.018	1.753	8.33
B	2.44	21.08	89.4	7.8	0.391	0.157	0.765	0.017	1.592	8.40
C	2.74	22.39	55.6	7.6	0.331	0.171	0.702	0.014	1.460	8.42
D	2.50	20.23	35.7	6.3	0.309	0.186	0.770	0.014		8.55
E	2.24	19.94	38.5	3.4	0.375	0.182	0.613	0.014	1.472	8.50
F	1.22	20.43	70.6	11.5	0.147	0.031	0.159	0.006	1.137	8.23
G	4.06	24.83	53.3	9.1	0.488	0.311	1.133	0.020		8.30
H	1.43	8.34	19.8	3.4	0.047	0.015	0.063	0.005	0.686	8.34
I	1.05	6.51	18.2	2.2	0.056	0.011	0.060	0.003	0.878	8.30
J	1.44	5.78	18.6	4.6	0.181	0.090	0.296	0.007	1.184	8.28
K	0.77	15.06	35.6	4.7	0.150	0.034	0.130	0.009	0.294	8.67
L	1.25	13.31	18.6	5.2	0.156	0.080	0.278	0.011	0.758	8.32
M	1.80	13.02	74.3	4.0	0.138	0.015	0.160	0.001	0.047	8.55
N	2.25	11.03	15.1	1.7	0.078	0.021	0.285	0.003	0.069	8.51
O	1.56	9.52	19.0	3.0	0.141	0.082	0.234	0.012	0.868	8.40
P	2.60	8.80	24.9	6.0	0.231	0.134	0.733	0.011	0.284	8.21
Q	2.70	12.54	15.8	2.5	0.234	0.126	0.421	0.010	0.308	8.15
R	2.61	3.74	18.4	2.8	0.181	0.118	0.544	0.008	0.300	8.20
S		16.08								
T	2.21	12.82			0.122	0.106	0.347	0.005	0.280	8.23
U	1.64	17.70			0.119	0.082	0.091	0.003	0.108	8.19
V	3.63	17.50	66.3	12.1	0.225	0.103	0.271	0.013	1.222	8.45
1	1.96	28.49	3.8	0.0	0.247	0.159	0.260	0.021	1.573	8.48
2	1.91	37.48	20.6	8.6	0.294	0.160	0.241	0.020	1.677	8.45
Z	37.4	90.04	112.3	80.0	1.194	0.379	3.233	0.015	1.252	8.30
Y	2.45	8.87	3.7	0.3	0.044	0.002	0.023	0.008	1.801	8.80

Table H-32. Stream monitoring data, sampling sites A to V, 1, 2, Z, and Y, April 6.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A	1.75	18.45	14.8	6.6	0.223	0.128	0.569	0.018	1.094	8.38
B	2.60	20.74	69.2	8.8	0.344	0.126	0.454	0.017	0.904	8.35
C	2.84	21.41	42.7	7.3	0.306	0.144	0.459	0.018		8.30
D	3.43	24.37	38.9	6.3	0.347	0.167	0.577	0.026	1.100	8.29
E	3.83	20.62	35.9	6.3	0.338	0.174	0.590	0.027	1.236	8.25
F	4.75	26.54	51.1	12.8	0.236	0.058	0.277	0.007	0.827	8.12
G	2.77	21.01	40.3	10.6	0.389	0.237	0.425	0.026	1.078	8.15
H	0.74	6.83	13.0	4.6	0.061	0.009	0.046	0.003	0.579	8.21
I	0.94	5.06	19.8	3.2	0.054	0.009	0.040	0.004	0.616	8.20
J	1.49	8.45	42.6	3.8	0.178	0.075	0.167	0.013	0.732	8.20
K	2.72	22.40	250.4	29.6	0.287	0.028	0.150	0.013	0.493	8.50
L	0.80	11.69	43.5	5.7	0.175	0.075	0.186	0.014	0.752	8.20
M	1.86	14.58	58.4	6.3	0.102	0.009	0.078	0.003	0.020	8.49
N	1.64	14.34	38.4	1.9	0.096	0.012	0.172	0.003	0.037	8.40
O	1.66	25.08	45.8	4.9	0.188	0.079	0.214	0.014	0.731	8.20
P	3.46	14.18	73.7	9.8	0.351	0.156	0.242	0.014	0.219	8.10
Q	3.82	21.21	85.7	3.2	0.370	0.155	0.217	0.013	0.185	8.10
R	3.65	32.86	92.5	10.2	0.379	0.140	0.232	0.012	0.203	8.11
S				No	Sample					
T	2.47	14.14	32.0	6.0	0.249	0.140	0.191	0.012	0.176	8.01
U	2.35	19.99	13.0	3.0	0.188	0.126	0.157	0.009	0.080	7.97
V	2.19	17.30	58.1	5.9	0.233	0.109	0.285	0.020	1.066	8.20
1	2.66	23.15	44.0	8.3	0.239	0.120	0.208	0.020	1.335	8.35
2	1.75	19.71	32.7	6.2	0.217	0.117	0.234	0.023	1.386	8.39
Z	9.8	53.00	170.0	48.0	0.905	0.250	1.328	0.038	0.641	8.09
Y	1.37	10.78	4.0	2.2	0.025	0.002	0.030	0.013	0.926	8.65

Table H-33. Stream monitoring data, sampling sites C, E, 4, and 5, April 14.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
C			91.9	10.0						
E			67.7	3.2						
4			935.6	166.7						
5			2.8	0.4						

Table H-34. Stream monitoring data, sampling sites A to V, 1, 2, Y, and Z, April 15.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A	1.43	19.95	11.2	2.0	0.125	0.078	0.154	0.014	0.914	8.10
B	3.70	28.24	62.8	1.2	0.326	0.186	0.301	0.014	0.743	8.15
C	2.27	22.75	43.6	5.0	0.250	0.134	0.342	0.017	0.791	8.05
D	2.64	24.57	44.7	5.0	0.257	0.148	0.248	0.016	0.813	8.30
E	2.91	24.10	56.0	5.6	0.296	0.148	0.257	0.016	0.813	8.32
F	1.31	12.36	50.0	9.0	0.095	0.025	0.107	0.003	0.811	8.35
G	4.19	18.05	64.7	7.0	0.329	0.184	0.770	0.018	0.912	8.30
H	0.94	14.02	16.0	2.0	0.036	0.011	0.058	0.007	0.693	8.40
I	0.92	4.50	18.8	3.6	0.043	0.012	0.049	0.006	0.672	8.30
J	1.84	9.52	25.8	2.8	0.119	0.071	0.301	0.012	0.771	8.25
K	1.29	8.89	96.0	13.1	0.191	0.011	0.065	0.004	0.331	8.50
L	1.88	10.07	33.8	4.8	0.165	0.066	0.226	0.015	0.704	8.30
M	1.06	8.33	53.6	7.2	0.082	0.006	0.065	0.004	0.237	8.50
N	1.28	7.43	50.6	5.9	0.148	0.006	0.071	0.004	0.237	8.45
O	1.88	10.86	40.2	4.0	0.142	0.068	0.189	0.015	0.739	8.35
P	3.73	16.39	63.2	8.2	0.329	0.176	0.314	0.015	0.338	8.20
Q	3.57	23.94	150.0	8.7	0.375	0.194	0.314	0.014	0.359	8.25
R	3.96	31.32	76.4	15.4	0.415	0.191	0.244	0.010	0.342	8.21
S				No	Sample					
T	2.67	23.38	49.1	7.2	0.290	0.180	0.197	0.013	0.337	8.20
U	1.60	17.18	4.4	1.2	0.221	0.175	0.265	0.010	0.168	8.10
V	1.61	9.28	42.4	5.7	0.181	0.081	0.128	0.009	0.772	8.40
1	1.61	18.41	17.0	4.6	0.201	0.117	0.165	0.015	1.235	8.49
2	2.20	20.70	28.2	6.8	0.224	0.130	0.152	0.014	1.089	8.50
Z	9.08	43.06	49.1	19.5	0.415	0.206	0.731	0.022	0.536	8.21
Y	1.81	1.50	3.8	2.4	0.036	0.002	0.031	0.013	0.848	8.65

Table H-35. Stream monitoring data, sampling sites A to V, 1, 2, Z, and Y, April 21.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A	2.80	21.59	75.7	11.7	0.208	0.090	0.099	0.006	0.211	
B	1.60	15.50	194.3	21.7	0.156	0.061	10.151	0.005	0.103	
C	2.40	9.65	170.5	21.0	0.134	0.056	0.142	0.005	0.205	
D	2.90	16.09	109.8	16.7	0.180	0.056	0.118	0.005	0.330	
E	2.83	17.27	156.5	19.2	0.214	0.063	0.115	0.007	0.152	
F	2.59	18.05	37.0	9.0	0.269	0.209	0.115	0.023	0.742	
G	1.89	13.74	117.2	14.8	0.205	0.087	0.097	0.014	0.471	
H	1.07	2.16	14.0	3.8	0.027	0.003	0.031	0.004	0.507	
I	0.94	5.42	17.4	3.0	0.067	0.003	0.026	0.004	0.580	
J	1.53	13.42	69.7	8.7	0.119	0.038	0.059	0.009	0.502	
K	3.39	6.44	60.3	6.9	0.113	0.040	0.070	0.011	0.450	
L	1.33	13.93	63.0	7.5	0.067	0.005	0.049	0.011	1.090	
M	1.90	9.03	43.5	6.3	0.058	0.006	0.043	0.009	0.175	
N	0.76	2.35	25.2	6.7	0.085	0.006	0.054	0.005	0.317	
O	1.55	10.20	40.7	8.7	0.116	0.049	0.132	0.012	0.492	
P	3.19	32.97	47.0	7.3	0.492	0.374	0.267	0.078	0.439	
Q	3.57	34.34	38.3	7.3	0.516	0.360		0.064	0.440	
R	depleted	42.58	43.0	31.0	0.653	0.395		0.066	0.399	
S				No	Sample					
T	2.44	27.98	41.0	11.0	0.632	0.444	0.236	0.068	0.397	
U	1.99	31.36	5.0	4.2	0.638	0.563	0.172	0.075	0.403	
V	3.20	18.92	57.5	14.6	0.195	0.081	0.125	0.014	0.465	
1	depleted	15.89	82.0	16.3	0.388	0.289	1.388	0.028	0.889	
2	0.85	4.32	13.3	5.8	0.110	0.098	0.071	0.014	1.187	
Z	2.37	10.20	26.0	6.9	0.067	0.026	0.061	0.003	0.064	
Y	0.99	4.24	7.8	4.0	0.024	0.009	0.061	0.002	0.207	

Table H-36. Stream monitoring data, sampling sites A to V, 1, 2, Z, and Y, April 28.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A	3.44	32.05	207.4	26.5	0.507	0.113	0.306	0.021	0.513	8.05
B	2.62	16.29	100.0	8.8	0.237	0.108	10.118	0.021	0.441	8.19
C	2.07	15.57	58.5	5.3	0.217	0.108	0.144	0.019	1.211	7.90
D	1.67	15.53	50.0	10.3	0.227	0.118	0.213	0.018	1.197	7.93
E	2.35	17.43	54.9	7.3	0.227	0.137	0.201	0.019	1.177	7.95
F	2.10	19.83	41.8	8.2	0.142	0.068	0.120	0.038	1.591	8.09
G	2.56	17.05	88.5	14.4	0.234	0.098	0.116	0.032	1.025	8.10
H	1.58	11.38	33.6	6.4	0.046	0.010	0.049	0.007	0.612	8.05
I	1.50	9.52	27.6	4.0	0.043	0.010	0.051	0.007	0.600	8.10
J	2.40	21.58	79.6	10.0	0.194	0.065	0.116	0.022	0.715	8.09
K	4.15	23.83	38.5	6.4	0.125	0.007	0.200	0.149	1.266	8.22
L	2.49	14.24	61.5	9.6	0.151	0.046	0.071	0.017	0.651	8.10
M	1.72	12.14	10.6	3.0	0.023	0.002	0.035	0.002	0.033	8.50
N	2.06	16.14	30.0	5.0	0.109	0.030	0.119	0.012	0.167	8.15
O	1.71	16.14	48.4	7.1	0.148	0.050	0.132	0.011	0.554	8.21
P	2.70	36.12	36.0	7.7	0.481	0.378	0.163	0.017	0.313	8.15
Q	2.60	38.10	12.6	4.0	0.543	0.428	0.144	0.019	0.350	8.11
R	2.66	33.84	20.6	4.4	0.530	0.430	0.136	0.019	0.327	8.17
S				No	Sample					
T	2.69	37.76	32.4	6.6	0.606	0.463	0.193	0.024	0.411	8.12
U	1.87	39.06	10.6	4.2	0.517	0.446	0.056	0.008	0.264	8.02
V	2.29	13.89	45.7	8.4	0.155	0.036	0.146	0.035	1.746	8.15
1	1.92	15.19	18.6	4.6	0.293	0.228	0.254	0.031	0.989	8.41
2	3.86	17.89	29.4	8.0	0.277	0.231	0.232	0.040	0.996	8.40
Z	2.32	4.91	37.6	8.8	0.043	0.017	0.035	0.002	0.146	8.45
Y	1.06	2.89	9.8	6.4	0.013	0.004	0.037	0.001	0.138	8.49

Table H-37. Stream monitoring data, sampling sites C, E, M, N, Z, and Y, May 4.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
C	1.85	8.81	25.8	3.4	0.228	0.113	0.656	0.023	1.407	7.75
E	3.52	27.08	69.6	14.4	0.393	0.244	1.057	0.030	0.995	7.85
M	4.20	33.33	13.4	3.4	0.063	0.003	0.016	0.001	0.038	7.90
N	4.19	33.15	13.8	3.2	0.069	0.013	0.018	0.002	0.126	7.83
Z	1.81	14.66	18.0	4.2	0.063	0.020	0.106	0.002	0.271	8.25
Y	1.38	4.66	14.2	3.2	0.023	0.003	0.023	0.002	0.365	8.35

Table H-38. Stream monitoring data, sampling sites C, E, M, N, Z, and Y, May 5.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
C		9.85	46.9	9.0	0.205	0.139	0.087	0.015		
E		15.48	54.2	8.4	0.364	0.246	0.158	0.020		
M		24.13	11.4	4.4	0.056	0.005	0.037	0.008		
N		23.37	8.4	3.4	0.056	0.016	0.053	0.010		
Z		13.79	35.3	10.5	0.099	0.033	0.045	0.002		
Y		8.91	7.2	3.0	0.013	0.003	0.044	0.002		

Table H-39. Stream monitoring data, sampling sites A to V, 1, 2, Z, and Y, May 6.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A	1.35	14.44	43.7	9.3	0.118	0.038	0.086	0.007		8.2
B	4.17	21.59	76.5	11.7	0.163	0.071	0.232	0.007		8.3
C	7.34	15.91	54.4	8.4	0.352	0.128	0.417*	0.020		8.2
D	2.45	21.59	63.3	11.0	0.240	0.096	0.215*	0.018		8.2
E	2.65	25.81	74.3	11.7	0.250	0.107	0.157	0.020		8.2
F	1.27	15.87	12.6	1.8	0.057	0.039	0.071	0.013		8.2
G	3.30	24.74	54.4	6.8	0.358	0.141	0.207*	0.025		8.3
H	1.70	12.17	12.8	3.4	0.218	0.174	0.160*	0.021		8.3
I	1.80	11.18	28.5	5.5	0.192	0.108	0.074	0.016		8.3
J	2.60	20.86	67.7	8.0	0.314	0.129	0.120	0.022		8.3
K	1.30	8.17	31.5	2.9	0.061	0.009	0.152*	0.011		8.4
L	2.75	20.89	35.3	6.2	0.339	0.136	0.201*	0.023		8.4
M	2.55	20.45	21.0	3.0	0.086	0.007	0.051	0.007		8.2
N	2.30	0.00	18.0	4.8	0.054	0.012	0.049	0.007		8.2
O	1.90	20.31	89.6	12.3	0.224	0.115	0.168*	0.021		8.2
P	3.00	21.04	37.2	5.0	0.320	0.203	0.329*	0.024		8.2
Q	6.30	26.54	51.9	14.4	0.410	0.229	0.359	0.026		8.15
R	5.60	33.58	47.7	10.3	0.384	0.231	0.363	0.025		8.15
T	9.60	41.90	62.7	17.6	0.499	0.271	0.427	0.024		8.05
U	2.95	33.47	56.9	12.3	0.330	0.203	0.165*	0.020		8.1
V	1.50	12.83	55.6	10.3	0.125	0.033	0.059	0.015		8.2
1	3.90	56.34	72.3	21.0	0.544	0.285	0.430	0.043		8.3
2	2.80	25.66	89.2	17.4	0.307	0.097	0.259*	0.018		8.4
Z	3.85	24.85	24.0	9.6	0.182	0.060	0.045	0.008		8.4
Y	1.40	6.74	13.0	6.6	0.048	0.010	0.031	0.002		8.5

*NH_3 done with phenothetein due to accidental addition of acid--see analytical log for details

Table H-40. Stream monitoring data, sampling sites C, E, M. N. Z, and Y, May 6.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
C		22.17	136.1	16.5	0.285	0.092	0.105	0.013		
E		19.99	128.0	16.4	0.256	0.107	0.115	0.014		
M		27.73	13.4	3.0	0.074	0.001	0.033	0.003		
N		25.93	12.4	5.0	0.032	0.012	0.030	0.004		
Z		12.93	28.8	8.4	0.051	0.027	0.058	0.003		
Y		5.04	5.6	3.8	0.064	0.002	0.038	0.003		

Table H-41. Stream monitoring data, sampling sites A to V, 1, 2, Z, and Y, May 7.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A		13.84	62.0	13.7	0.090	0.051	0.072			
B		13.23	42.3	10.8	0.235	0.112	0.102			
C		10.35	61.2	12.7		0.136	0.103			
D		14.65	70.7	11.6	0.308	0.144	0.099			
E		11.40	52.2	11.8	0.247	0.149	0.087			
F		8.03	15.0	5.2	0.138	0.098	0.055			
G		25.90	63.1	17.3	0.459	0.198	0.243			
H		6.69	10.6	3.6	0.106	0.071	0.061			
I		5.83	5.8	4.8	0.132	0.087	0.062			
J		14.84	86.0	12.6	0.235	0.119	0.162			
K		6.61	17.8	2.5	0.061	0.013	0.068			
L		13.90	103.8	13.8	0.251	0.112	0.171			
M		18.20	26.2	9.5	0.051	0.005	0.160			
N		18.72	17.8	7.2	0.058	0.006	0.046			
O		21.19	120.9	17.9	0.395	0.115	0.166			
P		27.47	81.1	17.2	0.363	0.215	0.280			
Q		23.99	121.9	21.4	0.476	0.239	0.247			
R		21.60	95.9	20.5	0.437	0.234	0.241			
T		17.75	95.3	19.5	0.414	0.259	0.261			
U		29.26	118.8	21.8	0.575	0.307	0.311			
V		11.81	268.0	34.3	0.244	0.108	0.090			
1		41.41	14.4	7.4	0.572	0.471	0.321			
2		42.49	15.8	6.0	0.578	0.471	0.076			
Z		5.04	14.6	6.4	0.042	0.019	0.045			
Y		5.12	7.0	6.4	0.010	0.005	0.028			

Table H-42. Stream monitoring data, sampling sites C, E, Z, and Y, May 7.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
C		19.92	144.9	17.8	0.395	0.079	0.099			
E		21.50	115.4	16.7	0.376	0.155	0.078			
Z		40.10	84.9	27.5	0.280	0.052	0.152			
Y		5.67	6.4	4.6	0.026	0.005	0.028			

Table H-43. Stream monitoring data, sampling sites A to V, 1, 2, Z, and Y, May 15.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A		20.27	49.4	3.9	0.139	0.017	0.050	0.004		8.19
B		16.66	75.3	0.7	0.126	0.030	0.077	0.005		8.21
C		15.76	90.4	0.0	0.092	0.029	0.074	0.006		8.20
D		10.19	93.1	4.4	0.066	0.030	0.098	0.006		8.20
E		14.82	95.3	5.1	0.076	0.043	0.089	0.006		8.25
F		11.21	10.2	2.6	0.089	0.048	0.080	0.014		8.05
G		14.25	41.0	2.3	0.190	0.065	0.146	0.017		8.25
H		8.05	12.2	1.2	0.028	0.006	0.030	0.006		8.25
I		8.80	14.4	3.0	0.044	0.010	0.039	0.006		8.19
J		10.34	53.0	5.7		0.046	0.096	0.014		8.15
K		12.37	40.7	3.3	0.063	0.021	0.055	0.010		8.30
L		11.43	9.9	0.7	0.092	0.003	0.020	0.006		8.21
M		11.32	63.3	4.3	0.028	0.038	0.077	0.012		8.50
N		11.21	22.6	3.8	0.044	0.014	0.061	0.008		8.45
O		16.92	66.0	3.3	0.126	0.051	0.111	0.014		8.29
P		50.32	82.2	15.9	0.677	0.337	0.068	0.023		8.15
Q		23.47	41.2	4.5	0.329	0.190	0.107	0.022		8.20
R		18.69	26.4	2.1	0.563	0.146	0.089	0.020		8.20
T		18.05	26.8	3.0	0.243	0.141	0.081	0.019		8.10
U		20.72	44.5	0.3	0.183	0.141	0.138	0.018		8.20
V		19.44	87.5	6.2	0.126	0.038	0.044	0.010		8.31
1		21.62	17.0	4.0	0.253	0.170	0.068	0.012		8.45
2		22.23	18.5	6.3	0.215	0.137	0.047	0.011		8.50
Z		10.12	22.0	4.2	0.038	0.014	0.032	0.003		8.50
Y		9.55	13.6	1.9	0.032	0.046	0.031	0.002		8.49

Table H-44. Stream monitoring data, sampling sites C, E, M. N, Z, and Y, May 16.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
C		37.59	32.4	6.2	0.231	0.061	0.061	0.008		8.15
E		34.32	5.6	-	0.221	0.071	0.146	0.010		8.00
M		10.11	15.8	-	0.032	0.013	0.051	0.007		8.45
N		13.76	25.8	-	0.054	0.008	0.048	0.005		8.35
Z		30.36	190.6	8.1	0.120	0.049	0.074	0.004		8.30
Y		8.57	178.7	10.7	0.025	0.014	0.039	0.003		8.30

Table H-45. Stream monitoring data, sampling sites A to V, 1, 2, Z, and Y, May 17.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	$o-PO_4$ mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A		30 48	97.7	4.3	0.291	0.083	0.112	0.007	0.379	8.19
B		39.31	122.3	19.2	0.496	0.077	0.150	0.007	0.290	8.25
C		44.78	162.9	12.0	0.689	0.086	0.164	0.010	0.592	8.25
D		61.90	263.2	23.2	0.882	0.089	0.060	0.012	0.513	8.31
E		70.18	531.8	28.2	0.803	0.157	0.306	0.016	0.657	8.40
F		10.32	26.6	-	0.076	0.022	0.054	0.008	0.913	8.11
G		34.04	140.6	5.1	0.405	0.111	0.159	0.015	0.726	8.29
H		6.06	11.7	0.7	0.038	0.003	0.049	0.004	0.515	8.30
I		7.23	7.7	0.2	0.028	0.003	0.050	0.004	0.599	8.31
J		22.39	70.5	5.1	0.243	0.077	0.121	0.012	0.671	8.25
K		19.23	19.1	-	0.092	0.017	0.033	0.010	0.744	8.40
L		20.28	88.4	3.3	0.221	0.055	0.097	0.010	0.667	8.29
M		9.07	6.9	0.8	0.044	0.005	0.021	0.011	0.263	8.65
N		12.08	13.8	-	0.057	0.016	0.033	0.007	0.415	8.45
O		19.23	70.0	2.3	0.196	0.060	0.102	0.010	0.608	8.25
P		34.23	61.9	3.4	0.357	0.190	0.109	0.012	0.495	8.25
Q		36.03	41.9	5.8	0.345	0.188	0.115	0.004	0.511	8.22
R		35.80	75.7	11.3	0.348	0.188	0.115	0.011	0.512	8.21
T		37.59	86.9	10.2	0.300	0.191	0.125	0.012	0.526	8.25
U		38.69	54.0	3.9	0.370	0.071	0.135	0.011	0.526	8.25
V		34.86	133.8	13.8	0.348	0.074	0.084	0.009	0.717	8.30
1		43.53	70.2	8.3	0.449	0.204	0.166	0.023	0.882	8.35
2		37.01	66.7	11.2	0.376	0.204	0.167	0.022	1.023	8.30
Z		10.90	17.4	3.0	0.085	0.039	0.050	0.003	0.235	8.49
Y		6.37	9.4	2.4	0.032	0.005	0.016	0.002	0.205	8.55

Table H-46. Stream monitoring data, sampling sites C, E, M, N, Z, and Y, May 19.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	$o-PO_4$ mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
C		27.29	222.4	16.0		0.094	0.106	0.007	0.326	8.01
E		26.36	116.6	14.0	0.408	0.112	0.152	0.008	0.295	8.13
M		15.26	23.2	4.0	0.365	0.014	0.048	0.007	1.380	8.20
N		8.95	12.8	0.8	0.074	0.008	0.024	0.007	0.414	8.21
Z		23.94	21.8	7.8	0.028	0.079	0.230	0.004	0.126	8.07
Y		6.99	8.8	2.0	0.193	0.003	0.022	0.002	0.080	8.32

Table H-47. Stream monitoring data, sampling sites C, E, M, N, W, X, Z, and Y, May 20.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	$o-PO_4$ mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
C	2.28	21.25	150.0	5.6	0.322	0.073	0.088	0.006		8.4
E	2.23	21.63	156.6	14.9	0.474	0.083	0.101	0.007		8.5
M	2.08	9.38	12.6	1.4	0.045	0.008	0.021	0.007		8.3
N	2.19	11.07	22.0	2.8	0.055	0.014	0.030	0.007		8.45
W	1.78	5.50	2.4	-	0.031	0.016	0.059	0.004		8.0
X	1.40	5.69	5.8	2.6	0.045	0.025	0.052	0.004		8.0
Z	0.89	9.53	19.4	5.2	0.078	0.031	0.059	0.003		8.3
Y	0.83	5.11	5.0	1.4	0.025	0.006	0.037	0.002		8.3

Table H-48. Stream monitoring data, sampling sites C, E, M, N, W, X, Z, and Y, May 26.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
C		19.40	141.7	52.5	0.255	0.047	0.491	0.010	0.359	
E		17.18	83.1	7.8	0.271	0.071	0.861	0.013	0.368	
M		7.32	26.0	3.0	0.028	0.001	0.043	0.005	0.286	
N		8.22	23.6	3.4	0.043	0.002	0.042	0.004	0.174	
W		4.91	22.6	5.0	0.083	0.030	0.038	0.003	1.085	
X		3.82	10.0	1.4	0.018	0.005	0.058	0.005	1.074	
Z		11.41	3.0	0.4	0.018	0.005	0.066	0.003	0.197	
Y		4.71	8.8	4.6	0.080	0.031	0.026	0.003	0.206	

Table H-49. Stream monitoring data, sampling sites A to V, 1, 2, Z, and Y, June 8.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A	1.61	18.59	109.4	6.1	0.158	0.105	0.075	0.011	0.301	8.19
B	4.14	27.98	47.0	1.8	0.393	0.305	0.276	0.039	1.126	8.03
C	1.13	15.46	22.6	3.2	0.162	0.125	0.091	0.029	2.044	7.79
D	1.66	14.29	26.4	0.8	0.240	0.167	0.158	0.037	1.854	7.78
E	1.50	7.83	16.6	5.8	0.256	0.178	0.166	0.039	-	7.78
F	2.10	15.66	11.0	2.2	0.149	0.090	0.096	0.031	0.934	7.86
G	1.11	6.65	20.0	2.4	0.103	0.067	0.065	0.020	0.623	7.81
H	2.20	10.76	40.5	4.1	0.057	0.014	0.026	0.021	0.636	8.09
I	1.75	19.37	46.2	5.8	0.060	0.025	0.020	0.026	0.748	8.08
J	2.15	17.03	46.6	7.4	0.087	0.038	0.051	0.031	0.883	7.98
K	2.70	14.68	47.3	9.9	0.093	0.043	0.043	0.028	0.750	8.01
L	2.40	13.70	52.3	4.6	0.093	0.043	0.046	0.035	0.841	8.05
M	2.10	25.64	10.2	2.4	0.047	0.011	0.032	0.002	0.039	8.34
N	4.50	40.51	30.9	2.9	0.093	0.024	0.047	0.002	0.029	8.04
O	2.20	16.44	49.4	5.8	0.100	0.043	0.121	0.031	0.772	8.01
P	2.12	35.81	59.7	5.6	0.315	0.233	0.126	0.025	0.671	8.17
Q	1.54	23.29	12.4	2.8	0.318	0.241	0.054	0.025	0.766	8.20
R	1.91	23.48	11.8	4.4	0.318	0.248	0.051	0.024	0.907	8.19
S										
T	1.25	27.79	23.6	3.8	0.351	0.279	0.081	0.016	1.073	7.88
U	1.26	37.38	10.2	1.2	0.361	0.283	0.055	0.010	0.453	7.80
V	2.64	24.85	25.1	5.1	0.227	0.138	0.147	0.067	2.152	7.78
W	0.70	4.89	3.0	-	0.031	0.013	0.031	0.004	0.857	7.92
X	0.90	9.98	3.8	2.2	0.047	0.027	0.051	0.005	0.743	7.79
1	1.18	54.99	12.4	2.4	0.132	0.083	0.068	0.022	0.570	8.39
2	2.61	28.38	12.0	4.0	0.191	0.124	0.063	0.023	0.776	8.42
Z	1.13	13.11	51.4	14.6	0.051	0.013	0.051	0.003	0.149	8.30
Y	1.11	22.11	18.2	3.8	0.024	0.006	0.032	0.003	0.076	8.39

Table H-50. Stream monitoring data, sampling sites A to V, 1, 2, Z, and Y, June 15.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A	1.08		63.0	6.4	0.063	0.044	0.044	0.044		8.25
B	1.48	6.73	61.4	6.6	0.107	0.042	0.100	0.007		8.19
C	0.93	0.37	17.8	1.4	0.143	0.118	0.108	0.027	2.897	7.72
D	1.58	1.40	34.8	4.6	0.227	0.169	0.156	0.028		7.69
E	1.08	5.61	26.4	4.6	0.247	0.187	0.221	0.029	2.605	7.78
F	2.22	8.60	7.2	5.6	0.093	0.069	0.021	0.027		8.03
G	2.07	11.21	48.5	3.9	0.307	0.245	0.065	0.038		8.02
H	2.46	7.10	54.0	6.0	0.023	0.003	0.025	0.007		8.11
I	1.92	55.70	30.8	4.4	0.030	0.005	0.028	0.008		8.10
J	2.02	58.32	48.2	8.5	0.083	0.035	0.037	0.011		8.05
K	1.53	2.99	9.4	6.2	0.027	0.002	0.037	0.006		8.44
L	2.42	4.11	61.6	10.9	0.110	0.042	0.039	0.014		8.09
M	0.98	3.74	10.8	1.8	0.017	0.003	0.076	0.001	0.048	8.50
N	1.52	5.98	19.4	3.4	0.060	0.025	0.080	0.007	0.097	8.39
O	1.92	4.11	65.8	9.8	0.093	0.055	0.053	0.016		8.11
P	2.61	21.31	123.5	23.2	0.263	0.171	0.083	0.036		8.31
Q	1.97	12.34	32.9	11.4	0.277	0.192	0.052	0.037		8.37
R	2.41	13.08	29.3	8.8	0.313	0.222	0.053	0.037		8.39
S										
T	2.22	11.59	16.0	12.6	0.407	0.309	0.056	0.047		8.20
U	3.05	17.20	64.0	16.4	0.480	0.387	0.080	0.057		8.25
V	1.08	8.22	4.6	4.2	0.173	0.134	0.196	0.066		7.72
W	1.18	2.24	3.2	2.8	0.040	0.020	0.084	0.006	0.677	7.95
X	1.57	2.99	2.4	-	0.043	0.022		0.007	0.691	7.98
1	2.16	12.34	9.8	4.6	0.193	0.141	0.043	0.013		8.25
2	1.87	6.36	9.2	4.8	0.190	0.153	0.065	0.018		8.32
Z	1.92	7.48	20.4	7.4	0.037	0.017	0.037	0.002	0.126	8.36
Y	0.98		9.4	6.0	0.010	0.002	0.025	0.001	0.098	7.90

Table H-51. Stream monitoring data, sampling sites C, E, M, N, W, X, Z, and Y, June 22.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
C			27.5	2.6		0.119	0.146	0.038	2.549	8.10
E			67.9	1.4		0.172	0.200	0.038	1.780	8.15
M			9.4	0.4		0.012	0.030	0.000	0.019	8.65
N			38.7	2.0		0.031	0.077	0.007	0.040	8.60
W			1.0			0.019	0.052	0.003	1.967	8.60
X			3.0	2.0		0.019	0.042	0.003	0.727	8.40
Z			15.0	3.6		0.009	0.023	0.001	0.127	8.10
Y			3.0			0.007	0.017	0.00	0.142	8.10

Table H-52. Stream monitoring data, sampling sites C, E, M, N, W, X, Z, and Y, June 29.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	$p-PO_4$ mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-n mg/l	pH mg/l
C		15.11	18.0	3.8				0.019	2.553	7.80
E		15.86	28.6	5.4				0.018	1.768	7.70
M		26.73	9.6	4.0				0.012	0.166	8.00
N		23.36	17.8	4.4				0.013	0.185	8.00
W		49.61	91.4	40.0				0.003	0.531	7.90
X		20.36	9.6	5.4				0.004	0.575	7.85
Z		9.86	21.6	4.8				0.001	0.099	8.35
Y		1.61	3.6	1.6				0.000	0.126	8.30

Table H-53. Stream monitoring data, sampling sites A to V, 1, 2, Z, and Y, June 29.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	$o-PO_4$ mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A		8.86	13.8	3.4			0.072	0.004	0.226	
B		24.35	15.2	5.0			0.087	0.010	0.505	
C		17.60	17.4	3.0			0.115	0.013	4.013	
D		12.73	18.2	4.0			0.133	0.017	3.820	
E		10.11	26.2	4.7			0.175	0.016	3.757	
F		4.12	4.6	2.6			0.076	0.032	1.975	
G		32.58	24.4	6.4			0.127	0.024	0.930	
H		10.11	7.8	6.0			0.043	0.007	0.598	
I		17.98	27.5	4.6			0.069	0.008	0.624	
J		11.61	57.4	10.2			0.067	0.016	0.799	
K		10.33	70.0	1.0			0.049	0.009	0.316	
L		7.49	44.6	5.4			0.066	0.015	0.762	
M		11.99	64.7	11.0			0.070	0.003	0.006	
N		19.48	33.6	7.7			0.076	0.008	0.090	
O		6.37	40.5	6.7			0.064	0.014	0.647	
P		32.47	23.8	30.0			01184	0.055	0.888	
Q		24.34	8.2	4.4			0.116	0.039	1.015	
R		22.10	11.2	4.8			0.161	0.039	1.090	
S				No	Sample					
T		18.73	8.8	5.8			0.098	0.017	1.423	
U		28.78	7.2	3.6			0.053	0.010	0.384	
V		5.54	1.2				0.110	0.034	1.716	
W		1.11					0.048	0.004	0.561	
X		10.70	28.6	11.8			0.100	0.005	0.560	
1		8.12	16.4	3.0			0.058	0.009	0.447	
2		4.80	16.2	14.0			0.076	0.008	0.425	
Z		3.32	2.6	3.0			0.023	0.001	0.132	
Y		5.90	2.6	3.8			0.024	0.001	0.150	

Table H-54. Stream monitoring data, sampling sites A to V, 1, 2, Z, and Y, July 7.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A	1.13				0.093	0.051				7.90
B	3.50				0.149	0.085				8.10
C	1.24				0.183	0.118				7.80
D	1.24				0.199	0.123				7.65
E	1.34				0.232	0.126				7.85
F	2.02				0.076	0.041				8.00
G	1.39				0.186	0.110				8.00
H	1.65				0.083	0.019				8.15
I	1.75				0.076	0.015				8.20
J	2.27				0.183	0.059				8.20
K	1.49				0.046	0.011				8.20
L	2.00				0.163	0.064				8.10
M	1.91				0.086	0.014				8.30
N	1.50				0.083	0.032				8.20
O	1.85				0.143	0.072				8.10
P	3.20				0.664	0.409				8.00
Q	1.75				0.511	0.419				8.20
R	2.06				0.541	0.441				8.20
S										
T	1.38				0.412	0.333				8.00
U	1.59				0.408	0.337				7.95
V	0.86				0.129	0.097				7.80
W	0.67				0.030	0.014				7.95
X	1.70				0.073	0.020				8.00
1	1.96				0.116	0.061				8.30
2	1.86				0.100	0.056				8.25
Z	0.98				0.023	0.006				8.40
Y	1.19				0.030	0.002				8.35

Table H-55. Stream monitoring data, sampling sites A to V, 1, 2, Z, and Y, July 21.

Sample	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH
A	2.02	14.02	7.6	1.2	0.072	0.025	0.036	0.007	0.288	8.60
B	3.42	37.80	26.8	4.2	0.198	0.104	0.076	0.021	0.903	8.40
C	2.48	24.53	25.8	5.4	0.162	0.101	0.112	0.016	1.343	8.10
D	2.28	23.14	18.8	5.4	0.214	0.134	0.148	0.021	1.464	7.90
E	2.04	21.04	15.0	3.0	0.259	0.159	0.162	0.022	1.423	8.00
F	3.30	19.30	7.0	3.2	0.198	0.126	0.083	0.016	0.749	8.20
G	4.99	27.33	78.0	12.3	0.500	0.257	0.142	0.059	1.331	8.20
H	2.86	13.02	18.6	2.8	0.059	0.003	0.065	0.018	0.836	8.20
I	3.31	11.97	19.6	2.4	0.088	0.002	0.067	0.018	0.836	8.20
J	4.13	26.28	111.9	8.1	0.365	0.135	0.124	0.055	1.005	8.20
K	3.42	13.37	8.0	0.0	0.056	0.017	0.086	0.033	0.532	8.20
L	4.50	22.09	96.3	6.5	0.336	0.115	0.131	0.052	0.898	8.20
M	2.75	20.35	20.4	1.4	0.069	0.013	0.088	0.083	1.132	8.30
N	3.49		24.0	4.6	0.082	0.016	0.055	0.083	0.802	8.30
O	4.06		57.1	4.9	0.275	0.126	0.109	0.063	0.982	8.20
P	3.67		86.0	11.4	0.442	0.239	0.130	0.075	1.175	8.30
Q	3.79		48.4	7.5	0.394	0.236	0.145	0.073	1.027	8.30
R	3.93		61.9	12.3	0.387	0.241	0.108	0.074	1.021	8.40
S										
T	4.49		47.5	3.4	0.374	0.257	0.161	0.075	1.140	8.20
U	5.43		19.0	7.4	0.471	0.000	0.103	0.036	0.369	8.10
V	1.55		4.0	2.6	0.101	0.085	0.091	0.020	0.855	8.00
W	2.50		19.8	12.4	0.095	0.028	0.061	0.009	0.576	8.30
X	2.24		5.5	3.9	0.047	0.024	0.085	0.009	0.551	8.10
1	2.42		11.8	2.6	0.092	0.050	0.084	0.008	0.252	8.40
2	2.35		8.8		0.108	0.058	0.099	0.011	0.259	8.40
Z	2.35		27.2	6.2	0.063	0.020	0.067	0.004	0.131	8.50
Y	1.76		7.8	3.8	0.081	0.002	0.051	0.004	0.136	8.50

APPENDIX I

STREAM WATER QUALITY DATA FOR ONE NORTH CACHE VALLEY FEEDLOT

Table I-1. Stream water quality data upstream and downstream of control and treated sections of northern feedlot facility, October 20, 1977.

Sample Number	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	$o\text{-}PO_4$ mg/l	$NH_3\text{-}N$ mg/l	$NO_2\text{-}N$ mg/l	$NO_3\text{-}N$ mg/l	pH	TKN	TDS	Date
AA	-	17.61	34.8	7.6	0.496	0.095	0.024	-	-	8.38	0.489	-	10/20/77
BB	-	18.32	41.4	7.2	0.701	0.113	0.013	-	-	8.46	0.538	-	10/20/77
CC	-	18.32	43.6	7.9	0.476	0.355	0.007	-	-	8.48	0.391	-	10/20/77

Table I-2. Stream water quality data upstream and downstream of control and treated sections of northern feedlot facility, October 27, 1977.

Sample Number	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	$o\text{-}PO_4$ mg/l	$NH_3\text{-}N$ mg/l	$NO_2\text{-}N$ mg/l	$NO_3\text{-}N$ mg/l	pH	TKN	TDS	Date
AA	4.46	11.39	40.4	8.2	0.219	0.105	0.151	0.016	0.68	7.92	1.390	-	10/27/77
BB	3.88	18.94	37.3	6.1	0.185	0.066	0.049	0.015	0.67	8.05	0.213	-	10/27/77
CC	4.22	23.21	62.4	10.0	0.393	0.122	0.092	0.018	0.70	8.16	0.342	-	10/27/77

Table I-3. Stream water quality data upstream and downstream of control and treated sections of northern feedlot facility, October 30, 1977.

Sample Number	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	$o\text{-}PO_4$ mg/l	$NH_3\text{-}N$ mg/l	$NO_2\text{-}N$ mg/l	$NO_3\text{-}N$ mg/l	pH	TKN	TDS	Date
AA	5.02	16.97	32.1	10.2	0.114	0.054	0.073	0.017	0.64	8.2	0.702	0.238	10/30/77
BB	4.34	18.94	46.7	13.0	0.123	0.057	0.078	0.016	0.66	8.3	0.450	0.262	10/30/77
CC	4.92	22.55	69.4	15.2	0.233	0.102	0.107	0.019	0.68	8.3	0.934	0.258	10/30/77

Table I-4. Stream water quality data upstream and downstream of control and treated sections of northern feedlot facility, October 31, 1977.

Sample Number	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	$o\text{-}PO_4$ mg/l	$NH_3\text{-}N$ mg/l	$NO_2\text{-}N$ mg/l	$NO_3\text{-}N$ mg/l	TKN	pH	Date
AA	9.50	17.95	34.4	6.7	0.142	0.062	0.059	0.020	0.69	8.2	-	10/31/77
BB	9.50	19.92	34.5	10.4	0.123	0.059	0.049	0.020	0.68	8.3	-	10/31/77
CC	8.50	26.82	48.5	12.3	0.208	0.097	0.068	0.023	0.69	8.3	-	10/31/77

Table I-5. Stream water quality data upstream and downstream of control and treated sections of northern feedlot facility, November 6, 1977.

Sample Number	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	$o-PO_4$ mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	TKN	pH	Date
AA	1.39	10.36	33.9	2.0	0.162	0.091	0.167	0.024	1.01	8.30	0.407	11/06/77
BB	1.29	8.98	26.6	2.7	0.162	0.087	0.158	0.022	1.03	8.31	0.703	11/06/77
CC	2.09	21.55	68.7	6.9	0.354	0.142	0.192	0.023	1.05	8.43	0.740	11/06/77

Table I-6. Stream water quality data upstream and downstream of control and treated sections of northern feedlot facility, November 17, 1977.

Sample Number	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	$o-PO_4$ mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	TKN	pH	Date
AA	-	15.59	50.2	1.6	0.162	0.103	0.171	0.021	0.95	8.42	0.792	11/17/77
BB	-	9.70	53.1	1.0	0.162	0.088	0.147	0.019	0.98	8.41	0.566	11/17/77
CC	-	24.60	66.7	4.6	0.354	0.125	0.141	0.021	0.98	8.40	0.642	11/17/77

Table I-7. Stream water quality data upstream and downstream of control and treated sections of northern feedlot facility, November 22, 1977.

Sample Number	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	$o-PO_4$ mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH	TKN	TDS	Date
AA	5.80	0.0	20.8	5.2	0.188	0.130	0.201	0.017	1.22	8.4	0.198	0.368	11/22/77
BB	0.50	5.54	22.8	2.8	0.216	0.139	0.215	0.017	1.22	8.4	0.356	0.360	11/22/77
CC	9.40	48.85	107.1	38.6	1.036	0.431	0.316	0.032	1.28	8.4	3.480	0.404	11/22/77

Table I-8. Stream water quality data upstream and downstream of control and treated sections of northern feedlot facility, November 27, 1977.

Sample Number	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	$o-PO_4$ mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	TKN	pH	TDS	Date
AA	-	18.1	18.0	3.6	0.213	0.130	0.260	0.029	1.08	8.32	0.073	0.380	11/27/77
BB	-	22.4	22.4	5.0	0.226	0.139	0.297	0.029	1.09	8.33	0.084	0.394	11/27/77
CC	-	26.5	69.2	19.6	0.558	0.248	0.336	0.031	1.11	8.30	0.099	0.362	11/27/77

Table I-9. Stream water quality data upstream and downstream of control and treated sections of northern feedlot facility, December 3, 1977.

Sample Number	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	$o-PO_4$ mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	TKN	pH	TDS	Date
AA	2.42	7.96	21.1	2.7	0.217	0.137	0.192	0.034	1.19	8.23	0.360	0.226	12/03/77
BB	1.73	14.53	20.2	4.0	0.223	0.146	0.205	0.027	1.21	8.32	0.600	0.108	12/03/77
CC	2.72	18.34	21.8	4.6	0.365	0.220	0.316	0.028	1.23	8.31	0.920	0.086	12/03/77

Table I-10. Stream water quality data upstream and downstream of control and treated sections of northern feedlot facility, December 15, 1977.

Sample Number	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	TKN	pH	TDS	Date
AA	2.77	11.85	32.5	3.5	0.252	0.160	0.282	0.042	1.29	-		0.238	12/15/77
BB	3.22	21.82	26.5	3.7	0.236	0.165	0.308	0.052	1.34	-		0.290	12/15/77
CC	3.41	27.81	43.0	7.3	0.364	0.226	0.509	0.038	1.34	-		0.264	12/15/77

Table I-11. Stream water quality data upstream and downstream of control and treated sections of northern feedlot facility, December 16, 1977.

Sample Number	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	TKN	pH	TDS	Date
AA	3.24	25.81	71.1	11.5	0.292	0.147	0.311	0.041	1.14	8.17		-	12/16/77
BB	8.86	47.35	80.0	15.9	0.400	0.200	0.329	0.055	1.19	8.14		0.248	12/16/77
CC	14.46	62.51	89.0	26.9	0.636	0.309	0.605	0.038	1.17	8.22		0.178	12/16/77

Table I-12. Stream water quality data upstream and downstream of control and treated sections of northern feedlot facility, December 18, 1977.

Sample Number	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	TKN	pH	TDS	Date
AA	-	22.22	-	-	0.207	0.140	0.189	0.023	1.21	-		0.338	12/18/77
BB	-	35.78	-	-	0.528	0.251	0.457	0.024	1.20	-		0.380	12/18/77
CC	-	38.98	-	-	0.833	0.284	0.506	0.026	1.21	-		0.390	12/18/77

Table I-13. Stream water quality data upstream and downstream of control and treated sections of northern feedlot facility, December 19, 1977.

Sample Number	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	TKN	pH	TDS	Date
AA	-	17.83	36.3	12.7	0.236	0.143	0.143	0.103	1.27			0.360	12/19/77
BB	-	48.95	24.8	3.8	0.203	0.147	0.144	0.023	1.23	8		0.312	12/19/77
CC	-	depleted	1674.4	381.4	10.067	1.114	0.594	0.027	1.24			0.330	12/19/77

Table I-14. Stream water quality data upstream and downstream of control and treated sections of northern feedlot facility, December 23, 1977.

Sample Number	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	TKN	pH	TDS	Date
AA	1.96	11.05	-	-	0.202	0.131	0.200	0.036	1.35	-	0.386	0.328	12/23/77
BB	3.56	9.45	25.9	19.9	0.195	0.144	0.170	0.032	1.34	-	0.561	0.326	12/23/77
CC	3.88	14.64	69.3	56.8	0.260	0.160	0.327	0.079	1.40	-	0.702	0.302	12/23/77

Table I-15. Stream water quality data upstream and downstream of control and treated sections of northern feedlot facility, December 30, 1977.

Sample Number	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	TKN	pH	TDS	Date
AA	1.93	10.46	19.6	2.2	0.198	0.145	0.198	0.025	1.28	8.24	0.386	0.356	12/30/77
BB	3.13	17.23	17.8	1.7	0.247	0.164	0.258	0.031	1.29	8.30	0.105	0.350	12/30/77
CC	22.0	35.93	110.7	52.0	2.166	0.965	2.260	0.039	1.31	8.28	7.860	0.370	12/30/77

Table I-16. Stream water quality data upstream and downstream of control and treated sections of northern feedlot facility, December 31, 1977.

Sample Number	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	TKN	pH	TDS	Date
AA	1.79	12.45	17.0	3.0	0.207	0.139	0.219	0.024	1.24	-	-	0.298	12/31/77
BB	4.25	16.43	22.5	7.0	0.306	0.169	0.313	0.050	1.30	-	-	0.314	12/31/77
CC	-	-	-	-	-	-	-	-	-	-	-	-	12/31/77

Table I-17. Stream water quality data upstream and downstream of control and treated sections of northern feedlot facility, January 4, 1978.

Sample Number	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	TKN	pH	TDS	Date
AA	-	22.80	25.4	3.9	0.258	0.169	0.256	0.025	1.35	-	2.562	0.372	01/04/78
BB	2.65	13.25	15.4	4.7	0.214	0.155	0.245	0.037	1.37	-	0.743	0.368	01/04/78
CC	6.4	27.18	20.4	3.1	0.277	0.193	0.309	0.038	1.41	-	1.300	0.376	01/04/78

Table I-18. Stream water quality data upstream and downstream of control and treated sections of northern feedlot facility, January 5, 1978.

Sample Number	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	TKN	pH	TDS	Date
AA	1.78	10.46	15.45	2.9	0.207	0.146	0.267	0.025	1.25	8.06			01/05/78
BB	1.97	7.28	13.69	1.6	0.220	0.150	0.253	0.029	1.27	8.12			01/05/78
CC	2.20	8.87	15.2	2.2	0.242	0.158	0.290	0.031	1.31	8.09			01/05/78

Table I-19. Stream water quality data upstream and downstream of control and treated sections of northern feedlot facility, January 6, 1978.

Sample Number	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	o-PO_4 mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	TKN	pH	TDS	Date
AA	1.17	5.83	-	-	0.194	0.143	0.213	0.027	1.28	-	0.149	0.322	01/06/78
BB	2.66	10.18	-	-	0.233	0.160	0.280	0.030	1.30	-	0.520	0.340	01/06/78
CC	11.16	45.06	-	-	0.720	0.371	0.812	0.035	1.32	-	3.231	0.352	01/06/78

Table I-20. Stream water quality data upstream and downstream of control and treated sections of northern feedlot facility, January 17, 1978.

Sample Number	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	$o\text{-}PO_4$ mg/l	$NH_3\text{-}N$ mg/l	$NO_2\text{-}N$ mg/l	$NO_3\text{-}N$ mg/l	TKN	pH	TDS	Date
AA	3.92	25.41	34.95	8.44	0.303	0.187	0.450	0.026	1.25	8.06	0.476	0.336	01/17/78
BB	2.87	22.30	29.08	7.84	0.293	0.200	0.455	0.026	1.29	8.02	0.443	0.300	01/17/78
CC	4.90	33.19	43.55	17.00	0.552	0.320	0.621	0.029	1.30	8.07	0.727	0.310	01/17/78

Table I-21. Stream water quality data upstream and downstream of control and treated sections of northern feedlot facility, January 18, 1978.

Sample Number	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	$o\text{-}PO_4$ mg/l	$NH_3\text{-}N$ mg/l	$NO_2\text{-}N$ mg/l	$NO_3\text{-}N$ mg/l	TKN	pH	TDS	Date
AA	4.13	26.58	57.96	13.87	0.329	0.179	0.356	0.035	1.26	7.96	0.355	0.316	01/18/78
BB	4.33	26.19	59.41	9.29	0.397	0.218	0.650	0.035	1.34	8.13	0.508	0.338	01/18/78
CC	7.47	44.47	44.84	13.42	0.821	0.516	0.938	0.033	1.35	8.16	0.979	0.328	01/18/78

Table I-22. Stream water quality data upstream and downstream of control and treated sections of northern feedlot facility, January 27, 1978.

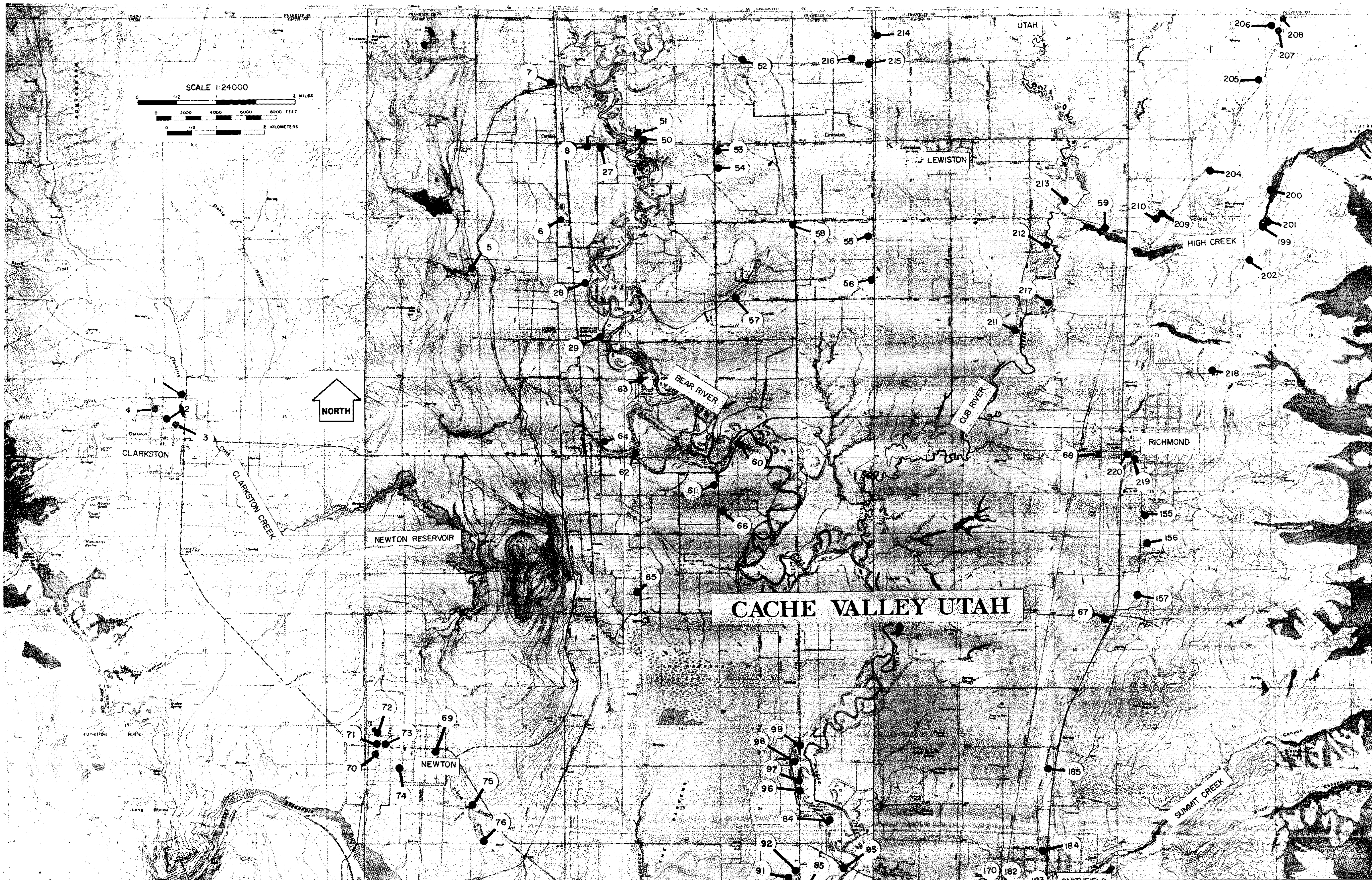
Sample Number	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	$o\text{-}PO_4$ mg/l	$NH_3\text{-}N$ mg/l	$NO_2\text{-}N$ mg/l	$NO_3\text{-}N$ mg/l	TKN	pH	TDS	Date
AA	-	-	-	-	-	-	-	-	-	-	-	-	01/27/78
BB	3.13	16.87	22.97	4.15	0.232	0.149	0.259	-	-	8.03	0.308	0.336	01/27/78
CC	2.53	20.73	23.73	5.76	0.285	0.184	0.298	-	-	8.12	0.271	0.378	01/27/78

Table I-23. Stream water quality data upstream and downstream of control and treated sections of northern feedlot facility, February 27, 1978.

Sample Number	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	$o\text{-}PO_4$ mg/l	$NH_3\text{-}N$ mg/l	$NO_2\text{-}N$ mg/l	$NO_3\text{-}N$ mg/l	TKN	pH	TDS	Date
AA	4.80	64.84	44.62	8.15	0.185	0.127	0.212	0.035	1.64	8.16	-	-	02/27/78
BB	3.50	19.69	50.45	7.12	0.253	0.136	0.234	0.030	1.66	8.09	-	27.0580	02/27/78
CC	6.90	64.09	85.92	27.68	0.278	0.402	0.871	0.035	2.06	8.20	-	27.5254	02/27/78

Table I-24. Stream water quality data upstream and downstream of control and treated sections of northern feedlot facility, April 17, 1978.

Sample Number	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TP mg/l	$o\text{-}PO_4$ mg/l	$NH_3\text{-}N$ mg/l	$NO_2\text{-}N$ mg/l	$NO_3\text{-}N$ mg/l	TKN	pH	TDS	Date
AA	2.30	19.81	65.08	9.41	-	-	0.061	0.011	0.56	8.13	-	-	04/17/78
BB	1.90	17.51	47.18	7.32	-	-	0.055	0.010	0.59	8.17	-	-	04/17/78
CC	2.80	34.72	-	-	-	-	0.062	0.008	0.60	8.16	-	-	04/17/78



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CUB RIVER
RICHMOND
HIGH CREEK
CACHE VALLEY UTAH
NEWTON
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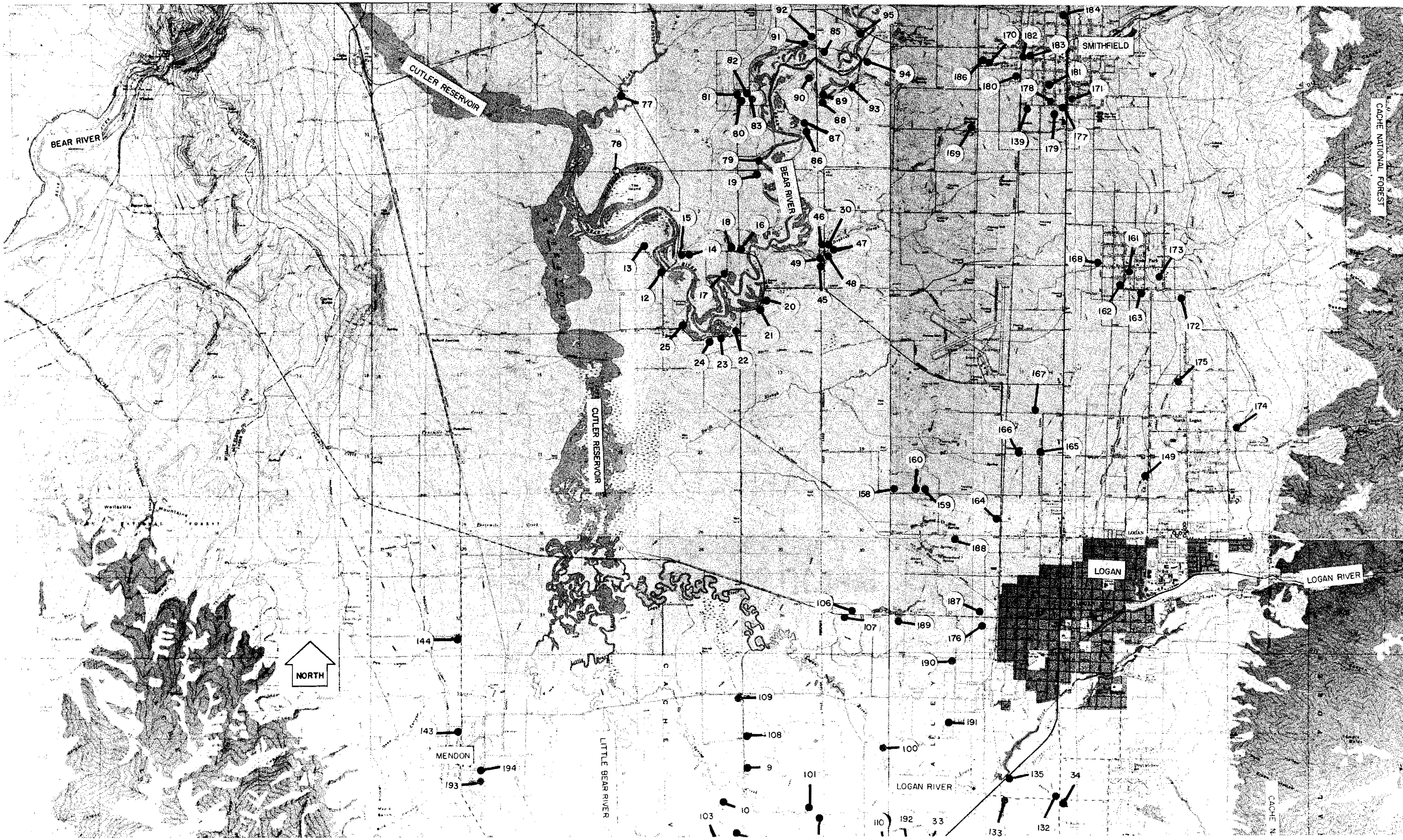
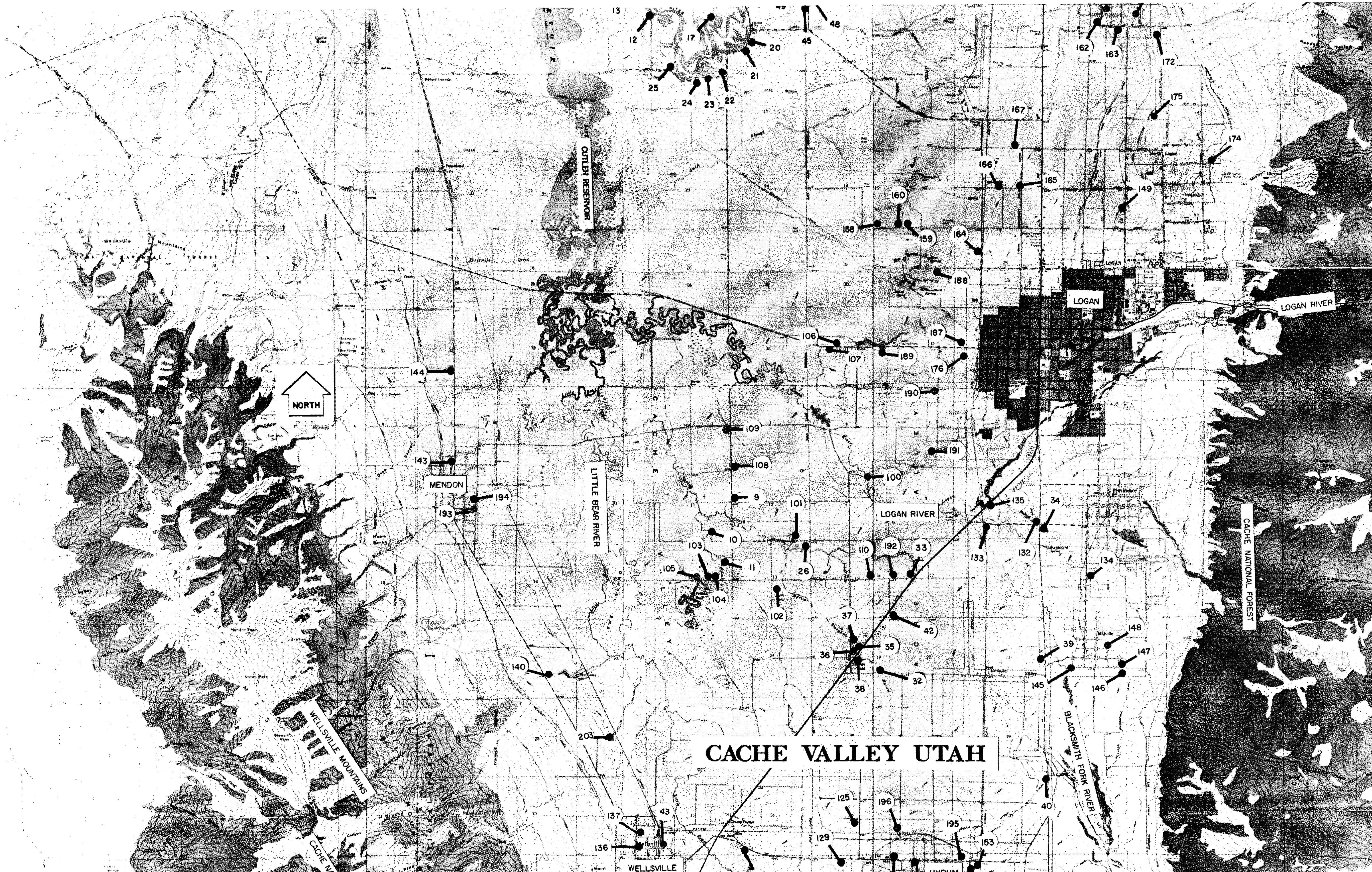


Map Showing Cattle Confinement Facilities in Northern Cache Valley, Utah (U.S. Geological Survey)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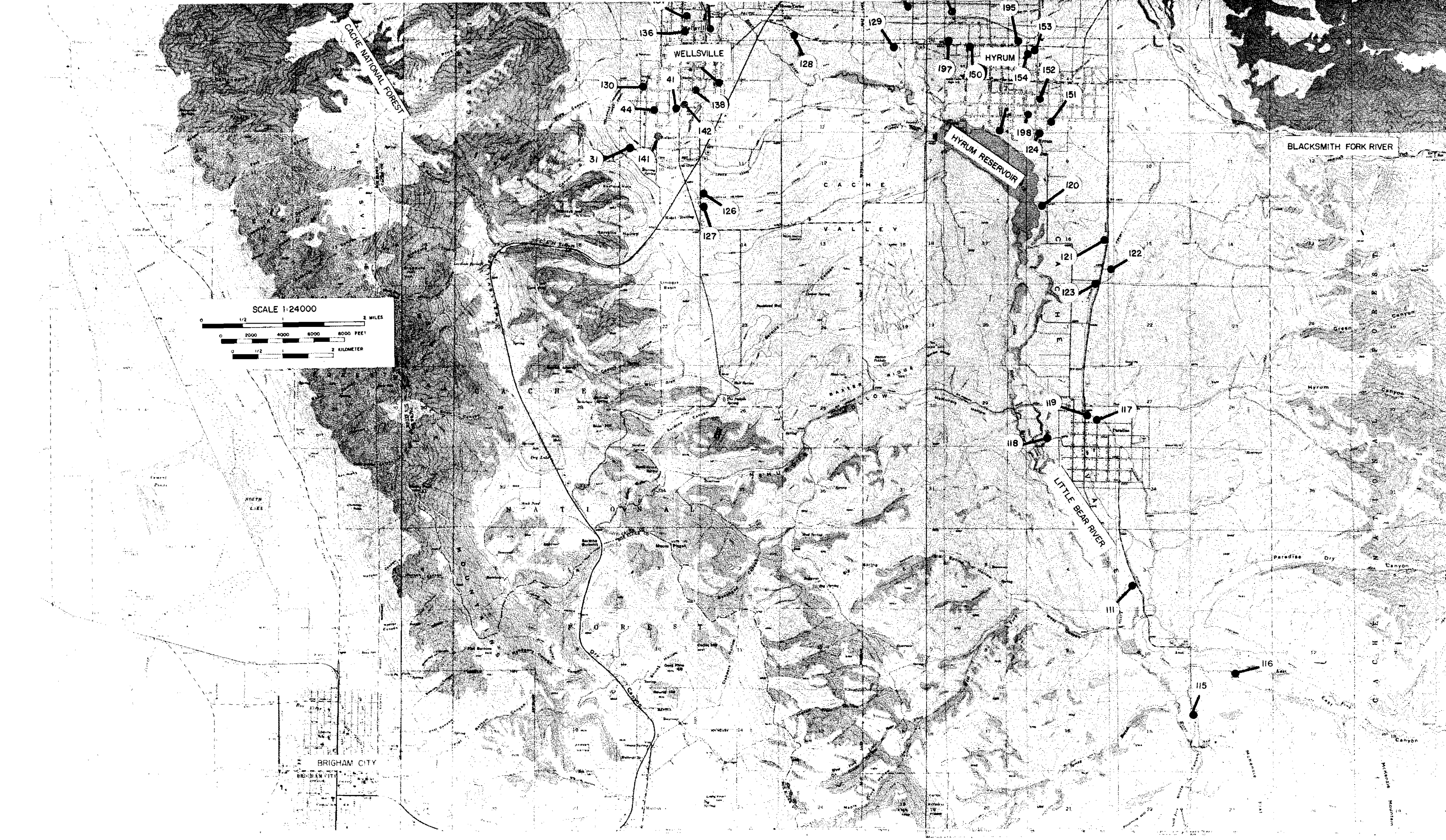
CUTLER RESERVOIR
LOGAN
LOGAN RIVER
LOGAN RIVER
MENDON
LITTLE BEAR RIVER
WELLSVILLE MOUNTAINS
CACHE NATIONAL FOREST
BLACKSMITH FORK RIVER
WELLSVILLE



Map Showing Cattle Confinement Facilities in Southern Cache Valley, Utah (U.S. Geological Survey)