Red Lake Watershed District

Dedicated to Water Management

PROJECT REPORT

Clearwater River Nonpoint Study

June 6, 1994

Prepared by:

Red Lake Watershed District
Thief River Falls, MN
and

HDR Engineering
Minneapolis, MN

In Association with:

Clearwater SWCD
Beltrami SWCD
Red Lake SWCD
Pennington SWCD
U of M Extention
U of M Crookston
Northwest RDC
Headwaters RDC
MnDNR
MPCA
The International Coalition
East Polk SWCD
Red Lake DNR

Table of Contents

Table of Contents (Continued)

Table of Contents (Continued)

List of Tables

List of Tables - Continued

List of Figures

List of Figures (Continued)

List of Figures (Continued)

List of Figures (Continued)

Acknowledgements

The cooperative effort between the various agencies and individuals involved in this study have made it a successful one. While it is nearly impossible to acknowledge everyone that has participated in this project we will make a sincere attempt to thank everyone involved. For those who are inadvertently left from our list we do apologize.

The Red Lake Watershed District was the primary sponsor for the study. Staff members include: David Fink, technician, water programs; Brad Johnson, technician; Brent Johnson, P.E., assistant engineer; Loren Sanderson, technician; Kevin Adolfs, P.E., district engineer; Sean Safranski, summer intern; Tammy Audette, secretary; Arlene Novak, bookkeeper; Sandy Radniecki, receptionist; Lowell Emerson, administrator. Several people provided additional assistance for sample collection, these include: Maggie Leach, Pennington SWCD; Jeff Hrubes and Brenda Nelson, Beltrami SWCD; Joel Rhode and his staff, Red Lake Band of Chippewa Indians DNR. We acknowledge Doug Thompson of the Clearwater SWCD for his long hours spent on the arduous task of gathering and assembling the land use data for this project. We also acknowledge and appreciate the efforts of Dr. Bobby Holder and Wendell Johnson of the University of Minnesota Crookston for their technical support and analytical oversight during the project.

A number of Soil and Water Conservation Districts were joint sponsors. The following list includes the remaining individuals who also played key roles in a successful completion to this project:

Doug Thompson, CLWRSWCD
Milayne Lundmark, CLWRSWCD
Dennis Johnson, MnDNR
Arlin Schalenkamp, MnDNR
Cliff Tweedale, HRDC
Wayne Weber, RLSWCD
Joseph Schafer, RLSWCD
Roger Ramthun, MPCA

A special thanks has to be given to Mark Deutschman of HDR Engineering for his dedication, commitment, and hard work put forth during this project from start to finish. Some of these work items include: writing the original grant application to get the project started, technical support, assistance assembling the computer model, and writing the final report to conclude the project. Other staff members with HDR who assisted in this project are: Pat Tufts, Biologist; Mark Manoleff, Water Resources Technician; Rod Headrick, Water Resource Engineer. Additional thanks must be given to Mike Hardy who is a graduate student in the statistics department at the University of Minnesota for his voluntary efforts in the statistical analysis of data for the project.

List of Abbreviations

2,4-D	Active ingredient commonly found in herbicides
BMPs	Best Management Practices
BSU	Bemidji State University
BWSR	Minnesota Board of Water and Soil Resources
COD	Chemical Oxygen Demand
COE	U.S. Army Corps of Engineers
DO	Dissolved Oxygen
EPPL7	Geographic Information System
FLUX	Computer program used to calculate tributary loads and flow-weighted mean concentrations
GIS	Geographic Information System
LMIC	Lead Management Information Center
MCPA	Active ingredient commonly found in herbicides
MINLEAP	Minnesota Lake Eutrophication Analysis Procedure
MnDNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
NCHF	North Central Hardwood Forest
NGP	Northern Glaciated Plains
NLF	Northern Lakes and Forests
NMW	Northern Minnesota Wetlands
NWRDC	Northwest Regional Development Commission
PCB	Polychlorinated Biphenyls
QUAL2E	Computer model used to assess water quality improvements associated with BMP implementation
RLWD	Red Lake Watershed District
SOPs	Standard Operating Procedures
SWCDs	Soil and Water Conservation Districts

TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
TP	Total Phosphorus
TN	Total Nitrogen
TS	Total Solids
TSS	Total Dissolved Solids
TVS	Total Volatile Solids
UMC	University of Minnesota Crookston

EXECUTIVE SUMMARY

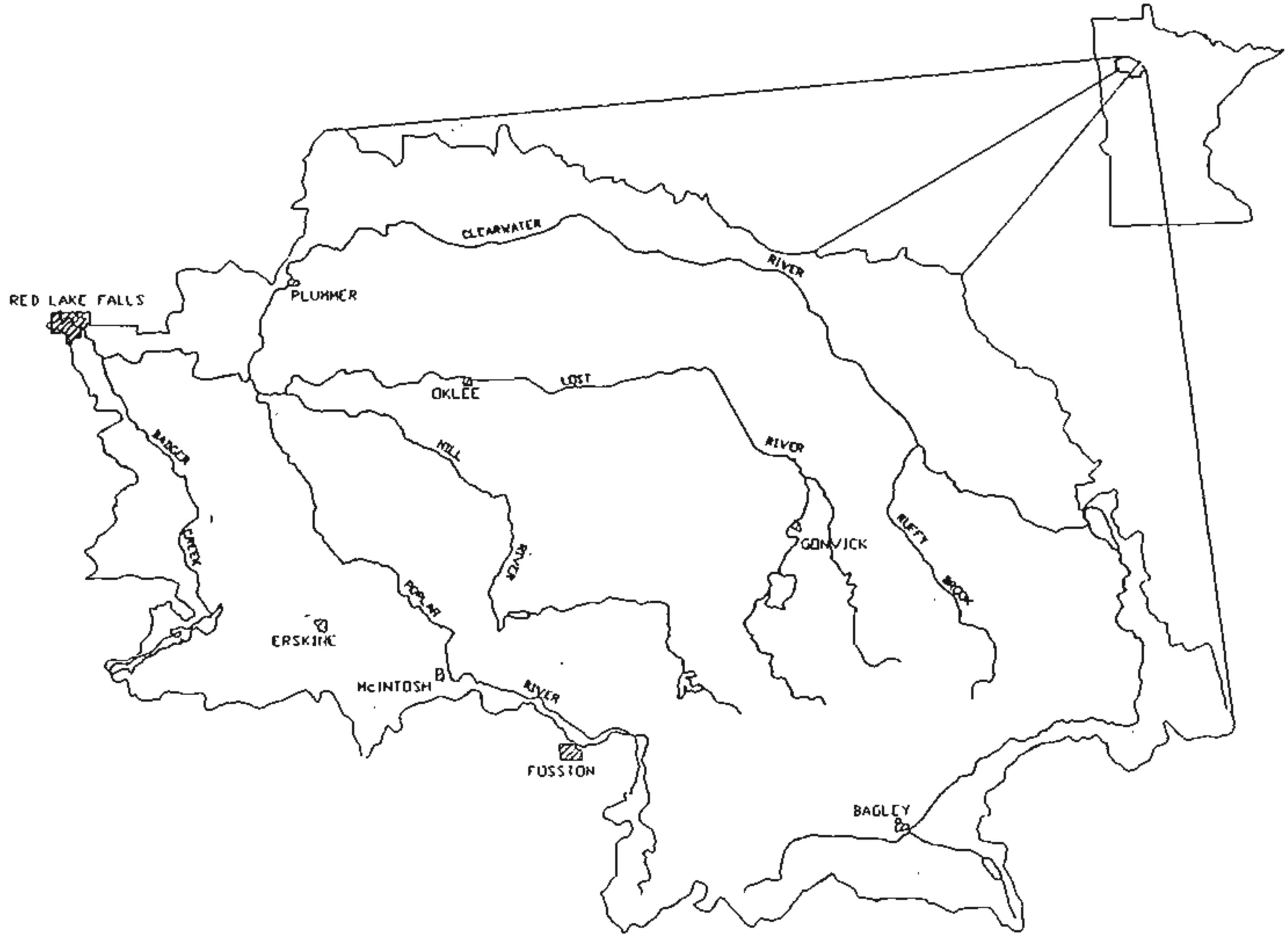
The Red Lake Watershed District (RLWD) in association with other units of government, began the Clearwater Nonpoint Study in April of 1992. The Clearwater River is a locally important river located in northwest Minnesota (Figure ES-1). The study is an outgrowth of local concern about water quality of the Clearwater River. The purposes of this study are to determine factors within the watershed affecting water quality, to develop a management plan for addressing these factors and to establish responsibilities for implementing the management plan.

Water quality problems prior to initiating this study were largely "suspected". Little detailed water quality data were available. Periodic sampling performed by the RLWD provided a good understanding of water quality and use attainment. People believe channelization within the middle reach of the river during the 1950s by the Corps of Engineers caused considerable water quality problems.

The study consisted of sampling 25 locations on the Clearwater, Lost, Hill and Poplar rivers from April 1, 1992-March 31, 1993. Analysis performed included nutrients, various forms of solids, physical characteristics, pesticides and biota. The reasons for degraded water quality within portions of the Clearwater River are multiple and complex. Point source discharges are the primary factors affecting water quality as evidenced by low dissolved oxygen and high nutrient concentrations in the upstream reaches of the Clearwater, Poplar River and possibly Ruffy Brook. Walker Brook is most influenced by ice and snow cover, resulting in low dissolved oxygen during the winter. Feedlots, channel scour, bank erosion, and agricultural practices are the primary factors within the middle, channelized portion of the Clearwater River, leading to elevated total suspended solids, total phosphorus, and chemical oxygen demand. These factors lead to low dissolved oxygen and ultimately influence the water quality within the downstream reaches of the Clearwater River.

Results from the study are many. Some of the more important results are:

- Total solids concentrations, largely composed of dissolved solids, increase from the headwater of the Lost, Clearwater, Poplar and Hill rivers. This phenomena naturally occurs in streams, but is accelerated in the case of the Clearwater River by the increased density of ditch outlets, increased intensity of agricultural practices, the degraded physical integrity of the channel and municipal and urban discharges (e.g., Bagley area). The one monitored agricultural ditch had the greatest solids concentrations.



HDR Engineering, Inc.

Figure ES-1

Location of the Clearwater River Watershed

- Storm events which caused increased nonpoint source pollution runoff was an important factor influencing water quality, primarily in the lower river reaches. The effect of smaller storm events, evidenced by lower dissolved solids, greater total suspended solids, and greater nutrients, lasts a few days. The effect of larger storms lasted one to two weeks.

- Total suspended solids concentrations compared favorably to water quality of minimally impacted streams in the Northern Minnesota Wetland and North Central hardwood Forest ecoregions. Concentrations within the channelized reach of the Clearwater River were more similar to the Red River Valley ecoregion.

- Municipal point source discharges, specifically from McIntosh, Bagley, and Clearbrook, most affect total phosphorus concentrations. This affect is most readily observable at upstream locations, where "background" concentrations are low. Measured total phosphorus concentrations in the upstream reaches were below measured concentrations for minimally impacted streams, but were comparable to the North Central Hardwood Forest and Northern Minnesota Wetlands in the mid and lower reaches.

- Municipal wastewater point sources have a less pronounced effect on total nitrogen concentrations, than on total phosphorus. Total nitrogen concentrations increased from upstream to downstream, a natural phenomena. Interestingly, the largest increase in total nitrogen occurred at the Kiwosay outlet, where flow from a large peat wetland enters the Clearwater River. Ammonia was generally not measurable. Nitrate concentrations within the headwaters of the Clearwater River compared favorable with the Northern Minnesota Wetlands ecoregion, but exceeded typical concentrations for the Red River Valley in the lower reaches. Concentrations were elevated in Ruffy Brook, compared to similar headwaters areas.

- Dissolved oxygen concentrations reach critically low values within portions of the Clearwater River, Walker Brook, the Lost River and the Poplar River. Natural low flow winter ice conditions presumably cause the low concentrations within Walker Brook although chemical oxygen demand is elevated in this reach. Municipal and urban discharges are the likely cause of the low dissolved oxygen. Dissolved oxygen also decreases through the channelized reach, as chemical oxygen demand increases, presumably the result of increased agricultural intensity.

- Monitoring locations below municipal point sources discharges showed greater variations in algae, as evidenced by chlorophyll-a concentrations.

- Fecal coliform bacteria are elevated below the municipal discharges of McIntosh and Gonvick, and within the middle portion of the channelized reaches. Concentrations throughout the watershed seem elevated, at least when compared to a reference concentration of 200 most probable number per 100 ml.

- Pesticides, as characterized by the two indicators MCPA and 2,4-D do not present a risk either in the water column or within sediments.

- Clearwater Lake is a mesotrophic trophic lake. The low retention of total phosphorus (37%), as compared to typical retention for lakes (76%), suggests additional sources of nutrients, other than upstream loading. There is reason for concern about increasing cultural eutrophication of Clearwater Lake.

- The greatest yields (lb/acre) of nutrients and solids occur in two general locations; immediately below Bagley and within the channelized reach. The yield within the channelized reach are considerably greater and of more importance. The high loads within the channelized reach are presumably from the increased density of ditch outlets in this reach and increased intensity in agricultural production. Monitoring locations impacted by point source discharges also show high loads.

- Greatest yields (lbs/acre) within the watershed for total nitrogen and total phosphorus occur below the Kiwosay outlet, a large peat wetland.

- The greatest monthly load for nutrients occurred during the spring runoff months of March, April and May.

- Total solids load compared favorably with yields for streams tributary to Big Stone Lake.

- The largest yields of chemical oxygen demand occurred within the channelized portion of the Clearwater River. Agricultural production and the increased number of ditch outlets presumably affect this reach.

- The biologic community (fish, macroinvertebrates and periphyton) is substantially altered within the channelized reach. This reach exhibits lower species diversity when compared to the upstream and downstream reaches. The lack of physical integrity is the primary factor for lower diversity.

- The study does confirm impairment of the Clearwater River between mile points 135 and 132 and 58 and 47. These areas are anticipated to be of primary concern for implementation measures for the next phase of the study.

Perhaps the most important purpose of the Clearwater Nonpoint Study, is to develop an effective management plan once water quality degradation was identified. The management plan is centered around developing a method of addressing each of the identified factors, evaluating the anticipated improvement in water quality by implementing these methods and providing estimated costs for these methods. Responsibility for selecting specific water quality improvement methods lies with the Technical Steering Committee and is based on specific water quality goals, determined through public interaction and set by the Technical Steering Committee. Overall, the study is intended to provide a rational methodology for maintaining and improving water quality within the Clearwater River to ensure the desired uses of the river are attained.

The primary factors affecting water quality within the Clearwater River basin can be categorized as:

- Streambank erosion
- Nonpoint source discharges
- Point source discharges
- Feedlots
- Lack of channel integrity

The MnDNR identified 14 locations subject to streambank erosion. The locations contribute to sediment loads. Traditional (rock riprap) methods for stabilizing streambank erosion have an estimated cost of $45,525. A summary of the management activities is provided in Table ES-1.

Using annual yields, each of the twenty five subwatersheds were prioritized with regard to their nonpoint source contribution. Subwatersheds were prioritized from "worst" (highest yields) to "best" (lowest yields) by evaluating the magnitude of the chemical oxygen demand, total solids, total phosphorus and total nitrogen annual yield. Five subwatersheds within the middle reach of the Clearwater River showed the greatest yields and were selected for the application of nonpoint source BMPs. These subwatersheds are CR-22, CR-10, CR-9, CR-11 and CR-12 and consistently had the largest solids, nutrient and COD yields. To achieve annual total solids and oxygen demanding load reductions of 10%, 20%, 30% and 40% using conservative tillage practices an estimated 7%, 14%, 21% and 28% of the subwatershed area respectively, requires treatment. This treatment is in addition to the set-aside (Conservation Reserve Program) acres already present within the watershed. The estimated cost for treatment at the 10% level is $944,640 compared to $3,786,240 at the 40% level. Treatment at the 40% level should ensure meeting 5 mg/l dissolved oxygen (Figure ES-2).

The commercial production of wild rice has long been suspected as a reason for degraded water quality within the channelized reach of the Clearwater River (Reach 2). Results from this study do not allow the clear separation of the effects of stream channelization from rice paddy discharge, and drainage ditch outlets. Operational data available from rice producers for 1992 suggest channelization may be at least as important in influencing water quality. Although the

Table ES-1

CLEARWATER RIVER MANAGEMENT PLAN SUMMARY TABLE

Problem	Activity	Implementation Responsibility	Estimated[1] Cost
Streambank Erosion (The MnDNR has identified 14 locations subject to erosion on the Clearwater River.)	Traditional and nontraditional stabilization measures	• Hydraulic design - RLWD • Habitat considerations - MnDNR • Landowner relation and easements - SWCDs and RLWD • Construction monitoring - SWCDs • Funding - MPCA, MnDNR, BWSR and local match	$45,500[2] (Approximate length 1,525 feet)
Nonpoint Source Discharges (High priority watersheds include CR-22, CR-10, CR-9, CR-11 and CR-20.)	Conservation practices	• BMP design - SWCDs and SCS • Estimate of load reduction - SCS, MPCA • Landowner relation and easements - SWCDs • Funding - MPCA, MnDNR, BWSR and local match	Conservation Practices[3] $944,640 (10% reduction in solids and COD) $3,786,240 (40% reduction in solids and COD) Construction of Pilot System for Drainage Ditch $26,100-65,340
Point Source Discharges (Nine point source discharges have been identified within Clearwater River basin.)	Regulation of point source discharges through NPDES program implemented by MPCA.	• Evaluation of effluent discharges from municipal discharges - MPCA • Development of stormwater retention basins - MPCA • Evaluation of unknown fluid at River Mile 2.3 - SWCD • Cleanup of construction debris at River Miles 1.0 and 31.2 - RLWD	Construction of stormwater retention basins ($0.020-0.050 per cubic foot of storage) No Cost Estimate Provided

Table ES-1

CLEARWATER RIVER MANAGEMENT PLAN SUMMARY TABLE - Continued

Problem	Activity	Implementation Responsibility	Estimated[1] Cost
Feedlots (Based on proximity to river, 27 high priority feedlots have been identified.)	Establish feedlot inspection program with minimum goal of ten feedlot inspections per year. Prioritize feedlots for corrective measures.	• Cataloging feedlots and determining characteristics within the portion of the county within the Clearwater River basin - SWCDs • Reprioritizing feedlots for implementation - SWCDs • Performing field inspections - SWCDs • Designing animal waste management units for manure management - SWCDs and SCS • Implement animal exclusion program - SWCD	Activities to be cost shared with the local landowner at a rate to be established by SWCDs. Inspection Program[4] Estimate is $20,000
Lack of Channel Integrity within channelized portion (Reach 2) of Clearwater River.	• Establishment of riparian buffer area along the river • Structural measures within existing channel (vortex rock weir, rootwad revetment) • Creating floodplain along trapezoidal channel • Diverting flow into old stream channel	• Hydraulic analysis of various designs - RLWD • Administration of land rights - RLWD • Mailing of questionnaires to determine landowner interest - SWCDs • Design of habitat improvements - MnDNR • Develop buffer area vegetation plan - SCS • Funding - EPA, MPCA, BWSR, LCMR, and local cost share • Conceptual design technical assistance for rehabilitation - EPA and private consultant	Revegetation of riparian area along river ($235/acre) Creating Floodplain (Option 2) Pilot Project for ½-mile $266,400-792,000
Disseminate Information	Develop Education Program	• Develop Program - Headwaters RDC • Prepare Technical Information - SWCDs and RLWD • Implement Program - Headwaters RDC and U of M Extension • Funding - MPCA, BWSR	$20,000

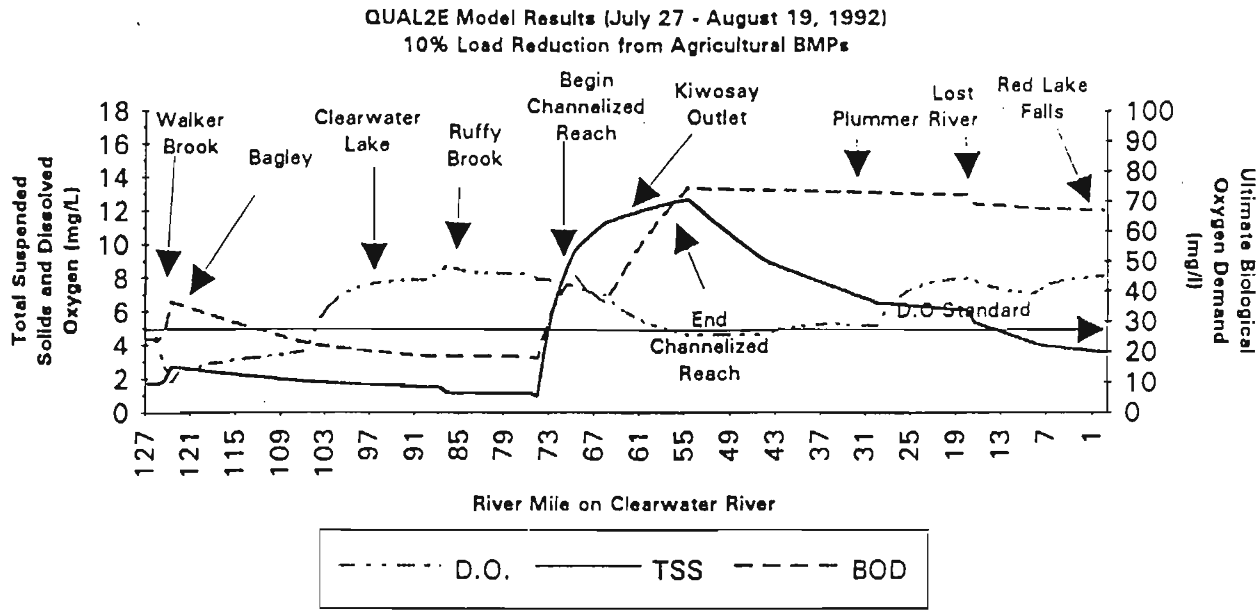
Total Estimated Cost
$1,322,640-4,729,080

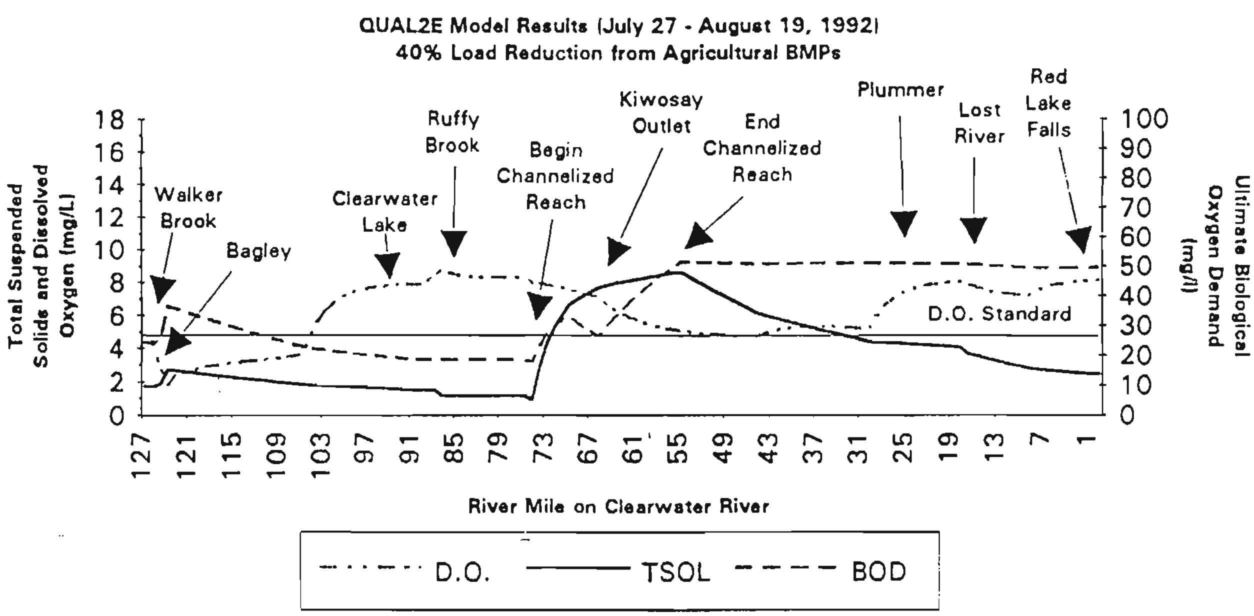
[1] Costs are for planning purposes only and to be used during Phase II application.

[2] Based on unit cost of $27 per lineal foot for "traditional" rock riprap.

[3] Estimate is for conservation tillage practices assuming $40/acre. Other practices could be used.

[4] Estimate assumes 16 hours per feedlot for 27 inspections.





HDR Engineering Inc.

Red Lake Watershed District — Dedicated to Water Management

Figure ES-2

Anticipated Improvement in Water Quality Within the Clearwater River for Various Percentage Reductions in Annual Load from Priority Subwatersheds magnitude of the load from rice producers can not be accurately quantified without additional information, rice growers should consider ways of improving water quality during or prior to discharge. Improvements to the gravity flow ditch could be made to increase sedimentation. Other methods include the use of level bottom ditches to encourage standing water within the ditch along with periodic removal of sediment, redesign of the drainage ditch to create a biofiltration system, and the use of specially designed systems to treat agricultural runoff. Estimated cost for a demonstration project ranges from $26,140-65,340, depending upon the volume of water to be treated.

Nine point sources are present within the Clearwater River basin. These are having a marked impact on water quality within the Clearwater River and tributaries to the Clearwater. Responsibility for addressing point source discharges lies with the MPCA.

Based on GIS analysis using 1992 land use data, an estimated 804 feedlots are present within the watersheds of the Clearwater, Lost, Hill and Poplar Rivers. GIS analysis showed 27 feedlots within 100 m (300 feet) of a watercourse. Feedlot characteristics such as number of animals or animal waste management practices were not determined. Because of their proximity to the river, the 27 feedlots have been identified as high priority for implementation purposes. The goal of the implementation strategy is to inspect 10 feedlots per year within each of the counties, and assess the need for corrective measures. Anticipated measures for addressing feedlots include animal exclusion from along the river by fencing and the construction of animal waste management. Estimated cost for the inspection program is $20,000.

Channelization has affected the water quality of the Clearwater River. Water quality degrades throughout the channelized portion of the Clearwater River. The influence of the channelized reach continues through the remaining portion of the Clearwater River until the confluence with the Lost River. Various approaches can be used to improve the structural integrity of the channelized reach. The strategy associated with each approach is to provide a mechanism for enhancing sedimentation by altering the velocity distribution within the river and reducing scour. The velocity distribution can be effectively altered by enhancing structural integrity.

Three approaches to improving structural integrity and "rehabilitating" the channelized reach are possible, depending upon the aggressiveness desired. Each of these approaches includes establishing a vegetated buffer area along the river - a riparian zone. Approaches to rehabilitate channel integrity include structural measures within the existing trapezoidal channel, creating a floodplain along the trapezoidal channel and diverting flow into the old stream channel.

Estimated costs for revegetation of the riparian area average $235/acre. Estimated cost for a demonstration project intended to rehabilitate ½-mile of channelized river ranges from $264,000-792,000. Detailed plans are needed prior to rehabilitation to establish rehabilitation goals, estimate costs accurately and prepare design plans and specifications.

An education program will be initiated during implementation of the management plan. The purpose is to inform area residents and project participants about project activities and assist with understanding the need for these activities.

The estimated cost, excluding administration and technical support (e.g., engineering) ranges from $1,322,640-4,729,080. The estimated cost range represents differing levels of aggressiveness for improving water quality.

Additional recommendations resulting from the study include:

- An intensive water quality and flow monitoring program should be performed during the low flow period, for a one week period. The purpose would be to intensively sample specific sources to understand their importance. Sampling performed at specific point source discharge outlets (e.g., lagoon, rice paddy discharge, ditch outlets) allows separation of their magnitude and allows considerable refinement of the water quality model. The sampling program should include a determination of sediment sources and sinks within the channelized reach.

- One local agency should be established for administering and coordinating the management plan and responsibilities assigned for various tasks. All project water quality and flow data should be maintained by RLWD. Geographic Information System data should be maintained by Clearwater SWCD. Activities related to education are the responsibility of the Headwaters RDC.

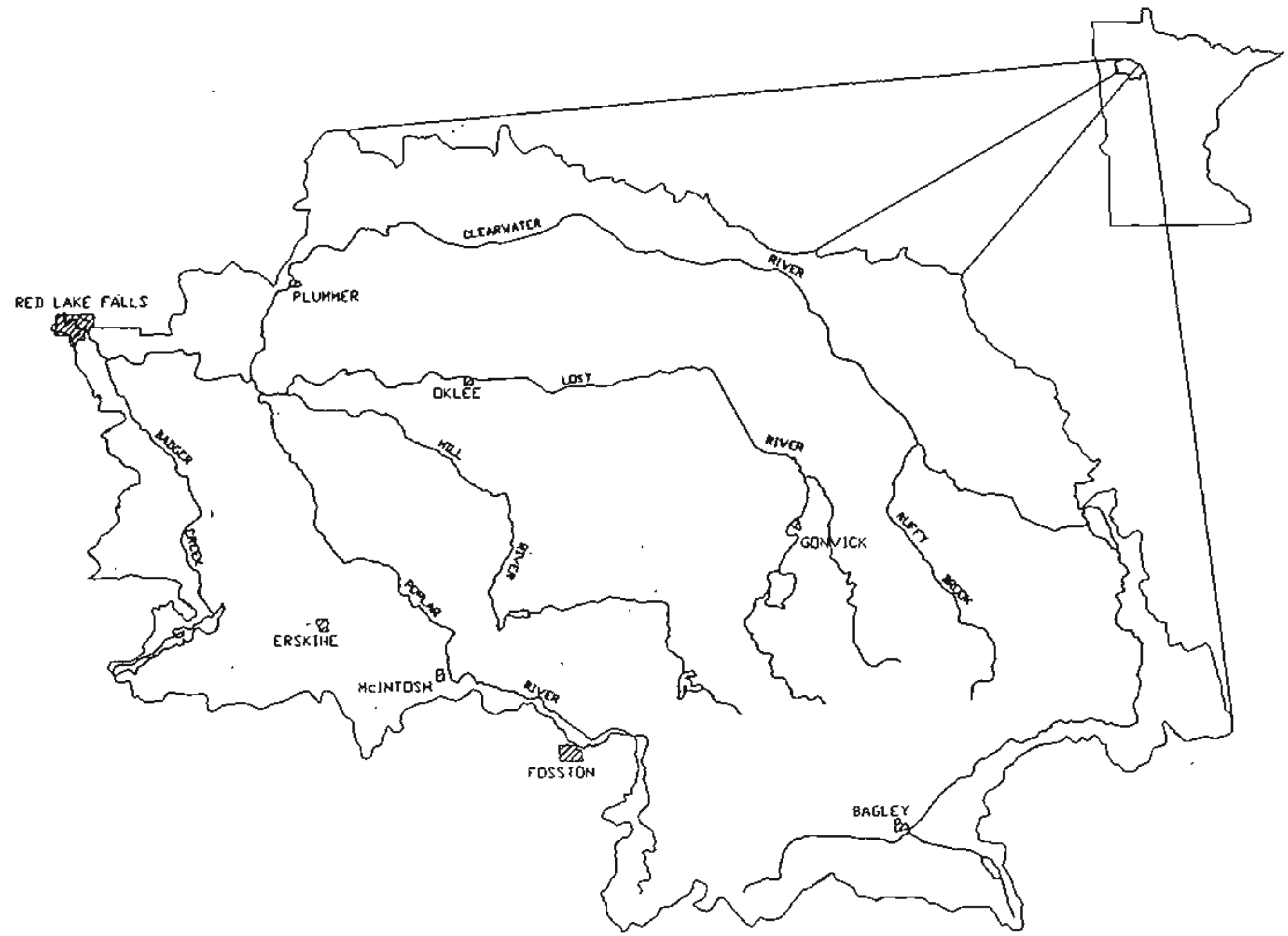
1.0 INTRODUCTION

The Red Lake Watershed District (RLWD) in association with other units of government, began the Clearwater Nonpoint Study in April of 1992. The Clearwater River is a locally important river located in northwest Minnesota (see Figure 1-1). The study is an outgrowth of local concern about the water quality of the Clearwater River. The purposes of this study are to determine factors within the watershed affecting water quality, to develop a management plan for addressing these factors, and to establish a structure for implementation of the plan. The study is designed to use to the maximum extent practicable, existing information with respect to hydrology, soils, land use, meteorology and water chemistry, to calibrate a mathematical model for dissolved oxygen, suspended sediment and nutrients within the Clearwater River. The model serves as a tool for the evaluation of Best Management Practices (BMPs) to attain specific water quality goals for the Clearwater River, determined through public interaction and set by a Technical Steering Committee. A Technical Steering Committee established by project sponsors and co-sponsors is responsible for the technical direction of the study. The study is intended to provide a rational methodology for maintaining and improving water quality within the Clearwater River to ensure the desired uses of the river are attained.

1.1 Historical Uses, Previous Water Quality Studies and Local Interest

The Clearwater River is a multipurpose water resource. Nonconsumptive uses include swimming, boating, tubing, fishing and municipal waste assimilation. Consumptive uses include water appropriation for wild rice production, commercial use and some irrigation. Previous studies of the Clearwater River include those by the Minnesota Pollution Control Agency (MPCA 1977, MPCA 1979) and a water quality study initiated in 1990, performed cooperatively by the University of Minnesota Crookston (UMC) and the RLWD, under a grant from the Minnesota Board of Water and Soil Resources (BWSR) (project title, "Clearwater Project: Pesticides and Land Use"). The early MPCA studies were performed to evaluate the possible impacts associated with commercial wild rice production along the Clearwater River. Work has also been performed by the U.S. Army Corps of Engineers (COE 1975) and Bemidji State University (BSU 1973) within the Red Lake River subbasin.

Local interest in the present project is exemplified by the initiation of routine water quality monitoring within the RLWD, by the District, during 1984. This effort is ongoing and serves



HDR Engineering, Inc.

Red Lake Watershed District
Dedicated to Water Management

Figure 1-1

Location of the Clearwater River Watershed

as baseline information with respect to the present status of water quality for the Clearwater River. An additional example of the extent of local interest in the present project is the fact that Clearwater, Red Lake, Polk and Pennington counties have identified a "Nonpoint Source Water Quality Study of the Clearwater River" as a primary implementation strategy within their respective County Comprehensive Local Water Plans. Each of the counties has identified the need for increased information about the water quality of the Clearwater River as well as the desire to undertake a nonpoint study of the river. This project will assist in fulfilling these goals.

Similarly, the RLWD has identified water quality and nonpoint source pollution abatement within their Updated Ten-Year Plan (RLWD 1988), as a primary concern. The RLWD identified within the plan specific activities for pollution abatement within the District.

1.2 Suspected Water Quality Problems, Impaired Uses and Known Water Quality Problems

The majority of the initial information about the water quality of the Clearwater River came from early studies and the water quality monitoring activities of the RLWD and UMC. The RLWD and UMC entered into a cooperative agreement in 1984 for monitoring the quality of the Clearwater River, due to concern about deteriorating water quality. The agreement is ongoing and was recently expanded through a grant from the BSWR to include an analysis of various agricultural practices on water quality of the Clearwater River.

Water quality data collected to date suggested elevated concentrations of nutrients within the Clearwater River. Recent results of monitoring performed by UMC also showed a 20 ug/l concentration of 2,4-D within one sediment sample (RLWD 1990). Additional monitoring proposed as a part of this project will assist in further identifying whether there is a problem. This is important considering the present MPCA designation of impaired use for the river is largely based upon a survey of area resource managers, with a paucity of monitoring data to support the designation.

The Minnesota Department of Natural Resources (MnDNR) completed a study of the fishery of the Clearwater River titled, "Clearwater River Population Assessment." This study, completed in 1988, provides information about the number of fish and the composition of the fishery along the Clearwater River. This report served as the basis for further fishery work performed during this study. The MnDNR feels winter habitat for trout is generally limiting a sustainable trout fishery within specific reaches of the river. Periodically, low dissolved oxygen is also believed by the MnDNR to be a problem.

Water quality problems within the Clearwater River are to a large extent suspected, by virtue of the identification of the river by the MPCA on various regulatory lists. There is a general feeling among local agencies like the Soil and Water Conservation Districts (SWCDs) that the water quality of the Clearwater River is poorer than it should be, and can be improved. The large agricultural watershed of the Clearwater River and intensive agricultural activity in the lower reaches, seems to be the primary reason for this attitude.

Sedimentation, eutrophication, and the possible accumulation of agricultural chemicals by sediments are water quality problems believed to be impairing the use of the Clearwater River. Recent surveys of the area resource managers (i.e., SWCD, MnDNR, regional MPCA, local Zoning Administration and Watershed District staff) by the MPCA, resulted in identifying the Clearwater River as "impaired" with respect to present and future uses (MPCA 1988a, MPCA 1990a). The MPCA has also included the Clearwater River on the 304(L) "long list," a listing of water bodies impacted by either point or nonpoint sources (MPCA 1988b, MPCA 1990a).

These classifications seem to be supported by the available surface water quality monitoring data. Surface water quality data for the Clearwater River were initially collected during the late 1970s as a result of concern about the impacts of commercial wild rice production along the Clearwater River (MPCA 1977, MPCA 1979). These studies showed elevated total phosphorus and total kjeldahl nitrogen in water being discharged from commercial wild rice production areas, with a concomitant 2-3 fold increase in downstream concentrations, the presumed cause being discharge from the rice paddies. The remainder of the available water quality monitoring data collected by the MPCA along the Clearwater River are for point source regulatory compliance purposes, and provide little additional information about "typical" water quality within the river. These samples are collected on the Clearwater River near Clearbrook, Bagley and Gonvick to determine possible impacts associated with the discharge of treated municipal wastewater.

The Clearwater River from the headwaters north of Itasca State Park to the confluence west of Red Lake Falls, Minnesota is classified by MPCA as 2B, 3B, 4A, 5 and 6 (see Table 1-1). The portion of the Clearwater River from the Clearwater County line to Clearwater Lake is presently managed as a cold water fishery by the MnDNR. This reach of the river is managed as a put/grow/take fishery for rainbow and brown trout.

Table 1-1. Stream Classification for the Clearwater River and Tributaries

				Applicable Standards[2]		
Class		Description	Parameter	CS	MS	FAV
2B	Fisheries and Recreation	The quality of this class of surface waters shall be such as to permit the propagation and maintenance of cool or warm water sport or commercial fish and their habitats and be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable. This class of surface water is not protected as a source of drinking water.	Ammonia un-ionized as N μg/l	40	none	none
			Dissolved oxygen mg/l	5 as a daily minimum	none	none
			Fecal coliform organisms	Not to exceed 200 organisms per 100 milliliters as a geometric mean of not less than five samples in any calendar month, nor shall more than 10% of all samples taken during any calendar month individually exceed 2,000 organisms per 100 milliliters. The standard applies only between March 1 and October 31.		
				pH value not less than 6.5 nor greater than 9.0		
			Turbidity value NTUs	25	none	none
2C	Fisheries and Recreation[1]	The quality of this class of surface waters shall be such as to permit the propagation and maintenance of rough fish or species commonly inhabiting waters of the vicinity under natural conditions, maintain the habitat for such fisheries, and be suitable for boating and other forms of aquatic recreation for which the waters may be usable.	Dissolved oxygen mg/l	5 as a daily minimum	none	none
				This standard applies to all Class 2 waters except for the reach of the Mississippi River from the outlet of the Metro Wastewater Works in St. Paul (River Mile 835) to Lock and Dam No. 2 at Hastings (River Mile 815) and except for the reach of the Minnesota River from the outlet of the Blue Lake Wastewater Treatment Works (River Mile 21) to the mouth at Fort Snelling. For this reach of the Mississippi River the standard is not less than 5 milligrams per liter as a daily average from April 1 through November 30, and not less than 4 milligrams per liter at other times. For the specified reach of the Minnesota River the standard shall be not less than 5 milligrams per liter as a daily average year-round.		

Table 1-1. Stream Clarification for the Clearwater River and Tributaries - Continued

				Applicable Standards[2]		
Class		Description	Parameter	CS	MS	FAV
3B	Industrial Consumption	The quality of this class of the waters of the state shall be such as to permit their use for general industrial purposes, except for food processing with only a moderate degree of treatment. The quality shall be generally comparable to Class 1D waters of the state used for domestic consumption	Fecal Coliform organisms	Not to exceed 1,000 organisms per 100 milliliters in any calendar month as determined by the logarithmic mean of a minimum of five samples, nor shall more than 10% of all samples taken during any calendar month individually exceed 2,000 organisms per 100 milliliters. The standard applies only between May 1 and October 31.		
4A	Agriculture and Wildlife	The quality of this class of the waters of the state shall be such as to permit their use for irrigation without significant damage or adverse effects upon any crops or vegetation usually grown in the waters or area, including truck garden crops.		NS[3]		
5	Aesthetic Enjoyment and Navigation	The quality of this class of the waters of the state shall be such as to be suitable for aesthetic enjoyment of scenery and to avoid any interference with navigation or damaging effects on property.		NS		
6	Other Uses	The uses to be protected in this class may be under other jurisdictions and in other areas to which the waters of the state are tributary and may include any or all of the uses listed in the foreign categories, plus any other possible beneficial uses. The agency therefore reserves the right to impose any standards necessary for the protection of this class, consistent with legal limitations.		NS		

[1] Applies only to the Hill River; 2B applies to all of the Clearwater and tributaries (Poplar, Lost River, Ruffy Brook and Walker Brook).

[2] CS means Chronic Standard
MS means Maximum Standard
FAV means Final Acute Value

[3] NS means narrative standard only.

1.3 Statement of Project Goals and Objectives

The purposes of this study are to determine factors within the watershed affecting water quality, to develop a management plan for addressing these factors and to establish a structure for implementation of the plan. The management plan describes technically achievable sediment and chemical oxygen demand load reductions needed to attain specific water quality goals, based on desired uses established by the Technical Steering Committee. The plan also describes the implementation mechanism and various responsibilities of each local unit of government for attaining the needed load reductions to maintain or restore the Clearwater River and meet the desired uses, as well as the technical data providing the basis for the decisions.

General goals and objectives of this study are to:

- Establish designated uses and corresponding water quality goals, through public interaction with the Technical and Education Steering Committees, for the Clearwater River.

- Quantify the source (subwatershed) and magnitude of sediment and nutrient, nonpoint source (and known point source) loadings to the Clearwater River.

- Relate land use and watershed characteristics to sediment and nutrient concentrations within the Clearwater River, using existing computer models if applicable. Use this method to forecast future water quality, and evaluate the effectiveness of selected BMPs in achieving water quality goals.

- Develop a management plan describing the BMPs, implementation structure and responsibilities, in accordance with County Comprehensive Local Water Plans. The plan would include recommendations for improving the fishery within the Clearwater River.

- Inform the public of the project and raise their awareness of nonpoint source pollution and methods to abate it. Utilize the Education Steering Committee to serve as an effective organization for obtaining information from the affected parties with respect to desired uses for the Clearwater River and communicating the results of the study and the methodology to be used to achieve the needed load reductions to project sponsors.

The following are anticipated ancillary benefits likely to result by performing the study:

- Determine the efficacy of using readily available water resource information resulting from MPCA, MnDNR and local County Water Planning efforts to address nonpoint source pollution on a regional basis.

- Technology transfer - provide an effective management tool (the mathematical model) for the RLWD and the counties of Clearwater, Red Lake, Polk, Pennington, and Beltrami, to use for forecasting water quality within the Clearwater River (and perhaps by extrapolation to other rivers within the area) based on present and future land use, in accordance with County Comprehensive Local Water Plans.

1.4 Early Project Coordination and Public Involvement

Representatives from the various groups involved in the Clearwater Nonpoint Study, attended a meeting to discuss the project on August 8, 1990, in Crookston, Minnesota. The project concept, the proposed budget, the management structure and roles of the various participants were discussed. The size of the project area was a significant point of discussion; i.e., whether the project area should be reduced or increased. Eighteen monitoring locations were initially contemplated. Meeting participants felt a project evaluating the entire river was more desirable, increasing the number of locations to 25, including tributaries. Also, the application of a water quality model was discussed. Hence the study included a task for evaluating the most appropriate model for the project and applying the selected model. Representatives from UMC shared their knowledge about changing land use and tributary locations, while identifying tentative sampling locations. Finally, each of the participants provided input with respect to their role in the project and the needed time for completing their tasks.

The following were in attendance during the August 8th meeting:

Lowell C. Enerson	Red Lake Watershed District
Paul Brekken	Red Lake Watershed District
Kevin Adolfs	Red Lake Watershed District
Jack Frederick	MPCA - Detroit Lakes
Dan Thul	Lower Red River Water Management Board/MnDNR
Bobby Holder	UMC
Wendell Johnson	UMC
Heidi Bauman	Northwest Regional Development Commission
Barbara Liukkonen	Minnesota Extension Service
Donna Vettleson	Soil Conservation Service
Eric Evenson	The International Coalition
Mark Deutschman	HDR Engineering, Inc.

Because of previous obligations, representatives from the Clearwater SWCD were unable to attend. Milayne Lundmark was contacted on August 9, 1990 and provided input for the Clearwater SWCD. Significant results from the meetings include a more active role by the Extension Service and the Northwest Regional Development Commission (NWRDC) in providing technical and education assistance, an increased number of monitoring locations, and the need for analytical results of known precision and accuracy for analyses performed. Comments obtained at the meeting were incorporated into the grant application. As a result of the meeting, the agencies involved established an organizational structure to complete the project (Figure 1-2).

Coordination during completion of the project consisted of a number of meetings. The following meetings were held during completion of the study.

Meeting Date	Description
August 8, 1990	Meeting regarding Clean Water Partnership Grant. Holder, Vettleson, Lee Thul, Frederick, Liukkonen, W. Johnson, Deutschman, Adolfs, Enerson, Bauman, Evenson, P. Brekken.
March 12, 1991	Meeting with NWRDC regarding Clearwater Nonpoint Study. Enerson, Adolfs, Heath, Warner-Coltom.
March 18, 1991	Work plan outline, financial budget. Yohe, Goehring, Holder, Adolfs, Paddock, W. Johnson, Enerson.
April 17, 1991	Technical Steering Committee meeting.
July 9, 1991	Citizens Advisory Committee and Technical Steering Committee meeting.
August 13, 1991	Citizens Advisory Committee and Technical Steering Committee.
January 9, 1992	Citizens Advisory Committee and Technical Steering Committee.
February 21, 1992	Public Education Advisory Committee meeting.
March 10, 1992	Meeting regarding the Monitoring Plan. Ramthun, Reetz, Mattison, Johnson, Courneya, Enerson, Adolfs, Johnson.
November 17, 1992	RRWMB met in Crookston for a progress report on the Nonpoint Study and to view the Lab.
October 22, 1992	Citizens Advisory Committee and Technical Steering Committee.
November 4, 1992	Public Education Advisory Committee meeting.
December 15, 1992	Citizens Advisory Committee and Technical Steering Committee.
January 22, 1993	Meeting regarding wrap-up of the grant and future extension of the grant. Courneya, Adolfs, Fink, Enerson.
February 4, 1993	Citizens Advisory Committee and Technical Steering Committee.

Meeting Date	Description
May 17, 1993	Meeting regarding remaining activities. Parkins, Deutschman, Adolfs, Fink, Enerson.
March 28, 1994	Meeting to discuss Working Draft Report.

These meetings were held to discuss project status, reassess project direction, share technical information and discuss desired uses. Public Education Committee meetings were also held to discuss strategies for improving water quality and the implementation of selected strategies (refer to Appendix F for results of the public education surveys).

In the early stages of the projects organization the original 18 proposed monitoring locations were expanded to 25. The original 18 sites were located essentially within Reach 2 (see Figure 2-2). These were expanded by the MPCA to include all reaches of the Clearwater River and most of its' tributaries. The site selection criteria used was as follows:

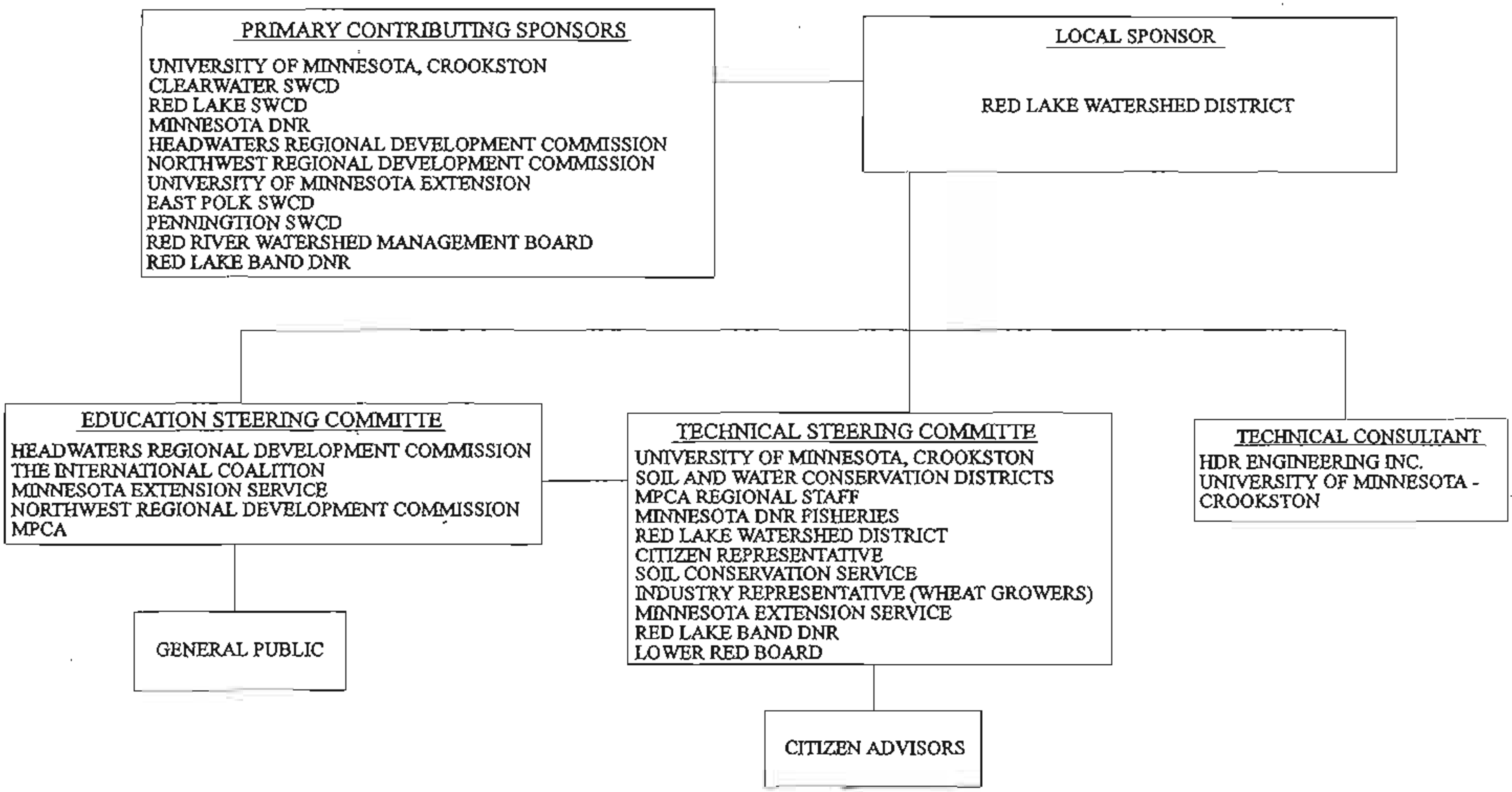
- Streamflow data (priority for established gage sites, or good sites for gaging;

- Hydrologic characteristics (priority to sites which characterize river reaches, subwatershed and tributary contributions, or changes in soils, topography, etc.);

- Major uses: (Priority to sites which characterize land use types, point sources, agricultural practices, etc.);

- Access (Priority to sites which afford all-year, all-weather access);

- Cost (Number of allowable sites is limited by the cost of sampling; priority to sites which will provide the best data within the budget.



HDR Engineering, Inc.

Red Lake Watershed District — Dedicated to Water Management

Figure 1-2

Organizational Chart - Clearwater Nonpoint Study

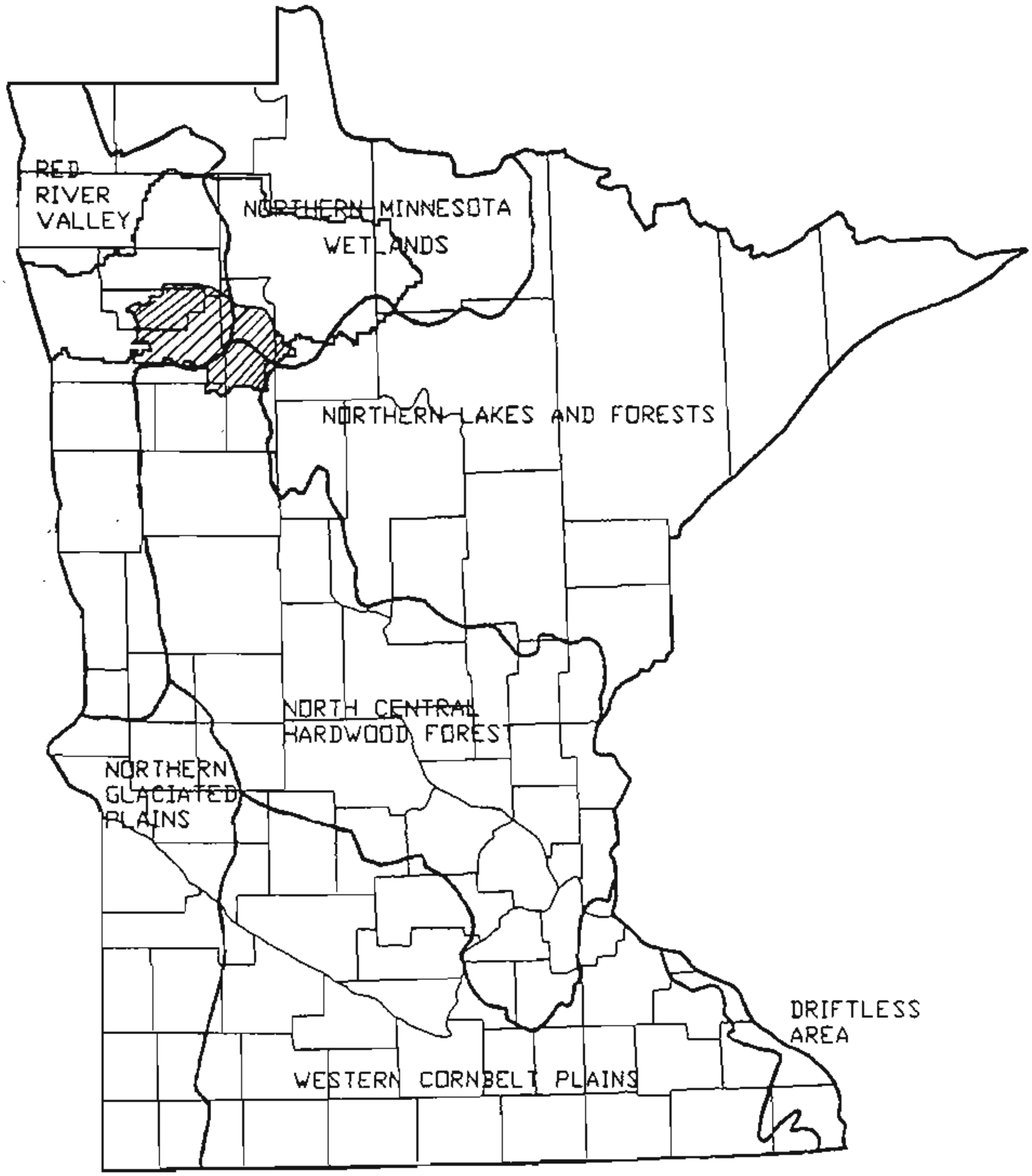
2.0 DESCRIPTION OF THE CLEARWATER RIVER WATERSHED

The Clearwater River is characteristic of many rivers traversing the northwestern portion of Minnesota with respect to physiography. The Clearwater River originates approximately 15 miles north of Itasca State Park in Clearwater County, within an area of transition between the North Central Hardwood Forest and Northern Lakes and Forest ecoregions (Figure 2-1). As the river flows initially north to Clearwater Lake and then west to its confluence with the Red Lake River, the river traverses the Northern Minnesota Wetlands and the Red River Valley ecoregion. The surrounding area changes from an area dominated by forests to an area dominated by agriculture. The Clearwater River traverses or lies within a portion of five counties: Clearwater, Beltrami, Pennington, Polk and Red Lake. However, the majority of the Clearwater River watershed lies within Clearwater and Red Lake counties. Total drainage area at Red Lake Falls, the mouth of the river, is approximately 1370 mi^2 (USGS 1988). Average discharge for the period of record at Red Lake Falls is 318 cubic feet per second (cfs), with maximum and minimum discharges of 10,300 cfs and 0 cfs respectively. Elevation of the area is approximately 1100 feet above sea level.

Soils are primarily loams within Clearwater County near the headwaters of the river with Nebish-Lengby-Beltrami, Solway-Nary, and Naytahwaush-Suomi being the predominant soil associations. These soil associations are characteristic of glacial Lake Agassiz within the agricultural counties, primarily Red Lake and Pennington. The Roliss-Kattson-Nereson and Grimstad-Rockwell-Kratka soil associations are the predominant soil associations within these more agricultural, western counties. Land use changes dramatically by the time the Clearwater and Lost rivers join west of Plummer, Minnesota. In excess of 85% of the land is used for agricultural purposes in Red Lake County, where the Clearwater River joins the Lost River.

2.1 Climatological Description

The climate is continental, with warm summers and cold winters. Daily average summer temperatures range from maximums in the high 70s to low 80s to minimums from the low to mid-50s. Maximum temperatures in the 100s in July are not uncommon. Daily average winter temperatures range from maximums in the teens to the mid-twenties and minimums from approximately 1 degree in December to -10 degrees in January. The average length of the growing season is 137 days, with the last spring freeze occurring near April 26th, and the first fall freeze occurring near October 9th.



Source: MPCA, 1990 b.

HDR Engineering, Inc.

Figure 2-1

Location of the Clearwater River Basin Relative to Minnesota's Ecoregions

The range for annual precipitation is between 20-25 inches with an average of 23 inches. Of the total annual precipitation, 18 inches or 75%, falls during the April through September growing season. In 2 years out of 10, the rainfall from April through September is less than 14 inches. The heaviest 1 day rainfall during the period of record was 9 inches in 6 hours in 1975. Thunderstorms occur on average 35 days each year and most occur during the summer.

2.2 Physical Characteristics of the Clearwater River[1]

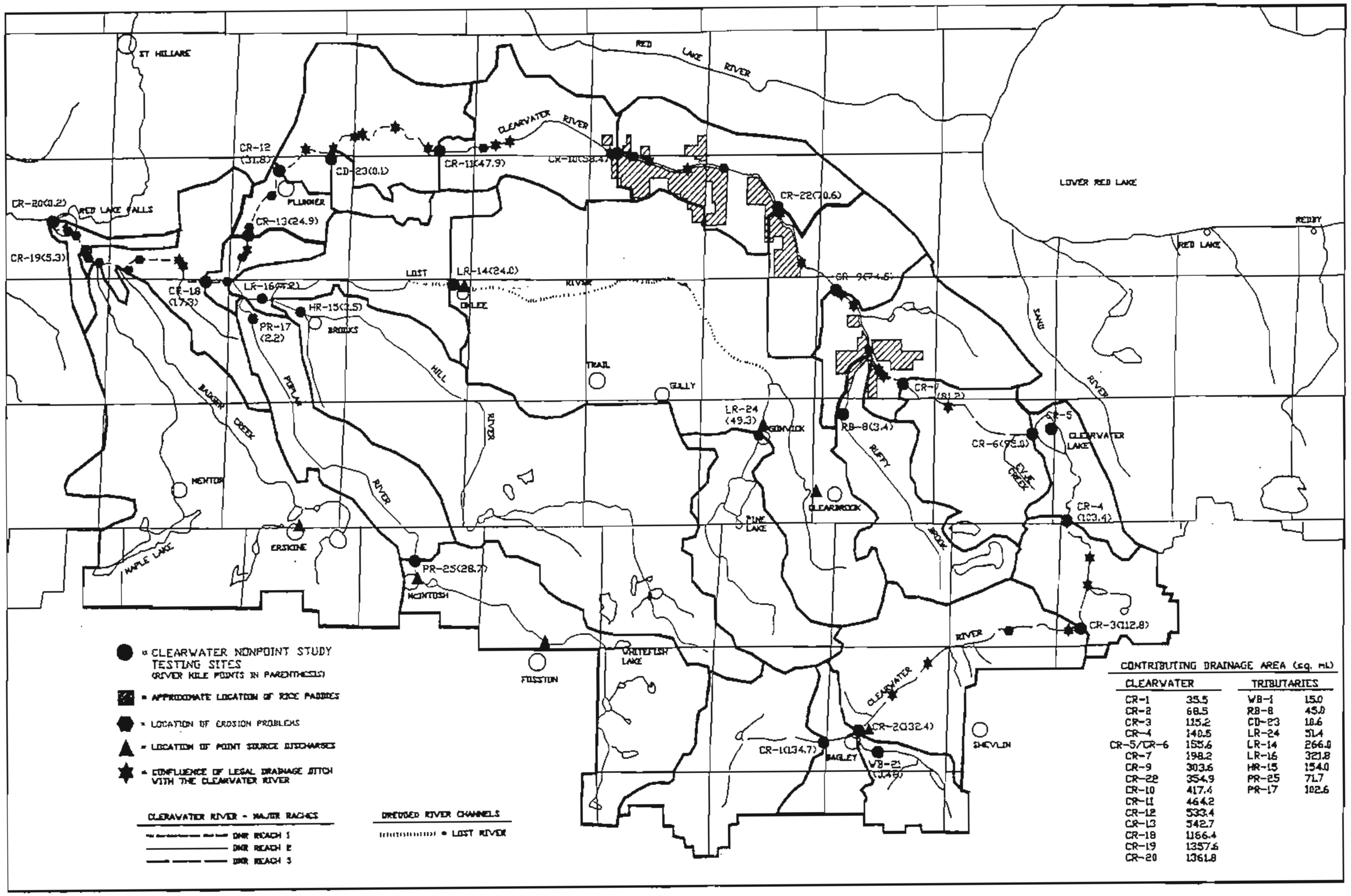
The Clearwater River can be conveniently divided into three separate reaches, based on the physical characteristics of the channel. The MnDNR used this approach, while performing a stream survey of the Clearwater River between July 20, 1992 and August 13, 1992. These reaches, the associated river miles and characteristics of each reach are as follows:

2.2.1 Reach 1 (River Mile 0.0 to 46.2)

Reach 1 is an unchannelized portion of the river extending from the mouth of the Clearwater River at Red Lake Falls to approximately 14 miles upstream of Plummer (Figure 2-2). The MnDNR classifies this reach as Class II warm water gamefish. Beaver dams generally do not pose a game fish management problem within this stream reach. The MnDNR has identified canoeing as an important use of this reach and "light" bank erosion has been identified within the reach (Figure 2-2). The percent of river shading by the canopy ranges from light to heavy. A good mixture of sand, gravel, boulder and rubble are present within pools, although most of this reach consists of "runs". The width of the river ranges from 35-149 feet and the average depth from 1.8-2.3 feet. The greatest width is near Red Lake Falls. The channel gradient near Red Lake Falls is 3.4 feet/mile with a sinuosity of 3.1.

Numerous drainage ditches enter the river (see Figure 2-2). Public access to the river is through a city park located in Red Lake Falls and at road crossings. Some development is present along the river, primarily near Red Lake Falls. Water quality sampling sites within this reach include CR-12, CR-13, CR-18, CR-19, CR-20 on the Clearwater River; sites on the Lost River, Poplar River and Hill River tributaries and County Ditch CD-23.

[1]This discussion is based on largely on a MnDNR stream survey performed by the Division of Fish and Wildlife, Bemidji Office.



CONTRIBUTING DRAINAGE AREA (sq. mi.)

CLEARWATER		TRIBUTARIES	
CR-1	35.5	WB-1	15.0
CR-2	68.5	RB-8	45.0
CR-3	115.2	CD-23	10.6
CR-4	140.5	LR-24	51.4
CR-5/CR-6	155.6	LR-14	266.0
CR-7	198.2	LR-16	321.8
CR-9	303.6	HR-15	154.0
CR-22	354.9	PR-25	71.7
CR-10	417.4	PR-17	102.6
CR-11	464.2		
CR-12	533.4		
CR-13	542.7		
CR-18	1166.4		
CR-19	1357.6		
CR-20	1361.8		

HDR
HDR Engineering Inc.

Red Lake Watershed District
Dedicated to Water Management

FIGURE 2-2

Characteristics of the Clearwater River

2.2.2 Reach 2 (River Mile 46.2 to 79.2)

Reach 2 is a channelized portion of the river extending from near Plummer to the confluence of the Clearwater River and Ruffy Brook. Channelization occurred under the direction of the U.S. Army Corps of Engineers during the 1930s and again in the 1950s. Beaver dams generally do not pose a game fish management problem within this stream reach. The MnDNR classifies this reach as Class II warm water gamefish. Canoeing has been identified by the MnDNR as an important use of this reach. Bank erosion has been identified as light to moderate within the reach and numerous drainage ditches enter the river (see Figure 2-2). Access to the river by the public is through a city park located in Plummer and at road crossings. Numerous agricultural ditches are present within this reach and commercial rice production occurs between miles 58.0 and 78.0.

The percent of river shading by the canopy ranges from light to moderate and the substrate consists of a mixture of sand, rubble, gravel and silt. The width of the river is approximately 50 feet with an average depth of 2.1 feet. The channel gradient is approximately 2 feet/mile with a sinuosity of 1.1. Water quality sampling sites within this reach include CR-9, CR-10, CR-11, CR-22 on the Clearwater River and the Ruffy Brook tributary site RB-8.

2.2.3 Reach 3 (River Mile 79.2 to 145.0)

The headwaters section starts at the channelized section near the confluence with Ruffy Brook and Red Lake Reservation and extends upstream to Bagley. The MnDNR classifies this reach a Class I Trout Waters. Areas of channelized stream reach occur at mile 96.8 below the Clearwater Lake dam, at mile 114.8 at Beltrami County Road 22 (Pinewood), mile 116.8 at the Beltrami County-Clearwater County line, at mile 124.5 at Clearwater County Road #2 south of Leonard, and from miles 143.4-145.0. This reach includes Clearwater Lake, an important recreational lake. Some development along the river has occurred at Bagley and considerable development is present along the shoreline of Clearwater Lake. Public access to the river may be gained through First, Second and Clearwater Lakes. A lake level stabilization dam at the outlet of Clearwater Lake presents a barrier to fish migration. Areas of bank erosion are not as prevalent as in lower stream reaches. Beaver dams are a serious problem in managing the trout fishery within this reach. Bank erosion is considered "light", springs are numerous, and there are fewer agricultural ditch outlets.

The percent of shading by the canopy ranges from light to heavy and the substrate consists of a mixture of sand, rubble, gravel and silt. The width of the river ranges from 24-52 feet and the average depth from 0.8-2.1 feet. The channel gradient is 3.9 feet/mile with a sinuosity of 2.8. Water quality sampling sites within this reach include CR-1, CR-2, CR-3, CR-4, CR-6, CR-7 on the Clearwater River and the Walker Brook tributary site WB-21.

2.3 Soils and Land Use

Soils and land use data were evaluated for each subwatershed within the Clearwater River watershed along streams and rivers classified by the MnDNR as "protected waters". These are generally second order or larger streams. Data were evaluated within differing lineal distances perpendicular to the river: within 100 meters[2] (m), 400 m, 800 m, 1600 m and 3200 m. These data are important for identifying critical areas, which exhibit the highest potential for nonpoint and point source pollution. For discussion purposes, the Clearwater River watershed was divided into the same three reaches previously defined by the MnDNR (see Section 2.2, Physical Characteristics of the Clearwater River).

2.3.1 Soils

A brief summary of the general soil properties which occur along the three stream reaches of the Clearwater River is presented in Table 2-1. Additional soil data and topographic slope data for each subwatershed, by distance from the river, are provided in Figures 2-3 and 2-7.

2.3.1.1 Soil Erodibility Factor

The soil erodibility factor, K-factor, indicates the susceptibility of a soil to erosion by water. The estimates are based primarily on the percentage of silt, sand, and organic matter and on soil structure and permeability. Values of K range from 0.05 to 0.69; the higher the value, the more susceptible the soil is to erosion.

Based on an index of erodibility, the soils within the Clearwater River watershed have a low to intermediate potential for soil erosion. On average, the K factors range from 0.07-0.30. In all subwatersheds, the highest potential for erosion occurs immediately adjacent to the river bank,

[2]Distances in this section are presented in meters. To convert to feet multiply by 3.28. One-quarter mile ≈ 400 m; one-half mile ≈ 800 m; one mile ≈ 1600 m; and two miles ≈ 3200 m.

Table 2-1. Typical Soil Properties Within the Clearwater River Watershed[1]

Soil Property	Reach 1	Reach 2	Reach 3
Soil Erodibility Index[2]	Low-Intermediate K = (.05-.30)	Low-Intermediate K = (.05-.30)	Low-Intermediate K = (.05-.30)
Slope Index[3]	1.0-1.5%	1.0-1.5%	2.0-12.5%
Soil Drainage Index[4]	Poorly to Very Poorly Drained	Very Poorly Drained	Moderately Well to Well Drained
Index of Organic Matter Content[5]	5.0%	5.0%	2.0%
Index of Soil Phosphorus Content[5]	5 lb/acre	5 lb/acre	2-4 lb/acre

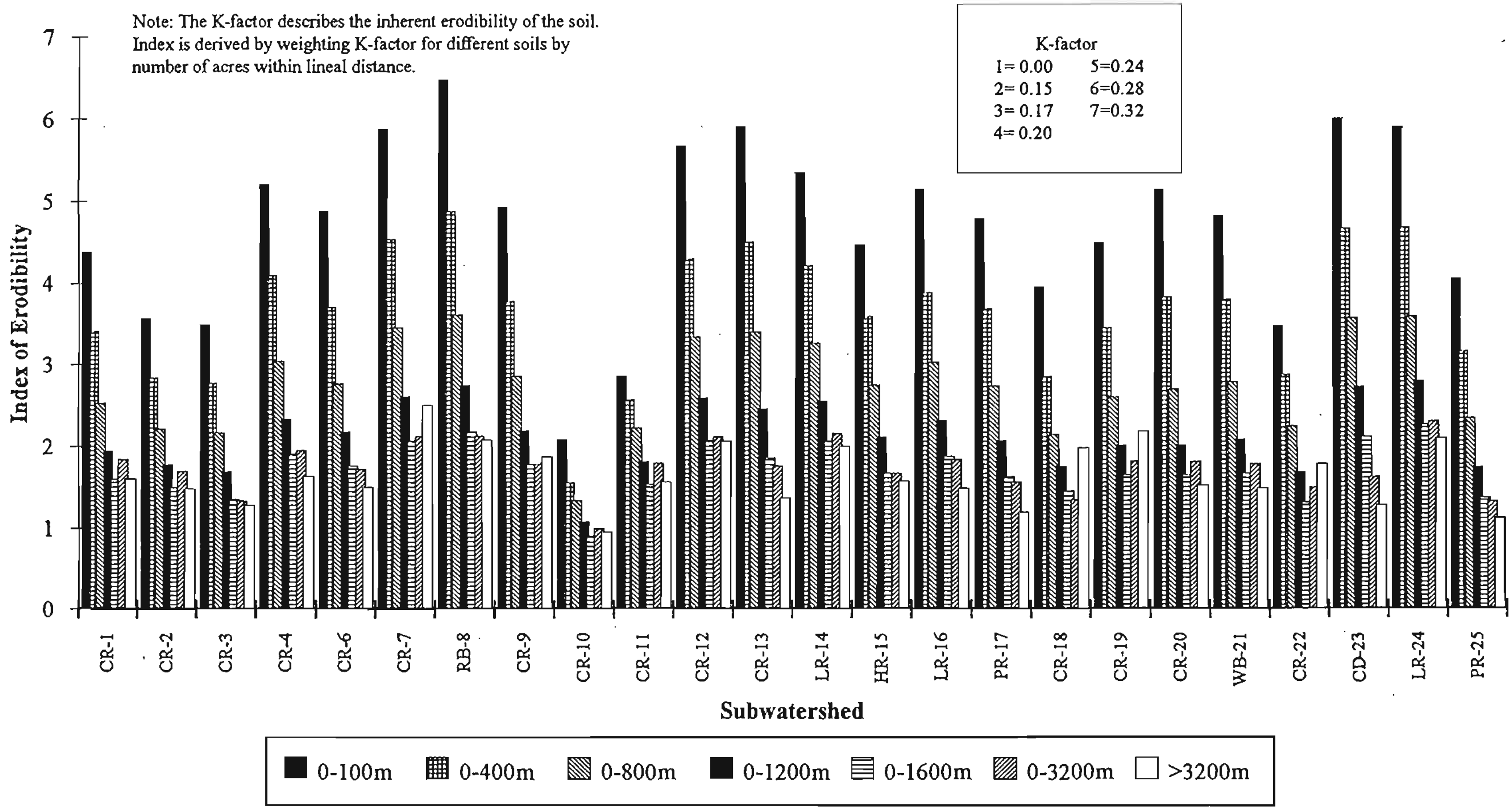
[1] Data based on GIS analysis for subwatersheds within each reach.

[2] Highest potential for erosion occurs immediately adjacent to river in all reaches.

[3] Steepest slopes are located immediately adjacent to river in all reaches.

[4] Poorest drained soils occur immediately adjacent to river in all reaches.

[5] Greatest organic matter and phosphorus content occurs immediately adjacent to river in all reaches.



Note: Analysis performed for MnDNR protected waters (2nd order streams and larger)

HDR

HDR Engineering, Inc.

Red Lake Watershed District
Dedicated to Water Management

Figure 2-3

Index of Soil Erodibility by Lineal Distance From River

within 100 m (Figure 2-3). There is a sharp decrease in erodibility with increasing distance from the river bank. At approximately 1600 m soil erodibility decreases and remains low throughout the subwatershed regions.

2.3.1.2 Soil Drainage

The soils in Reach 3 are loamy, sandy glacial outwash areas which occur under forest vegetation. Soils are moderately well to well drained within 100 m (Figure 2-4), because of greater slope. Soil permeability decreases with increasing distance from the river as slope decreases. Poorly drained soils occur within 1600 m and extend throughout the subwatersheds.

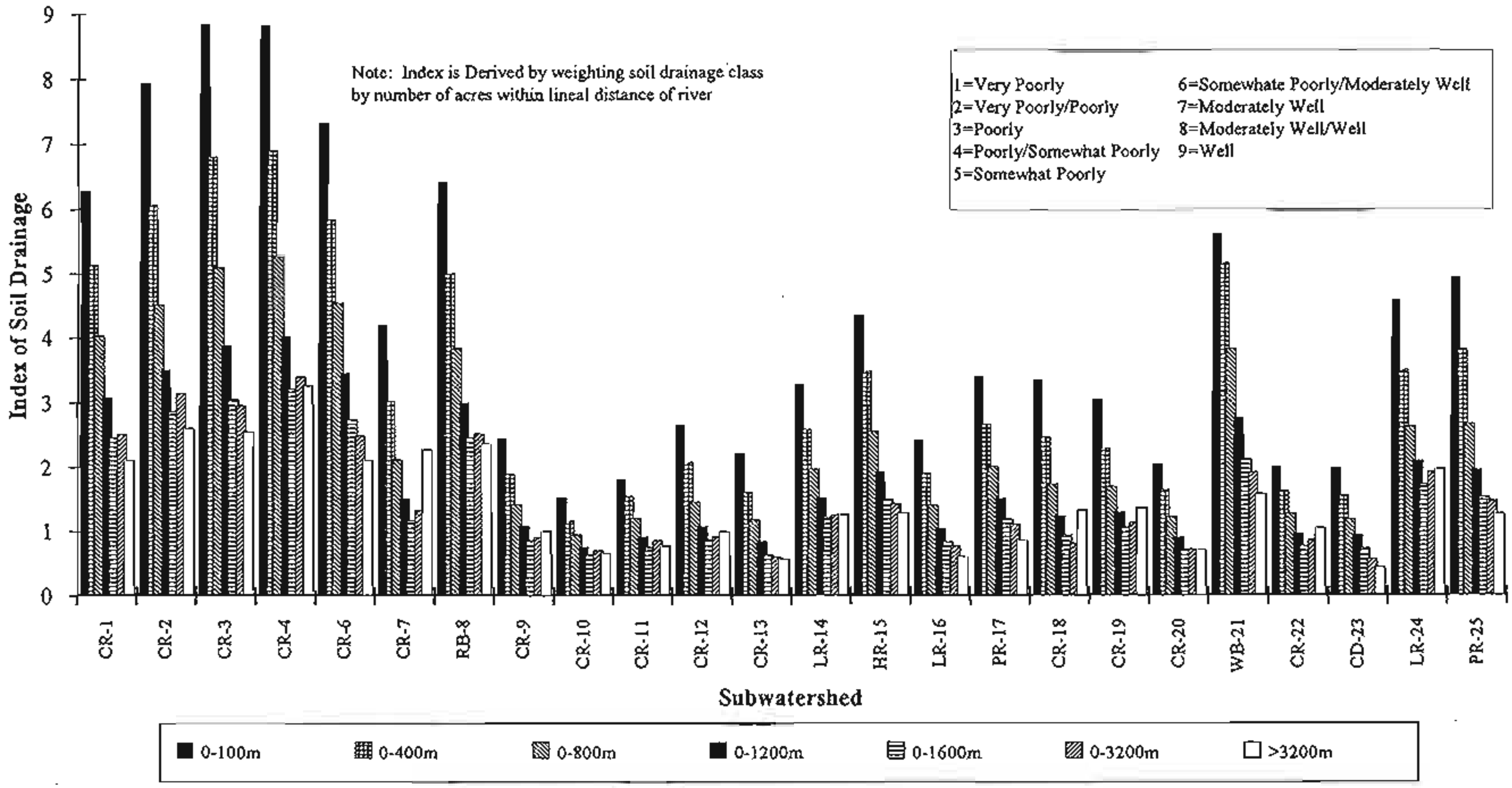
Reach 2 has the poorest drained soils. Very poorly drained sand loam soils are found throughout the subwatershed within this reach. Soil drainage increases slightly within subwatersheds to Reach 1. Poorly to very poorly/poorly drainage classifications are found within 100 m. With increasing distance from the river, soil permeability decreases to very poorly drained. In general, very poorly drained soils are encountered at 1200 m and extend throughout the subwatershed regions.

2.3.1.3 Organic Content

There is a sharp transition in soil organic matter content between the forested and agricultural regions of the watershed (Figure 2-5 and Table 2-1). The lowest soil organic matter content occurs within the forested region of Reach 3. A significantly higher soil organic matter content is found within Reach 2 and Reach 1. In general, the highest organic matter content is found within 1200 m.

2.3.1.4 Soil Phosphorus

Soil phosphorus levels are fairly consistent throughout the subwatersheds, and between reaches (Table 2-1). However, root zone phosphorus content declines considerably, by a factor of 3, moving away from the river (Figure 2-6).



Note: Analysis performed for MnDNR protected waters (2nd order streams and larger)

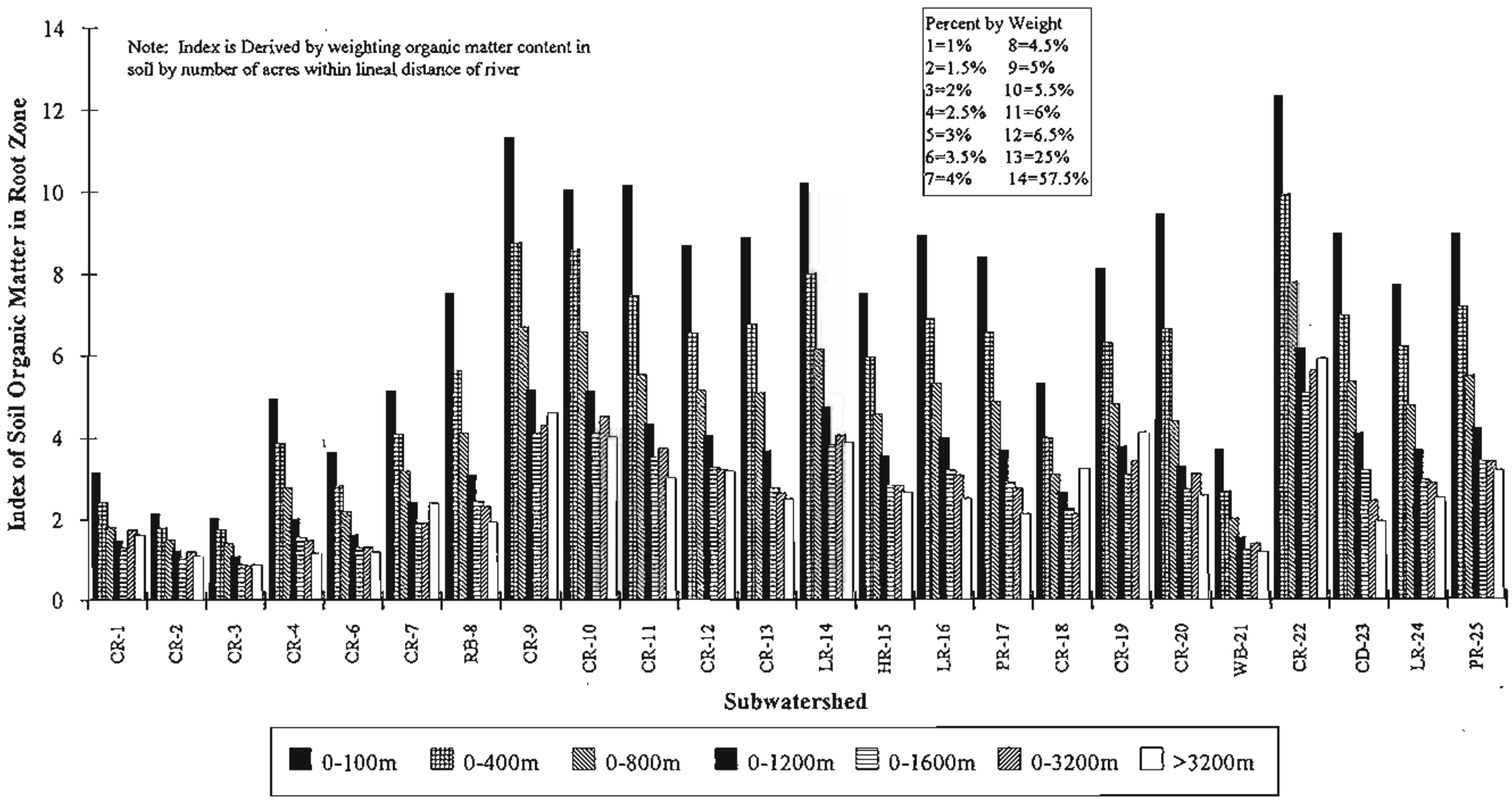
HDR

HDR Engineering, Inc.

Red Lake Watershed District — Dedicated to Water Management

Figure 2-4

Index of Soil Drainage by Lineal Distance From River



Note: Analysis performed for MnDNR protected waters (2nd order streams and larger)

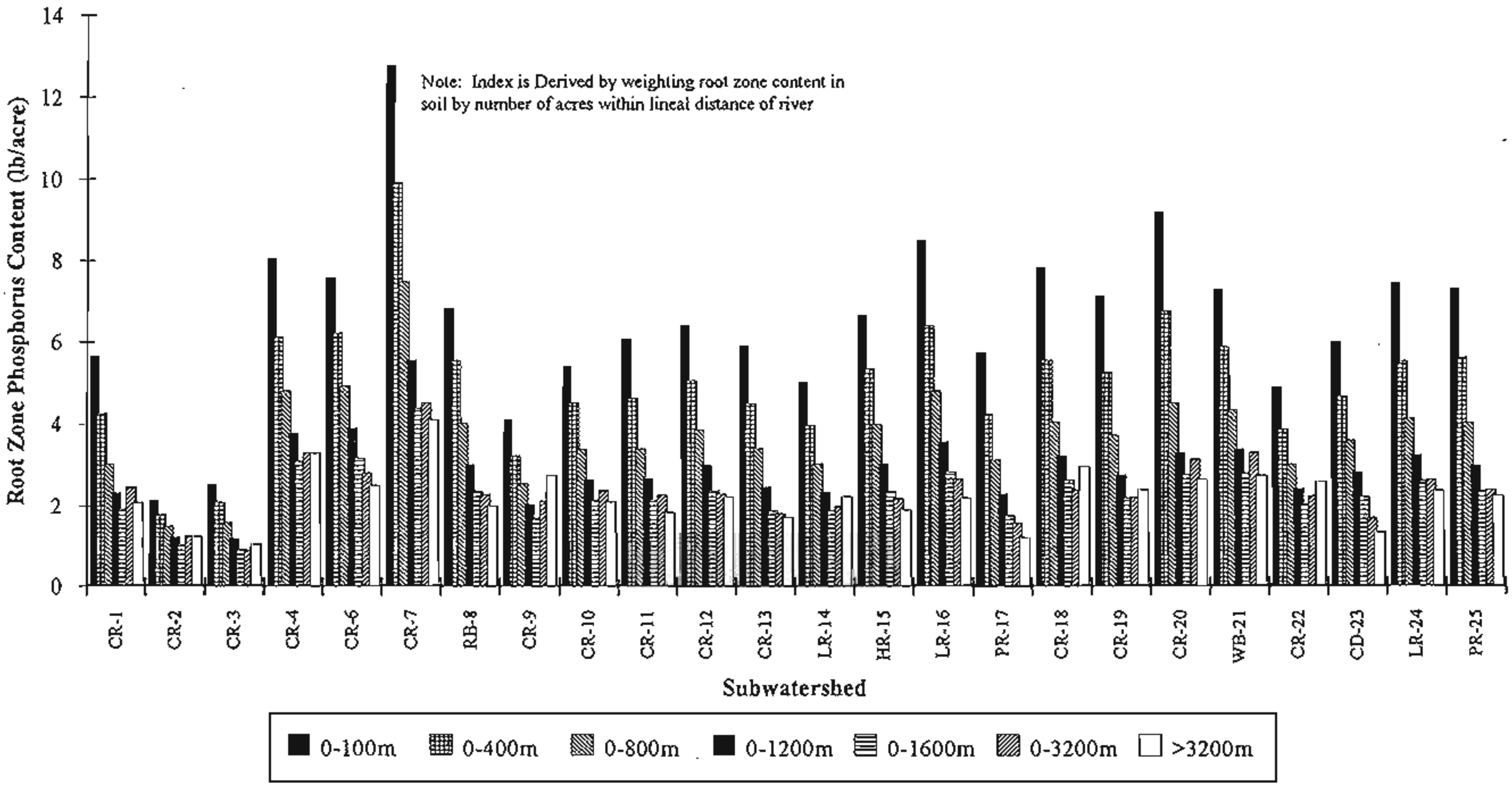
HDR

HDR Engineering, Inc.

Red Lake Watershed Dedicated to Water Management

Figure 2-5

Index of Soil Organic Matter Content by Lineal Distance From River



Note: Analysis performed for MnDNR protected waters (2nd order streams and larger)

HDR Engineering, Inc.

Red Lake Watershed District — Dedicated to Water Management

Figure 2-6

Index of Soil Phosphorus Content within Root Zone by Lineal Distance From River

2.3.1.5 Slope Index

The most important influence on soil erosion is topography (slope) and its effect on the movement of surface water. Within the Clearwater River watershed the steepest slopes are found within the headwaters section of Reach 3. On average, slopes range from 2.0-12.5%. A high potential for erosion exists since the steepest slopes are located immediately adjacent to the river bank within 100 m (Figure 2-7). In general, slopes decline sharply with increasing distance from the river. Slopes of less than 1% occur at 1600 m.

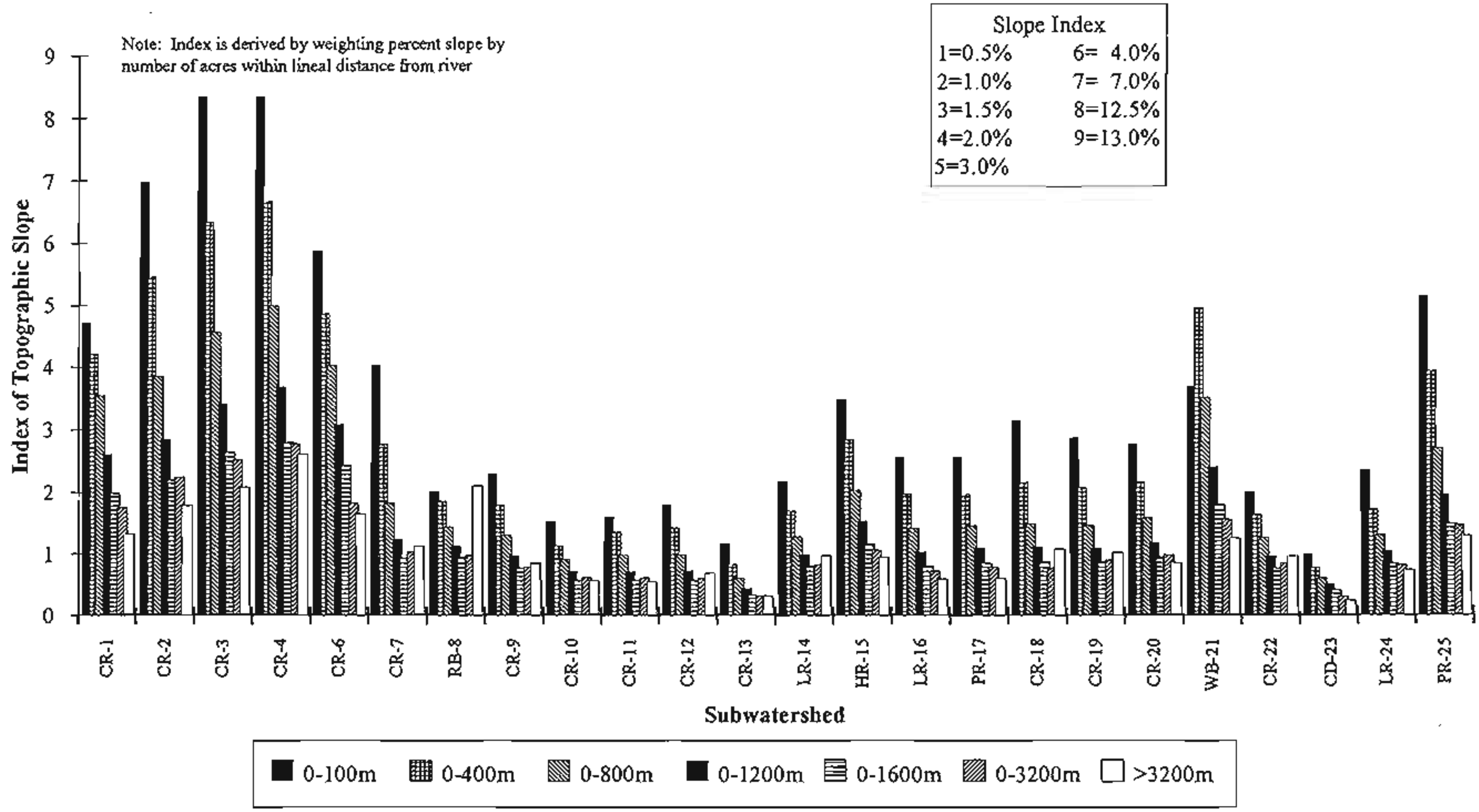
A change in topography occurs between Reach 2 and Reach 3. Within Reach 1 and Reach 2 nearly level topography is present. The steepest slopes range from 1.0-1.5% within 100 m. Slopes decrease to less than 0.5% after 1600 m and remains low after this distance.

2.3.2 Land Use

Based on land use data provided by the Clearwater Soil and Water Conservation District twelve and then four land use categories, were developed. These categories were used to identify land use areas which have the potential for high surface water runoff and to identify natural vegetative buffers.

The land use categories were determined based on cover and management factors ("C" factor; see Section 3.6, "River Land Use and Regression Analysis: for description). The C-factor indicates the influence of cropping systems, management practices and cover types on soil loss. Forest and grass land provide the best natural protection against surface runoff. Forage crops are next in protective ability due to their dense cover. Small grains are intermediate and offer some protection to surface erosion. Row crops offer relatively little cover. Most subject to erosion are fallowed areas where no crop is grown.

A description of the land use categories and related C-factors are outlined in Table 2-2 and a summary of land use presented in Table 2-3. Additional land use characterization data for each subwatershed are presented in Figures 2-8 and 2-9. (See Appendix A for additional land use data.)



Note: Analysis performed for MnDNR protected waters (2nd order streams and larger)

HDR

HDR Engineering, Inc.

Red Lake Watershed District — Dedicated to Water Management

Figure 2-7

Index of Topographic Slope by Lineal Distance From River

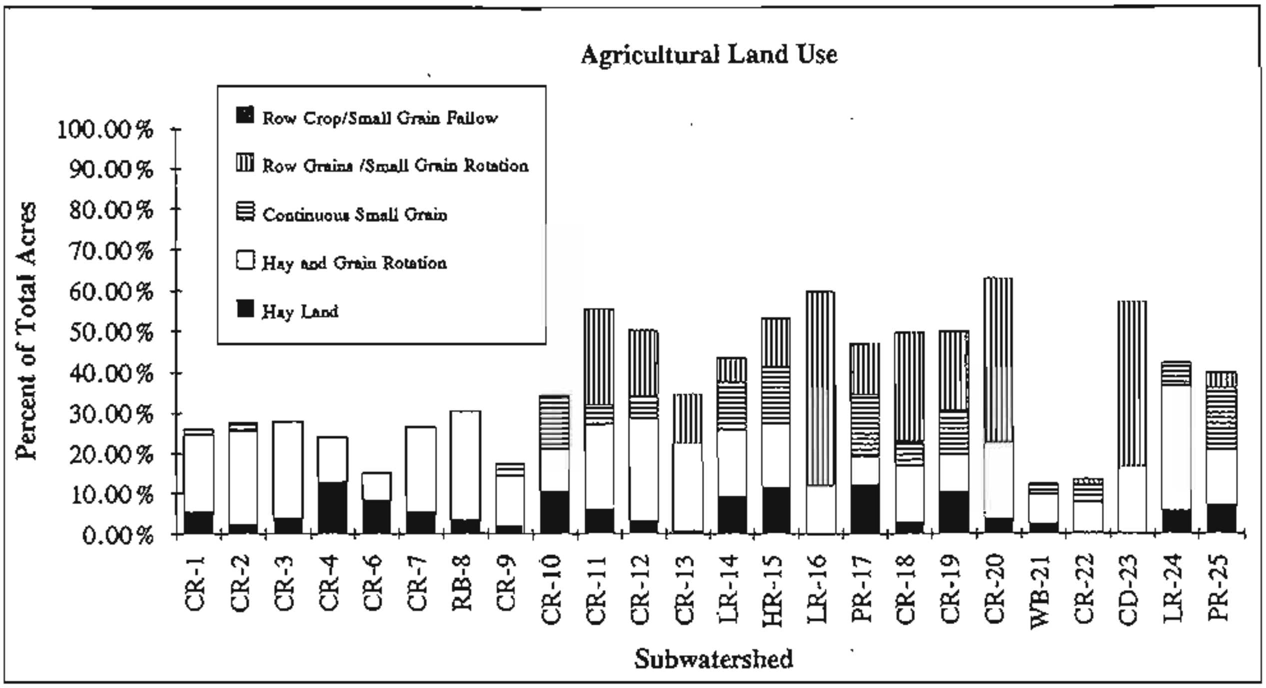
Table 2-2. Land Use Categories and C-Factors

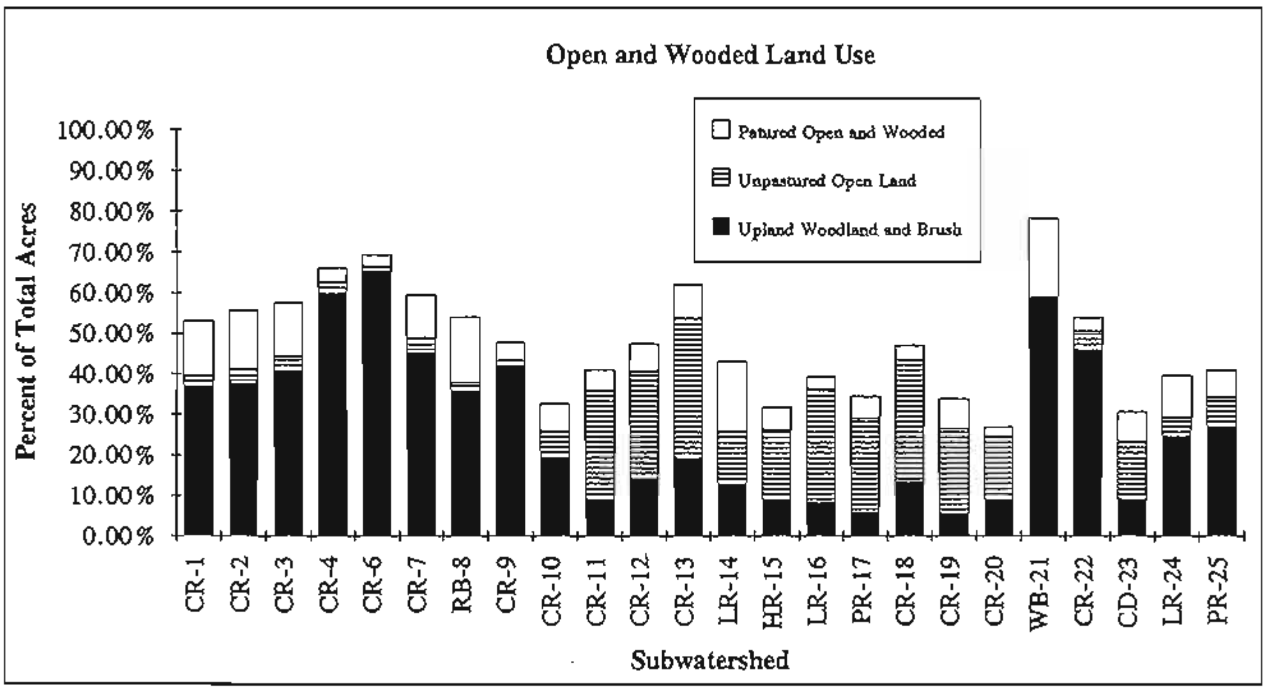
Land Use	C-Factor
Agriculture	
Row crop/Small Grain Fallow	.430-.560
Row Grains/Small Grain Rotation	.310-.375
Continuous Small Grain	.190
Hay and Grain Rotation	.091-.211
Hay Land	.032
Open and Wooded	
Pastured Open and Wooded	.112-.120
Unpastured Open Land	.003
Upland Woodland and Brush	.001-.041
Water Resources	
Open Water	0
Vegetated Wetland	.003
Commercial and Residential	
Commercial, Rural, Residential and Extractive	.010-.10
*Wild Rice and Wild Rice Rotation	.095-.248

Table 2-3. Land Use Percentages for Subwatersheds by Clearwater River Stream Reach

Reach	Agricultural	Open/Wooded	Water Resources	Urban and Commercial
1 (Mouth)	35-60%	25-60%	<5-20%	5-10%
2	10-55%	30-50%	5-20%	10% *(Ricing)
3 (Headwaters)	10-25%	50-70%	10-20%	5%

*Wild Rice and Wild Rice Rotation that appear in these tables, the following graphs and the corresponding graphs in Appendix A are grouped with the urban and commercial land use category. This more accurately would be grouped with agriculture.





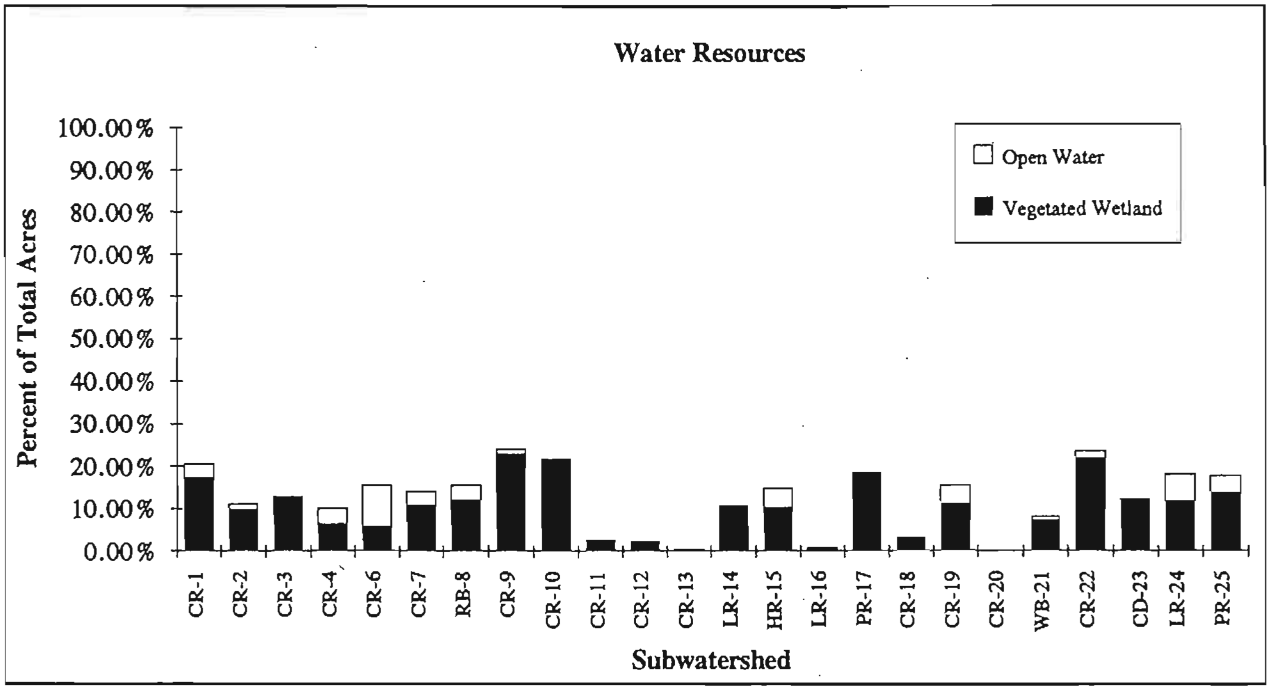
Note: Analysis performed for MnDNR protected waters (2nd order streams and larger)

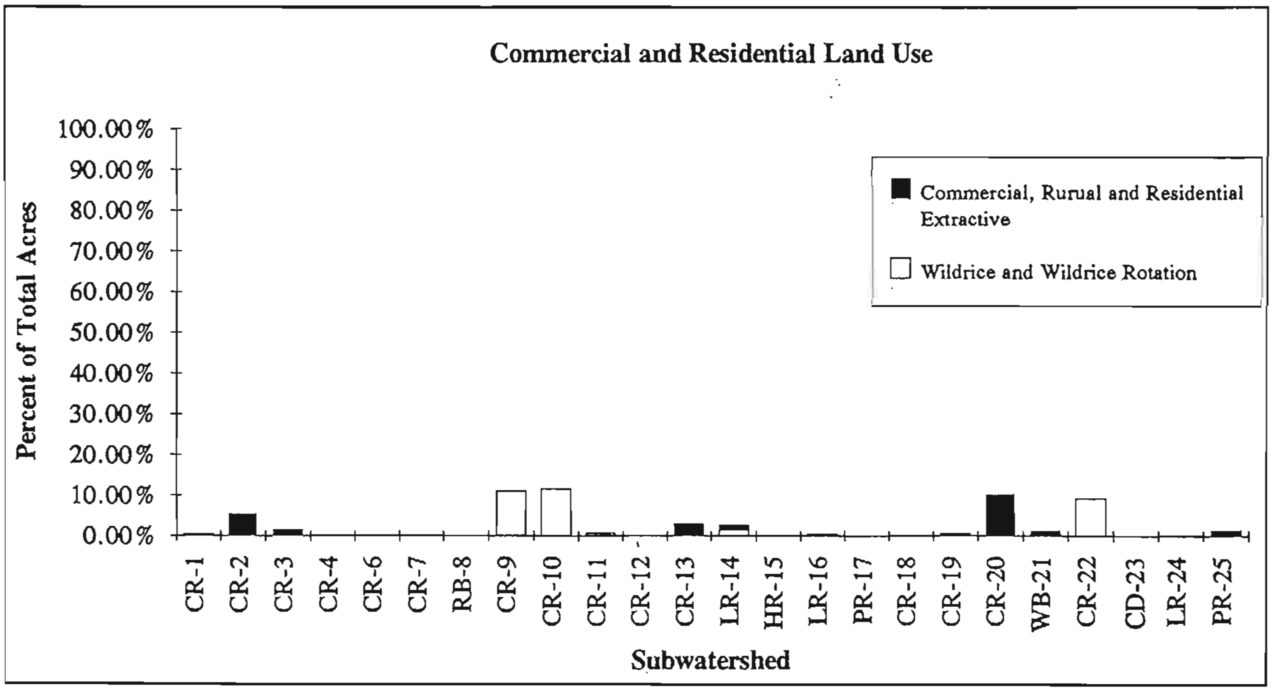
HDR Engineering, Inc.

Red Lake Watershed District
Dedicated to Water Management

Figure 2-8

Agricultural, Open and Wooded Land uses within Subwatersheds to Monitoring Sites





Note: Analysis performed for MnDNR protected waters (2nd order streams and larger)

HDR Engineering, Inc.

Figure 2-9

Water Resource, Commercial and Residential Land Uses within Subwatersheds to Monitoring Sites

2.3.2.1 Agricultural Land Use

Within the headwaters section, approximately 10-25% of the land use within subwatersheds is related to agriculture. The predominant farming practices are hay/small grain rotation and hay land. Approximately 50% of the land use is agricultural within 100 m of the river. The number of feedlots within the subwatersheds of Reach 3 range from 13-65. Typically, over 75% of the of feedlots occur within 3200 m of the river.

A transition from low to high agricultural land use occurs between Reach 3 and Reach 2. Agricultural accounts for 10-55% of the land use of subwatersheds within Reach 2. On a subwatershed basis, the dominant agricultural land use is hay and grain rotation and small grain production. Upstream areas of Reach 2 are mainly comprised of hay and grain rotation and hay land. More intensive grain production occurs near the downstream section of Reach 2 within 100 m of the river. Within 100 m of subwatersheds 10, 11 and 22, row cropping and grain fallow comprise approximately 5% of the land use. The number of feedlots per subwatersheds within Reach 2 range from 12-51. Over 50% of the feedlots occur within 3200 m of the river.

Land use within Reach 1 is primarily related to agriculture. Between 35-60% of the land use within subwatersheds within this reach are in crop or hay production. Hay and grain rotation and row grains/small grain rotation are the main farming practices. Continuous small grain is also common in tributary regions. Less intensive agriculture is typically found within 100 m; hay and grain rotation and hay land account for 50% of the land use. However, fallowed areas are 10-20% of the land use within 100 m, at select locations. In general, continuous small grain and row grain/small grain rotation practices increase from 400-1600 m, accounting for over 50% of the land use. The total number of feedlots within subwatersheds of Reach 1 range from 0-119. Typically, over 50% of the feedlots are located within 3200 m.

2.3.2.2 Open and Wooded Land Use

Between 50% and 70% of the total land use within subwatersheds of Reach 3 is open and wooded vegetation (Figure 2-8). Upland woodland and brush comprise over 80% of the vegetation type located within 1600 m along the river corridor. Unpastured and pastured open land comprise about 20% of the land use.

Reach 2 is a transition zone between upland woodland and brush and unpastured open land. Open and wooded land use comprises approximately 30%-50% of the total land use within the subwatersheds of Reach 2. At the upstream section of Reach 2 the dominant vegetation type is classified as upland woodland and brush. Downstream near Reach 1, the land use changes to unpastured open land.

Within Reach 1, open and wooded land use accounts for 25-60% of the land use within subwatersheds. Unpastured open land is the primary land use within the subwatershed regions. Upland woodland and brush is the dominant land use within 100 m. There is a sharp transition from upland brush to unpastured open land after 400 m.

2.3.2.3 Water Resources

Within Reach 3, vegetated wetlands comprise between 10-20% of the total land use within subwatersheds (Figure 2-9). The largest percentage of wetlands occur within 100 m and decline with increasing distance from the river. Open water systems generally account for less than 5% of subwatershed land use.

Water resources comprise 5-20% of the subwatershed land use within Reach 2. Vegetated wetlands are the dominant water systems. These wetlands are typically found within 100 m of the river.

Within Reach 3, water resources account for <5-20% of the subwatershed land use. The primary water systems are vegetated wetlands. In general, these wetland systems are located within close proximity to the Clearwater River.

2.3.2.4 Commercial and Residential Land Use

The only urbanized land use within Reach 3 is near Bagley. Approximately 5% of the total land use is related to commercial and residential development (Figure 2-9). The primary development is located within 100 m of the river. No major urbanized areas occur within Reach 2. The predominant commercial land use is wild rice production. Wild rice production accounts for approximately 10% of the total land use within this region. Most of the wild rice production occurs within the 1600 m of the river.

Red Lake Falls is the largest urban area within Reach 1, accounting for 10% of the total land use. Plummer, Oklee and McIntosh are also located within this reach, but account for less than

5% of the total land use. The primary development is located within the immediate vicinity of the river.

2.4 Point Sources

Seven point source discharges, are present with the study area (see Table 2-4). These point sources are primarily lagoon systems associated with municipalities. The city of Bagley discharges to the Clearwater River, while Clearbrook discharges to Ruffy Brook. Fosston and McIntosh discharge to the Poplar River. Gonvick and Oklee discharge to the Lost River. One industrial discharge, Solheim Oil Company, discharges to Cameron Lake. Bagley, Fosston and Solheim Oil Company discharge the largest quantity of oxygen demanding material.

2.5 Biological Description - Concept of Ecosystem Integrity

Karr et al., (1986) grouped the environmental factors that most affect aquatic ecosystems into five major classes (Figure 2-10). Changes to the physical, chemical, or biological processes associated with these classes may affect aquatic biota and the integrity of the ecosystem. Efforts to manage water resources that focus on only one or two of these major classes, or only a few factors within a class, will fail if other factors are wholly or partially responsible (Karr et al., 1986). Efforts to maintain and improve the quality of surface water resources in general must be guided by methods that identify perturbations associated with the factors. Broad-based approaches to water resource management are not only more likely to provide solutions with real results, but are more likely to prove cost-effective. Out of necessity, this report concentrates largely on the chemical variables affecting the integrity of the stream. Other factors are identified to the extent possible.

Table 2-4

Point Source Discharges Within the Clearwater River Basin
During the Clearwater Nonpoint Source Study

Point Source (Recieving Water)	Discharge Volume (gal*10^6)	Dissolved Oxygen (kg)	Total Solids (kg)	Chlorine (kg)	Carbon. Oxygen Demand (kg)	Ammonia (kg)
Bagley (Clearwater River)						
Apr-92	37.8	114.58	7153.65		3801.45	
May-92	43.5	1317.18	3660.11		1592.14	
Sep-92	23.1	393.45	218.58		131.15	
Oct-92	47.1	1069.64	1069.64		534.82	
Nov-92	21.9	870.36	953.25		414.46	
Apr-93	23.1	612.03	3206.19		1923.54	
Clearbrook (Silver Creek)						
May-92	30	692.65	794.85		170.32	
Jun-92	30	1056.01	454.2		170.32	
Sep-92	30	692.65	420.13		306.58	
Oct-92	30	862.98	454.2		454.2	
Nov-92	22.8	992.43	172.6		172.6	
Fosston (Poplar River)						
Jun-92	107.52	203.48	12005.41		4476.6	
Oct-92	95.7	2535.57	2897.8		905.56	
Nov-92	97.74	2589.62	739.89		554.92	
Gonvick (Lost River)						
Apr-92	3.42	80.33	38.87	40.82	12.96	
May-92	3.47	78.69	32.79	40.82	13.12	0.13
Jun-92	2.4	70.86	36.34	40.82	13.63	0.14
Jul-92	2.4	65.4	22.71	40.82	9.08	
Aug-92	2.55		48.26	40.82	19.3	
Sep-92	28.32	771.78	428.76	40.82	160.79	
Oct-92	2.16	58.86	36.79	40.82	32.7	
Nov-92	1.92	50.87	43.6		7.27	
Dec-92	2.1	60.41	63.59		23.85	
Jan-93	2	53.02	30.3		18.93	
Feb-93	1.91	46.29	47.02		14.47	
Mar-93	2.3	60.89	60.89	27.21	17.4	
Apr-93	2.47	59.81	88.78	27.21		1.68

Table 2-4 - Continued

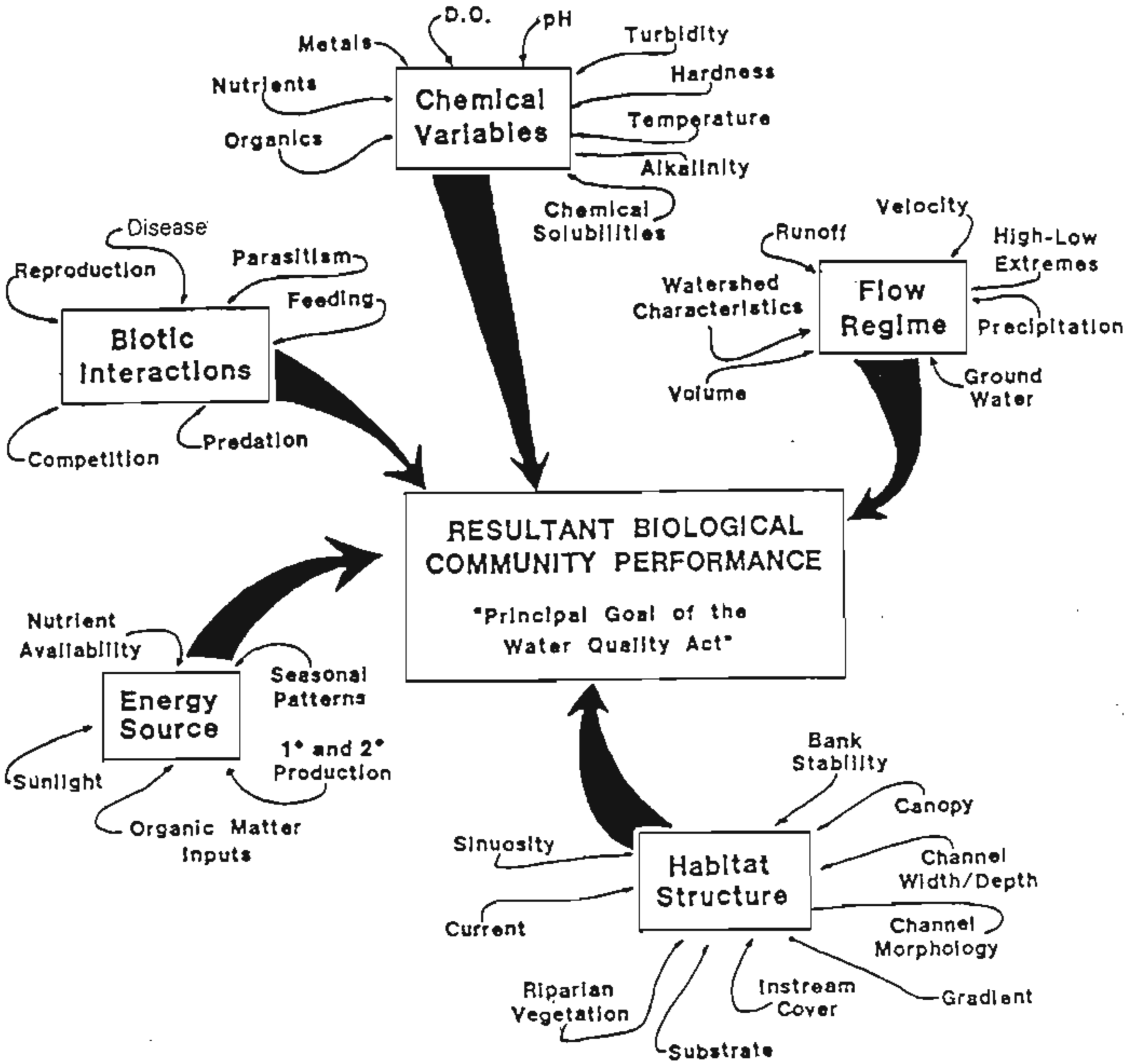
Point Source Discharges Within the Clearwater River Basin During the Clearwater Nonpoint Source Study

Point Source (Recieving Water)	Discharge Volume (gal*10^6)	Dissolved Oxygen (kg)	Total Solids (kg)	Chlorine (kg)	Carbon. Oxygen Demand (kg)	Ammonia (kg)
McIntosh (Poplar River)						
May-92	13.05	330.94	98.79		49.39	
Sep-92	13.05	326	296.37		98.79	
Oct-92	13.05	330.94	172.88		98.79	
Nov-92	1.29	32.23	17.09		9.77	
Oklee (Lost River)						
Oct-92	15.18	804.39	287.28		258.55	

Point Source (Recieving Water)	Discharge Volume (gal*10^6)	Total Organic Carbon (kg)	Toluene (kg)	Benzene (kg)	Hydrocarbons (kg)	Xylene (kg)
Solheim Oil Co. (Cameron Lake)						
Jun-92	1.3	108.07	0.04	0.05	7.67	0.06
Sep-92	1.23	116.67	1.45	1.31	449.42	1.4
Dec-92	1.32	0.19		0.17	382.33	0.19

Note 1: No discharges reported for Plummer. Erskine discharges are land applied. Data based on Minnesota Pollution Control Agency Effluent Discharge Mass Loading Report. No discharge reported for those months not included.

Note 2: Bagley plant has experienced a chronic problem of overtopping its' lagoons as a result of hydraulic overloading. Observed overflow dates during the study included: 7/1/92, 7/8/92, and 5/3/93 (refer to letter in Appendix D).



Source: Karr et al 1986.

HDR Engineering Inc.

Red Lake Watershed District
Dedicated to Water Management

Figure 2-10

Major Classes of Environmental Factors Affecting Aquatic Ecosystems

3.0 METHODS

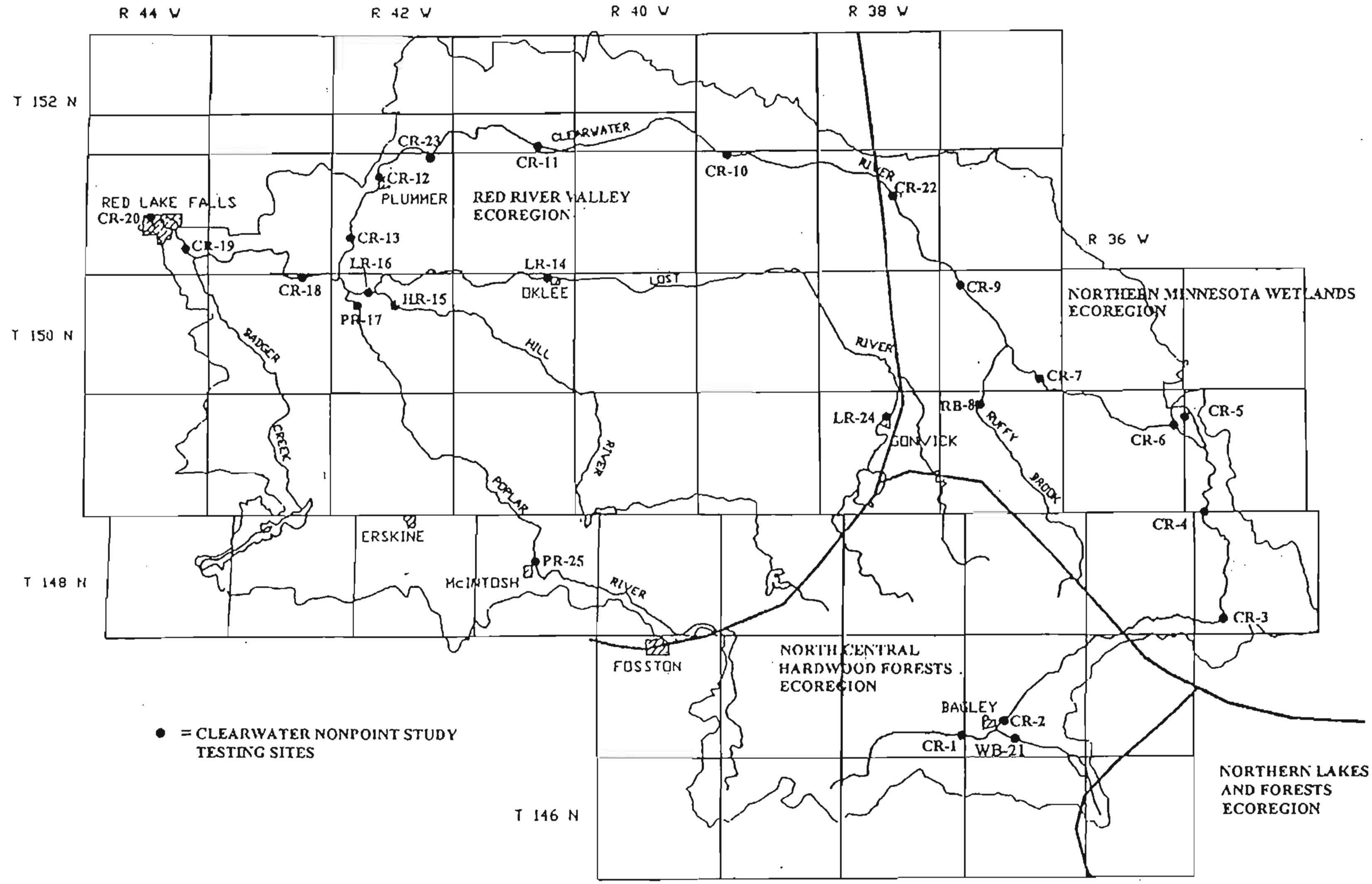
3.1 Sample Collection and Handling

The purposes of the water quality monitoring were to: 1) analyze longitudinal trends in water quality within the Clearwater River; 2) evaluate use attainability; 3) identify areas of concern within the river; and 4) use the data to calibrate a mathematical water quality model used to evaluate the effectiveness of various management strategies.

Monitoring performed during this study followed the guidance presented in "Water Quality Monitoring for the Clean Water Partnership" (MPCA 1989). Only a summary of the methods is provided here. Detailed methods are described in "Red Lake Watershed District Clearwater Nonpoint Study Monitoring Plan" (RLWD 1992a) which includes Standard Operating Procedures (SOPs).

Samples were generally collected in a systematic manner during the study. The collection of samples required one day to complete. Figure 3-1 shows the monitoring locations within the study area. These locations represent changing land use, physical characteristics of the river, or tributary inflow. Table 3-1 presents a written description of each location and the approximate sampling time. Water quality samples were first collected at CR-12. The remaining samples were collected following the most expedient route and schedule to meet with the other agency representatives assisting in sample collection. Sampling generally ended at CR-20. Samples from CR-1, CR-2, CR-3, CR-4, CR-5 and WB-21 were collected by the Beltrami and Clearwater SWCDs. Samples from CR-22 were collected by the Red Lake DNR and analyzed by ERA Lab of Duluth. A representative from RLWD collected samples from the remaining sites.

Consistent sample handling occurred regardless of the collecting agency. Agencies collecting samples met on April 1, 1992, to discuss and standardize sample collection methods. Samples from the river were collected at mid-depth in the center of the channel. Individuals collecting the samples faced upstream during sample collection, minimizing potential contamination or collected samples from structures (e.g., bridges). Samples were then placed in labeled sterile bags and placed on ice for transport. Samples remained iced until delivery to the laboratory at UMC. All further sample preparation including preservation occurred at UMC. Samples were refrigerated until preparation for analysis. A sample collection data form accompanied each sample to UMC. The sample collection data form included information about weather conditions



HDR Engineering Inc.

Red Lake Watershed District
Dedicated to Water Management

Figure 3-1

Monitoring Locations for the Clearwater River Nonpoint Study

Table 3-1. Description of Clearwater River Nonpoint Study Monitoring Locations

Monitoring Location (River Mile)	River/ Tributary	Depth Measurement Method	Description (Reason for Selection)	Approximate Time of Sampling	Drainage Area[1] (mi^2)
CR-1 (134.7)	Clearwater River	SG	Sec. 36, Popple Twp., CSAH #25 (upstream of Bagley, previous water quality site).	10:35	35.46
CR-2 (132.4)	Clearwater River	SG	Bagley, Hwy. 2 (downstream of Bagley; downstream of Sewage Treatment Ponds, previous water quality site).	11:00	18.05
CR-3 (112.8)	Clearwater River	SG	Sec. 32, Buzzle Twp. (trout reach; some logging; change in flow velocity).	11:20	46.73
CR-4 (103.4)	Clearwater River	SG	Roosevelt-Buzzle Twp., CSAH #24 (closest access upstream of Clearwater Lake, trout reach, some logging, previous water quality site).	11:45	25.28
CR-5	Clearwater Lake	SG	Clearwater Lake (lake reach).	12:45	—
CR-6 (95.9)	Clearwater Lake	SG/CR	Outlet (developed gage site; used in previous studies; good access; previous water quality site).	12:00	15.13
CR-7 (81.2)	Clearwater River	SG	Sec. 35, Greenwood Twp., CSAH #11 (developed gage site [USGS]; upstream of Ruffy Brook; upstream of rice paddies; upstream of dredged areas).	11:25	42.52
RB-8 (3.4)	Ruffy Brook	SG/CR	Ruffy Brook (developed gage site [USGS]; near mouth of Ruffy Brook; previous water quality site).	11:45	45.03
CR-9 (74.5)	Clearwater River	SG	Clearbrook Road, Sec. 8, Greenwood Twp., CSAH #5 (good gaging site; good access; past water quality site, downstream of Butcher-Knife Creek and Ruffy Brook; near upstream end of dredged areas, previous water quality site).	10:30	60.37
CR-10 (58.4)	Clearwater River	SG	Trail Road, Sec. 32, Hickory Twp., (developed gage site [RLWD]; good access; downstream end of rice areas, previous water quality site).	9:50	113.83
CR-11 (47.9)	Clearwater River	SG	Clearwater River, 1 mile west of Oklee Rd., Sec. 34, 35, N. Garness Twp. (good access; small grains area; near downstream end of dredged area).	9:15	46.85

Table 3-1. Description of Clearwater River Nonpoint Study Monitoring Locations - Continued

Monitoring Location (River Mile)	River/ Tributary	Depth Measurement Method	Description (Reason for Selection)	Approximate Time of Sampling	Drainage Area[1] (mi^2)
CR-12 (31.8)	Clearwater River	CR	Plummer Gage, Sec. 4, Emardville Twp. (developed gage site [USGS continuous]; past water quality site; upstream of Plummer; downstream of dredged portion).	8:30	58.55
CR-13 (24.9)	Clearwater River	CR	Above Lost River, Sec. 20, 29 Emardville Twp. (only road between Plummer and Terrebonne; downstream of Plummer; upstream of Lost, Hill, and Poplar rivers).	8:50	9.29
LR-14 (24.0)	Lost River	SG	Oklee Gage, Sec. 1, Lambert Twp. (developed gage site [USGS continuous]; major tributary of Clearwater River; upstream of Hill River; within dredged area; previous water quality site).	2:35	214.57
HR-15 (3.5)	Hill River	SG/CR	Brooks, Sec. 11, Poplar River Twp. (west of Brooks; USGS low flow rate at Hwy. 59; major tributary of Lost River).	3:00	154.0
LR-16 (4.2)	Lost River	SG	Below Hill River, Sec. 4, 9 Poplar River Twp. (good access; downstream of Hill River; upstream of Poplar River).	3:45	55.8
PR-17 (2.2)	Poplar River	SG/CR	Sec. 8, 17 Poplar River Twp., Hwy. 92 (good access; major tributary of Lost River; small grains and potatoes).	4:00	30.88
CR-18 (17.3)	Clearwater River	SG	Terrebonne Bridge, Sec. 2 Terrebonne Twp. (good access; downstream of Lost River; previous water quality site).	4:10	45.31
CR-19 (5.3)	Clearwater River	SG	Near Red Lake Falls, Sec. 26, Red Lake Falls Twp. (fair access; upstream of Red Lake Falls; downstream of Badger Creek).	5:10	191.14
CR-20 (0.2)	Clearwater River	CR	Near Red Lake Falls gage, Klondike Bridge, Sec. 22, Red Lake Falls Twp. (developed gage site [USGS continuous]; past water quality site; good access).	5:00	4.26
WB-21 (0.46)	Walker Brook	SG	Upstream of Bagley (tributary to Clearwater River; upstream of Bagley Treatment Ponds).	9:20	15.0
CR-22 (70.6)	Clearwater River	SG	In Sec. 36, Hangaard Twp. (downstream of Ke Wo Sa; middle of rice area).	12:00	258.54

Table 3-1. Description of Clearwater River Nonpoint Study Monitoring Locations - Continued

Monitoring Location (River Mile)	River/ Tributary	Depth Measurement Method	Description (Reason for Selection)	Approximate Time of Sampling	Drainage Area[1] (mi^2)
CD-23 (0.1)	Clearwater River	SG	Ditch System, Sec. 1, Emardville Twp. (County Ditch 57; large ag ditch in small grains area).	9:10	10.63
LR-24 (49.3)	Lost River	SG	Hwy. 92 at Gonvick (developed gage site; upstream of Oklee; downstream of Pine Lake).	12:00	51.43
PR-25 (28.7)	Poplar River	SG	North of McIntosh (downstream of Fosston and McIntosh Treatment Ponds; upstream of Poplar River Diversion; previous water quality site).	2:15	71.72

CR = Continuous recorder
SG = Staff gage

Note: Each site was video taped at the onset of the project and during the last sampling run to show the physical characteristics of the river at each site. This tape is available from RLWD.

[1] Drainage area is additional contributing area from upstream monitoring location.

at the time of collection, time of sample collection, problems encountered during collection and field measurements. Field measurements included surface water temperature, specific conductance, pH and dissolved oxygen. With the exception of dissolved oxygen, these measurements were performed using electronic meters. Dissolved oxygen concentrations were determined in the field using the Winkler titration method. Table 3-2 shows the water quality parameters measured, approximate sampling frequency and number of storm events. Dates of actual sample collection in relation to storm events and flow at Red Lake Falls are shown in Figure 3-2.

Sampling during the study focused on both baseflow and storm runoff. One goal was to sample three to six storm events, during the study. Because of the size of the Clearwater River watershed, sampling after a storm event could potentially yield storm runoff or base flow, depending on sampling location. To minimize this problem storm event criteria were established. Based on precipitation-duration-frequency curves and county soils atlases it was determined that rainfall exceeding 1 inch in 24 hours or 3 inches in ten days would be defined as a storm event. In addition to the existing rain gage network in and around the Clearwater River basin, extra gages were added for the study. Following a rainfall occurrence, precipitation amounts were collected from the gage network and these data mapped to determine amounts and areal coverage. Given these data and the criteria defined above it was then determined if a sample run should be made and what areas within the watershed should be sampled.

Figure 3-2 shows the dates of sample collection in relation to rainfall at Red Lake Falls. The May 16th storm generated 0.3-0.6 inches of rainfall over the basin and no samples were taken. The storm on June 15-17th similarly did not meet the established storm event criteria. However, this storm event happened to coincide with the routine sampling date on June 18th. The event on July 1st was considered a major storm event resulting in heavy rainfall on the upper Clearwater River. Only the upper portion of the Clearwater basin was sampled as a result of this event. On August 17th, because precipitation was centered over the middle and lower portions of the Clearwater River basin, only this area was sampled. A major storm event which occurred August 21-24th resulted in 3 to 6 inches of precipitation over the entire watershed and all locations were sampled. The September 4-7th event failed to meet the storm event criteria, but did coincide with a planned routine sampling.

Sampling within Clearwater Lake differed slightly from the described protocol. Samples were collected at the deepest location within the lake using a integrated water sampler. Sample handling was as previously described.

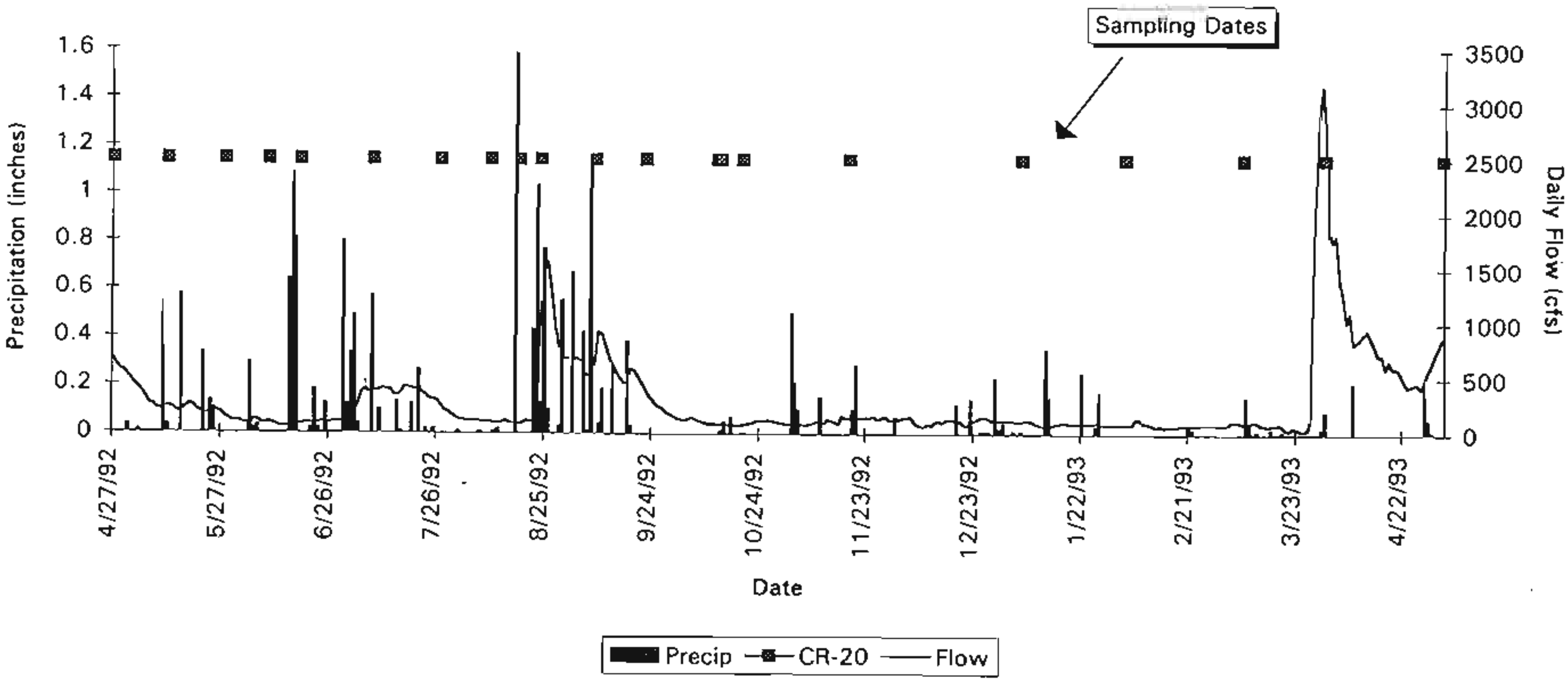
Table 3-2. Clearwater River Sample Collection and Parameter Analysis for Clearwater Nonpoint Study

Parameter	Field/Lab Analysis (F.L.)*	Sampling Frequency (BM, M)** Apr-Sept	Oct-Mar
Chemical			
Total Phosphorus (as P)	L	BM	M
Orthophosphate (as P)	L	BM	M
Total Organic Phosphorus (as P)	L	BM	M
Total Kjeldahl Nitrogen (as N)	L	BM	M
Ammonia (as N)	L	BM	M
Nitrate + Nitrite (as N)	L	BM	M
Total Suspended Solids	L	BM	M
Total Volatile Solids	L	BM	M
Total Alkalinity (as $CaCO_3$)	L	BM	M
Dissolved Oxygen	L	BM	M
Chemical Oxygen Demand	L	BM	M
pH	F,L	BM	M
Conductivity (umhos/cm)	F,L	BM	M
Agricultural Chemical Scan (sediment and water)	L	Quarterly	
Physical			
Temperature	F	BM	M
Color	L	BM	M
Flow	F	Daily	
Channel Index	F	During MnDNR Fish Survey (late July)	
Turbidity	L	BM	M
Bottom Sediment		During MnDNR Fish Survey (late July)	

Table 3-2. Clearwater River Sample Collection and Parameter Analysis for Clearwater Nonpoint Study - Continued

		Sampling Frequency (BM, M)**	
Parameter	Field/Lab Analysis (F.L.)*	Apr-Sept	Oct-Mar
Biological			
Fecal Coliform	L	BM	M
Phytoplankton			
Chlorophyll-a	L	Quarterly	
Enumeration	L	Quarterly	
Microinvertebrates	L	During MnDNR Fish Survey (late July)	
Periphyton (attached algae)	L	Monthly (Summer)	
Fisheries			
Tissue analysis	L	During MnDNR Fish Survey (late July)	
Density	L	During MnDNR Fish Survey (late July)	

*F = field, L = laboratory
**BM = twice a month, M = monthly



HDR Engineering Inc.

Red Lake Watershed District
Dedicated to Water Management

Figure 3-2

Date of Sample Collection in Relation to Rainfall and Flow at Red Lake Falls

Water and sediment were also collected and analyzed for MCPA and 2,4-D. These parameters were selected as indicator chemicals. Each is a common ingredient in commonly used herbicides. Water samples for analysis were collected in the same manner as previously described. Sediment samples were collected using a PVC sampler to an approximate depth of 6 inches. Sediment samples were removed from the sampler and placed in sterile bags and labeled with the date and time of collection and site identification number. Samples were placed on ice and shipped overnight to the analytical laboratory for testing. Analyses for MCPA and 2,4-D were performed by Minnesota Valley Testing, New Ulm, Minnesota.

3.2 Laboratory Quality Assurance/Quality Control

With the exception of MCPA and 2,4-D samples and all samples taken at CR-22, all sample analysis occurred at UMC. Table 3-3 presents a summary of the analytical accuracy, precision and data completeness for collected samples. Details of the laboratory quality assurance and quality control can be found in "Quality Assurance Manual Red Lake Watershed District Surface Water Quality Monitoring Program" (RLWD 1992b).

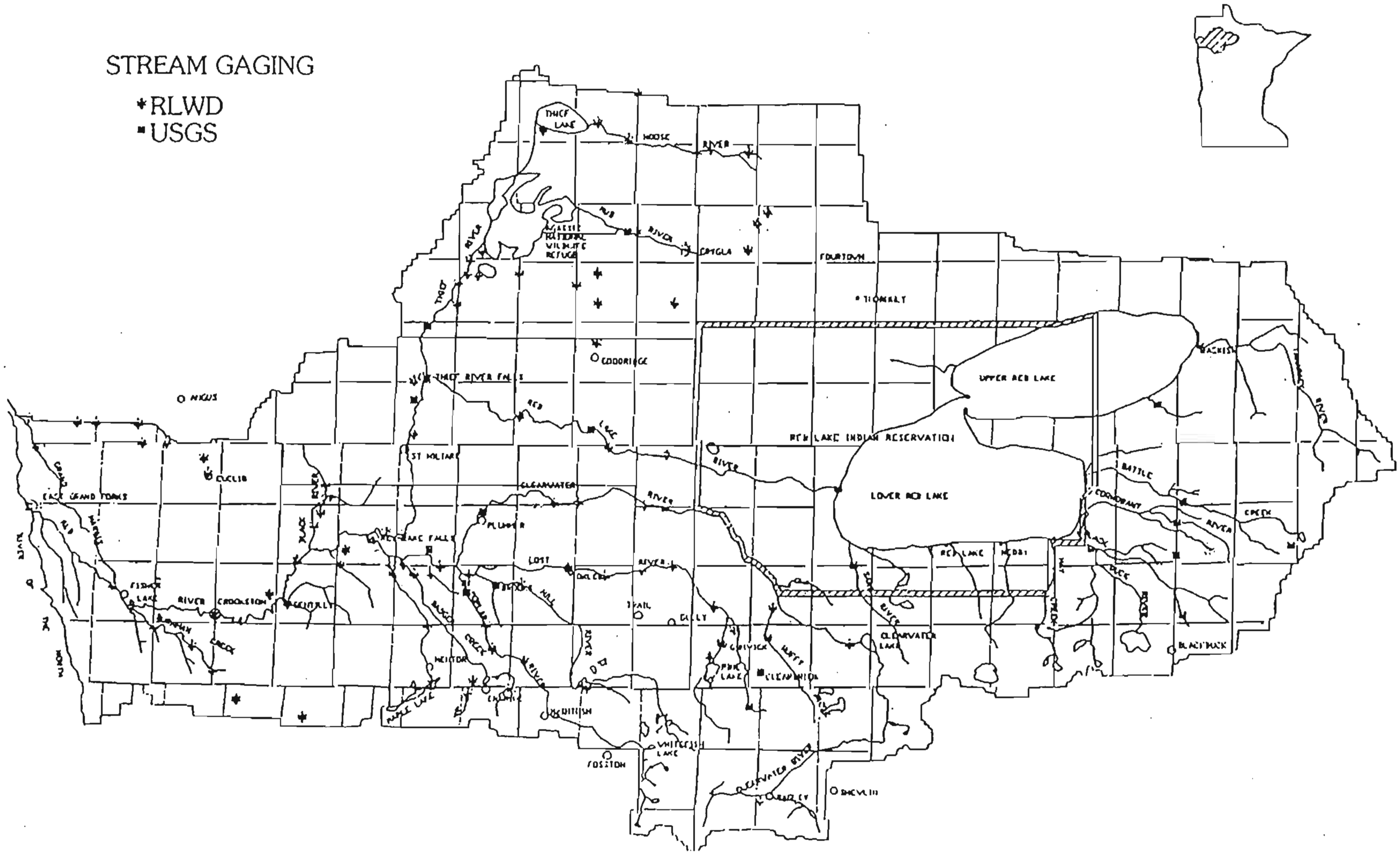
3.3 Flow Estimation and Hydrology Data

Most monitoring locations were gaged prior to the start of the study. Figure 3-3 shows stream gaging activities within the RLWD. The RLWD operates additional gage stations through the use of cooperative observers. Additional gages are operated by the U.S. Geological Survey with periods of record ranging from 28-55 years. Generally, at each of these locations, stream stage (depth) is measured. Stream flow is calculated from measured depth, either by developing a relationship between depth and flow based on actual field measurements of flow (a rating curve) or using mathematical relationships between stream stage and flow from gages.

Table 3-3. University of Minnesota Crookston Laboratory Precision, Accuracy and Data Completeness for Period of Study (April 1992-March 1993)

Parameter	Precision (%)[1]	Accuracy (%)[2]	Range (µg/l)	Units	Data Completeness[3]
Alkalinity (as $CaCO_3$)	0.3 - 4.1	88 - 110	10 - 500	µg/L	100
Ammonia	0 - .17	80 - 116.3	.02 - 2	µg/L	100
Chemical Oxygen Demand	0 - 15.9	N/A	0 - 150	µg/L	100
Color	0 - 17.1	N/A	0 - 500	Pt/Co	100
Conductivity[4]	0 - .75	N/A	0 - 20,000	µmho/cm	100
Fecal Coliforms	0 - 33.6	N/A	0 - TNC	colonies/100 ml	100
Nitrate (as N)	0 - 5.3	87 - 108	1 - 100	µg/L	100
Orthophosphate (as P)	0 - 12.5	67.7 - 128.2	2 - 100	µg/L	100
pH	0 - .59	N/A	40 - 10.0	pH units	100
Total Dissolved Oxygen	0 - .74	N/A	0 - 10,000	µg/L	100
Total Kjeldahl Nitrogen (as N)	0 - 26.5	80.8 - 123.2	.1 - 5.0	µg/L	100
Total Phosphorus (as P)	0 - 24.2	85.4 - 125.2	2 - 100	µg/L	100
Total Suspended Solids	0 - 25.9	N/A	0 - 500	µg/L	100
Turbidity	0 - 8.7	N/A	0 - 200	NTU	100
Total Volatile Solids	0 - 182	N/A	0 - 500	µg/L	100
MCPA-Soil	0 - 10	65 - 120	.05[5]	mg/l	100
MCPA-Water	0 - 10	65 - 120	3.0[5]	µg/l	100
2,4-D-Soil	0 - 10	70 - 120	0.01[5]	mg/l	100
2,4-D-Water	0 - 10	70 - 120	0.5[5]	µg/l	100

[1] Based on duplicate analysis of laboratory split samples. Equals absolute difference of splits samples divided by mean of splits.
[2] Based on spike sample recovery. Percentage of spike recovered.
[3] Percentage of sample analyzed, which were delivered to the laboratory.
[4] Conductivity used to calculate dissolved solids.
[5] Detection limits (mg/l).



HDR Engineering Inc.

Red Lake Watershed District
Dedicated to Water Management

Figure 3-3

Stream Gaging Network Within the Red Lake Watershed District

Table 3-4 shows the various methods used to estimate flow during the study. Flow data for monitoring locations CR-12, CR-14, and CR-20, were obtained from the United States Geological Survey (USGS). These sites had USGS continuous gages in place with well established rating curves. Flow data for ice-over periods at these locations were estimated using standard USGS regression formulae based in part on gage readings. Some locations within the watershed had long-term gages and rating curves established by the Red Lake Watershed District (see Table 3-4). The district also gaged and developed rating curves for sites specifically for this study. Sites CR-9, CR-19, and CR-22 had no gages installed. Sites CR-13, CR-18, and CR-25 had gages for measuring stage, but no rating curves were developed. In addition, sites CR-6, CR-8, CR-15, and CR-17 had Stevens Recorders installed for continuous monitoring. These recorders were in use from June through freeze-up in November.

The watershed district determined daily flow at each monitoring location within the study area. The degree of accuracy for each location varies depending upon the method used. Locations CR-6, CR-12, CR-14, and CR-20 had continuous measurement of stage, converted to a daily average stage, and are believed to have the greatest accuracy. These sites were used directly or indirectly to obtain flows at other gaged and nongaged sites. All sites that had gages and rating curves, used the gage readings along with linear interpolation between reading dates, to develop daily flows. For periods when no gage readings were made, flows were estimated based on data from one of the four sites mentioned above. These were usually obtained by adjusting the flow by a factor based on a ratio of drainage areas. Flow data for sites with no gages or rating curves were obtained entirely from data adjusted from other sites. Table 3-4 shows the formulae used to develop daily flows for each site during the study.

The MnDNR recently performed two dye studies on the Clearwater River between Clearwater Lake and Plummer, under medium and low flow conditions. These data are suitable for estimating time of travel and water quality model parameters such as dispersion coefficients (see Table 3-5).

3.4 Rainfall Data

Daily rainfall totals were collected by a number of volunteer observers throughout the Clearwater River watershed. Some of these same observers measured ambient air temperature. The data were forwarded to the State Climatologist for data reduction and coding and subsequently provided to RLWD for use in this study.

TABLE 3-4
METHODS USED TO DERIVE DAILY FLOW, BY MONITORING LOCATION

MONITORING LOCATION	GAGE TYPE	DEVELOPED RATING CURVE	AVG. GAGE READINGS PER MONTH	FORMULA USED TO DEVELOP DAILY FLOWS	COMMENTS
CR-1	STAFF	YES	9.5	APRIL '92 - NOV. '92 = LINEARLY INTERPOLATED BETWEEN GAGE READINGS NOV. '92 - MARCH '93 = (CLEARWATER LAKE FLOW) x (0.23) $0.23 = \frac{\text{(SITE 1 D.A.)}}{\text{(CLEARWATER LAKE D.A.)}}$	
CR-2	STAFF	YES	9.0	APRIL '92 - NOV. '92 = LINEARLY INTERPOLATED BETWEEN GAGE READINGS NOV. '92 - MARCH '93 = (CLEARWATER LAKE FLOW) x (0.44) $0.44 = \frac{\text{(SITE 2 D.A.)}}{\text{(CLEARWATER LAKE D.A.)}}$	
CR-3	STAFF	YES	3.4	APRIL '92 - OCT. 20 '92 = LINEARLY INTERPOLATED BETWEEN GAGE READINGS OCT. 20 '92 - MARCH '93 = (CLEARWATER LAKE FLOW) x (0.74) $0.74 = \frac{\text{(SITE 3 D.A.)}}{\text{(CLEARWATER LAKE D.A.)}}$	
CR-4	MEASURE DOWN	YES	3.4	APRIL '92 - OCT. 20 '92 = LINEARLY INTERPOLATED BETWEEN GAGE READINGS OCT. 20 '92 - MARCH '93 = (CLEARWATER LAKE FLOW) x (0.90) $0.90 = \frac{\text{(SITE 4 D.A.)}}{\text{(CLEARWATER LAKE D.A.)}}$	
CR-5/6	WIRE WEIGHT AND STEVENS RECORDER	YES	7.8	APRIL '92 - JULY 5 '92 = LINEARLY INTERPOLATED BETWEEN GAGE READINGS JULY 6 '92 - NOV 30 '92 = CONTINOUS READ GAGE DEC 1 '92 - MARCH '93 = LINEARLY INTERPOLATED BETWEEN GAGE READINGS	
CR-7	WIRE WEIGHT	YES	12.2	APRIL '92 - DEC. 16 '92 = LINEARLY INTERPOLATED BETWEEN GAGE READINGS DEC. 17 '92 - MARCH '93 = (CLEARWATER LAKE FLOW) x (1.27) 1.27= (SITE 7 D.A.) x (CLEARWATER LAKE D.A.)	

HDR Engineering Inc.

Red Lake Watershed District — Dedicated to Water Management

TABLE 3- (CONT.)

METHODS USED TO DERIVE DAILY FLOW, BY MONITORING LOCATION

MONITORING LOCATION	GAGE TYPE	DEVELOPED RATING CURVE	AVG. GAGE READINGS PER MONTH	FORMULA USED TO DEVELOP DAILY FLOWS	COMMENTS
RB-8	STAFF AND STEVENS RECORDER	YES	15.3	APRIL '92 - MAY 25 '92 = LINEARLY INTERPOLATED BETWEEN GAGE READINGS MAY 26 '92 - NOV. 12 '92 = CONTINUOUS READ GAGE NOV. 13 '92 - NOV. 30 '92 = LINEARLY INTERPOLATED BETWEEN GAGE READINGS DEC. 1 '92 - MARCH '93 = (PLUMMER FLOW) x (0.08) 0.08= (SITE 8 D.A.)/(PLUMMER D.A.)	
CR-9	NONE	NO	0	APRIL '92 - OCT. 15 '92 = ((SITE 10 + RICE ALLOCATION) - (SITE 7)) x (0.484) + (SITE 7) OR (SITE 7) x (1.484) OCT. 16 '92 - MARCH '93 = (SITE 10 - SITE 7) x 0.28 + (SITE 7 FLOW) 0.28= (SITE 10 CUM. D.A.) - (SITE 7 CUM. D.A.) / (SITE 9 D.A.)	USED THIS EQUATION WHEN RICE GROWERS WERE PUMPING USED THIS EQUATION WHEN NO RICE PUMPS WERE OPERATING THIS EQUATION BETTER ESTIMATED ICE FLOW CONDITIONS
CR-10	STAFF	YES	14.1	APRIL '92 - DEC. 11 '92 = LINEARLY INTERPOLATED BETWEEN GAGE READINGS DEC. 12 '92 - MARCH '93 = (PLUMMER FLOW) x (0.78) 0.78= (SITE 10 D.A.) / (PLUMMER D. A.)	
CR-11	STAFF	YES	4	APRIL '92 - SEPT. '92 = LINEARLY INTERPOLATED BETWEEN GAGE READINGS OCT. 92 - MARCH '93 = (PLUMMER FLOW) x (0.87) 0.87= (SITE 11 D.A.) / (PLUMMER D.A.)	STAFF GAGE WAS DESTROYED AT END OF SEPTEMBER
CR-12	CONTINUOUS	YES		USGS CONTINOUS READ GAGE OBTAINED FLOWS FROM THE USGS	
CR-13	STAFF	NO	0	APRIL '92 - MAY '93= (PLUMMER FLOW) x (1.02) 1.02= (SITE 13 D.A.) / (PLUMMER D.A.)	DID NOT STREAM GAGE ENOUGH TO DEVELOP A GOOD RATING CURVE

HDR Engineering Inc.

Red Lake Watershed District — Dedicated to Water Management

TABLE 3-4 (CONT.)
METHODS USED TO DERIVE DAILY FLOW, BY MONITORING LOCATION

MONITORING LOCATION	GAGE TYPE	DEVELOPED RATING CURVE	AVG. GAGE READINGS PER MONTH	FORMULA USED TO DEVELOP DAILY FLOWS	COMMENTS
LR-14	CONTINUOUS	YES		APRIL '92 - DEC 16 '92 = USGS CONTINUOUS READ GAGE DEC 17 '92 - MARCH '93 = LINEARLY INTERPOLATED BETWEEN GAGE RREADINGS	GAGE WAS MALFUNCTIONING DURING THIS PERIOD AND HAD ONLY SPORADIC READINGS
HR-15	STAFF AND STEVENS RECORDER	YES	4.4	APRIL '92 - JUNE 7 '92 = LINEARLY INTERPOLATED BETWEEN GAGE READINGS JUNE 8 '92 - NOV. 11' 92 = CONTINUOUS READ GAGE VOV. 12 '92 - MARCH '93 = (PLUMMER FLOW) x (0.29) $0.29 = \frac{\text{(SITE 15 D.A.)}}{\text{(PLUMMER D. A.)}}$	
LR-16	STAFF	YES	4.4	APRIL '92 - OCT. '92 = LINEARLY INTERPOLATED BETWEEN GAGE READINGS NOV. '92 - MARCH '93 = (OKLEE FLOW) x (1.21) $1.21 = \frac{\text{(SITE 16 D. A.)}}{\text{(OKLEE D.A.)}}$	
PR-17	STAFF AND STEVENS RECORDER	YES	11.1	APRIL '92 - JUNE 10 '92 = LINEARLY INTERPOLATED BETWEEN GAGE READINGS JUNE 11 '92 - NOV. 10 '92 = CONTINOUS READ GAGE NOV. 19 '92 - MARCH '93 = (PLUMMER FLOW) x (0.19) $0.19 = \frac{\text{(SITE 17 D.A.)}}{\text{(PLUMMER D.A.)}}$	
CR-18	WIRE WEIGHT	NO	0	APRIL '92 - MARCH '93 = (RED LAKE FALLS FLOW) x (0.90) $0.90 = \frac{\text{(SITE 18 D.A.)}}{\text{(RED LAKE FALLS D.A.)}}$	DID NOT HAVE SUFFICIENT STREAM GAGE RESULTS TO DEVELOP A GOOD RATING CURVE
CR-19	NONE	NO	0	APRIL '92 - MARCH '93 = (RED LAKE FALLS FLOW) x (0.99) $0.99 = \frac{\text{(SITE 19 D.A.)}}{\text{(RED LAKE FALLS D.A.)}}$	

HDR Engineering Inc.

TABLE 3-. (CONT.)
METHODS USED TO DERIVE DAILY FLOW, BY MONITORING LOCATION

MONITORING LOCATION	GAGE TYPE	DEVELOPED RATING CURVE	AVG. GAGE READINGS PER MONTH	FORMULA USED TO DEVELOP DAILY FLOWS	COMMENTS
	CONTINUOUS	YES		USGS CONTINOUS READ GAGE OBTAINED FLOWS FROM THE USGS	
WB-21	MEASURE DOWN	YES	8.9	APRIL '92 - OCT 26 '92 = LINEARLY INTERPOLATED BETWEEN GAGE READINGS OCT 27 '92 - MARCH '93 = (SITE 2 FLOW - SITE 1 FLOW) x (0.454) 0.454= (SITE 21 D.A.) / (SITE 2 CUM. D.A. - SITE 1 CUM. D.A.)	PROPORTIONED FLOWS BETWEEN SITE 2 AND SITE 1 BASED ON DRAINAGE AREAS
CR-22	NONE	NO	0	APRIL '92 - OCT 15 '92 = (SITE 9 FLOW) x (1.31) 1.31= (SITE 22 RIVER MI.POINT - SITE 9 RIVER MI. POINT) / (SITE 10 RIVER MI. POINT - SITE 9 RIVER MI. POINT) OCT 16 '92 - MARCH '93 = (SITE 10 FLOW - SITE 7 FLOW) x (0.37) + (SITE 7 FLOW) 0.37= (SITE 22 RIVER MI. POINT - SITE 7 RIVER MI. POINT) / (SITE 10 RIVER MI. POINT - SITE 7 RIVER MI. POINT)	USED RIVER MILES INSTEAD OF D.A.'S BECAUSE IT BETTER REFLECTED EFFECTS OF RICE PUMPING THIS EQUATION BETTER REFLECTED ICE FLOW CONDITIONS
CD-23	MEASURE DOWN	YES	2.1	APRIL '92 - DEC '92 = LINEARLY INTERPOLATED BETWEEN GAGE READINGS JAN '93 - MARCH 20 '93 = BOTTOM FROZE - ZERO FLOW MARCH 21 '93 - MARCH 31 '93 = (OKLEE FLOW) x (0.13) 0.13= ________ / (OKLEE D.A.)	
LR-24	STAFF	YES	3.5	APRIL '92 - SEPT '92 = LINEARLY INTERPOLATED BETWEEN GAGE READINGS OCT '92 - MARCH '93 = (OKLEE FLOW) x (0.19) 0.19= (SITE 24 D.A.) / (OKLEE D.A.)	
PR-25	MEASURE DOWN	NO	0	APRIL '92 - MARCH '93 = (SITE 17 FLOW) x (0.699) 0.699= (SITE 25 D.A.) / (SITE 17 D.A.)	

D.A. = DRAINAGE AREA

HDR Engineering Inc.

Red Lake Watershed District
Dedicated to Water Management

Table 3-5. Time of Travel and Dispersion Estimates for the Clearwater River

High Flow Conditions (300 cfs)

MnDNR Reach Number	Reach Length (miles)	Time to Peak (hr)	Variance (hr^2)	Mean Transport Velocity (fps)	Longitudinal Dispersion Coefficient (ft^2/s)	Longitudinal Dispersion Coefficient (m^2/s)
1	8.2	9.53	2.43	1.26	731.0	68.4
2	8.9	10.69	1.48	1.22	371.6	34.7
3	3.9	4.21	0.22	1.36	173.6	16.2
4	4.1	3.61	0.15	1.67	207.5	19.4
5	5	3.88	0.12	1.89	198.9	18.6
6	3.8	3.49	0.25	1.60	328.8	30.8
7	4.4	3.44	0.16	1.88	294.6	27.6
8	3.3	3.5	0.33	1.38	324.5	30.4
9	5.4	4.75	0.003	1.67	3.2	0.3
10	4.1	3.47	0.13	1.73	202.5	18.9
11	3.8	3.17	0.18	1.76	315.9	29.5
12	14.6	15.24	1.95	1.41	454.7	42.5

Dispersion coefficient calculated using one-point method D = (Variance ^{2} x Mean Transport Velocity) ÷ 2 (Time to Peak)
Dispersion coefficient calculated using dye study data from MnDNR (1991)

Low Flow Conditions (36 cfs)

MnDNR Reach Number	Reach Length (miles)	Time to Peak (hr)	Variance (hr^2)	Mean Transport Velocity (fps)	Longitudinal Dispersion Coefficient (ft^2/s)	Longitudinal Dispersion Coefficient (m^2/s)
1	8.2	14.54	2.71	0.83	229.5	21.5
2	8.9	13.84	1.68	0.94	194.4	18.2
3	3.9	4.65	0.15	1.23	87.9	8.2
4	4.1	6.21	0.32	0.97	87.0	8.1
5	5	7.59	0.39	0.97	86.3	8.1
6	3.8	5.21	0.29	1.07	114.7	10.7
7	4.4	6.73	0.46	0.96	113.1	10.6
8	3.3	6.01	2.42	0.81	470.1	44.0
9	5.4	13.66	11.3	0.58	500.6	46.8
10	4.1	7.88	2.11	0.76	280.7	26.2
11	3.8	5.74	0.83	0.97	245.4	22.9
12	14.6	38.89	22.81	0.55	320.1	29.9

Dispersion coefficient calculated using one-point method D = (Variance ^{2} x Mean Transport Velocity) ÷ 2 (Time to Peak)
Dispersion coefficient calculated using dye study data from MnDNR (1991)

3.5 Load Estimation

The computer program FLUX was used to calculate tributary loads and flow-weighted mean concentrations. FLUX is an interactive menu driven program, which consists of six unique methods for load estimation (Walker 1986). The program uses daily stream volume and chemistry data, and is supported by the Corps of Engineers, Vicksburg, Mississippi.

The goal of the load estimation procedure is to minimize the error associated with the load estimate. This is accomplished by first estimating the load using each of the techniques and noting the variance associated with each estimate. Often the variance can be reduced by stratifying the data either by flow or season. RLWD typically evaluated whether the variance of the estimate was reduced by using two flow strata; one greater and one less than the mean flow. After stratification, most of the estimation methods converged toward the same load estimate. RLWD then selected the estimate with the lowest variance. This tended to be "Flow Weighted Concentration," (see page II-7, Walker 1986). The method selected is shown in Equation 1.

$$W = \text{Mean}(w)\,[\text{Mean}(Q)/\text{Mean}(q)]$$ *Equation 1*

where

W = estimated mean flux over N days (kg/yr)
w = measured flux during a sample i (kg/yr)
Q = mean flow on day j (hm^3/yr)
q = measured flow during sample i (hm^3/yr)

Load estimates were performed on an annual and monthly basis. Monthly loads within FLUX are "back-calculated" using the annual flow-weighted mean concentration and monthly runoff volume.

3.6 River Land Use and Regression Analysis

The SWCDs, with assistance from RLWD, performed an analysis of land use and soil characteristics within the study area. The geographic information system EPPL7 served as the tool for performing the analysis. The analysis used 20 m x 20 m (~ 0.10 acre) parcels of land within the study area. The SWCDs classified the land use of each parcel as 1 of 36 categories. These 36 categories (see Table 3-6) were then reclassified to 1 of 12 categories based on the C-factor for the parcel (see Table 3-7). Point source and feed lot locations were similarly identified and entered into EPPL7. Also created was a digitized map showing the study boundary and the contributing drainage area boundary for each monitoring location.

The Land Management Information Center provided data related to soil drainage class, soil phosphorus content, soil organic matter content, soil erodibility and slope for 40 acre x 40 acre parcels. Clearwater SWCD then digitized detailed soil classification information gathered by the SWCDs on 20 m x 20 m parcel. The Clearwater SWCD then correlated and reclassified the LMIC data on a 20 m x 20 m parcel basis.

Land use, slope and soil characteristics are considered important factors affecting water quality. A multiple regression approach and correlation analysis was used to assess the importance of the characteristics with regard to water quality. The chemical parameters monitored (e.g., chemical oxygen demand, total phosphorus, etc.) were "regressed" on a series of independent variables which described conditions within a specified lineal distance of the stream ("buffer widths"). Independent variables used in the analysis included:

- Erodibility index
- Number of feedlots
- Index of runoff intensity
- Slope Index
- Land use percentages
- Season (& Month)
- Soil Phosphorus Index
- Soil Organic Matter Index
- Flow

Table 3-6. Geographic Information System Land Use Categorization

Land Use Category	Original GIS Classification Number	C-Factor*	Reclassified Category (source Clearwater SWCD)
Brush	11	.003[3]	1
Timber	12	.001[3]	1
Logged	13	.041[3]	1
P. Woodland	14	.112[3]	2
Undef. Cropland	15	(.211)[4]	12
Undef. Openland	16	(.004)[4]	5
Hay	20	.032[1]	6
Hay/Sm. Grain	21	.091[1,3]	12
Sm. Grain	22	.190[3]	11
Sm. Grain/Fallow	23	.470[3]	9
Hay/Sm. Grain/Row	24	.211[1,3]	12
Sm. Grain/Row Grain	25	.310[3]	10
Row Grain	26	.430[3]	9
Row Veg.	27	.560[1]	9
Wild Rice	28	.095[2,4]	7
Rice/Veg./Sm. Grain	29	.248[1,2,4]	7
Veg./Sm. Grain	30	.375[1,2,4]	10
Open Water Basin	31	0[2]	4
Impoundments	32	0[2]	4
Open Meadow Wetland	42	.026[2]	3
Marsh Wetland	44	.003[3,4]	3
Shrub-Shrub Wetland	46	.003[3,4]	3
Wooded Wetland	48	.003[3,4]	3
Rural Residential	51	.010[2]	8
Urban Residential	52	.010[2]	8
Extractive	61	.100[2]	8
Non-Pastured	71	.003[2]	5
Pastured	72	.120[2]	2

Table 3-6. Geographic Information System Land Use Categorization - Continued

Land Use Category	Original GIS Classification Number	C-Factor*	Reclassified Category (source Clearwater SWCD)
Feedlot	73	(.750)[2]	-
CRP	74	.004[2]	5
Commercial	81	.010[2]	8
Point Source	82	-	-
Undefined Forest	141	(.001)[4]	1
Undefined Water	150	(0)[4]	4
Undefined Wetlands	161	(.003)[4]	3
Gravel Pits	171	.100[2]	8

*C-Factor = A cover and management factor for the universal soil loss equation (USLE). It is the ratio of soil lost from a particular land use to a corresponding loss from a clean-tilled, continuous fallow condition. Variables: crop stage, residue, percentages of various uses in a crop rotation, & locality as it affects storm intensity and distribution.

1 Wischmeier, W.H. and Smith, D.D. 1978. Predicting rainfall erosion losses - guide to conservation planning. USDA Ag Handbook No. 537. U.S. Supt. of Doc. Washington, D.C.

2 Young, Robert A., Charles A. Onstad, David D. Bosch, and Wayne P. Anderson. 1987. AGNPS, Agricultural non-point source pollution model. A watershed analysis tool. Conservation Research Rept. 35, 80 pp., Agr. Res. Serv., USDA Washington, D.C. 77 pp.

3 Soil Conservation Service, 1993. Technical guide. Section III. Conservation Management Systems. USDA Soil Conservation Service. St. Paul, MN.

4 Estimated, based on the prior references.

Table 3-7. Land Use Categories Resulting from Reclassification of Original 36 Land Use Categories

Land Use Category		Original Land Use Category[1]	Respective C-Factors
1	Upland Woodland & Brush	11, 12, 13, 141	.003, .001, .041, .001
2	Pasture - Open & Wooded	14, 72	.112, .120
3	Vegetated Wetland	42, 44, 46, 48, 161	.026, .003, .003, .003, .003
4	Open Water	31, 32, 150	0, 0, 0
5	Unpastured Open Land	16, 71, 74	.004, .003, .004
6	Hay Land	20	.032
7	Wild Rice & Wild Rice Rotations	28, 29	.095, .248
8	Residential, Commercial & Extractive	51, 52, 81, 61, 171	.010, .010, .010, .100, .100
9	Row Crops & Small Grain Fallow	26, 27, 23	.430, .560, .470
10	Row Grain/Small Grain Rotation	25, 30	.310, .375
11	Continuous Small Grain	22	.190
12	Hay & Grain Rotations	21, 24, 15	.091, .211, .211

[1] See Table 3-6.

Indices were derived by weighing each factor (e.g. K-factor, % organic matter) by the acreage of land within some distance of the river (buffer width). The analysis included only MnDNR protected waters (primarily Lost, Hill, Poplar and Clearwater rivers; Ruffy Brook and Walker Brook) for distance of 0-100 m, 0-400 m, 0-800 m, 0-1600m, 0-3200 m and greater than 3200 m.

3.7 QUAL2E Modeling

The Technical Steering Committee selected QUAL2E for assessing water quality improvements with BMP implementation (HDR Engineering 1993). The committee selected the July 27 - August 10, 1992 period for modeling purposes because of the critically low dissolved oxygen (~2-3 mg/l) represented by this period and the low flow conditions.

Tables 3-8 and 3-9 show flow and water quality data respectively, based on the 1992 monitoring data, used to develop the QUAL2E model. (Appendix B contains calibrated model input and output). The QUAL2E is a steady-state model, mean flow is relatively constant during the period being modeled. The period selected for modeling satisfied the steady-state assumption. The developed model incorporates the entire Clearwater River from CR-1 and WB-21 to Red Lake Falls, portions of the Lost and Poplar rivers, the Hill River and Ruffy Brook. The Point source discharge at Bagley and incremental discharges through the channelized reach are also included.

The model developed for this study is suitable for planning purposes, to evaluate the relative improvement in water quality if activities are implemented. The primary parameter used for dissolved oxygen calibration was sediment oxygen demand. For total suspended solids, the full velocity was used as the calibration parameter. Calibrated values for these parameters fall within reasonable ranges. An intensive sampling survey is needed to use the model to evaluate the effect of specific point sources.

Table 3-8. Flows (Daily cfs) Used to Develop the Clearwater River, QUAL2E Model

	Monitoring Location																							
Date	CR-1	WB-21	CR-2	CR-3	CR-4	CR-5	CR-7	RB-8	CR-9	CR-22	CR-10	CR-11	CD-23	CR-12	CR-13	LR-24	LR-14	HR-15	LR-16	PR-25	PR-17	CR-18	CR-19	CR-20
7/27/92	5	0	36	47	51	62	47	1	139	182	238	215	0	224	228	3	17	1	19	1	1	239	262	265
7/28/92	6	0	36	49	48	58	44	1	133	174	229	169	0	194	198	3	16	1	20	1	1	198	218	220
7/29/92	10	4	41	51	41	52	43	1	128	168	219	150	0	173	176	3	14	1	19	1	1	176	193	195
7/30/92	13	3	46	52	37	50	40	1	122	160	210	135	0	146	149	3	13	1	18	1	1	158	173	175
7/31/92	17	2	50	54	34	48	38	1	117	147	201	116	0	134	137	3	13	1	17	1	1	137	150	152
8/1/92	12	2	45	47	33	45	37	1	112	140	192	113	0	130	133	3	13	1	17	1	1	122	135	136
8/2/92	7	1	40	40	32	43	36	1	107	132	182	109	0	125	128	3	13	1	17	1	1	116	128	129
8/3/92	2	0	35	33	31	42	33	1	101	126	173	97	0	112	114	3	12	1	16	1	1	112	123	124
8/4/92	3	0	35	26	30	42	33	1	96	122	164	108	0	124	126	2	12	1	16	1	1	101	111	112
8/5/92	3	0	34	19	29	40	36	1	93	115	154	110	0	127	130	2	13	1	17	1	1	107	118	119
8/6/92	4	0	32	12	34	38	34	1	88	107	145	96	0	110	112	2	15	1	18	1	1	113	124	125
8/7/92	3	0	31	23	33	38	32	1	82	102	136	97	0	112	114	2	18	1	19	1	1	99	109	110
8/8/92	4	0	28	33	38	38	33	1	78	98	127	99	0	114	116	3	30	1	20	1	1	100	110	111
8/9/92	5	0	24	44	43	42	35	1	75	93	117	88	0	101	103	5	33	1	21	1	1	101	111	112
8/10/92	6	0	21	54	51	40	36	1	71	93	108	215	0	81	83	7	28	1	22	1	1	96	106	107
Min	2	0	21	12	29	38	32	1	71	93	108	88	0	81	83	2	12	1	16	1	1	96	106	107
Max	17	4	50	54	51	58	44	1	133	174	229	215	0	194	198	7	33	1	22	1	1	198	218	220
Mean	7	1	35	36	35	43	36	1	96	121	160	118	0	119	122	3	17	1	18	1	1	117	128	130
Std. Dev.	5	1	10	16	7	6	3	0	20	26	39	42	0	28	29	2	8	0	2	0	0	29	32	32

Table 3-9. Clearwater River Water Quality Data Used to Develop the QUAL2E Model (average for samples collected July 27 and August 10, 1992)

Monitoring Location	Water Temp (C)	Specific Cond. (umhos)	pH	Field D.O. (mg/l)	Chemical Oxygen Demand (mg/l)	Nitrate (mg/l as N)	Ammonia (mg/l as N)	Total Kjeldahl (mg/l as N)	Ortho Phos. (mg/l as P)	Organic Phos. (mg/l as P)	Total Phos. (mg/l as P)	Fecal Coliforms (Col. /100 ml	Total Suspended Solids (mg/l)
CR-1	17.80	498.5	6.95	3.9	19	0.00	0.005	0.05	0.005	0.025	0.034	20	1.8
WB-21	17.69	470	7.23	1.5	48	0.00	0.005	0.05	0.012	0.038	0.054	11	4.7
CR-2	18.66	509	7.135	1.0	34.5	0.00	0.005	0.05	0.042	0.024	0.066	60	2.7
CR-3	17.42	538.5	7.515	5.6	21.5	0.03	0.005	0.05	0.040	0.025	0.064	203	2.4
CR-4	18.80	519.5	7.825	8.6	29	0.01	0.005	0.05	0.033	0.025	0.058	261	2.4
CR-5	20.62	440.5	8.255	9.8	20.5	0.00	0.005	0.05	0.001	0.025	0.025	0	2.0
CR-6	20.50	424.5	8.17	9.3	23	0.00	0.005	0.05	0.006	0.020	0.021	40	1.5
CR-7	20.55	426	8.23	7.7	19	0.01	0.005	0.05	0.013	0.022	0.035	361	1.4
RB-8	19.50	648	8.055	6.6	43	0.02	0.005	0.05	0.066	0.044	0.110	633	3.4
CR-9	19.75	599.5	7.995	6.9	42	0.08	0.005	0.56	0.120	0.041	0.161	186	11.8
CR-22	21.10	550.5	7.78	6.9	48	0.13	0.056	1.13	0.112	0.050	0.167		14.7
CR-10	18.50	708.5	7.67	4.5	86	0.25	0.005	0.57	0.225	0.083	0.308	185	15.1
CR-11	18.20	726.5	7.69	4.2	85	0.55	0.005	0.38	0.211	0.080	0.291	360	7.4
CD-23	NO FLOW												
CR-12	18.55	729	7.905	5.5	80	0.25	0.005	0.56	0.188	0.042	0.230	268	5.8
CR-13	21.40	713.5	8.08	6.7	89	0.57	0.005	0.18	0.162	0.051	0.212	143	6.2
CR-18	23.30	699.5	8.585	10.4	77.5	0.39	0.005	0.74	0.131	0.040	0.171	49	4.3
CR-19	23.60	655.5	8.885	10.3	74	0.29	0.005	1.15	0.106	0.040	0.146	59	1.3
CR-20	24.00	649.5	8.83	10.4	74.5	0.27	0.005	0.33	0.107	0.058	0.165	38	3.8
LR-24	19.05	443.5	7.755	6.9	48	0.00	0.005	0.05	0.028	0.033	0.061	325	2.2
LR-14	20.95	804.5	7.935	5.0	71	0.02	0.005	0.18	0.000	0.032	0.036	250	1.0
LR-16	25.00	672	8.69	11.4	42	0.00	0.005	0.16	0.000	0.028	0.031	95	1.7
HR-15	22.80	559	8.285	9.0	27.5	0.01	0.005	0.05	0.083	0.044	0.126	253	2.4
PR-25	20.45	886.5	7.65	4.8	76.5	0.01	0.005	0.87	0.090	0.050	0.140	3695	5.2
PR-17	22.65	652.5	8.305	8.6	61	0.02	0.005	1.64	0.112	0.080	0.192	640	5.4

4.0 STUDY PERIOD CLIMATOLOGY AND HYDROLOGY

4.1 Climatology

Data obtained from the Minnesota State Climatology Office were used to compare monthly temperature and precipitation measurements taken during the study period to long term normals for the area. Long term normals were available for Red Lake Falls, Fosston, Oklee, and Red Lake, Minnesota. These locations are in or near the Clearwater River basin and reflect general climatological trends within the basin.

Figure 4-1 shows a comparison between mean daily temperature by month during the study compared to long-term or "period of record" temperatures. Slightly cooler than normal summer temperatures occurred during the study at each of these locations, while temperature for the non-summer months remained near normal or slightly below normal.

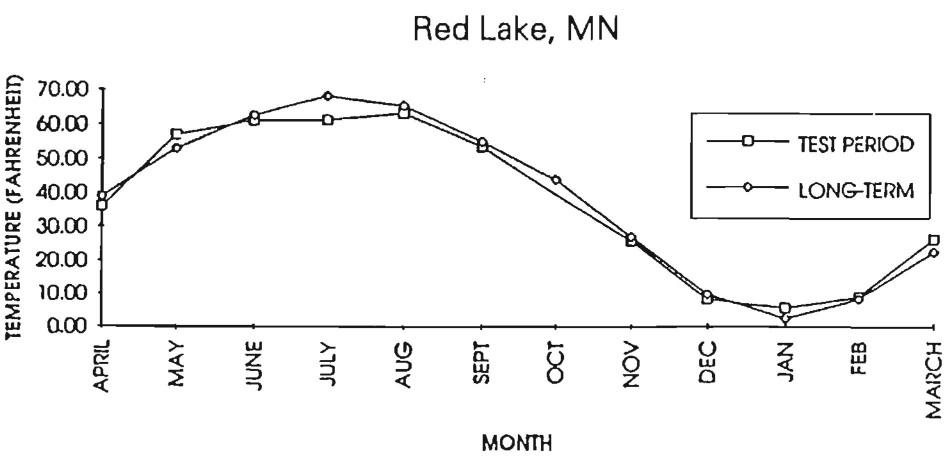
Figure 4-2 shows a similar comparisons for monthly precipitation at specific locations. Spring and early summer precipitation amounts were below normal at each of these locations. The late summer and early fall precipitation amounts were above normal, while the late fall and winter amounts were near normal. As would be expected, this trend correlates to the same trend shown when comparing flows.

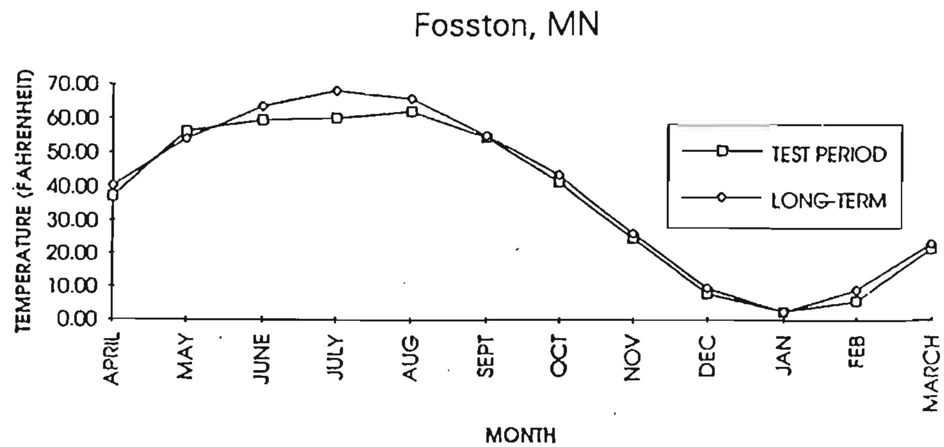
A more accurate estimate of the monthly rainfall within the Clearwater River basin can be achieved by weighting the precipitation at each specific gage, by the area represented by that gage. Precipitation totals by month using the Theissen Polygon method are presented in Figure 4-3. These data tend to show slightly greater monthly precipitation amounts than the "point estimates" presented in Figure 4-2.

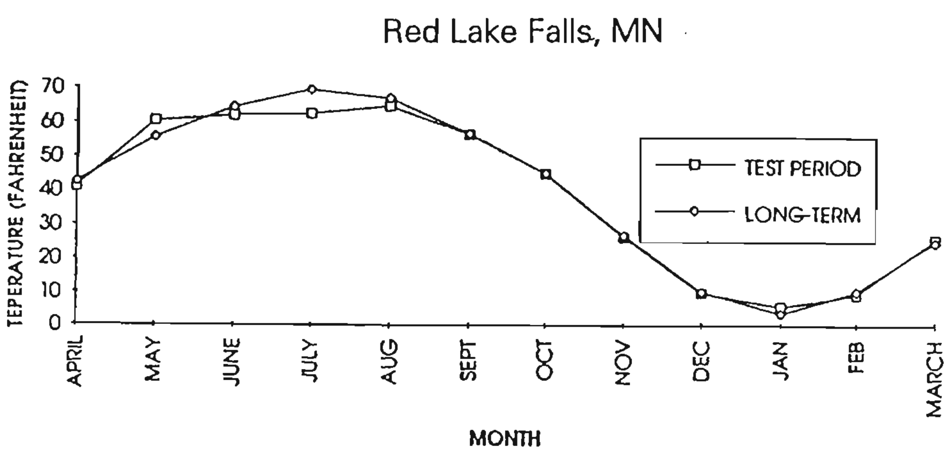
4.2 Hydrology

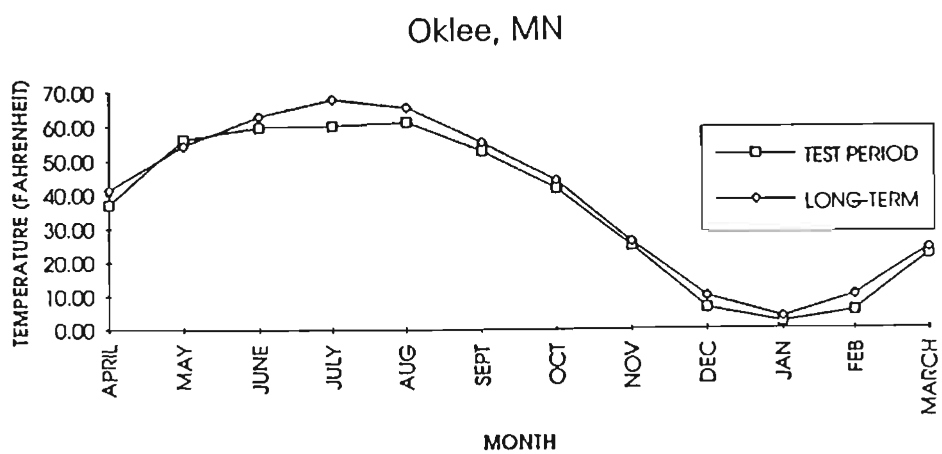
4.2.1 Comparison of Mean Daily Flows by Month

Stream flow during the spring and early summer was considerably below normal, based on a comparison of the mean daily flow by month using USGS gaging station data (see Figure 4-4). However, stream flow exceeded normal during the late summer and early fall and stayed near normal during the winter months. This pattern in stream flow essentially mimics the seasonal







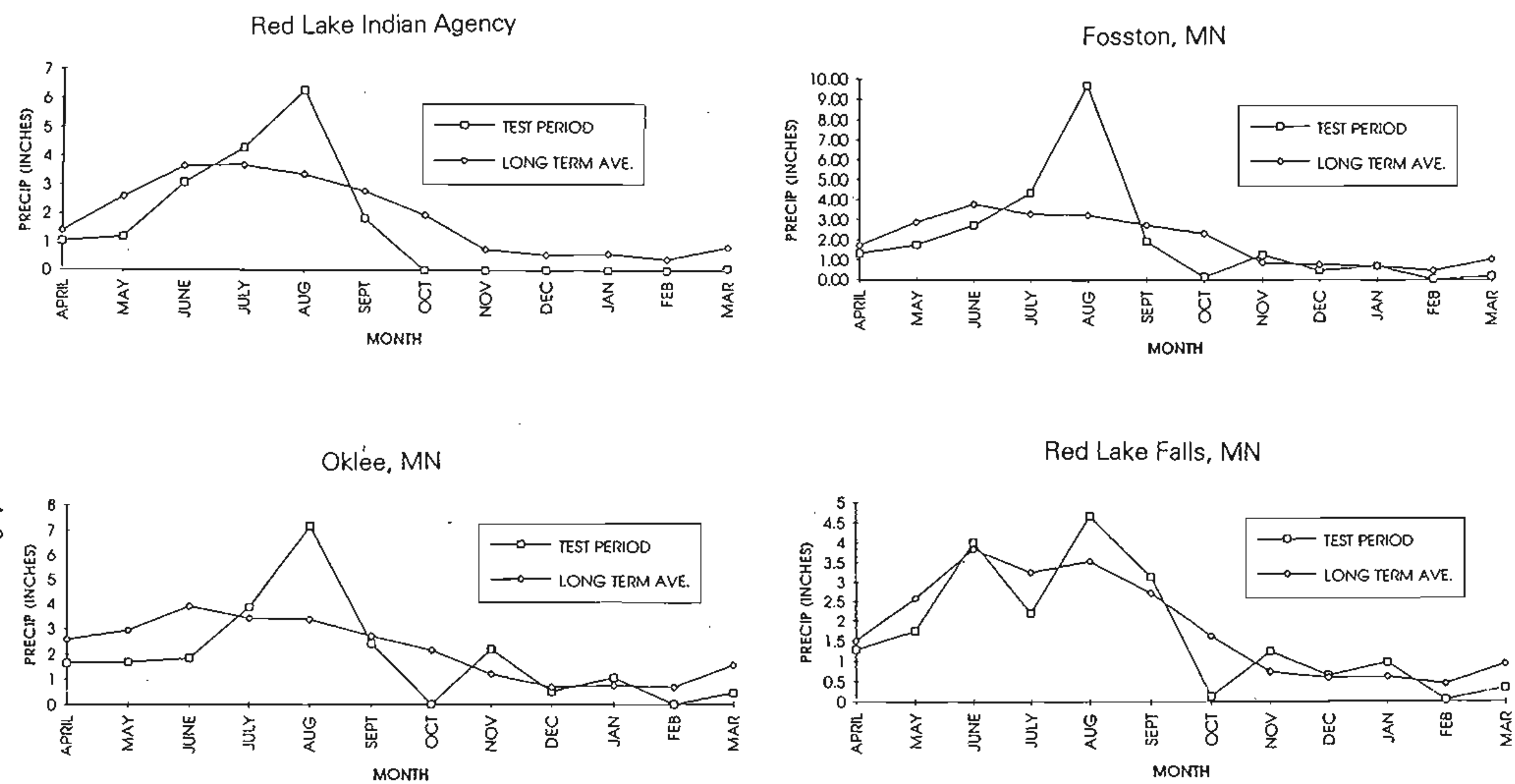


HDR Engineering Inc.

Red Lake Watershed District
Dedicated to Water Management

Figure 4-1

Mean Daily Temperature by Month Relative to Normal for Select Locations within the Clearwater River Basin



HDR Engineering Inc.

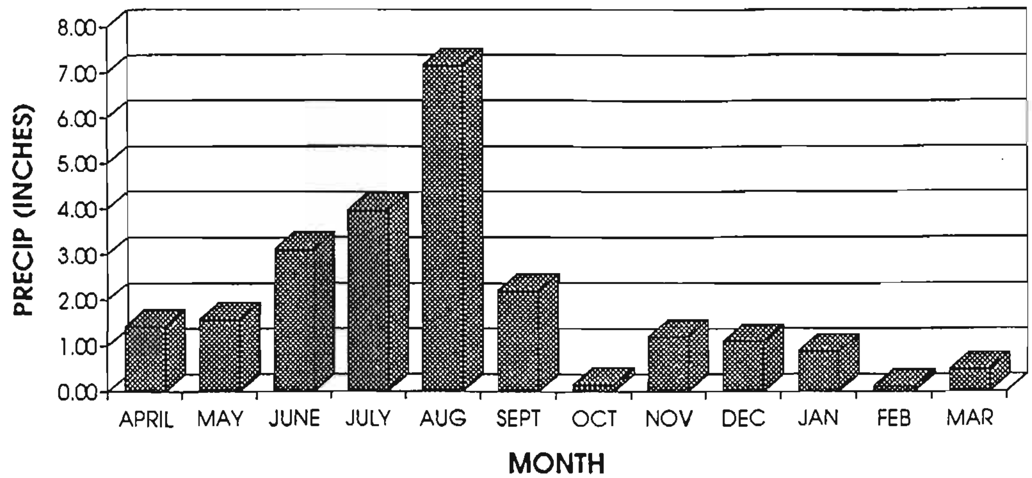
Red Lake Watershed District
Dedicated to Water Management

Figure 4-2

Monthly Precipitation Amount Relative to Normal at Select Locations within the Clearwater River Basin

MONTHLY WEIGHTED PRECIPITATION

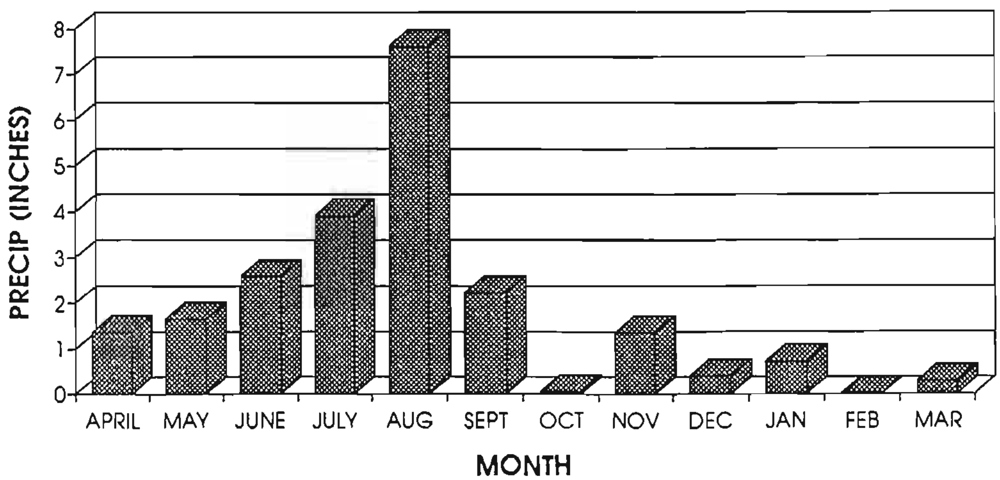
CLEARWATER RIVER TO PLUMMER GAGE



Monthly Precipitation	
April	1.43
May	1.56
June	3.12
July	3.97
August	7.14
September	2.21
October	0.16
November	1.20
December	1.10
January	0.88
February	0.12
March	0.49
	23.40

MONTHLY WEIGHTED PRECIPITATION

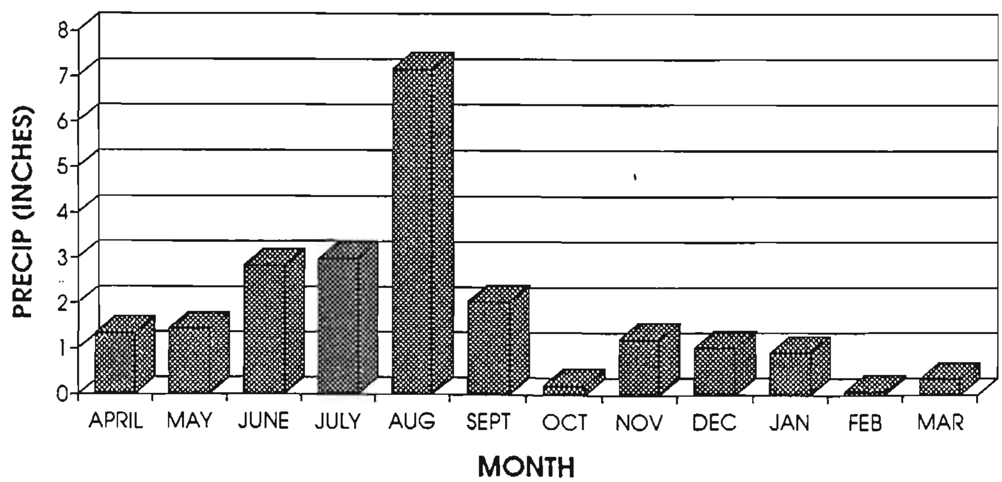
CLEARWATER RIVER TO RED LAKE FALLS GAGE



Monthly Precipitation	
April	1.37
May	1.65
June	2.58
July	3.92
August	7.61
September	2.22
October	0.06
November	1.36
December	0.04
January	0.73
February	0.01
March	0.28
	22.19

MONTHLY WEIGHTED PRECIPITATION

LOST RIVER TO OKLEE GAGE



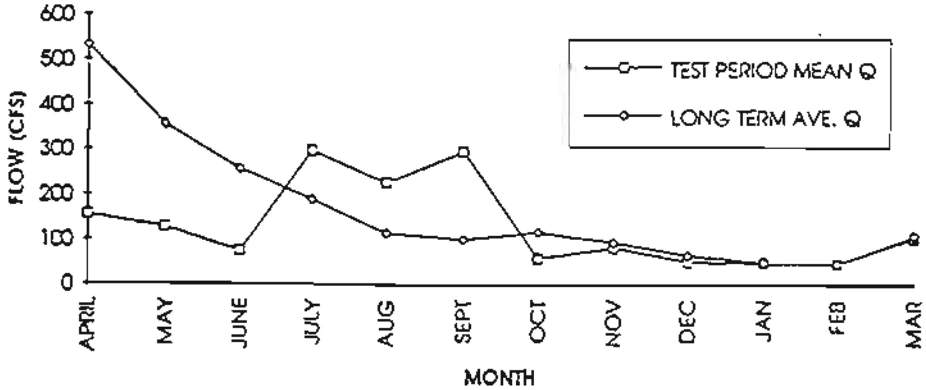
Monthly Precipitation	
April	1.34
May	1.44
June	2.85
July	2.97
August	7.16
September	2.05
October	0.22
November	1.22
December	1.04
January	0.92
February	0.07
March	0.36
	21.64

HDR Engineering Inc.

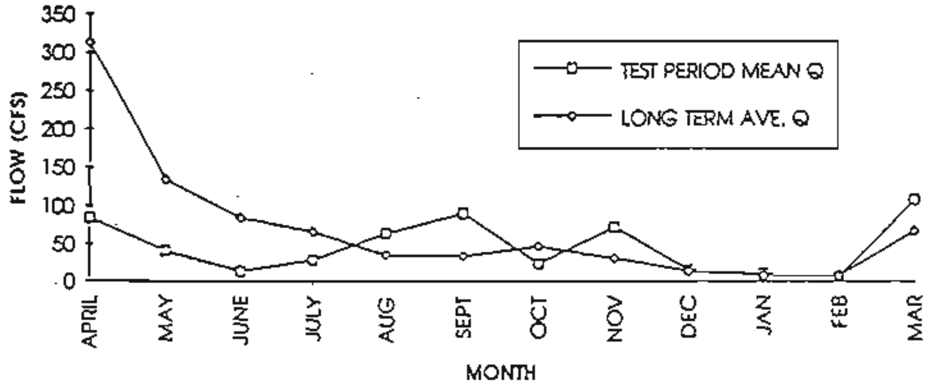
Red Lake Watershed District — Dedicated to Water Management

Figure 4-3
Monthly Precipitation Amount within the Clearwater River Basin using the Thiessen Polygon Method

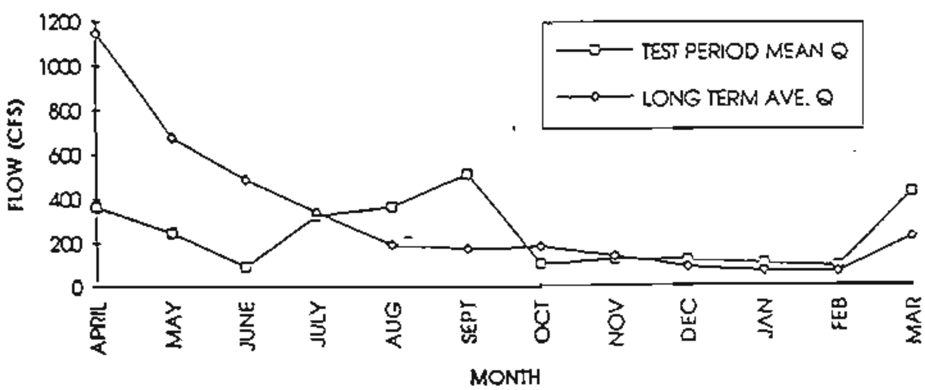
Site 12 - Plummer Gage



Site 14 - Oklee Gage



Site 20 - Red Lake Falls Gage



HDR Engineering Inc.

Red Lake Watershed District — Dedicated to Water Management

Figure 4-4

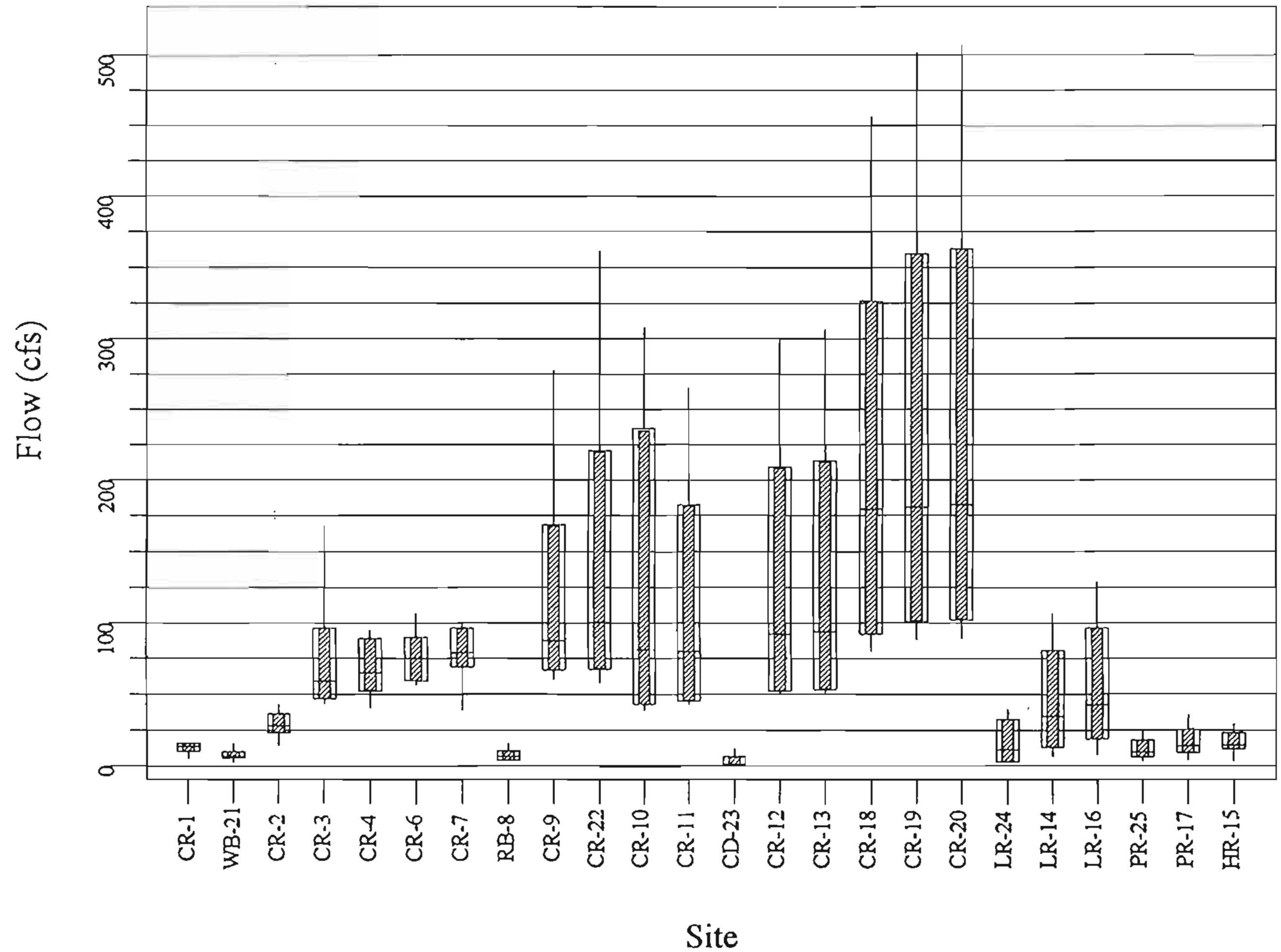
Mean Daily Flow by Month, Relative to Long-Term Average at Select Locations within the Clearwater River Basin distribution of rainfall (see Figures 4-2 and 4-3). This same general trend is believed to represent the other locations as well.

4.2.2 Descriptive Statistics for Stream Flow

Figure 4-5 shows descriptive statistics for daily stream flow, by monitoring location, using box and whisker plots. These plots show the percentiles in daily flow (the whiskers and outside box), the median flow and the 95% confidence interval (the inside box). These data show relatively little variation in daily stream flow (small standard deviation) for the upper Clearwater River. This likely reflects the small drainage area relative to downstream locations, and the importance of groundwater providing base flow. These areas also tend to have a greater amount of upstream storage as a result of more lakes and wetlands and the least amount of land in agriculture. The primary factors affecting stream flow are drainage area, time of concentration, ground water discharge and land use. All other sites within the study area tended to show a higher fluctuation in stream flow.

4.2.3 Importance of Storm Events

Specific spring and summer rainfall events tended to be important with regard to the streamflow characteristics within the basin. The three largest storm events during the study began on June 15th, July 1st, and August 17th. The largest of these storms began on August 17th with an initial storm, followed by an additional storm event on August 21st (see Figures 4-6 to 4-9). The Clearwater River showed a gradual increase in flow over several days, for the smaller (< 1 inch) storm events. For larger rain events the Clearwater River at Plummer showed a lag of two to three days from peak rainfall to peak flow, while at Red Lake Falls, the lag was three to five days. These time periods reflect the approximate time needed for the "wave" to move from the contributing drainage area to the gaging station. Based on these data, the Clearwater River could be termed as "moderately flashy" for medium to intense rainfall events.



Legend

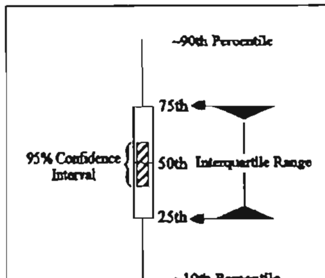
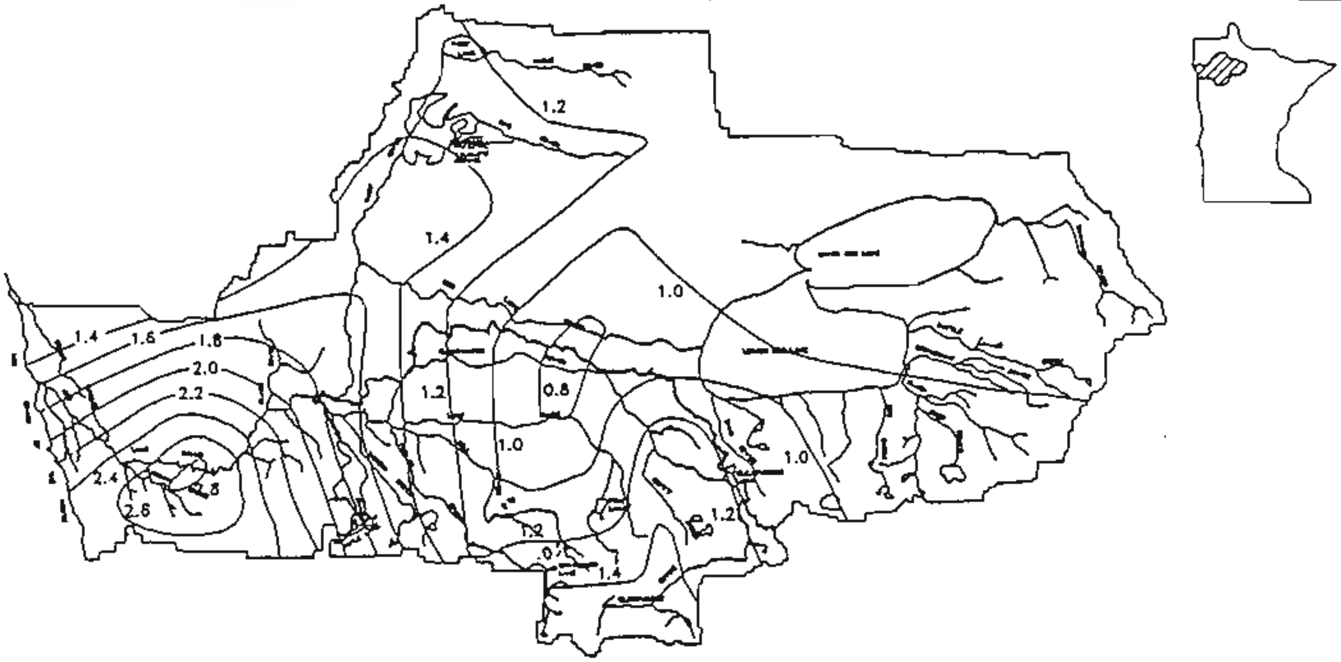


Figure 4-5

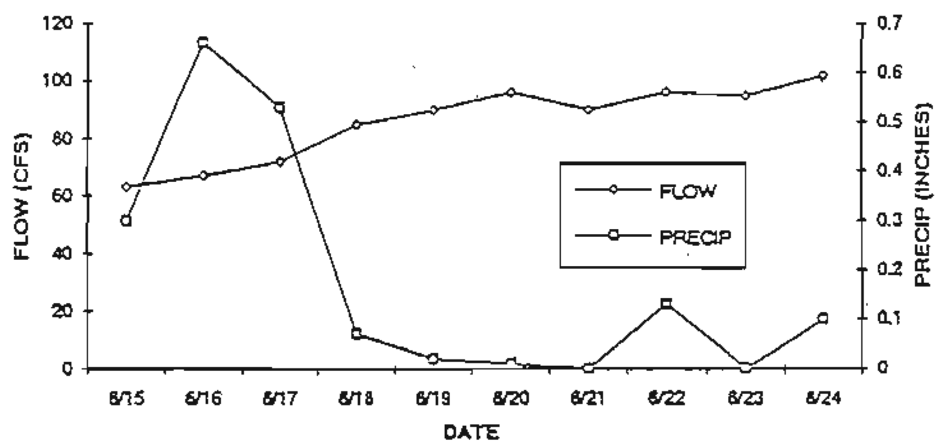
Box and Whisker Plots for Daily Flow (cfs) at Water Quality Monitoring Locations, April 1, 1992-March 31, 1993

HDR Engineering Inc.

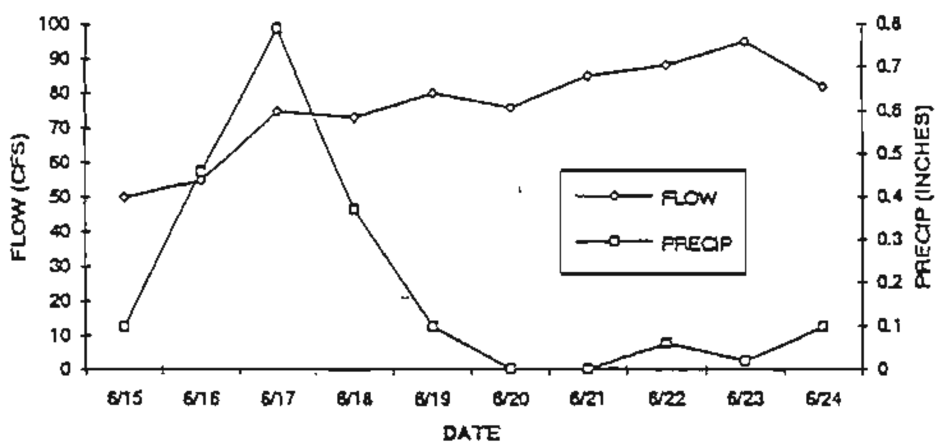
Red Lake Watershed District
Dedicated to Water Management



CLEARWATER RIVER AT RED LAKE FALLS - JUNE 17, 1992 STORM EVENT



CLEARWATER RIVER AT PLUMMER - JUNE 17, 1992 STORM EVENT

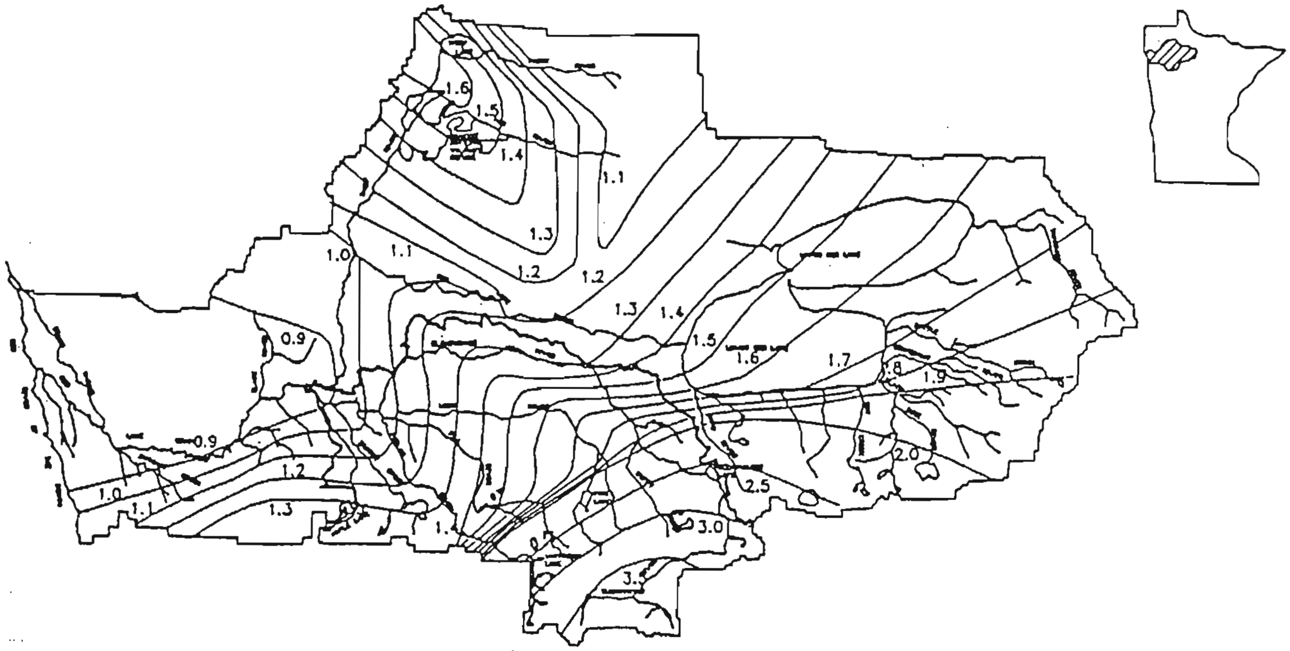


HDR
HDR Engineering Inc.

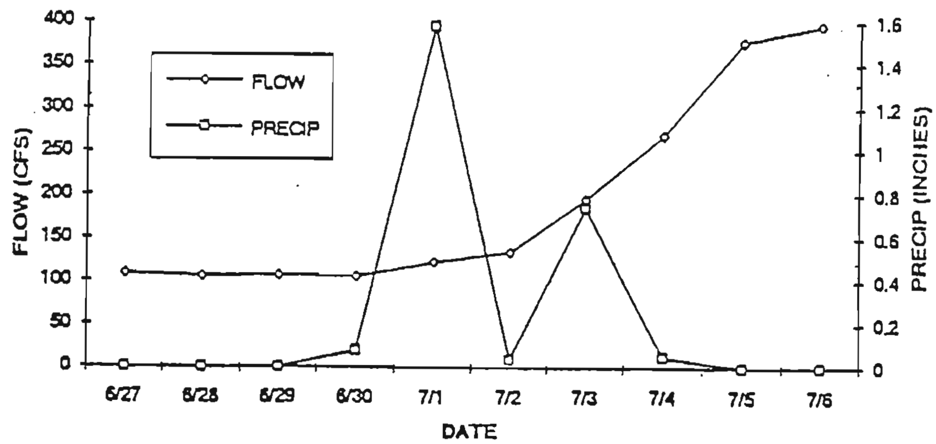
Red Lake Watershed District
Dedicated to Water Management

Figure 4-6

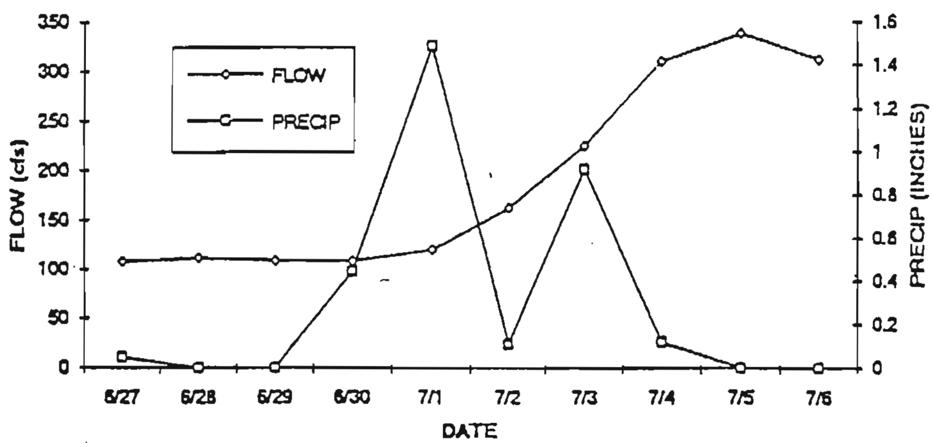
Areal Rainfall Distribution and Streamflow Response for June 15, 1992 Storm



CLEARWATER RIVER AT RED LAKE FALLS - JULY 1, 1992 STORM EVENT



CLEARWATER RIVER AT PLUMMER - JULY 1, 1992 STORM EVENT

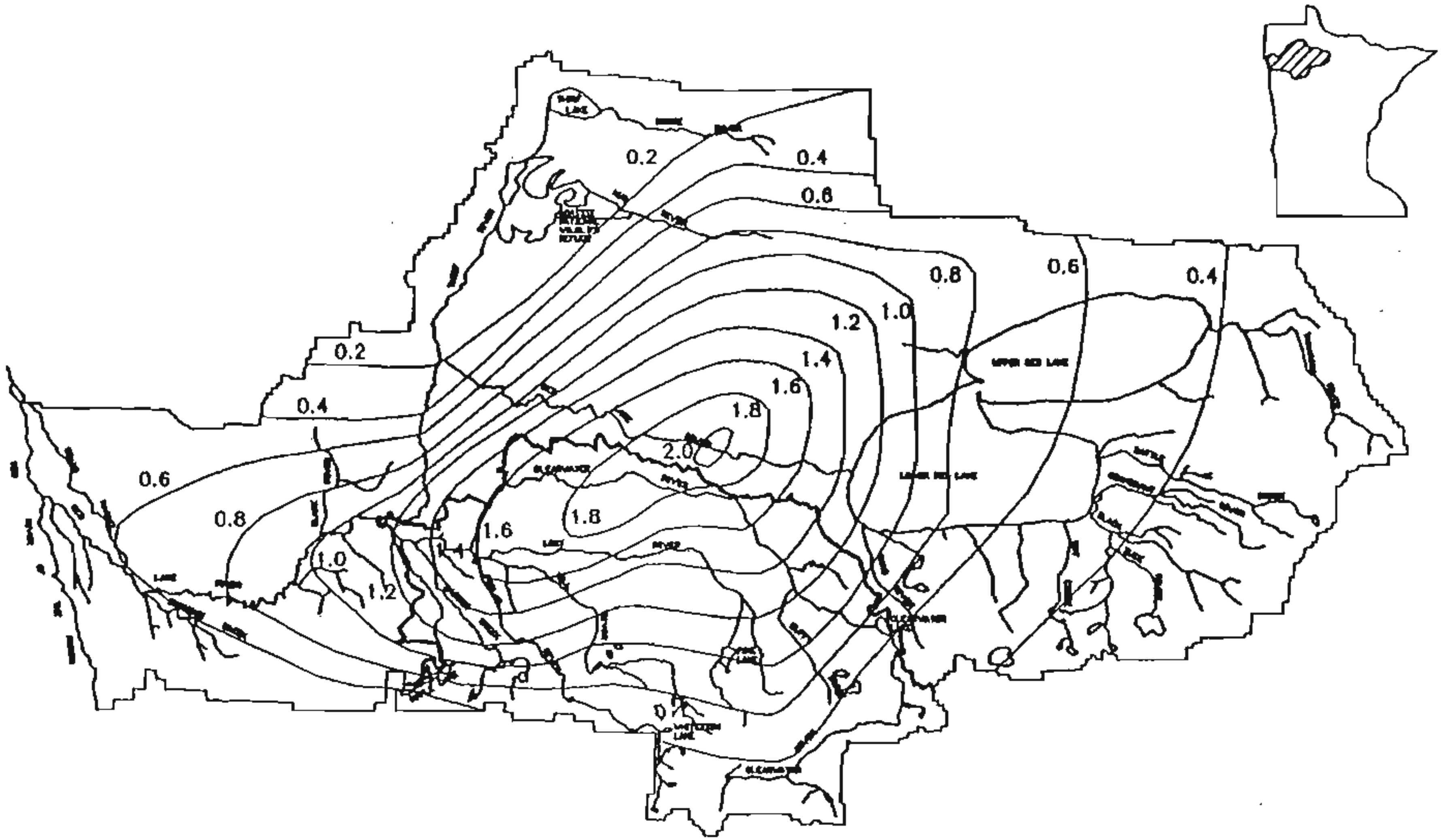


HDR Engineering Inc.

Red Lake Watershed District
Dedicated to Water Management

Figure 4-7

Areal Rainfall Distribution and Streamflow Response for July 1, 1992 Storm

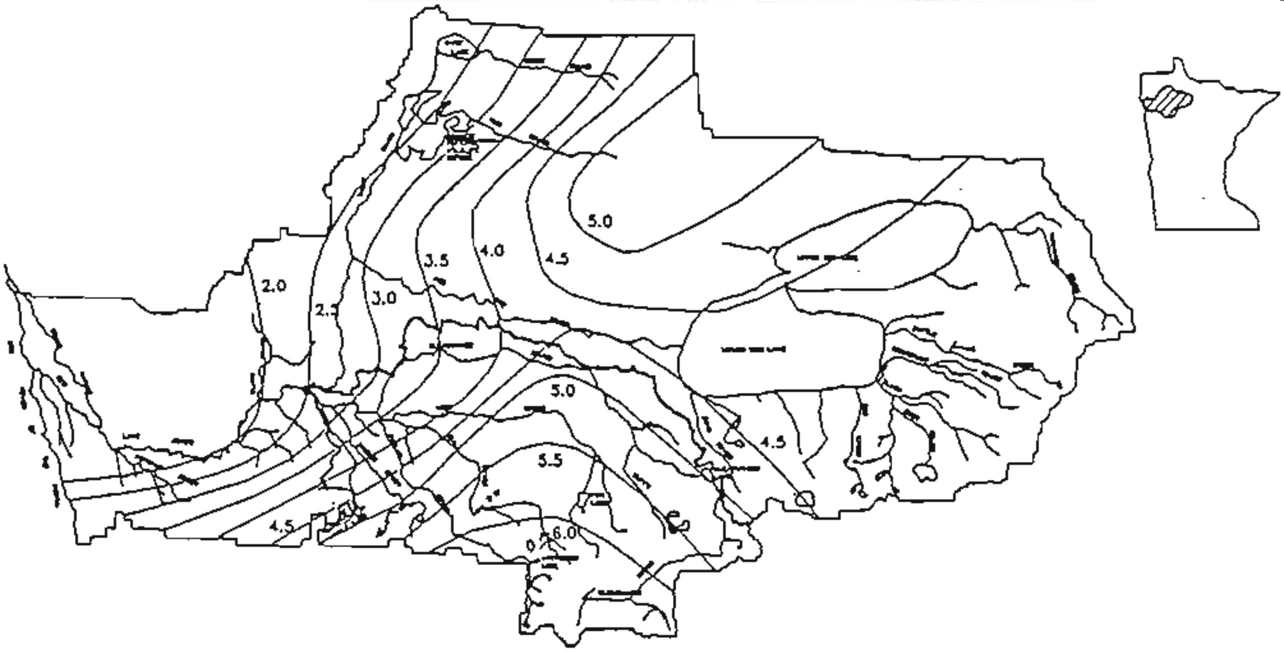


HDR Engineering Inc.

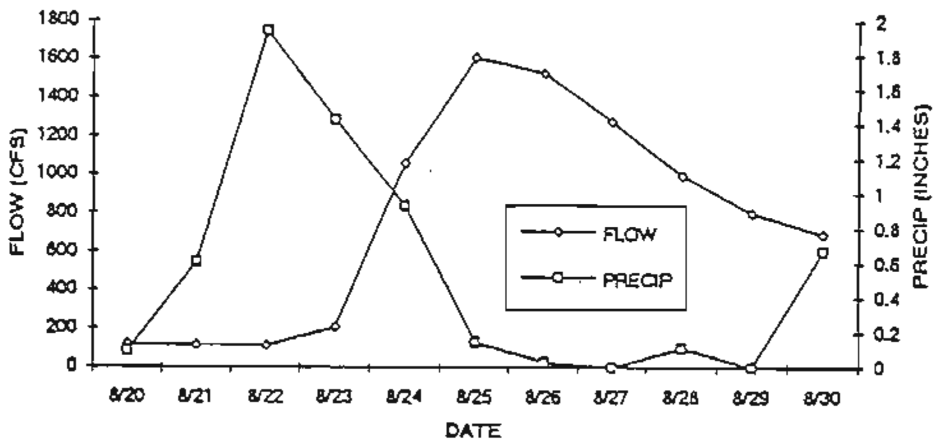
Red Lake Watershed District
Dedicated to Water Management

Figure 4-8

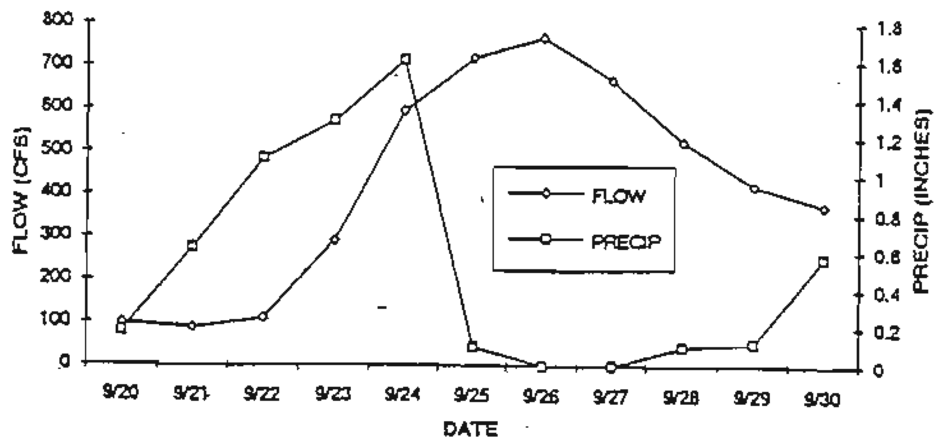
Areal Rainfall Distribution for
August 17, 1992 Storm



CLEARWATER RIVER AT RED LAKE FALLS - AUGUST 24, 1992 STORM EVENT



CLEARWATER RIVER AT PLUMMER - AUGUST 24, 1992 STORM EVENT



HDR

HDR Engineering Inc.

Red Lake Watershed District — Dedicated to Water Management

Figure 4-9

Areal Rainfall Distribution and Streamflow Response for August 17 and August 21, 1992 Storm

4.2.4 Annual Runoff Volume

An index of the amount of annual runoff can be calculated using the information provided in Figure 4-3 and the flow data from the USGS gage sites located at Plummer, Oklee and Red Lake Falls (Figure 4-4). These data can be used to calculate a "runoff coefficient" which provides a relative indication of percentage of rainfall which runs off. Although this method is an over simplification of a complicated process, the results are acceptable when the following factors are considered:

- While estimating runoff volume for long time periods, the contribution of groundwater relative to surface water runoff is considered small.
- The separation of the importance of groundwater versus surface water runoff may not be essential because precipitation contributes to both, and this relationship may be at steady-state.
- Variations in antecedent conditions tend to average out, and refinements necessary in storm event rainfall-runoff relations become less important.

Table 4-1 shows total weighted precipitation in relation to total flow at three locations within the basin and the same data on a volume basis. These data show that approximately 11-14% of the annual precipitation is measured as runoff within the Clearwater River at these location.

Table 4-1. Annual Runoff Volume and Coefficient for Select Locations on the Clearwater River

SITE	TOTAL WEIGHTED PRECIPITATION	TOTAL FLOW
Plummer	23.40 inches	48,006 cfs
Oklee	21.64 inches	16,960 cfs
Red Lake Falls	22.19 inches	86,789 cfs

SITE	TOTAL PRECIP. VOLUME (V_P)	TOTAL FLOW VOLUME (V_R)	ANNUAL RUNOFF COEFFICIENT (V_R/V_P)
Plummer	665,721 ac.ft.	95,052 ac.ft.	0.14
Oklee	306,999 ac.ft.	33,501 ac.ft.	0.11
Red Lake Falls	1,611,680 ac.ft.	171,842 ac.ft.	0.11

5.0 DIAGNOSTIC STUDY RESULTS

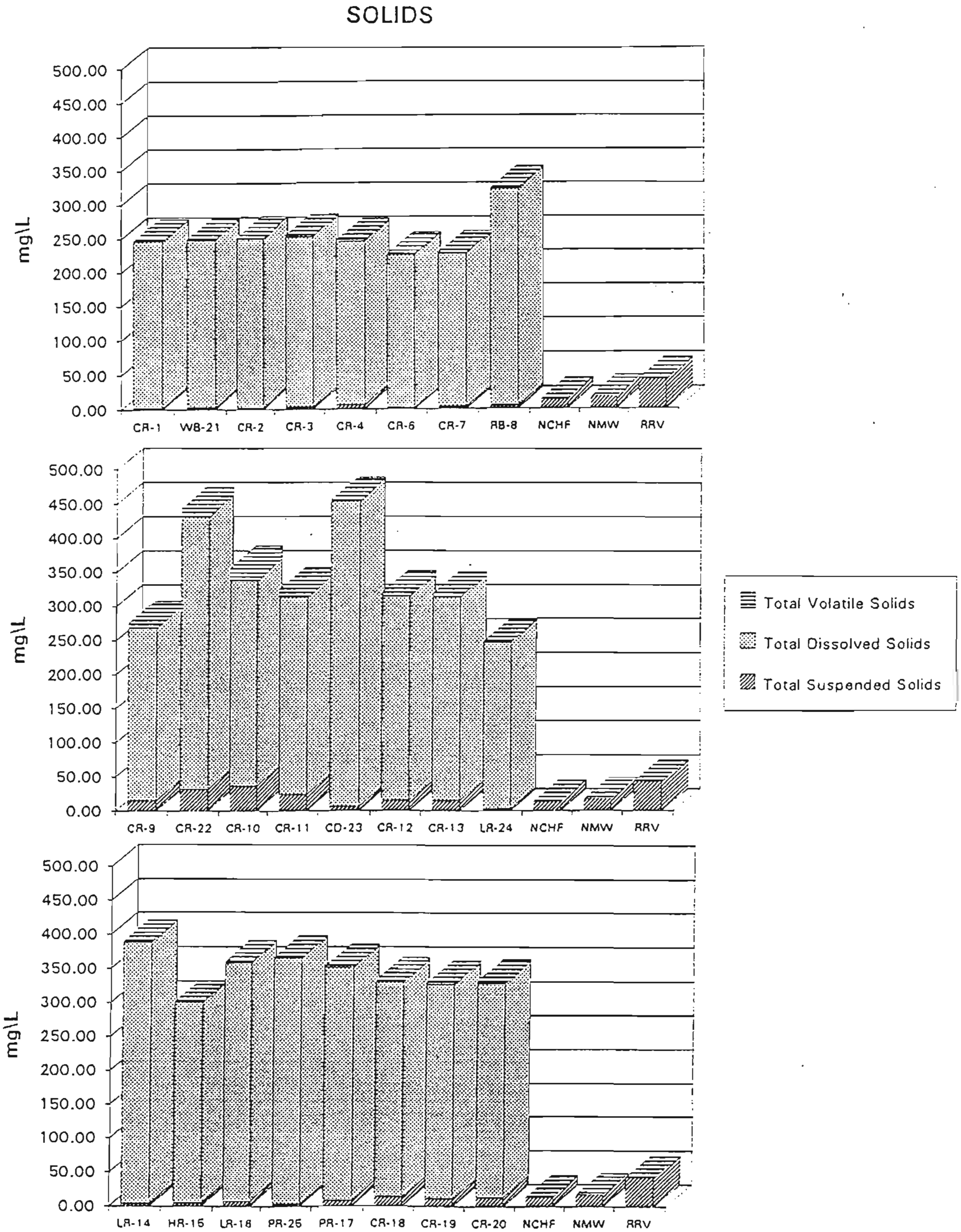
5.1 Water Quality Characteristics

This section presents the results of water quality sample collection and analysis for April 1, 1992-March 31, 1993. The judgment as to whether water quality is "good" or "degraded" is difficult without some frame of reference. Several references are available for evaluating the quality of water, but the most common is comparison to samples collected by others within the region. A second reference is comparison to stream sample locations, presumably uninfluenced by humans (minimally impacted streams). Yet a third is by comparing the longitudinal trends in water quality to factors believed to affect water quality (e.g., land use, point source discharges, eroded stream banks). The importance of these factors are discussed below.

5.1.1 Solids

Solids refers to inorganic or organic matter suspended or dissolved in water. Solids are a general indicator of water quality. Total solids includes "total suspended solids" the portion of total solids retained by a 0.45 μ filter, and "total dissolved solids", the portion which passes through the filter. Volatile solids are a measure of the organic matter fraction of total suspended solids. Phosphorus and agricultural chemicals are often associated with other or attached to suspended solids.

At most locations, total suspended solids are less than 10% of the total solid concentrations (see Figure 5-1). Total suspended solids concentrations increased in the area of the channelized reach and the Kiwosay Outlet (a large wetland bog), presumably because of greater ditch density and decreased channel integrity. Based on median concentrations, total suspended solids increased from approximately 2.5 mg/l in the headwaters of the Clearwater River to 17 mg/l at the downstream site CR-22, within the channelized reach. Between sites CR-10 and CR-11 median concentrations decreased to approximately 7 mg/l and decreased to 2 mg/l by Red Lake Falls. The median total suspended solids concentration on the Lost River remained at 2.5 mg/l upstream downstream between LR-24 and LR-16 (see Figure 5-2). Concentrations were generally least in the upper reaches of the Clearwater River, Lost, and Hill rivers. The observed concentrations are generally lower or typical of the North Central Hardwood Forest and Northern Minnesota Wetland ecoregions.



Note 1: Height of bar equals total solids concentration. Ecoregion (NCHF, NMW, RRV) values are total suspended solids.
Note 2: Ecoregion values represent limited sample size and are not necessarily representative of least impacted areas.

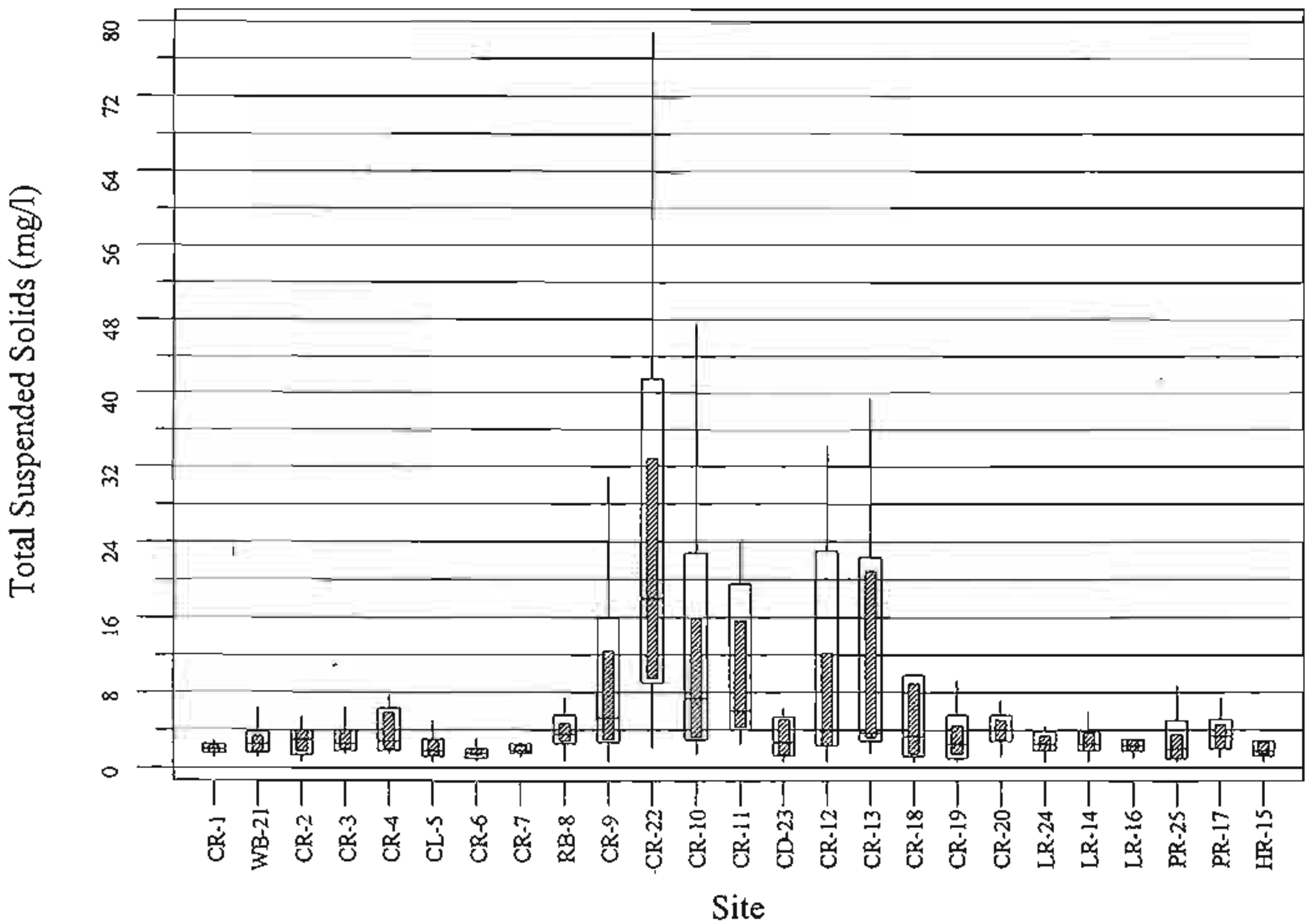
HDR

HDR Engineering Inc.

Red Lake Watershed District — Dedicated to Water Management

Figure 5-1

River Solids Composition
Based on Annual Mean Arithmetic
Concentration



Note: Ecoregion Means for "Minimally Impacted Streams" are:

Red River Valley 48.1 mg/l

Northern Minnesota Wetland 17.1 mg/l

North Central Hardwood Forest 13.7 mg/l

HDR Engineering Inc.

Red Lake Watershed District

Dedicated to Water Management

Legend

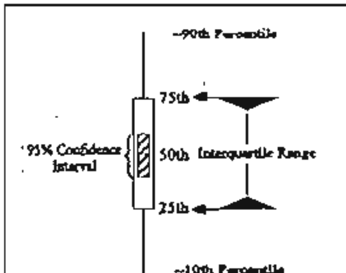


Figure 5-2

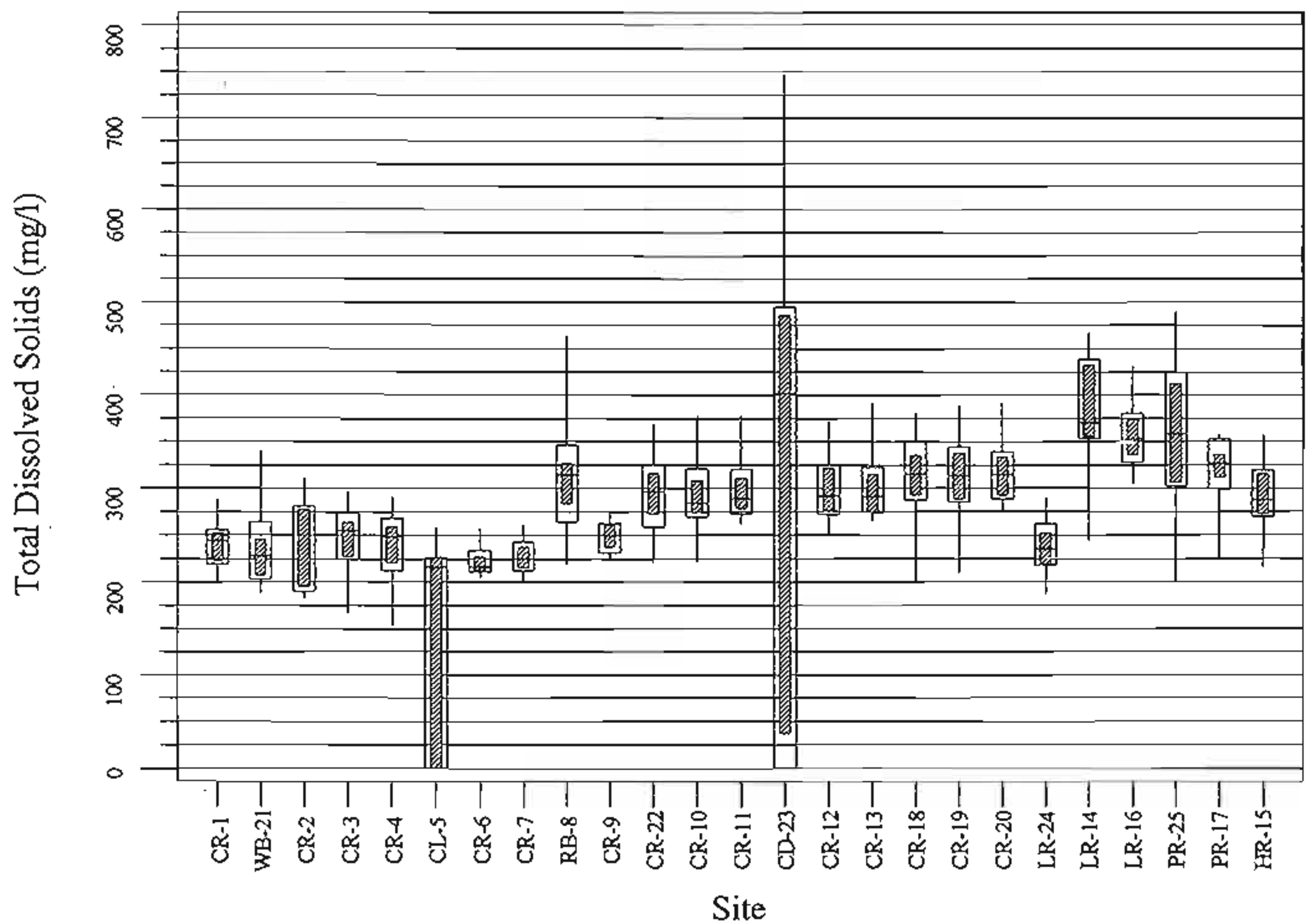
Box and Whisker Plots for Total Suspended Solids, April 1, 1992-March 31, 1993

Total dissolved solids increased longitudinal moving downstream in the Clearwater River. Total dissolved solids increased from approximately 240 mg/l in the headwaters to approximately 280 mg/l at the downstream site CR-20 at Red Lake Falls (see Figure 5-3). The greatest concentrations occurred at CD-23, the location of the County Ditch, and the least within Clearwater Lake (CL-5). Total dissolved solids were generally greater on the Poplar River than the other rivers. Based on median concentrations, total dissolved solids generally comprised more than 90% of the total solids within the Clearwater, Lost and Hill rivers except within the channelized reach (see Figure 5-1).

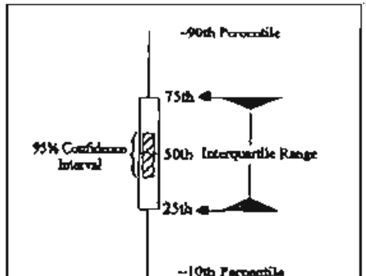
As measured by volatile solids, the organic fraction of total suspended solids comprised up to 50% of total suspended solids (see Figure 5-1 and Figure 5-4). Volatile solids showed the same general longitudinal trend as total suspended solids. Median concentrations were generally less than 2.5 mg/l, except at CR-22 (Kiwosay Outlet) where the median concentration reached 6 mg/l. The large wetland area entering the river at Kiwosay Outlet seems to be a source of total suspended solids, most being organic matter.

Each form of solids, except for total dissolved, exhibited the greatest amount of variability beginning at CR-9 within the channelized reach. The increase in total suspended and volatile solids within these specific regions on the Clearwater River is likely resulting from a number of factors: 1) the degraded physical condition of the Clearwater River, which resulted from channelization and straightening by the U.S. Army Corps of Engineers during the 1950s; 2) the increased density of agricultural ditch and outlets; 3) agriculture as the dominant land use immediately adjacent to the river near these areas; and 4) increased organic matter from the Kiwosay Outlet.

The seasonality of solids concentrations appear to be most related to sample site location and occurrence of rainfall events (Figures 5-5 to 5-8). Total solids concentrations at the headwater locations (CR-1 and WB-21) increased gradually from early June until early October when concentrations tended to decrease when spring runoff occurred. Concentrations of total solids within the upper Clearwater, Poplar and Hill rivers also tended to be somewhat greater during the winter months. By contrast, site RB-8 on the Ruffy Brook tributary, shows no discernible seasonal trend in total solids. Concentrations tended to oscillate throughout the year with peaks in May and October.



Legend

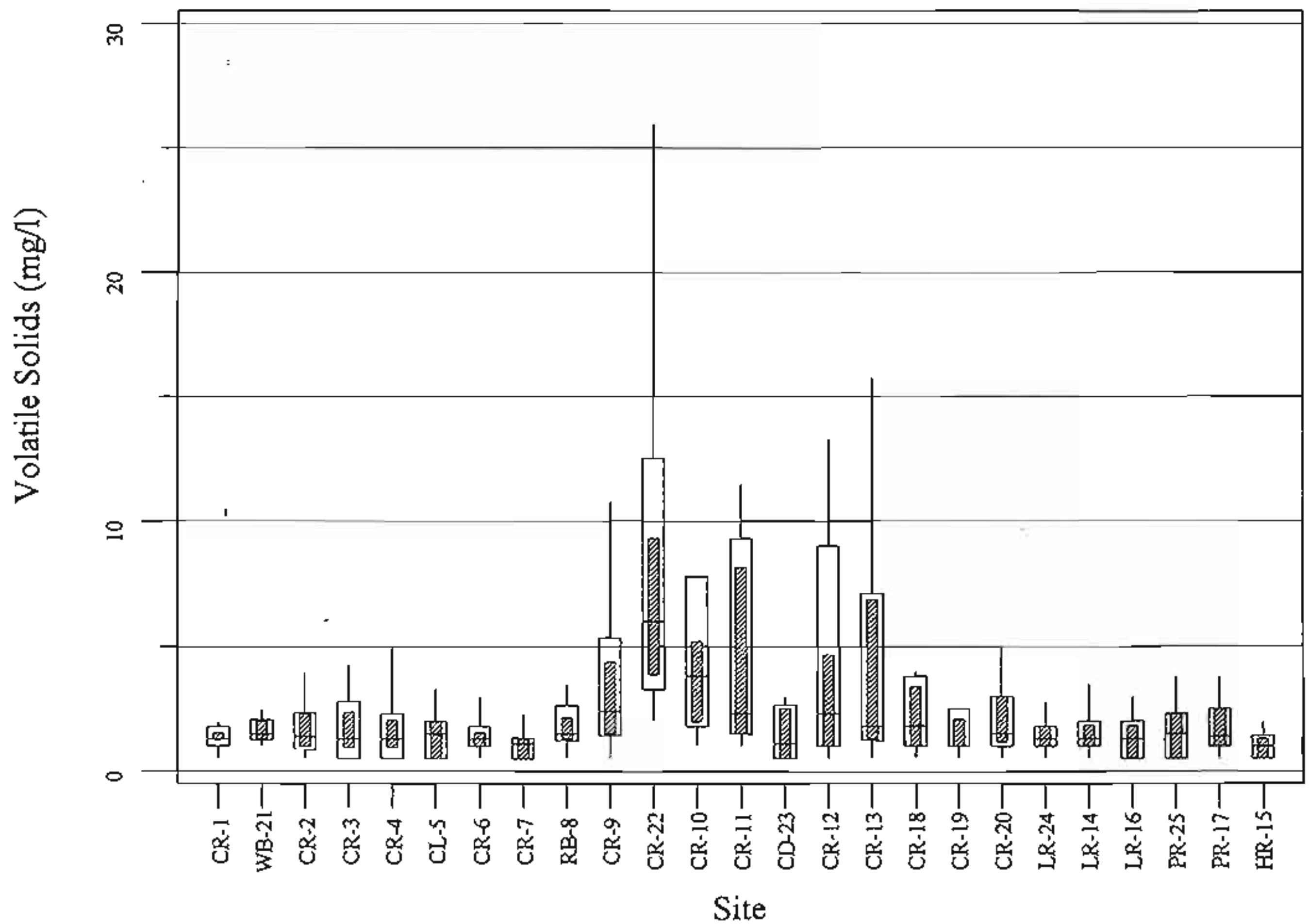


HDR Engineering Inc.

Red Lake Watershed District
Dedicated to Water Management

Figure 5-3

Box and Whisker Plots for
Total Dissolved Solids,
April 1, 1992-March 31, 1993



Legend

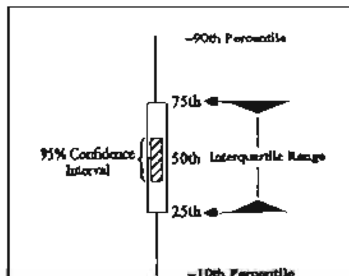
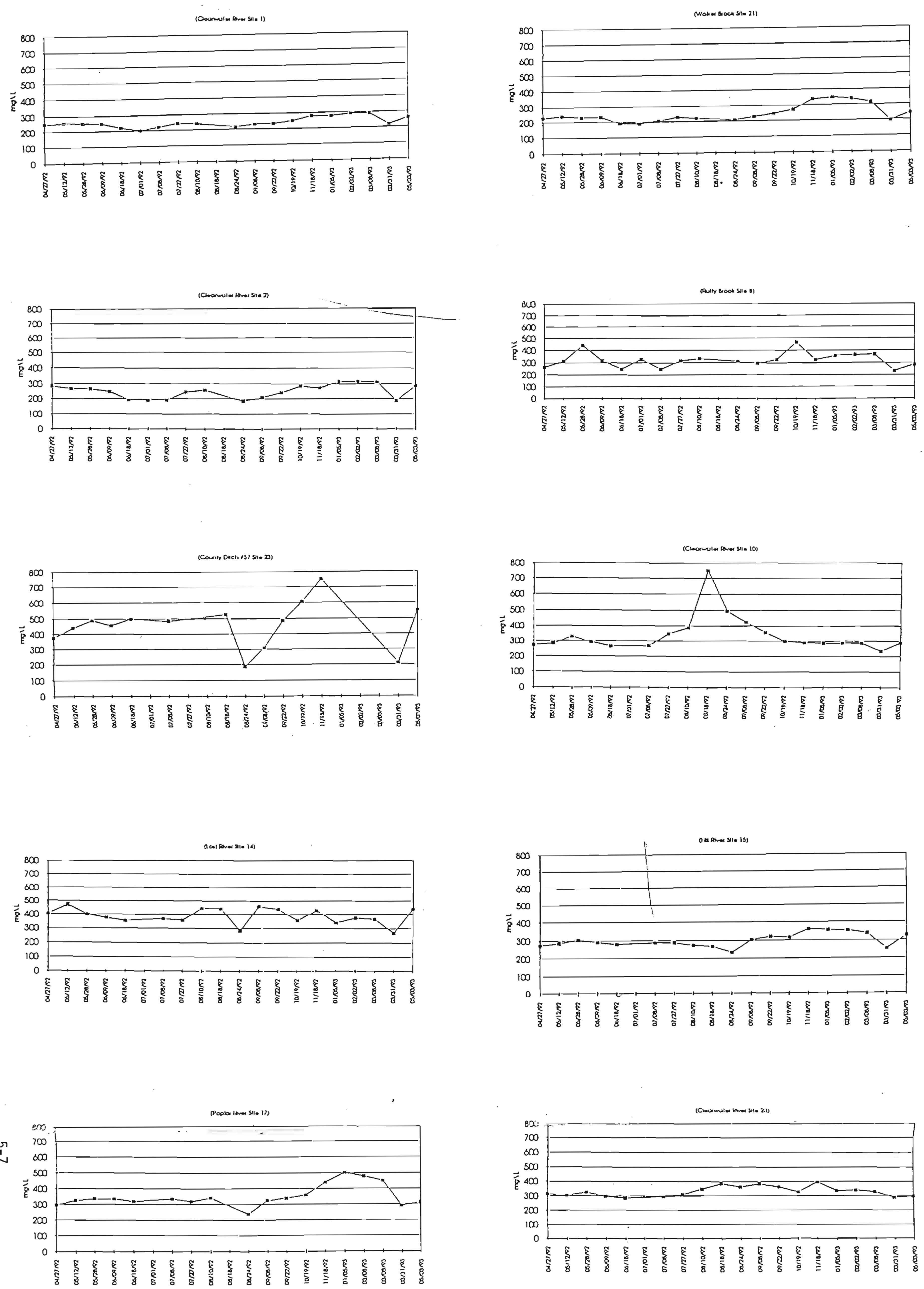


Figure 5-4

Box and Whisker Plots for Volatile Solids, April 1, 1992-March 31, 1993

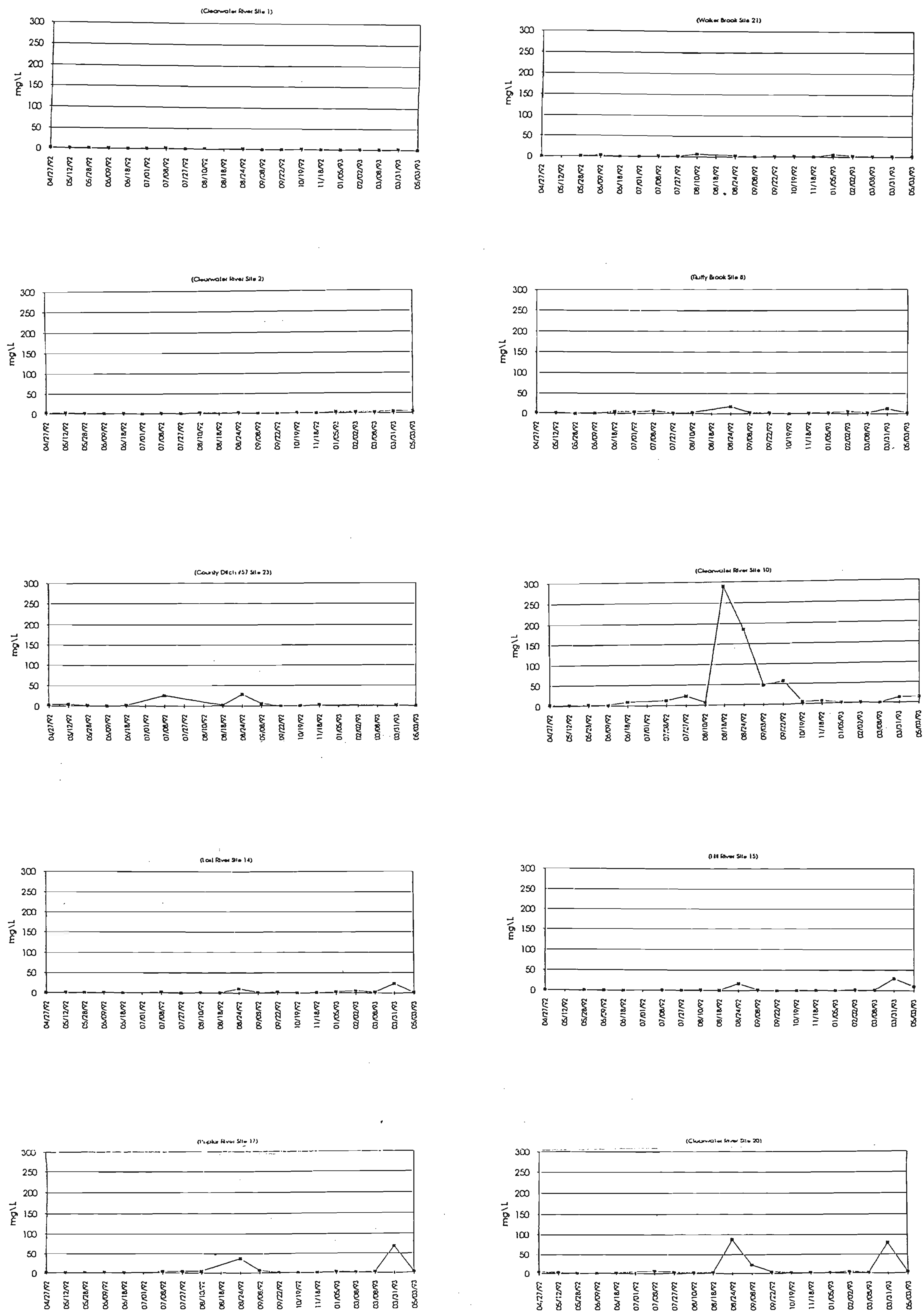
HDR Engineering Inc.



HDR Engineering Inc.

Figure 5-5

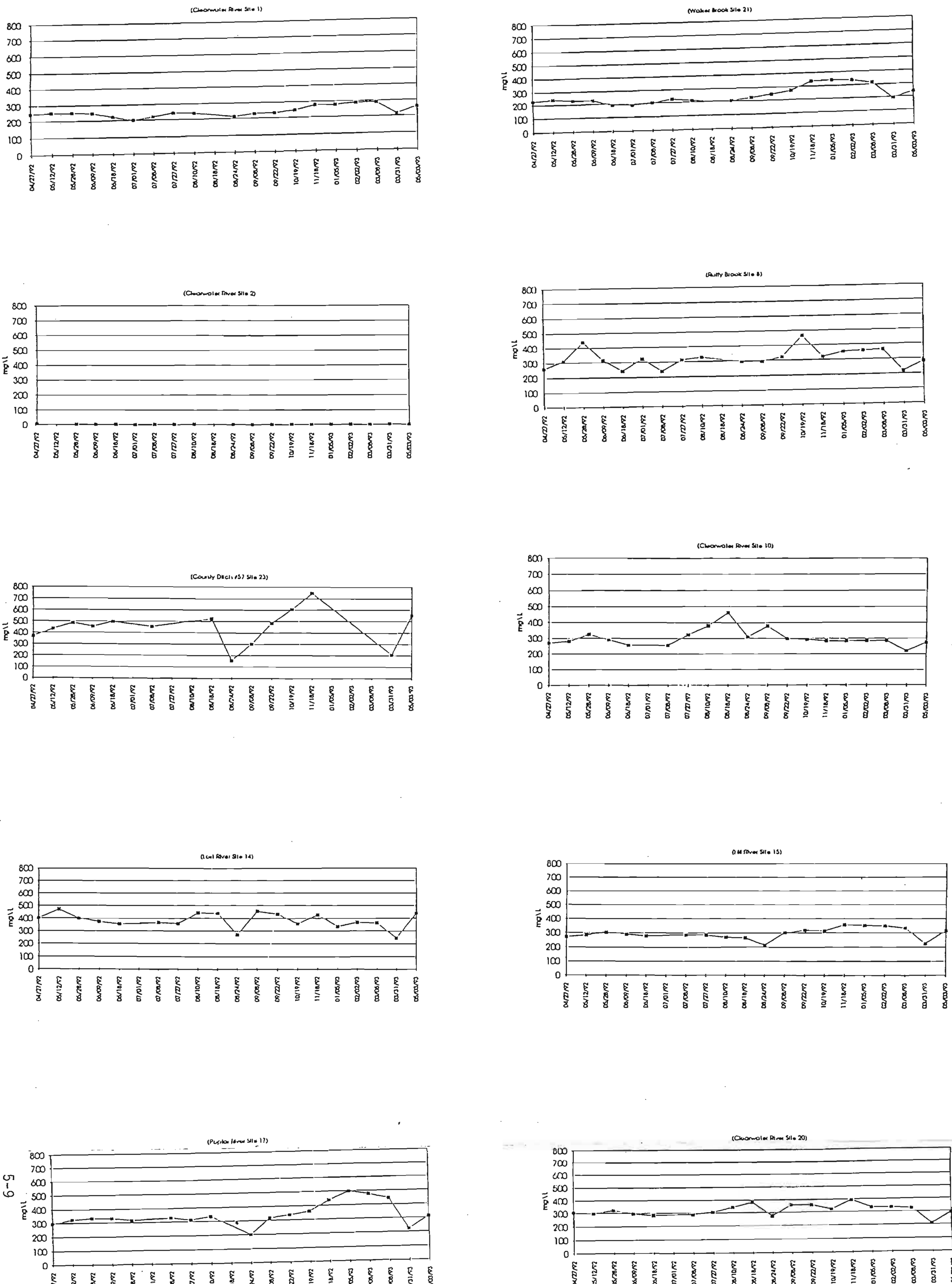
Seasonal Trends in Total Solids Concentrations at Select Locations



HDR Engineering Inc.

Figure 5-6

Seasonal Trends in Total Suspended Solids Concentrations at Select Locations

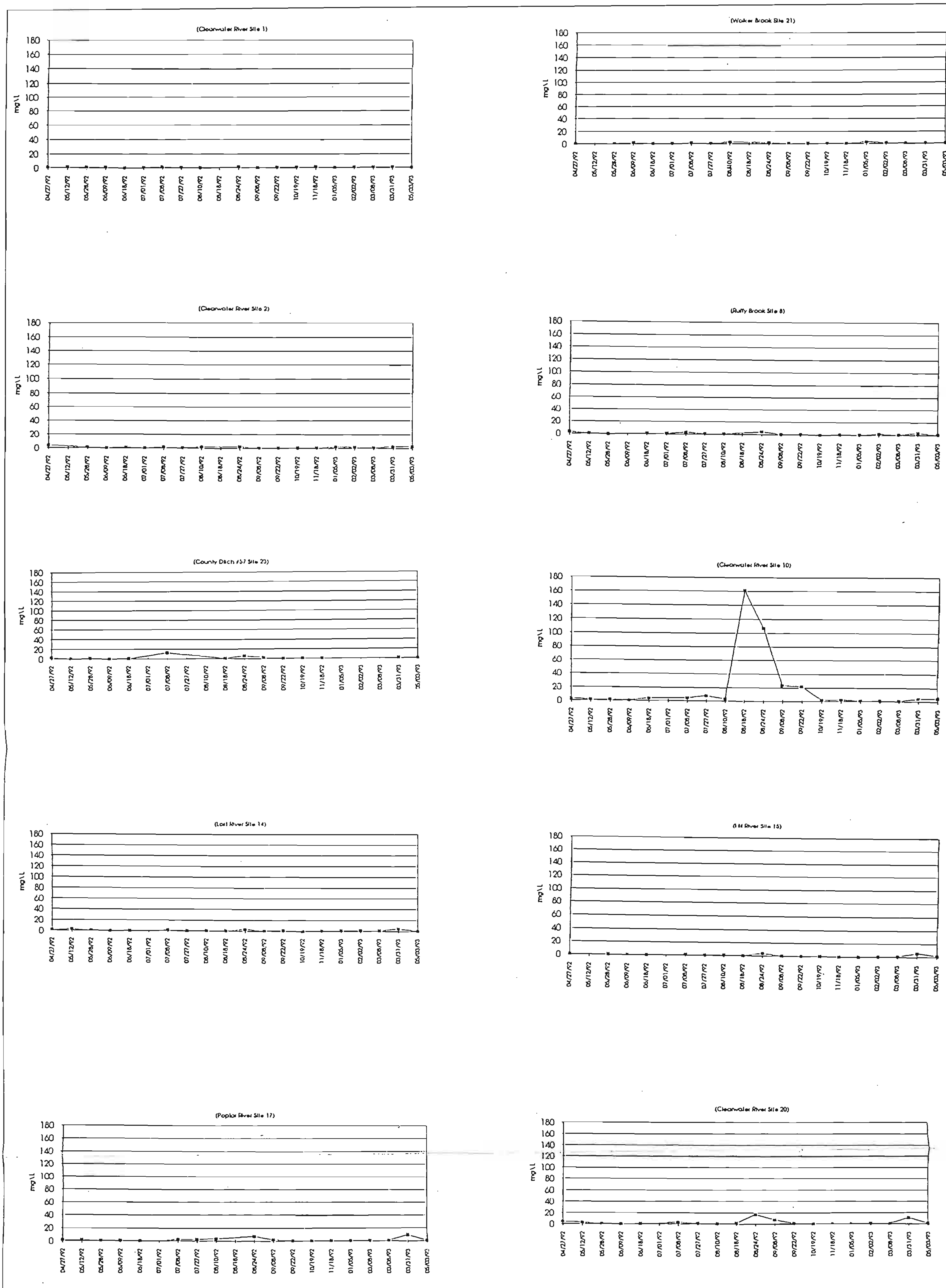


HDR Engineering Inc.

Red Lake Watershed District
Dedicated to Water Management

Figure 5-7

Seasonal Trends in Total Dissolved Solids at Select Locations



HDR
HDR Engineering Inc.

Red Lake Watershed District
Dedicated to Water Management

Figure 5-8

Seasonal Trends in Volatile Solids
at Select Locations

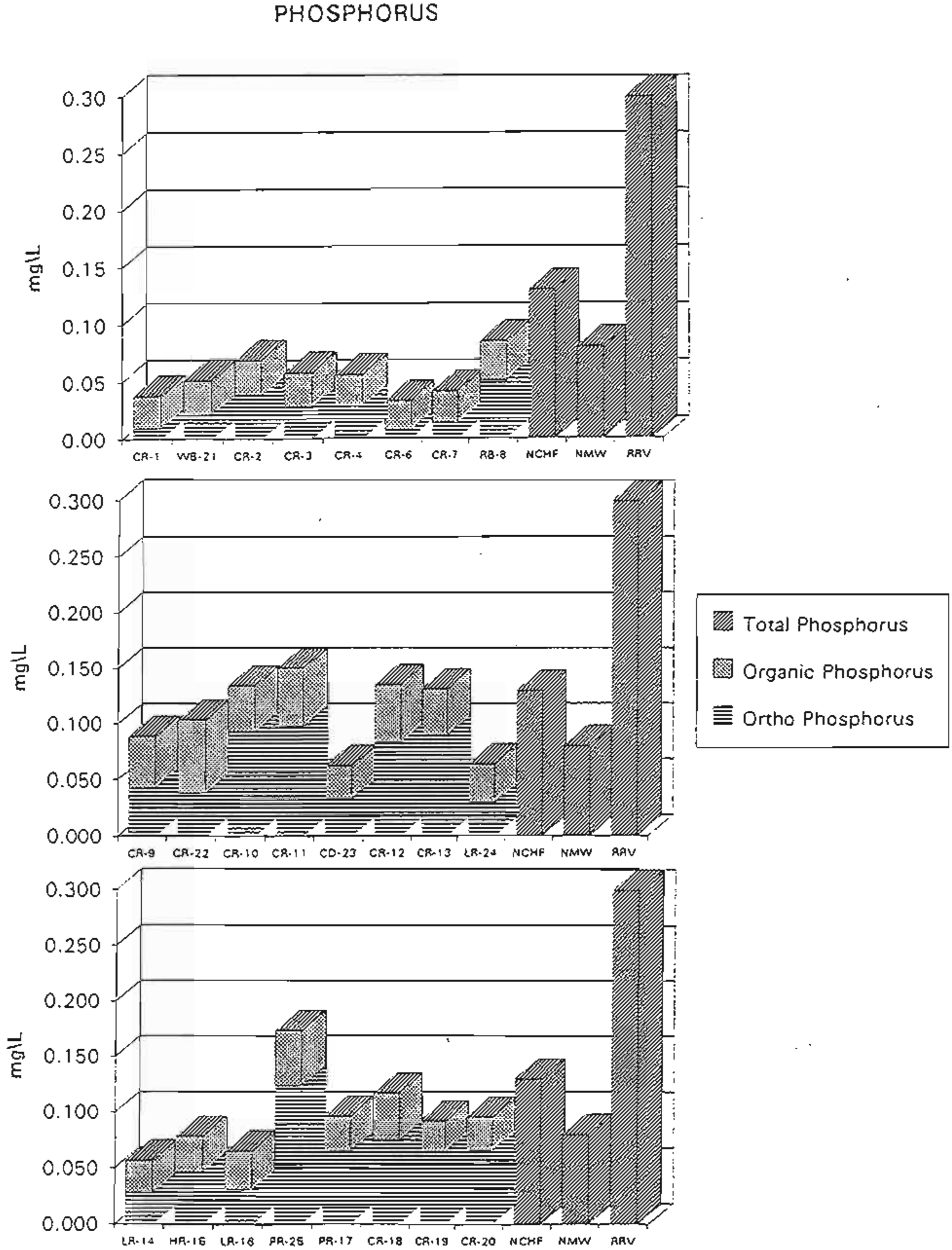
Within the middle portion of the Clearwater River, CR-10 showed a large increase in all forms of solids beginning in late July and ending in early September (Figures 5-5 to 5-8). The largest peak in solids corresponds with the August 21st storm, and is superimposed on the gradual increase during the period of discharge from agricultural rice producers. Discharge from agricultural rice producers is typically completed by late July. The relatively large proportion of volatile solids suggests a considerable portion of the solids are organic in nature. In general, volatile solids tend to remain constant through much of the year, with small increases during storm events.

Data obtained from CD-23 (County Ditch 57) shows the influence of seasonal storm events on solid concentrations. A decrease in total solids and total dissolved solids on August 24, 1992 corresponds with the occurrence of a large basin wide storm event. At the downstream most location on the Clearwater River (CR-20), the total solids concentration increased gradually from late March through mid November. The August storm event, produced a marked, but temporary increase in total suspended and volatile solids.

Limited data are available for comparing the solids concentrations measured during this study with "typical" regional concentrations. The U.S. Geological Survey (Tornes and Bringham 1994) reported median total suspended sediment concentrations at mainstream locations on the Red River and tributaries to the Red River ranging from 10-100 mg/l. The USGS developed a regression relationship between suspended sediment and total suspended solids for a limited number of select locations within Minnesota. These limited data, although preliminary, resulted in a slope of 2.27 (i.e., suspended sediment ~2.27 times greater than suspended solids). Using these preliminary data, solids data obtained in this study and from those stations evaluated by the USGS within the basin compare favorably. The MPCA has also characterized "minimally impacted streams" by ecoregion within Minnesota. Figure 5-1 shows that most sites within the Clearwater River watershed have lower total suspended solid concentrations than minimally impacted streams located in the Northern Central Hardwood Forest ecoregion.

5.1.2 Phosphorus

Phosphorus is an important nutrient that affects the biological productivity of fresh waters. Total phosphorus is comprised of inorganic (orthophosphates) and organically bound forms. Annual mean total phosphorous concentrations ranged from near 0.045 mg/l in the headwaters of the Clearwater River to nearly 0.150 mg/l downstream at CR-11 (Figure 5-9). The largest mean



Note: Ecoregion values represent limited sample size and are not necessarily representative of least impacted areas.

HDR Engineering Inc.

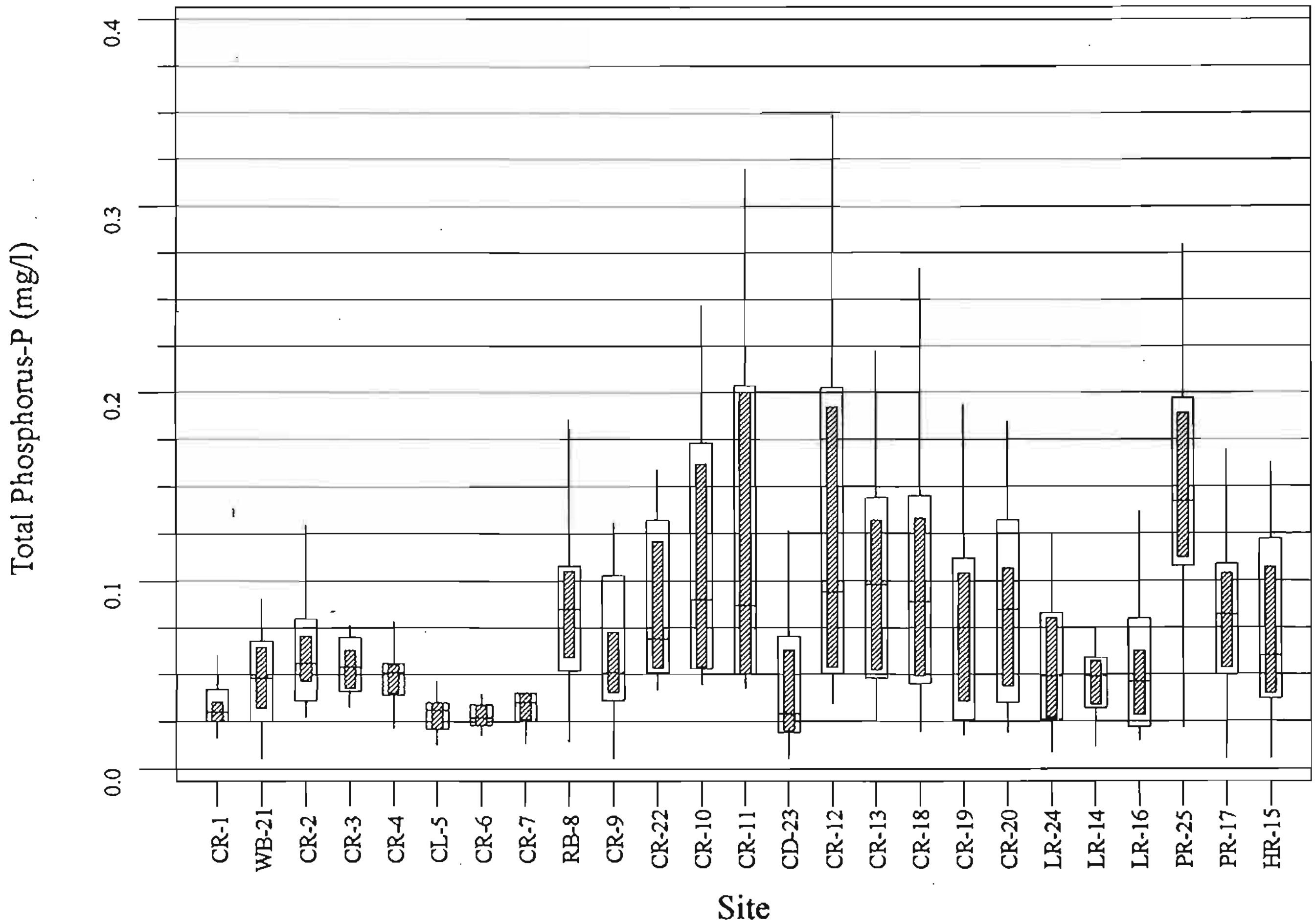
Red Lake Watershed District
Dedicated to Water Management

Figure 5-9
Phosphorus Composition (as P)
Based on Annual Mean
Arithmetic Concentrations,
April 1, 1992-March 31, 1993

concentration exceeded 0.150 mg/l and occurred on the Poplar River at PR-25, immediately downstream from McIntosh. This high total phosphorus concentration is likely the result of discharge from their wastewater stabilization lagoons. High concentrations of total phosphorus for the upper reaches of the Clearwater River also occur immediately downstream from Bagley at CR-2 (see Figure 5-10). This location is also presumably influenced by domestic discharges, after treatment within lagoons at Bagley. Concentrations of total phosphorus and orthophosphate were generally greater in the channelized reach. Organic phosphorus concentrations were more "stable" from upstream to downstream, with the greatest median concentration at the Kiwosay outlet. Figures 5-10 through 5-12 show descriptive statistics for phosphorus "species". Interestingly, concentrations measured within County Ditch 57 (CD-23) were lower than many locations.

Total phosphorus concentrations measured in the Clearwater River watershed were generally lower than the concentrations reported by the USGS for locations with larger drainage areas within the Red River Basin (Tornes and Bringham 1994). Most locations evaluated by the USGS showed median concentrations between 0.1 and 0.2 mg/l, compared to 0.03 and 0.1 mg/l in the study. Notable exceptions reported by the USGS occurred at the Ottertail River, Wild Rice River at Twin Valley, the South Branch of Two Rivers at Hallock and the Roseau River at Malung. These sites showed median concentrations near 0.05 mg/l. The MPCA (1993) reported mean total phosphorus concentrations for minimally impacted streams of 0.3 mg/l, 0.07 mg/l and 0.15 mg/l for the Red River Valley, Northern Minnesota Wetland and North Central Hardwood Forest ecoregions, respectively. Maximum concentrations occurred in the channelized reach near CR-12. Total phosphorus concentrations were generally comprised of nearly equal portions of orthophosphate and organic phosphorus in headwater areas but greater portions of orthophosphate at downstream locations (see Figure 5-9).

Seasonal trends in total phosphorus concentrations at headwater locations (CR-1 and WB-21) were not readily discernable (Figure 5-13). However, many locations showed maximum total phosphorus concentrations in early spring or during periods of high runoff (e.g. storms). This same general trend is present with regard to orthophosphate and organic phosphorus (see Figures 5-14 and 5-15). Total phosphorus concentrations were greatest within the lower reaches of the Clearwater and Poplar rivers (Figures 5-14 and 5-15) and these same rivers also showed high concentrations in late March, corresponding with spring runoff.



Note: Ecoregion Means for "Minimally Impacted Streams" are:
Red River Valley 0.3 mg/l
Northern Minnesota Wetland 0.07 mg/l
North Central Hardwood Forest .13 mg/l

HDR Engineering Inc.

Red Lake Watershed District
Dedicated to Water Management

Legend

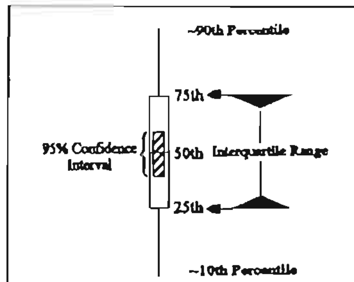
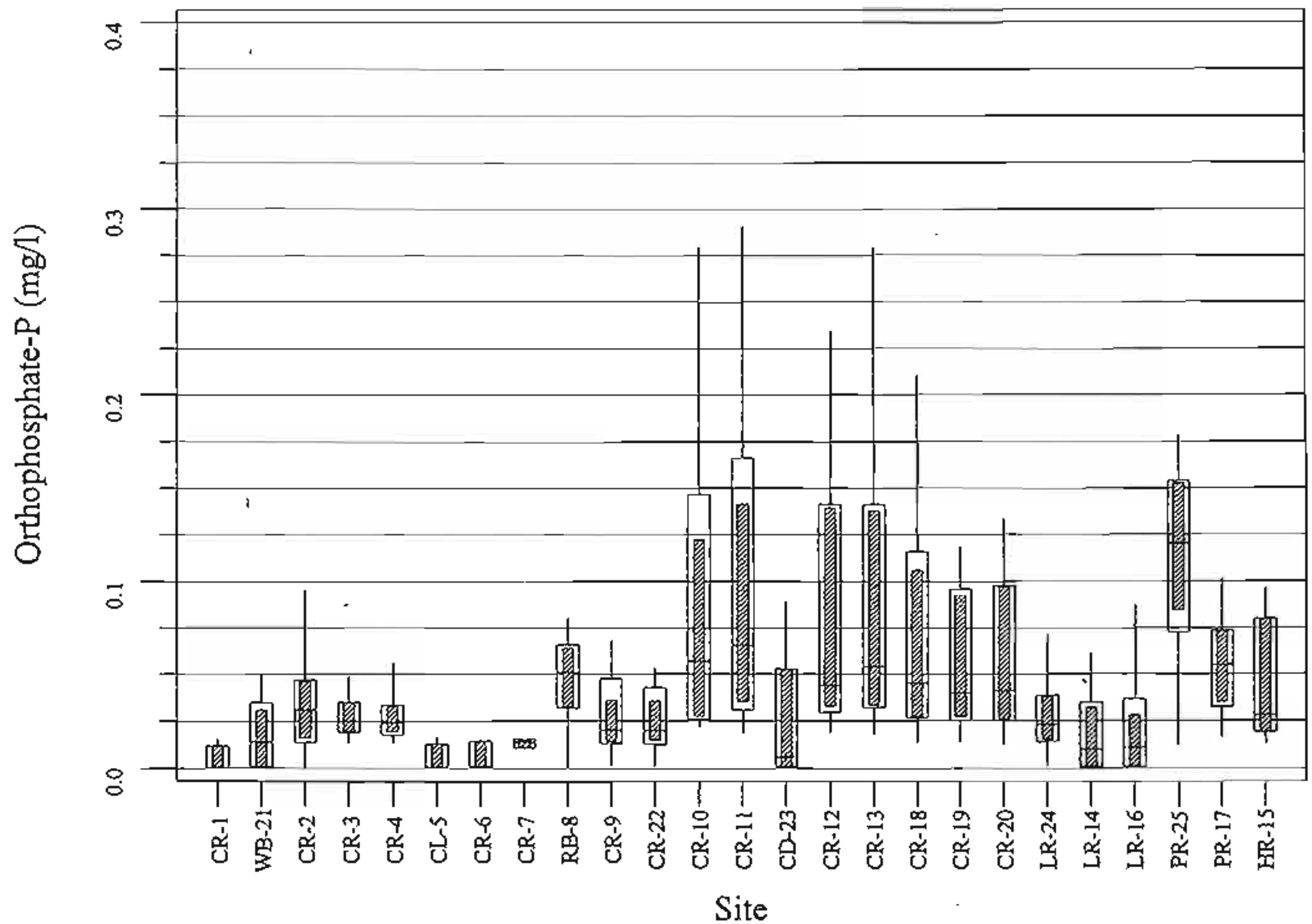


Figure 5-10

Box and Whisker Plots for Total Phosphorus (as P), April 1, 1992-March 31, 1993



Legend

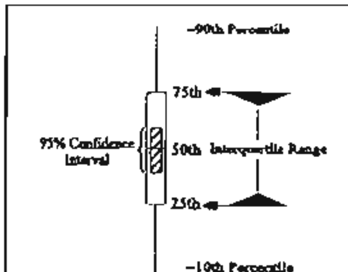
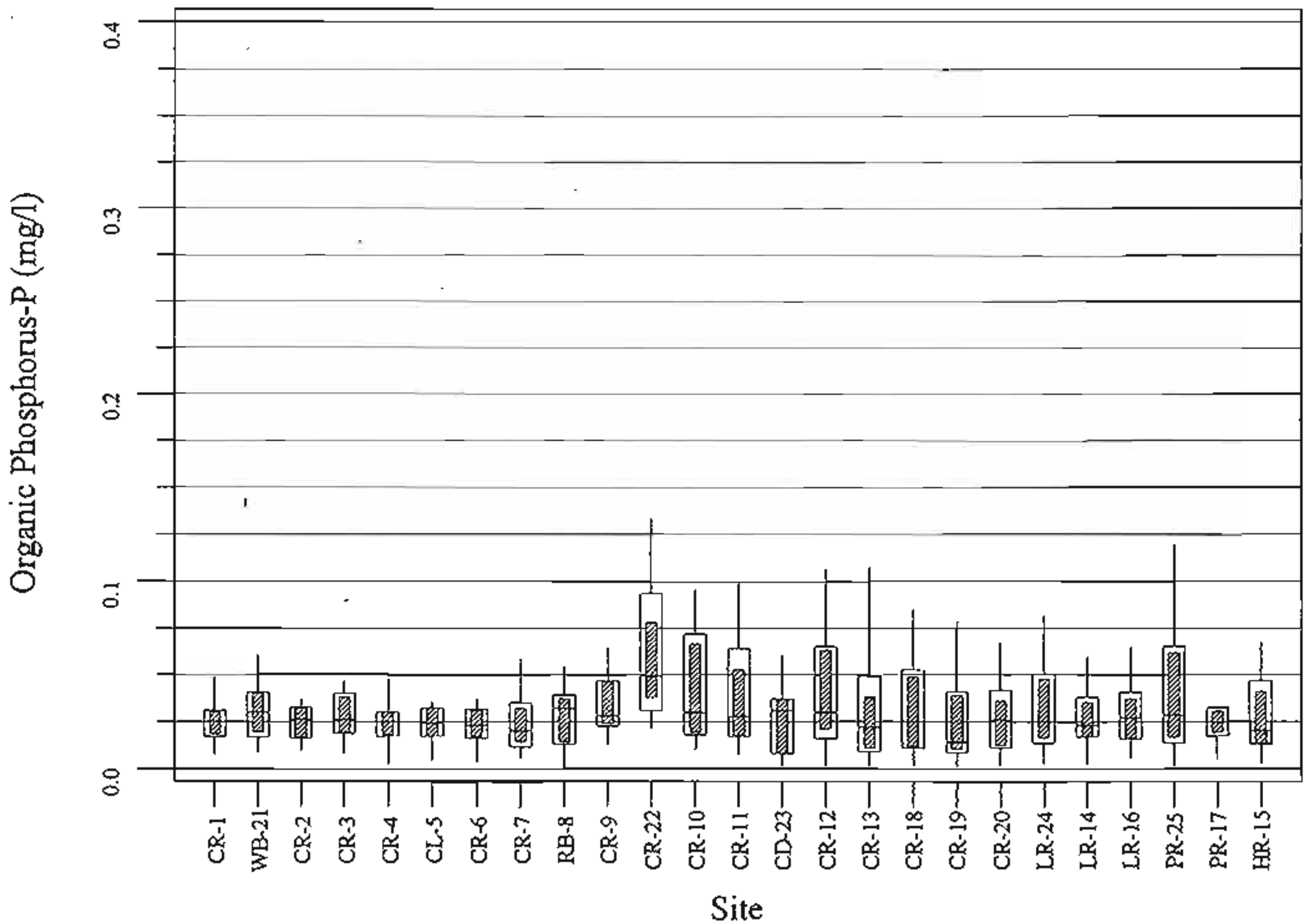


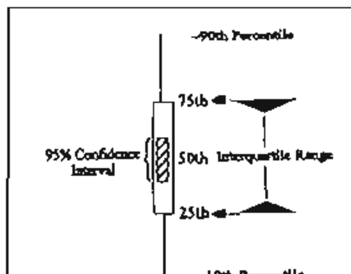
Figure 5-11

Box and Whisker Plots for Orthophosphate (as P), April 1, 1992-March 31, 1993

HDR Engineering Inc.



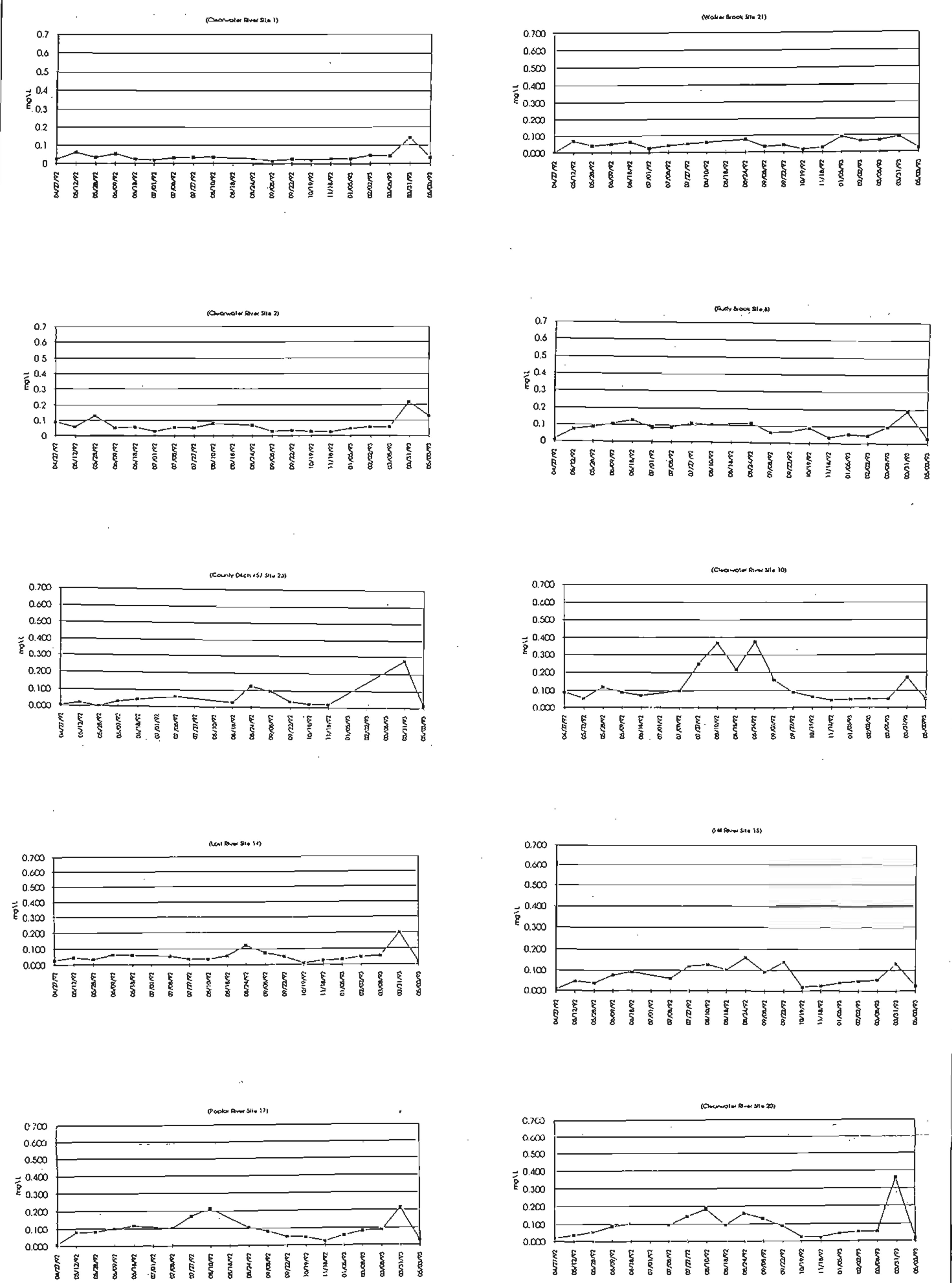
Legend



HDR Engineering Inc.

Figure 5-12

Box and Whisker Plots for Organic Phosphorus (as P), April 1, 1992-March 31, 1993

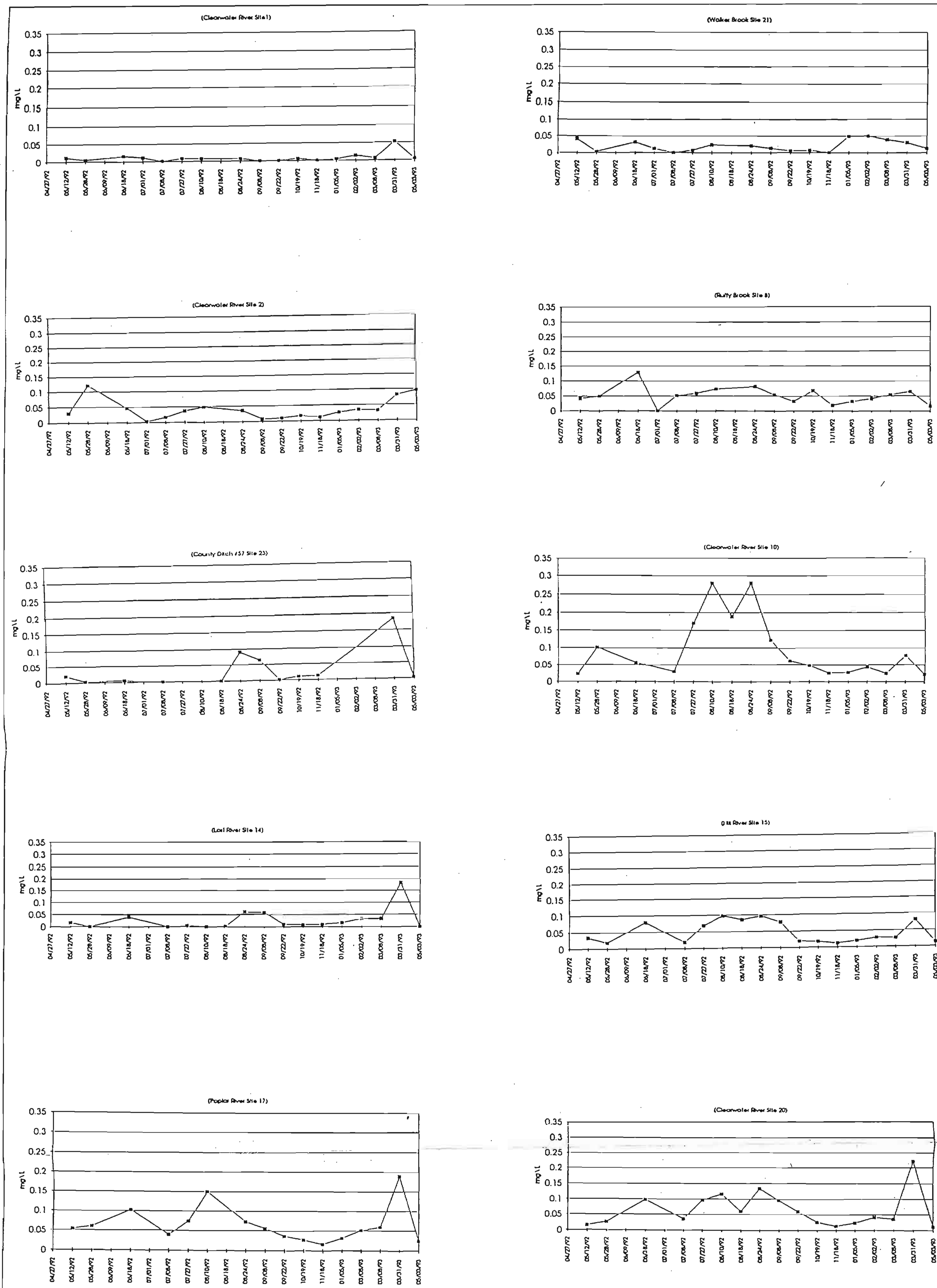


HDR Engineering Inc.

Red Lake Watershed District
Dedicated to Water Management

Figure 5-13

Seasonal Trends in Total Phosphorus (as P) at Select Locations



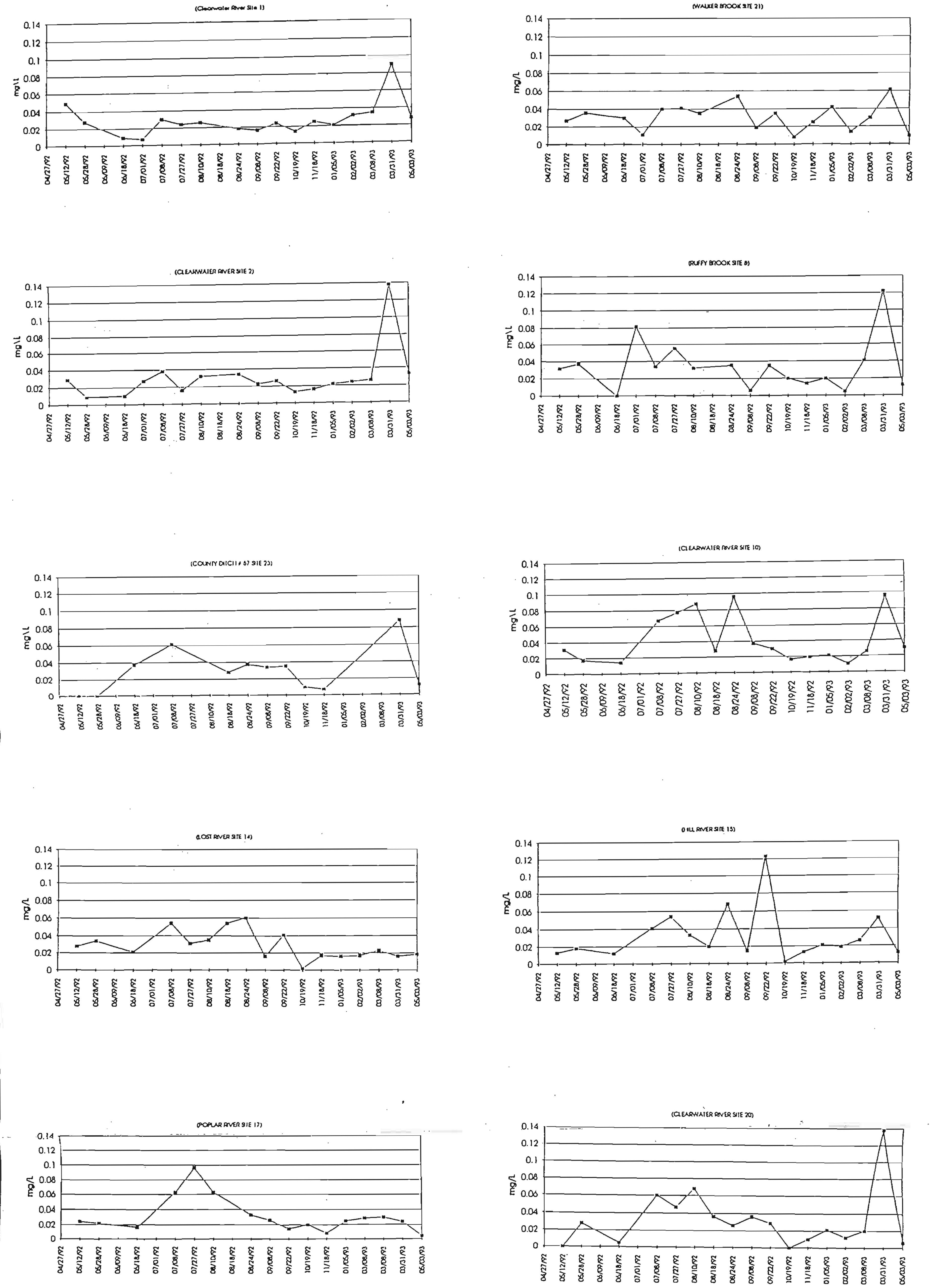
HDR

HDR Engineering Inc.

Red Lake Watershed District
Dedicated to Water Management

Figure 5-14

Seasonal Trends in Orthophosphate (as P) at Select Locations



HDR Engineering Inc.

Red Lake Watershed District
Dedicated to Water Management

Figure 5-15

Seasonal Trends in Organic Phosphorus (as P) at Select Locations

The concentrations of total phosphorus and orthophosphate reached maxima in late August and early March at CD-23 (County Ditch 57). The maxima in late August occurred during the period of a major storm event. The March peak is believed to be the result of early spring runoff. Land use also appears to influence phosphorus levels within certain regions of the Clearwater River. Site CR-10, located in the middle reaches of the Clearwater River showed maximum total phosphorus and orthophosphate concentrations beginning in late July through early September (for more information see data on pages 6-11 through 6-17). This is the same phenomena present for solids. At the mouth of the Clearwater River, CR-20 showed seasonal patterns similar to the Lost and Hill rivers.

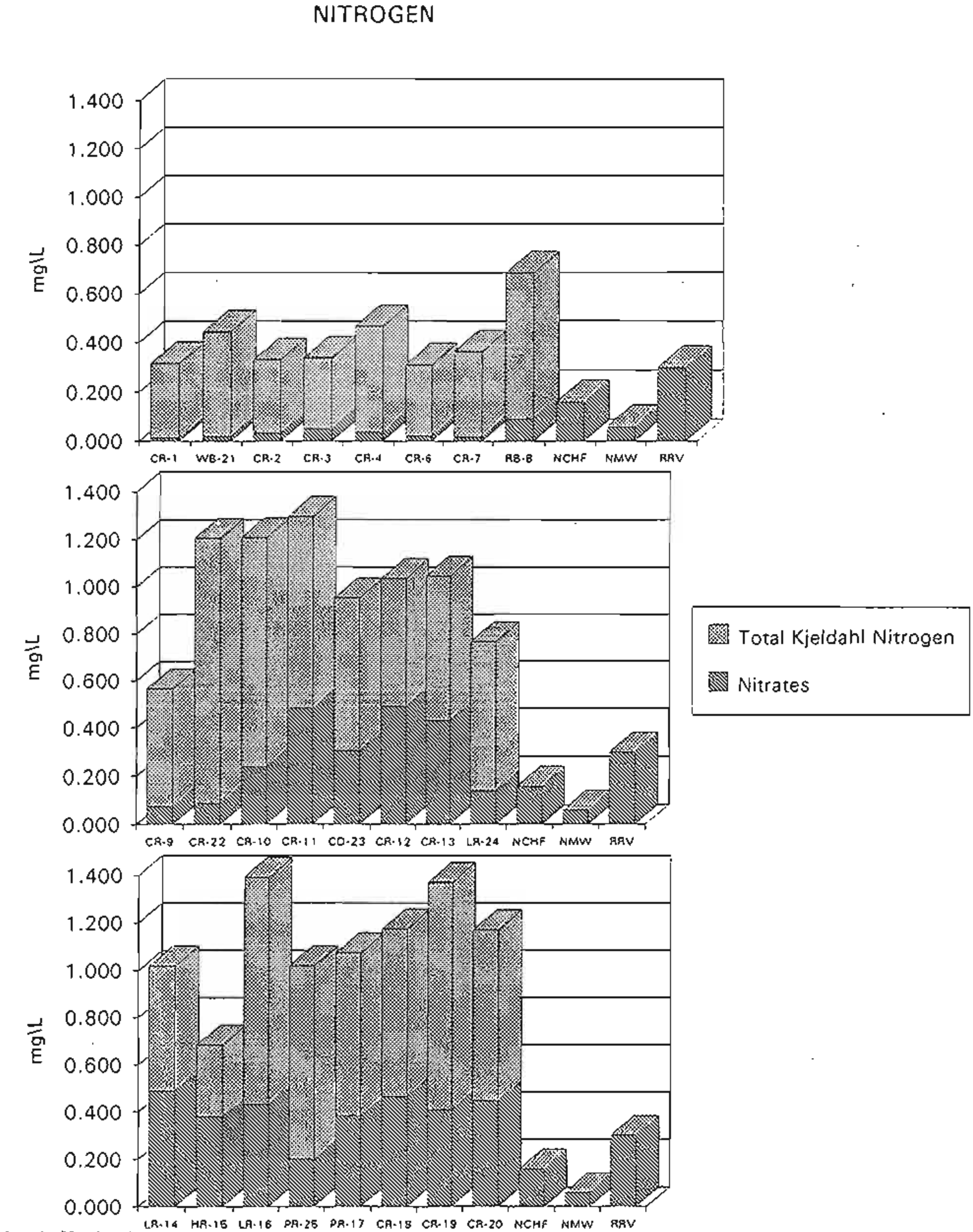
5.1.3 Nitrogen

Like phosphorus, nitrogen is also an important nutrient that affects productivity in fresh waters. In fresh water systems, nitrogen occurs in numerous forms. The forms measured in this study include: total nitrogen, Total Kjeldahl Nitrogen (TKN), ammonia and nitrate. Although nitrite was not measured, it is generally present in very small amounts in surface waters.

Total nitrogen is comprised primarily of organic nitrogen in the upstream reaches of the Clearwater River, and nearly equal proportions of nitrate and organic nitrogen in the lower reaches (Figure 5-16). The change in land use from predominantly forested to agricultural appears to influence nitrate concentrations. Nitrate concentrations on the Hill River, Poplar River and Lost River were similar to the lower reaches of the Clearwater River (Figure 5-17). The lowest nitrate concentrations occurred on the upper reaches of the Clearwater River increased through the channelized reach, remaining nearly constant to the mouth at Red Lake Falls. This initial increase occurs near the Kiwosay Outlet, a large peat wetland. The concentrations observed at CD-23 (County Ditch 57) were low, being comparable to values obtained for the upper reaches of the Clearwater River.

Nitrate concentrations measured during this study were lower than previously reported. The USGS reported a wide range in nitrate plus nitrite concentrations within the Red River Basin, with median values ranging from less than 0.01 mg/l to nearly 0.8 mg/l. The MPCA reported mean concentrations of 0.30, 0.16 and 0.08 mg/l for the Red River Valley, North Central Hardwood Forest and Northern Lakes and Forests ecoregions, respectively.

Median TKN ranged from 0.01-0.85 mg/l among the sites (see Figure 5-18). Concentrations were greatest at CR-22 (Kiwosay Outlet), CR-10, within Clearwater Lake and downstream at CR-19. Concentrations on the Hill river were generally least. The concentrations measured were

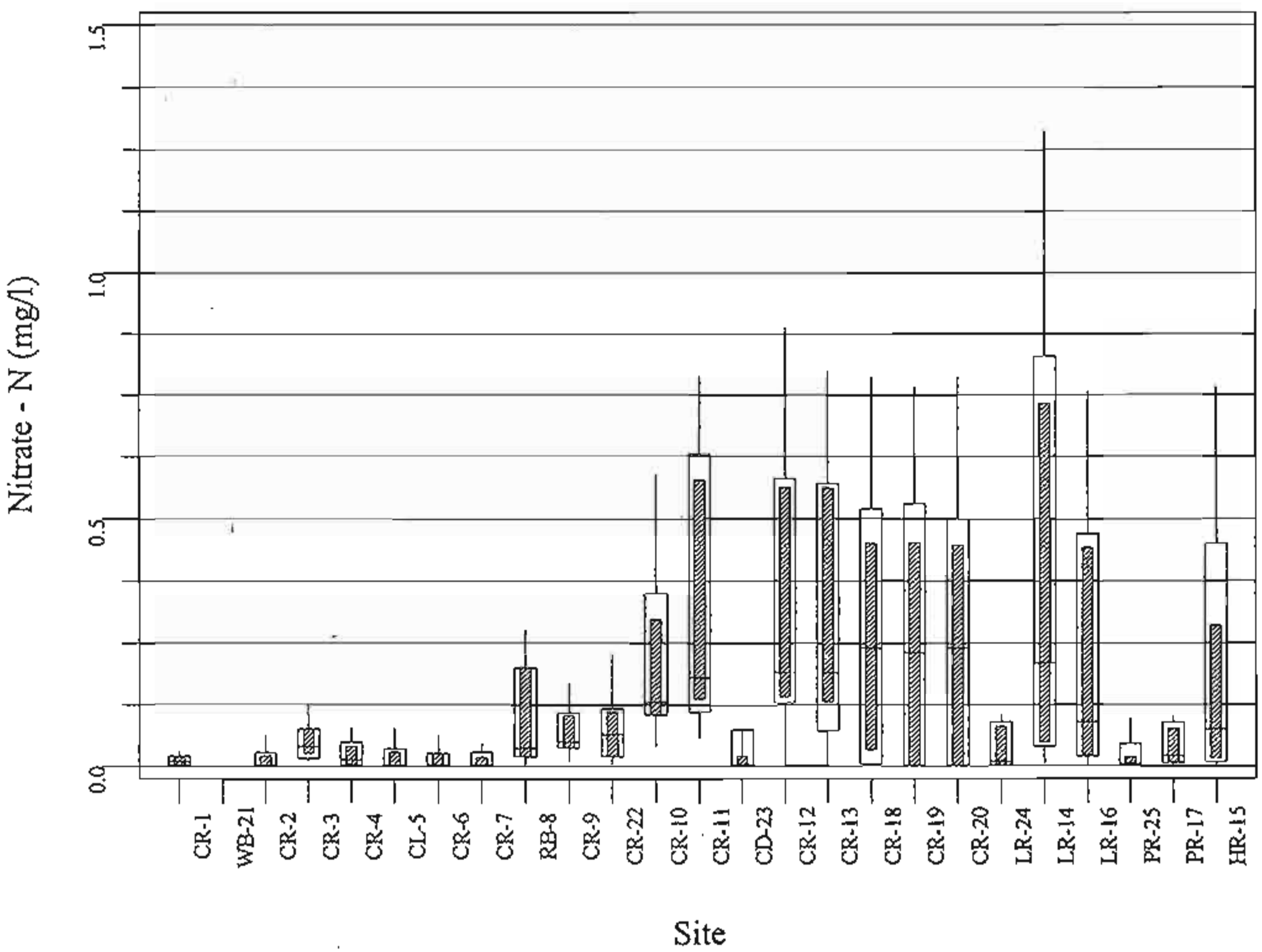


Note 1: Height of bar equals total nitrogen concentration. Ecoregion (NCHF, NMW, RRV) values are nitrate + nitrite.
Note 2: Ecoregion values represent limited sample size and are not necessarily representative of least impacted areas.
Note 3: Ammonia Nitrogen was generally less than minimum detection limit.

HDR Engineering Inc.

Red Lake Watershed District — Dedicated to Water Management

Figure 5-16
Nitrogen Composition (as N)
Based on Annual Mean
Arithmetic Concentrations,
April 1, 1992-March 31, 1993



Legend

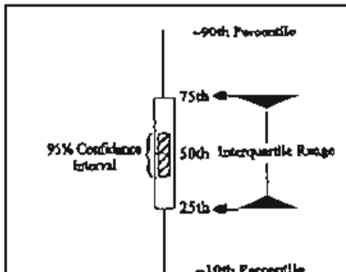
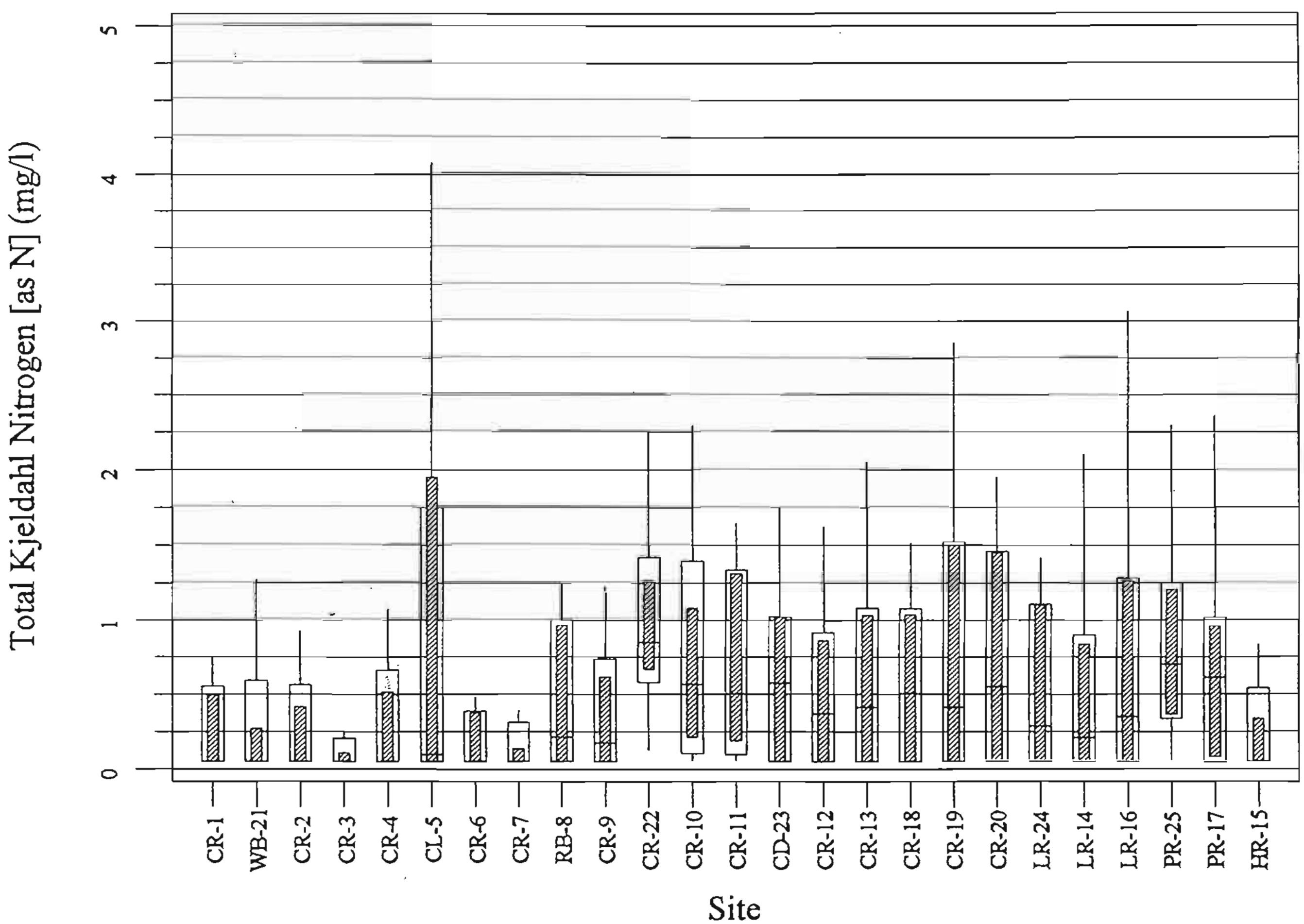


Figure 5-17

Box and Whisker Plots
for Nitrate (as N),
April 1, 1992-March 31, 1993

HDR Engineering Inc.

Red Lake Watershed District
Dedicated to Water Management



Legend

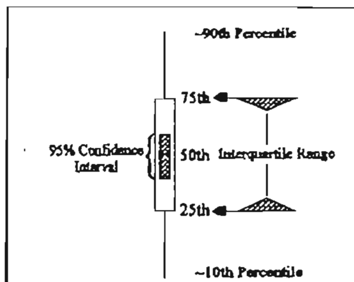


Figure 5-18

Box and Whisker Plots for Total Kjeldahl Nitrogen (as N), April 1, 1992-March 31, 1993

Red Lake Watershed District
Dedicated to Water Management

HDR Engineering Inc.

generally less than those reported by the USGS within the Red River Basin. Ammonia concentrations were below the minimum detection limit at nearly all sites throughout the study (see Figure 5-19). The Kiwosay Outlet (CR-22) was the only location showing measurable ammonia concentrations. This suggests a reducing environment within the peat wetland followed by rapid volatilization and biological uptake.

On a seasonal basis, increases in the various forms of nitrogen corresponded to storm runoff (Figures 5-20 to 5-22). Concentrations were typically greatest during the spring months and around August 24, when a large rainfall occurred.

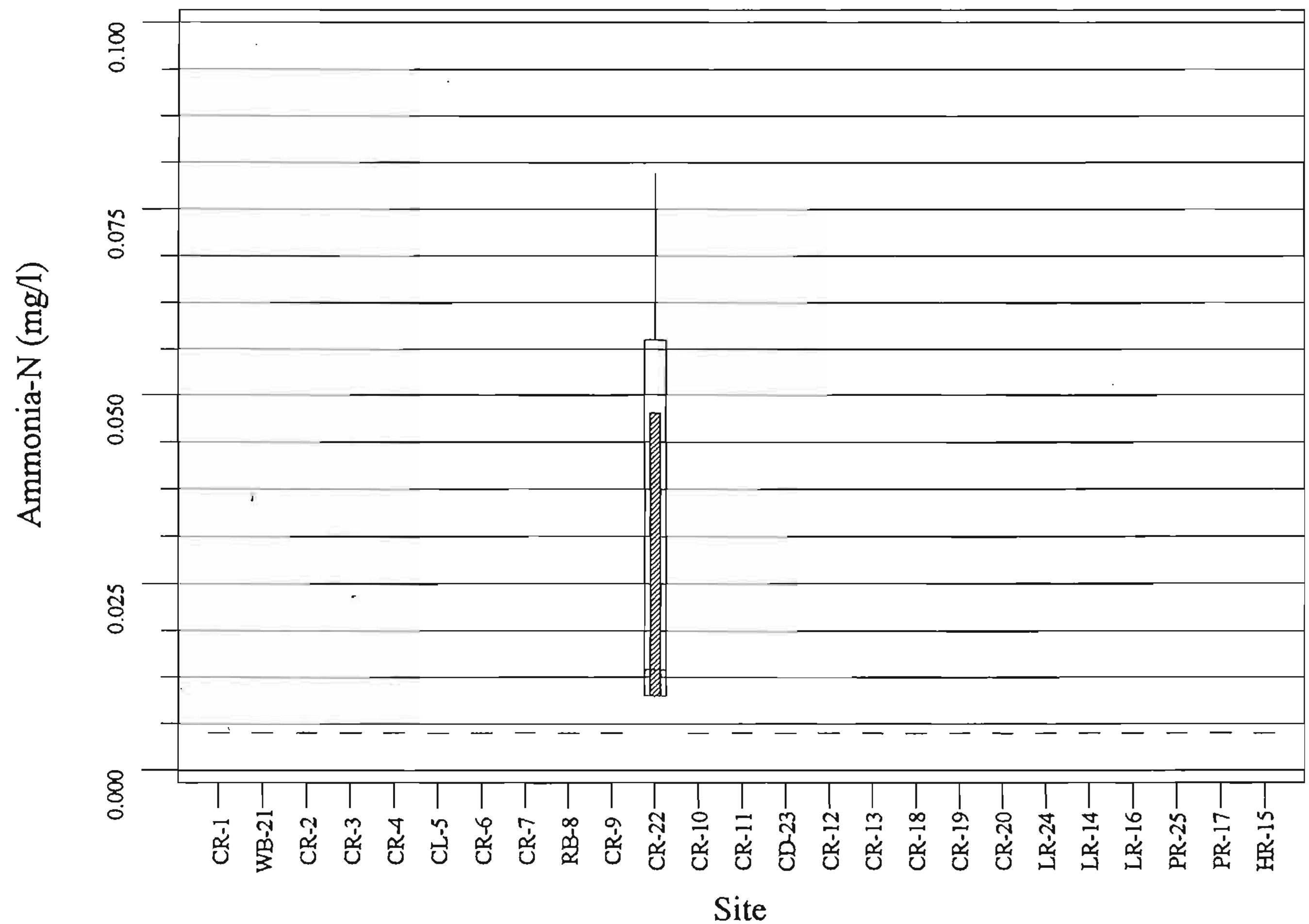
5.1.4 Chlorophyll-a

The median concentration of chlorophyll-a at most sites was less than 0.006 mg/l, considerably less than that which occurs in lake systems. The greatest concentrations occurred at CR-2, CR-11 and CR-13 where concentrations reached or exceeded 0.025 mg/l (see Figure 5-23). High biological productivity within specific regions on the Clearwater River can be related to correspondingly high nutrient loads. For example, it appears that the high chlorophyll-a concentrations occurring immediately downstream of Bagley (CR-2) may be directly attributable to high phosphorus concentrations in wastewater discharge.

5.1.5 Dissolved Oxygen and Chemical Oxygen Demand

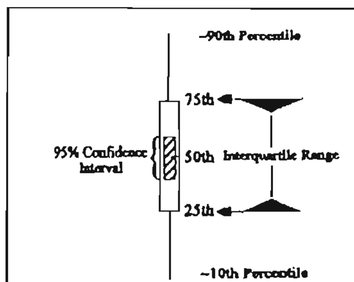
Most monitoring locations within the Clearwater River watershed showed dissolved oxygen concentrations sufficient for sustaining aquatic life with median concentrations exceeding 5 mg/l (Figure 5-24). Exceptions occurred at CR-1, WB-21 and CR-2 in the headwaters of the Clearwater River where minimum concentrations were less than 2 mg/l. Exceedingly low concentrations, near 3 mg/l, also occurred in the channelized reach (CR-10 and CR-11) within the Clearwater River. Regions of the Clearwater River with the lowest dissolved oxygen tended to have the greatest chemical oxygen demand (Figure 5-25). The low observed concentrations at CR-2 and PR-25, are believed to result from municipal waste discharges at Bagley and McIntosh, respectively.

The minimum dissolved oxygen concentration at most locations occurred in late August and corresponded with maximum chemical oxygen demand resulting from the August 24th storm. The gradual decrease beginning early July within the channelized reach corresponds to low flow



Note: Horizontal line indicates Concentrations below 0.01 mg/l Detection Limit.

Legend

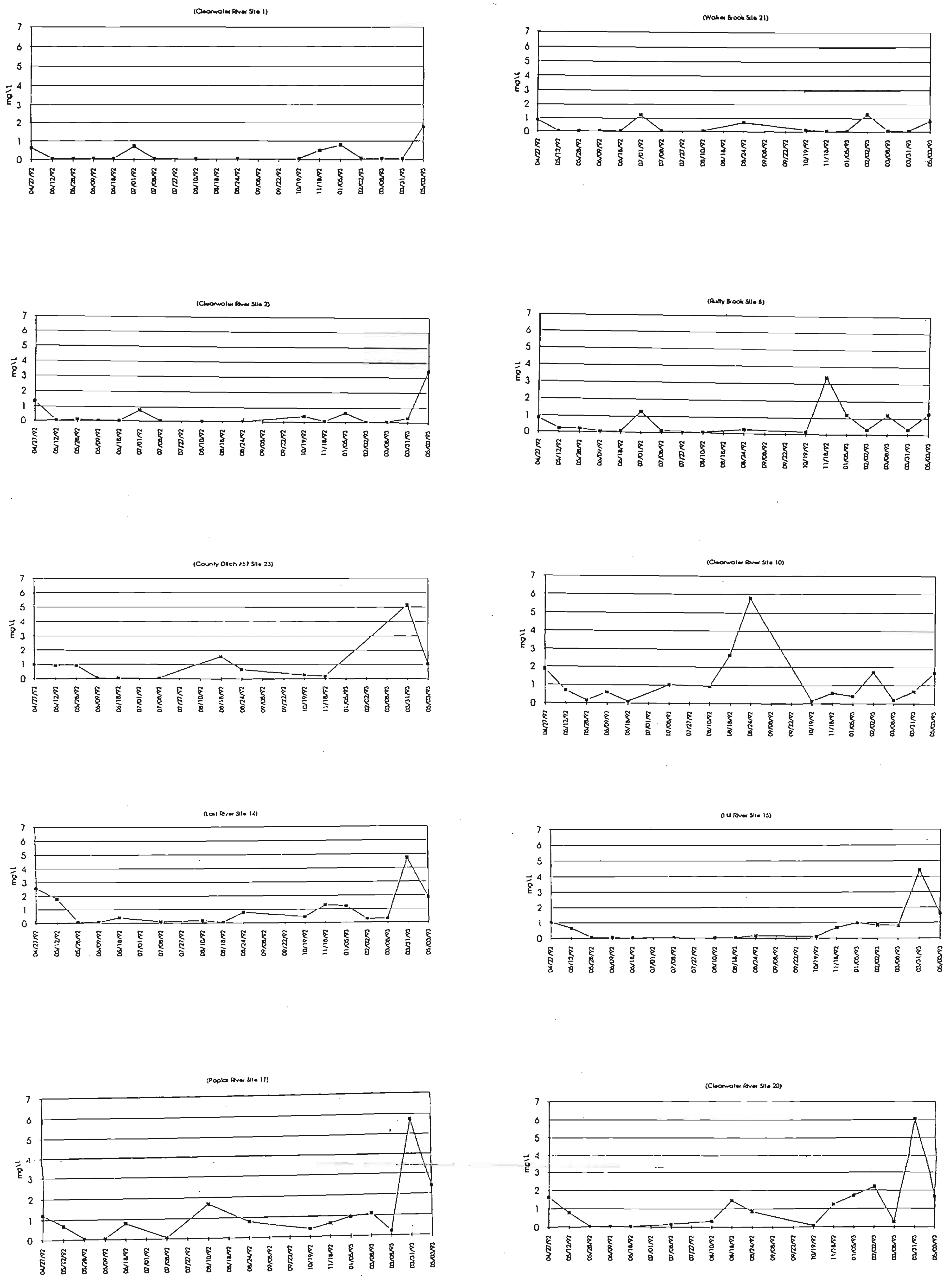


HDR Engineering Inc.

Red Lake Watershed District
Dedicated to Water Management

Figure 5-19

Box and Whisker Plots
for Ammonia (as N),
April 1, 1992-March 31, 1993

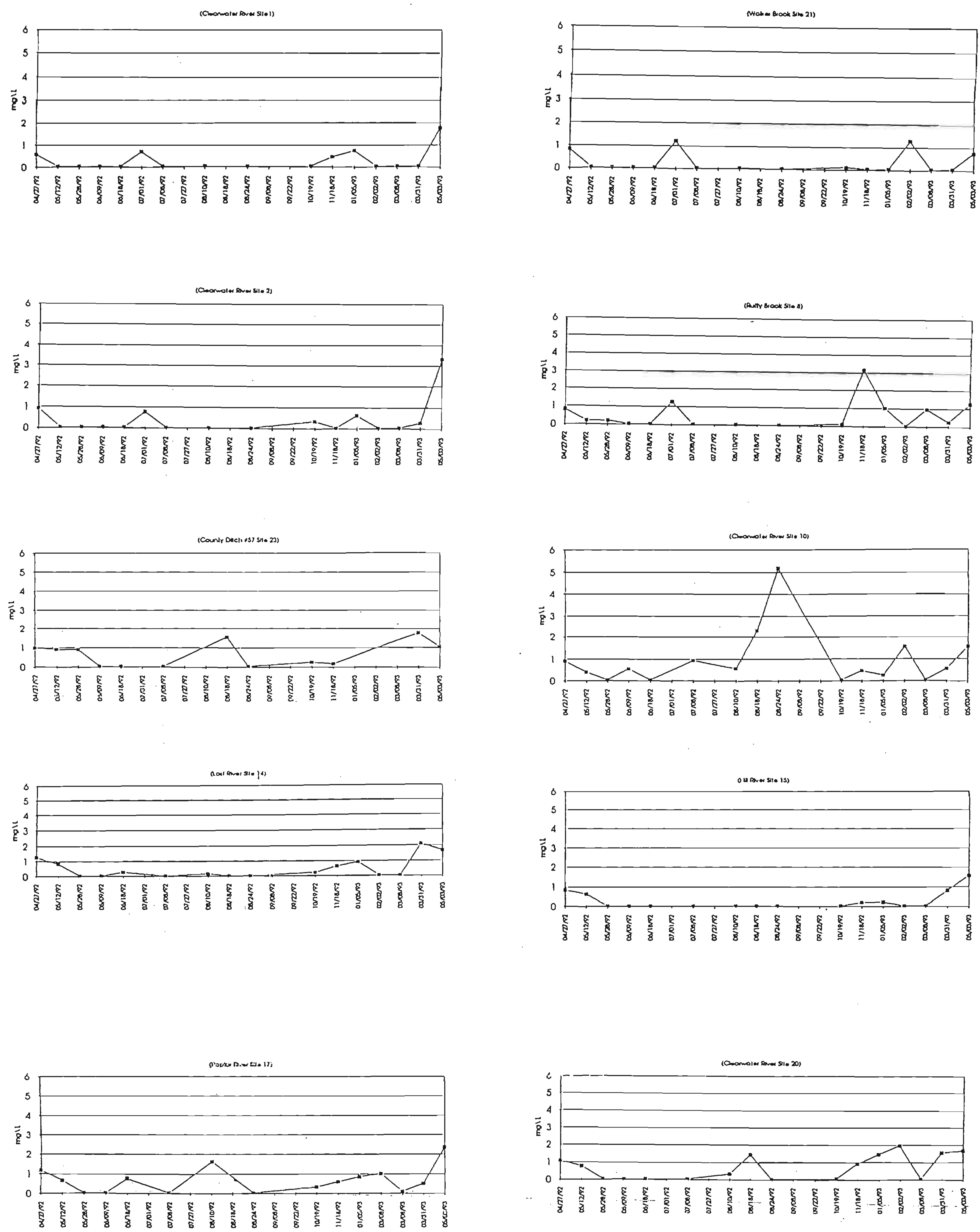


HDR Engineering Inc.

Red Lake Watershed District
Dedicated to Water Management

Figure 5-20

Seasonal Trends in Total Nitrogen (as N)
at Select Locations

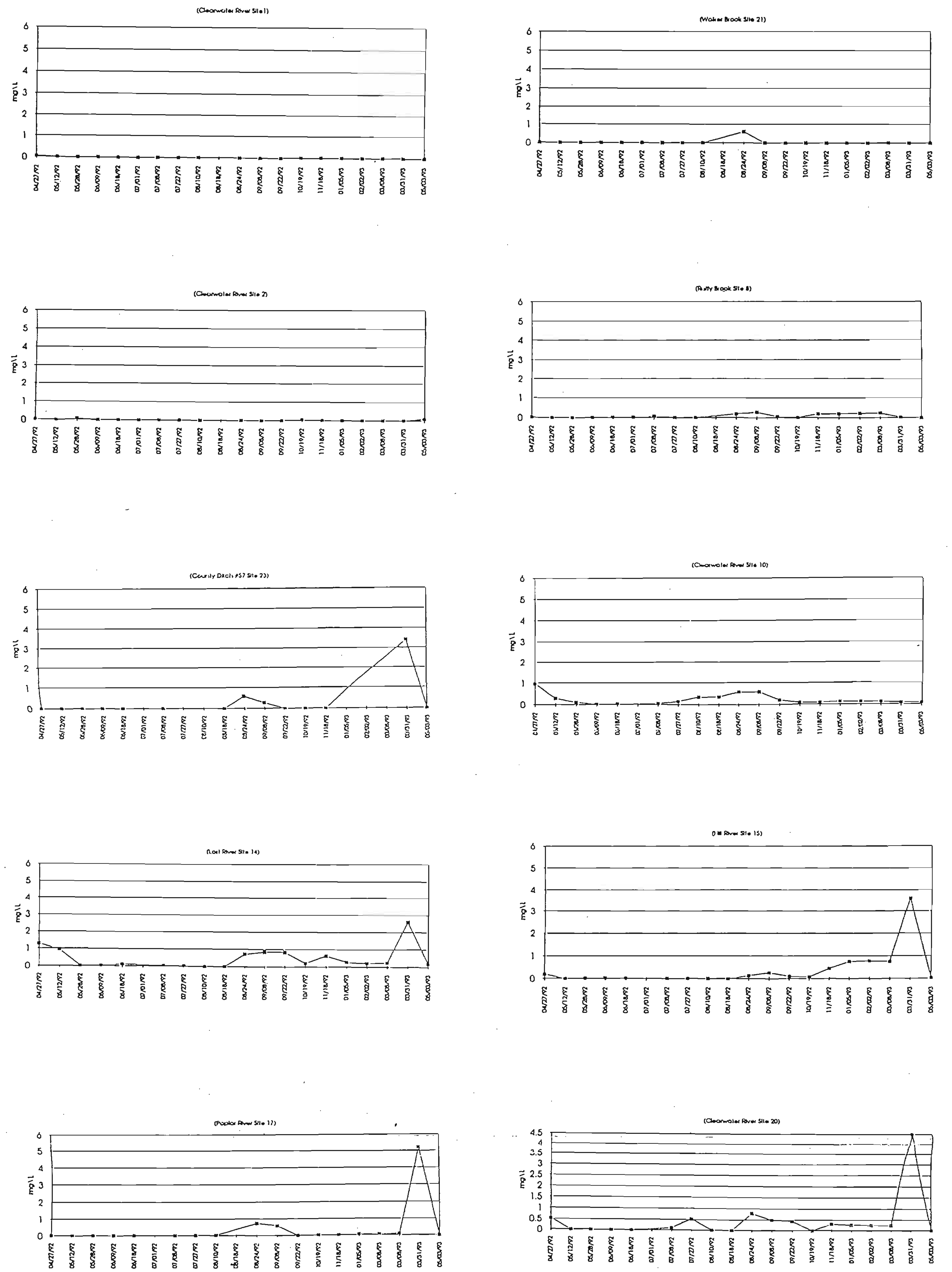


HDR Engineering Inc.

Red Lake Watershed District — Dedicated to Water Management

Figure 5-21

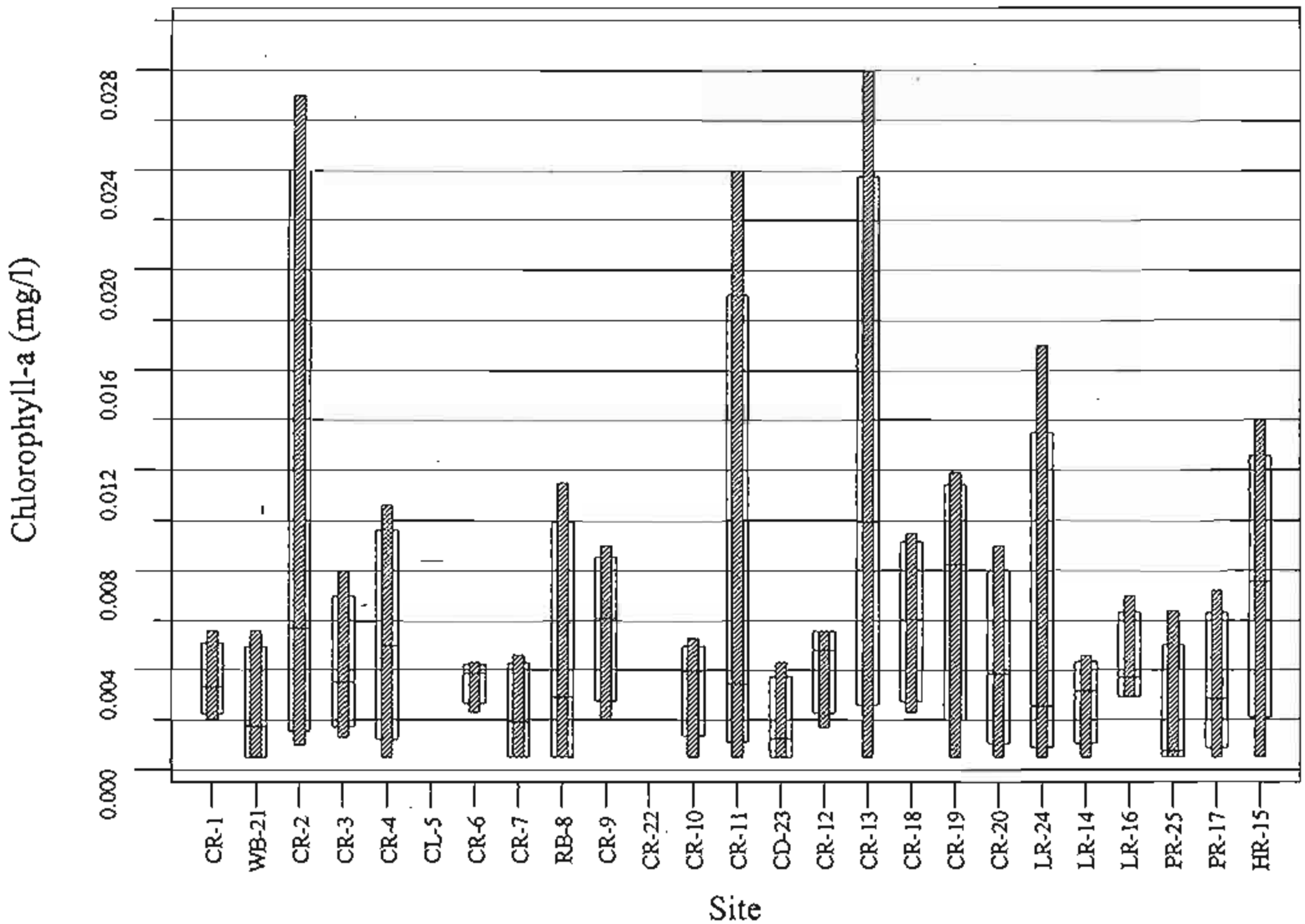
Seasonal Trends in Total Kjeldahl Nitrogen (as N) at Select Locations



HDR Engineering Inc.

Figure 5-22

Seasonal Trends in Nitrate (as N) at Select Locations



Note: Based on quarterly sampling; only one sample within Clearwater Lake (CL-5).

Legend

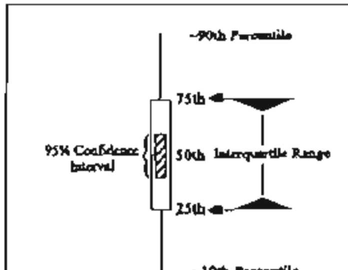
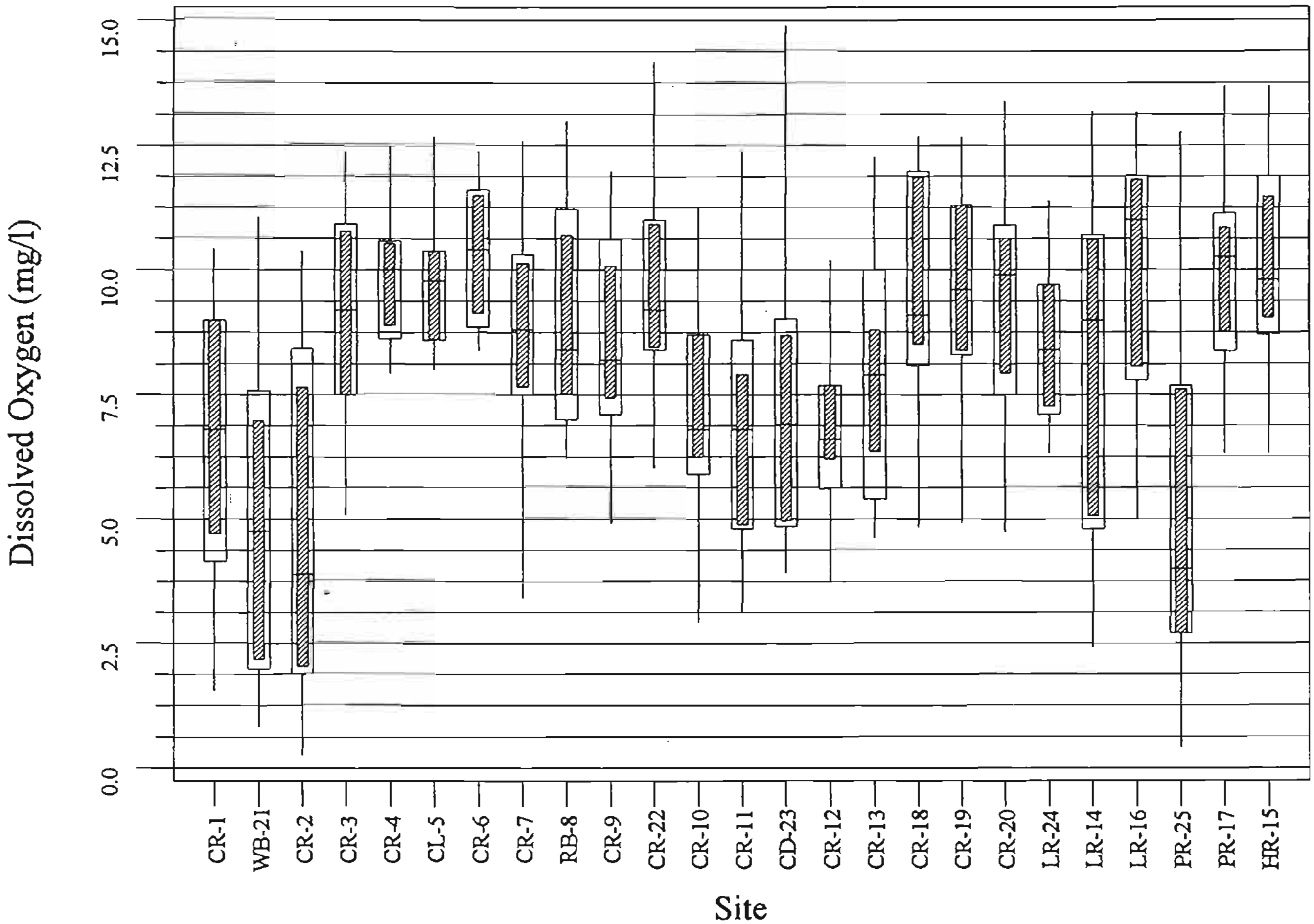


Figure 5-23

Box and Whisker Plots for Chlorophyll-a, April 1, 1992-March 31, 1993

HDR Engineering Inc.

Red Lake Watershed District
Dedicated to Water Management



See Table 3-1 for approximate measurement times.

HDR Engineering Inc.

Red Lake Watershed District
Dedicated to Water Management

Legend

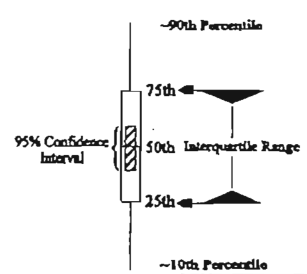
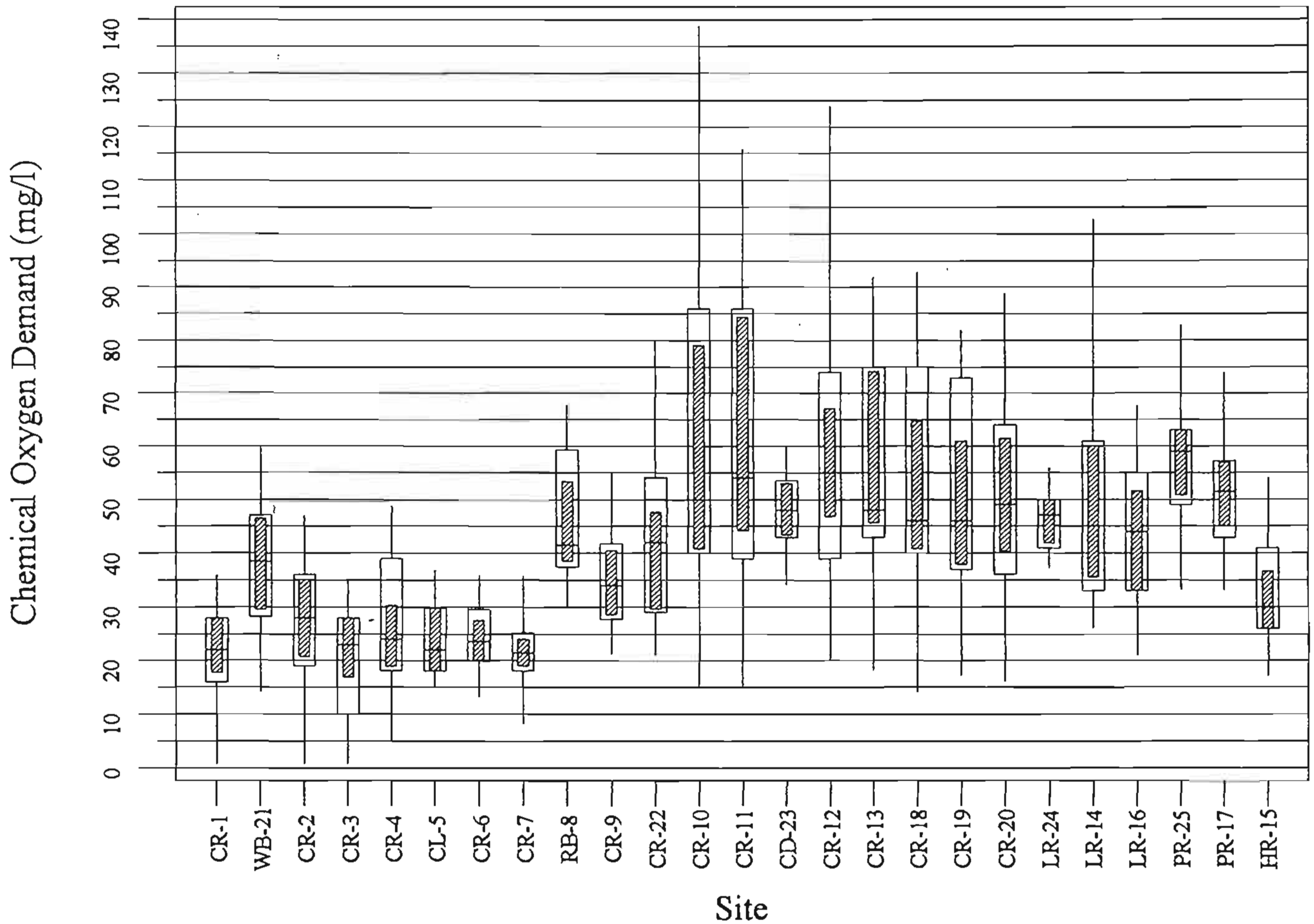
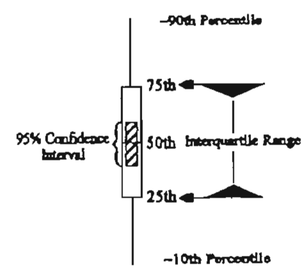


Figure 5-24

Box and Whisker Plots
for Dissolved Oxygen,
April 1, 1992-March 31, 1993



Legend



HDR Engineering Inc.

Figure 5-25

Box and Whisker Plots for Chemical Oxygen Demand, April 1, 1992-March 31, 1993 and discharge from agricultural rice paddies (Figures 26 and 27). Dissolved oxygen within County Ditch 57 (CD-23) remained above 4 mg/l throughout the year. Concentrations at PR-25 reached seasonal lows, less than 1 mg/l, in late August and early January presumably for reasons similar to the upper reaches of the Clearwater River, i.e., municipal discharges and winter ice cover respectively. The Clearwater River maintained dissolved oxygen concentrations above 6 mg/l at the mouth near Red Lake Falls, except in January during ice cover.

Seasonal data show minimum dissolved oxygen concentrations occurring within the upper reaches of the Clearwater River from August 10-24 and again in early February. Low concentrations during late August and early February are likely related to the large amount of runoff from the August 24 storm event and limited rearearation during the winter months, respectively.

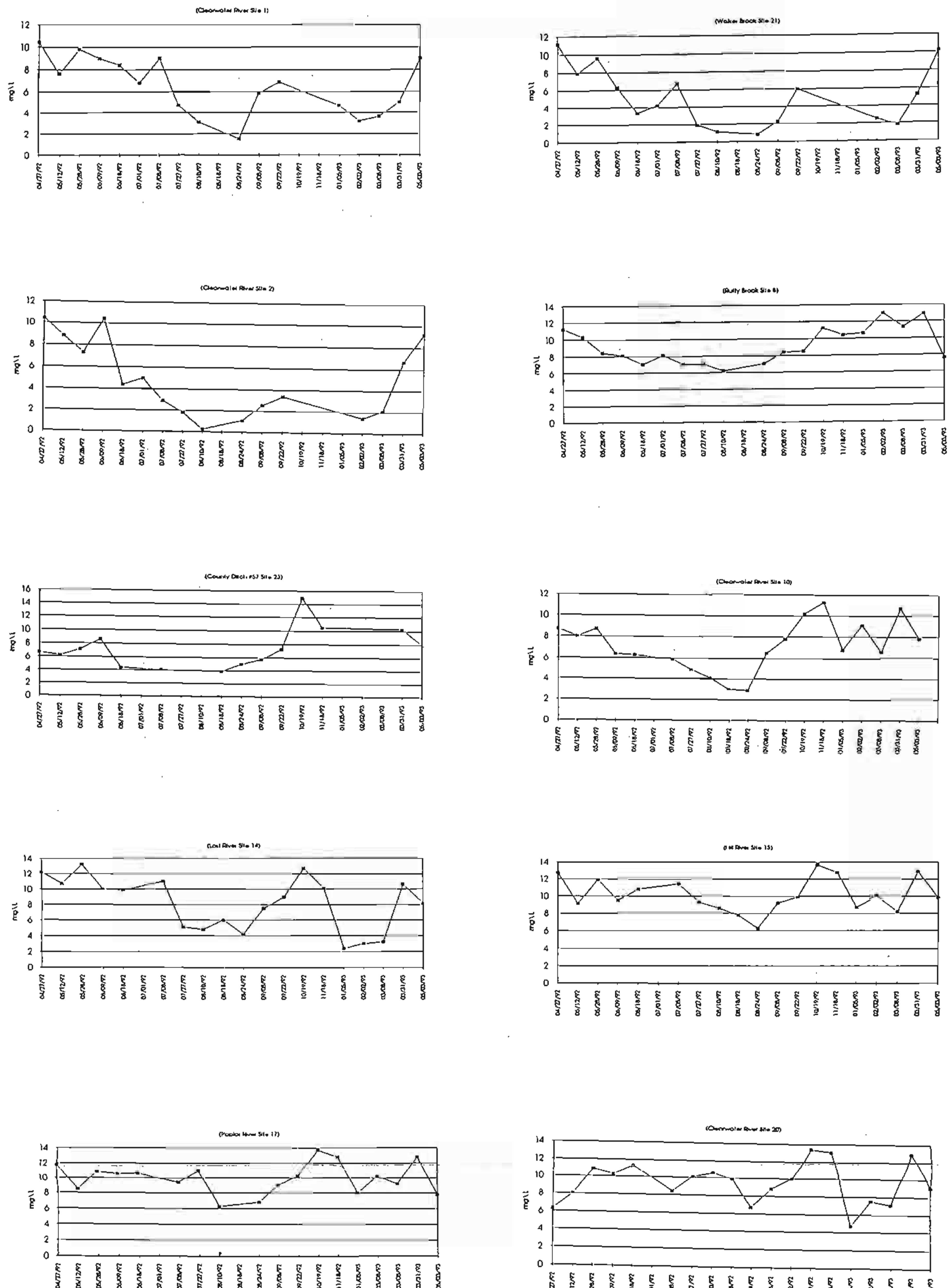
5.1.6 Fecal Coliform Bacteria

Fecal coliform bacteria concentrations reached problematic (greater than 200 colonies/100 ml) concentrations at Ruffy Brook and on the Lost River. Concentrations were also elevated within County Ditch 57 (CD-23) and on the Poplar River below McIntosh (Figure 5-28). Ruffy Brook is believed to be impacted by feedlots and LR-14 by Oklee. The increased fecal coliform concentrations within Walker Brook corresponded to the July 1st and August 24th storm events (Figure 5-29). Smaller peaks occurred at CR-2 near the end of March. This same general trend occurred throughout the basin; increased fecal coliforms corresponding to rainfall events, although PR-17 tended to show greater variation throughout the year.

5.1.7 Physical Measurements

Median water temperature throughout the basin remained below 20°C (Figure 5-30). Within the upper reaches of the Clearwater River the surface water temperature remained below 20°C, a satisfactory temperature for trout, except on July 8. Water temperature remained less than 20°C within Ruffy Brook, throughout the year, and downstream within the Clearwater River to CR-12.

Measured pH typically remained within the 6.0-9.0 range needed for supporting aquatic life at all locations (Figure 5-31). Median specific conductance at all sites ranged from approximately 450-950 umhos/cm (see Figure 5-32). The greatest median specific conductance occurred within County Ditch 57 (CD-23). Arithmetic mean values of 298, 908, 197, 193 and 575 umhos/cm

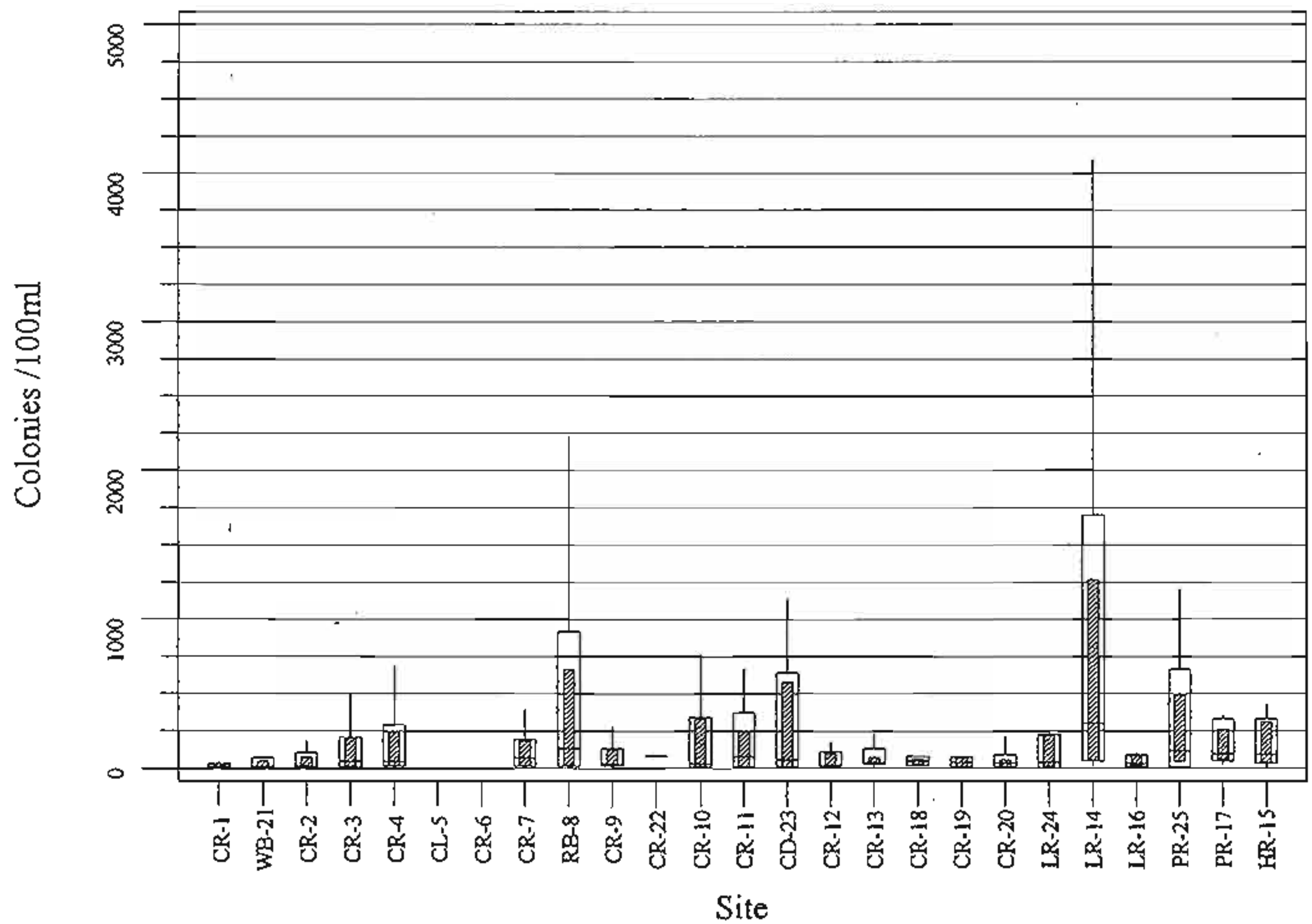


HDR Engineering Inc.

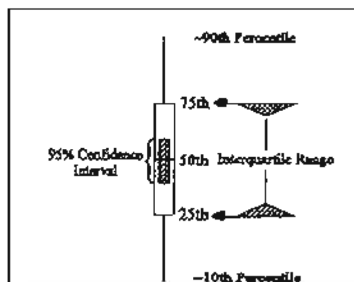
Red Lake Watershed District
Dedicated to Water Management

Figure 5-26

Seasonal Trends in Dissolved Oxygen Concentrations at Select Locations



Legend

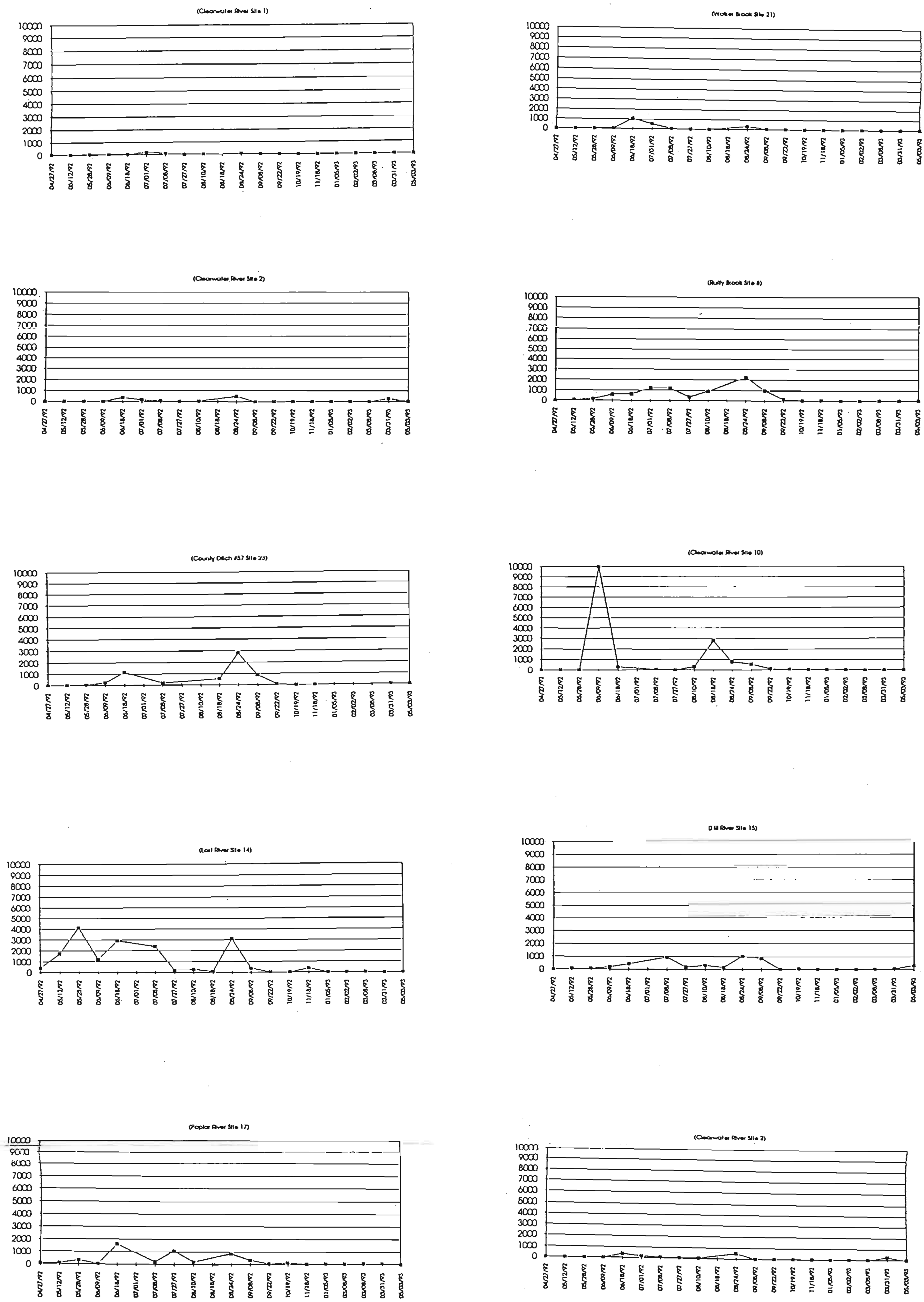


HDR Engineering Inc.

Red Lake Watershed District
Dedicated to Water Management

Figure 5-28

Box and Whisker Plots for Fecal Coliform Bacteria, April 1, 1992-March 31, 1993

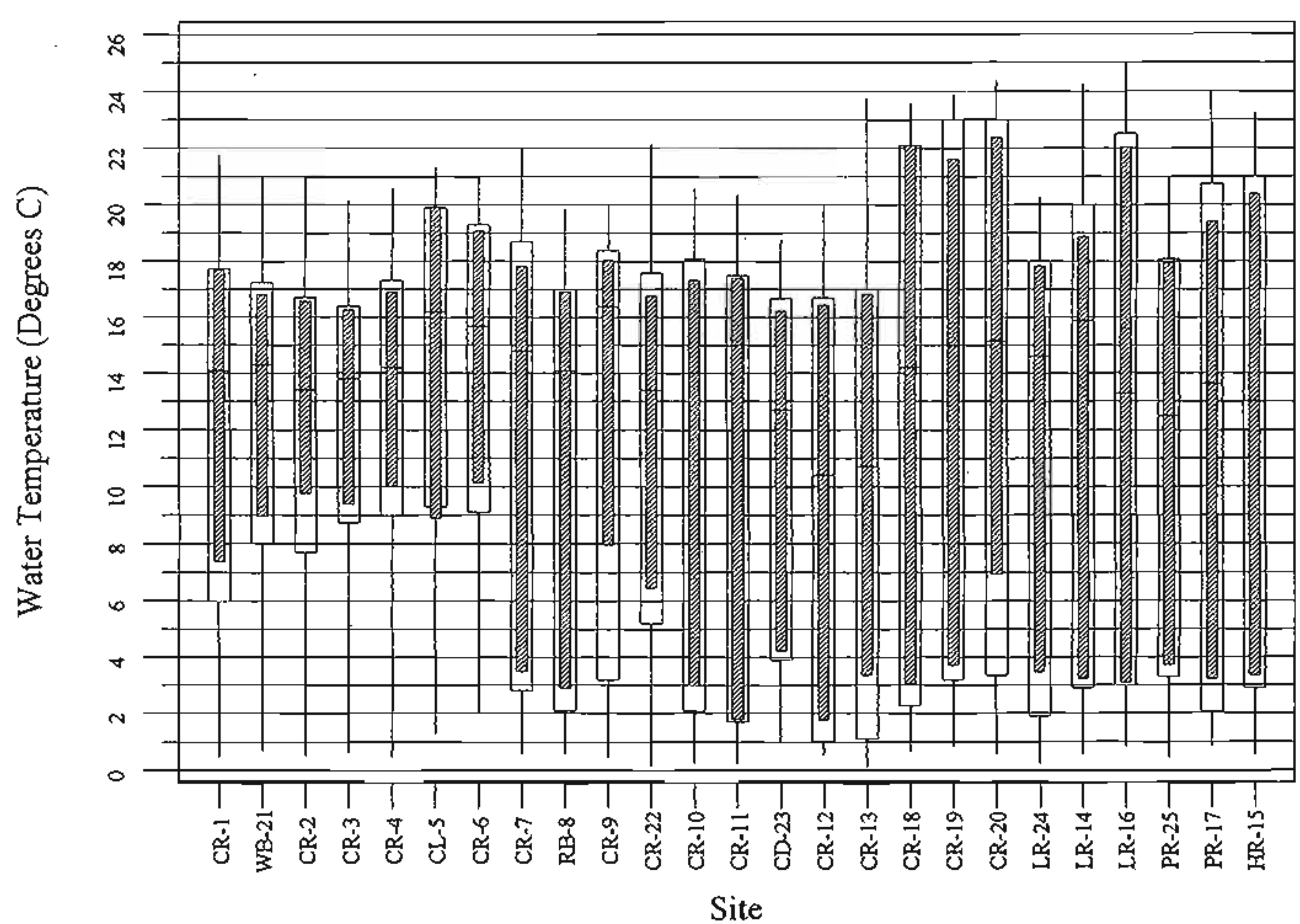


HDR Engineering Inc.

Red Lake Watershed District
Dedicated to Water Management

Figure 5-29

Seasonal Trends in Fecal Coliform Bacteria at Select Locations Colonies / 100ml



Legend

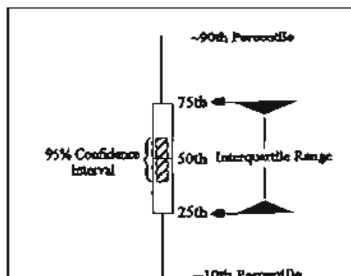
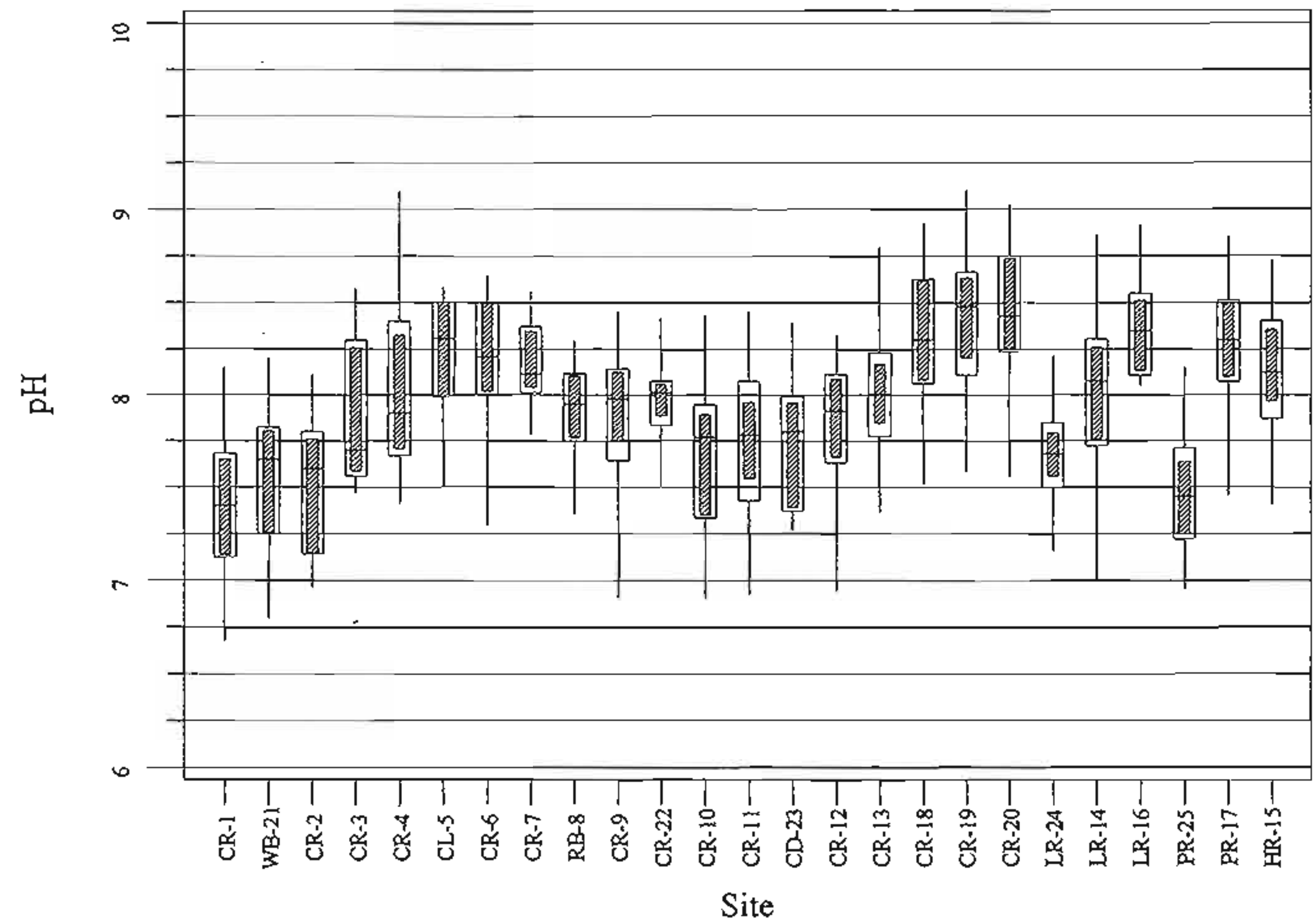


Figure 5-30

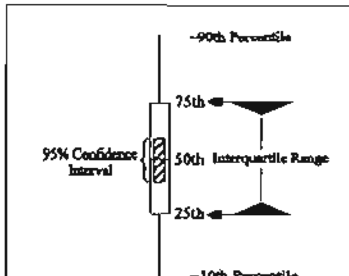
Box and Whisker Plots for Field Water Temperature, April 1, 1992-March 31, 1993

Red Lake Watershed District
Dedicated to Water Management

HDR Engineering Inc.



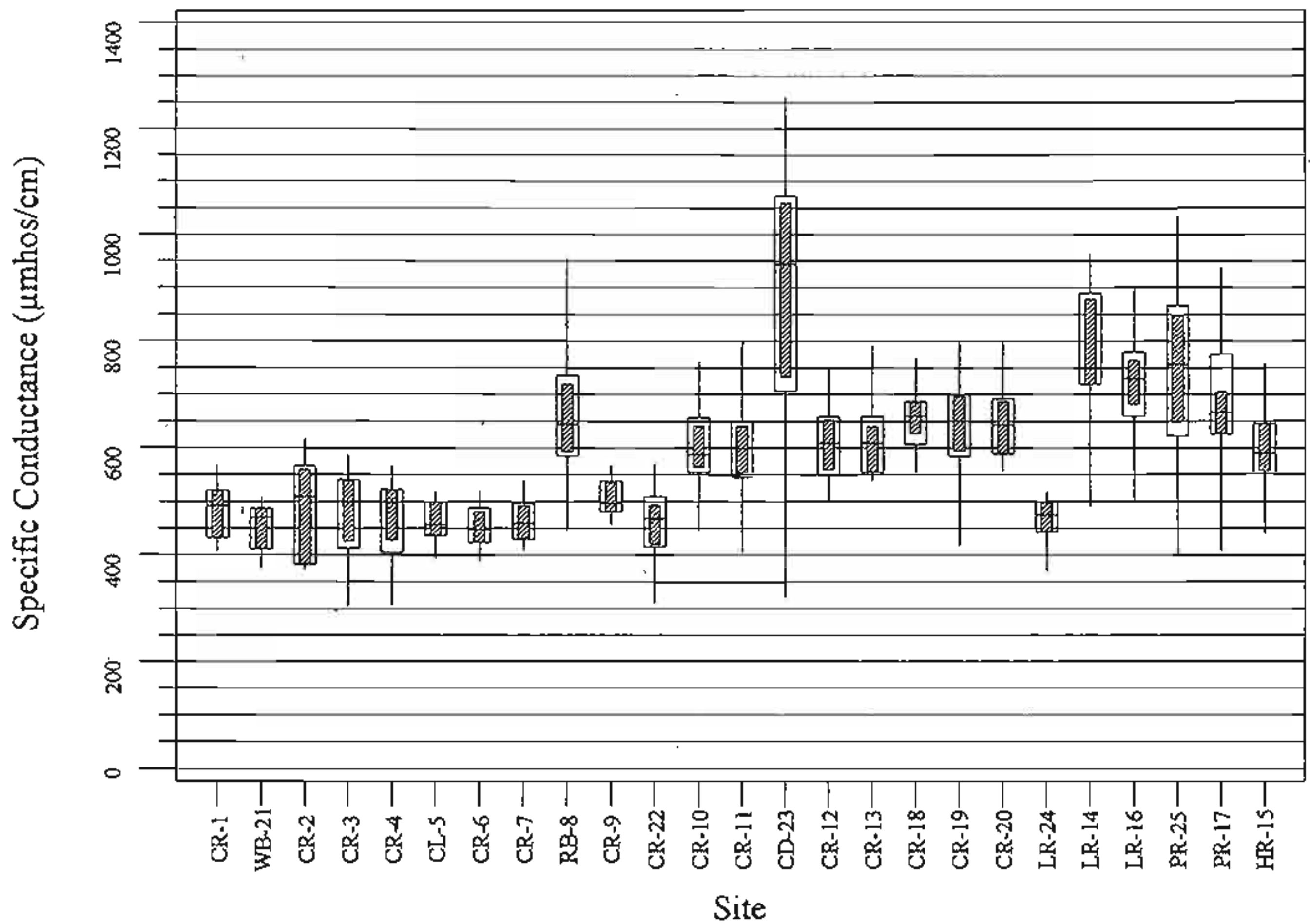
Legend



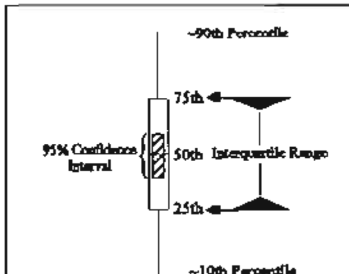
HDR Engineering Inc.

Figure 5-31

Box and Whisker Plot
for pH,
April 1, 1992-March 31, 1993



Legend



HDR Engineering Inc.

Figure 5-32

Box and Whisker Plots for Specific Conductance, 1992 are reported for minimally impacted streams within the North Central Hardwood Forests, Northern Glaciated Plains, Northern Lakes and Forests and Northern Minnesota Wetlands and Red River Valley ecoregions, respectively.

5.1.8 Pesticides

Sediment samples and surface water samples were collected to assess potential accumulation of agricultural pesticides. Two representative pesticides were selected for analysis, MCPA and 2,4-D. Each is a commonly used agricultural chemical. Table 5-1 shows the results of the analysis. No measurable levels of MCPA were present. Measurable, albeit small, concentrations of 2,4-D were present, primarily in sediment. The water column concentrations do not pose a risk, as the EPA maximum contaminant level is 70 ppb for 2,4-D in water.

5.2 Estimated Loading and Yields

The following discussion concentrates on the total annual loads and yields of solids, phosphorus, and nitrogen entering the Clearwater River and associated tributaries.

5.2.1 Solids

On an annual basis, total solid yields within the Clearwater watershed range from 99-503 lbs/acre (Figures 5-33). The lowest total solids yields are generally found within the Poplar River, Hill River, Lost River, Ruffy Brook and Walker Brook tributaries. Total solid yields occurring within these tributaries are primarily in the form of dissolved solids.

The greatest yields occur within two regions of the Clearwater River. The first region is located immediately downstream of Bagley (CR-2) and extends downstream into the designated trout region of the Clearwater River (CR-3, CR-4, and CR-6). The total solids yields in this area is primarily in the form of dissolved solids. On a watershed basis, these sites also contribute significantly high yields of total solids into the Clearwater River. The highest yield (503 lbs/acre) within the watershed occurred at sample site CR-3.

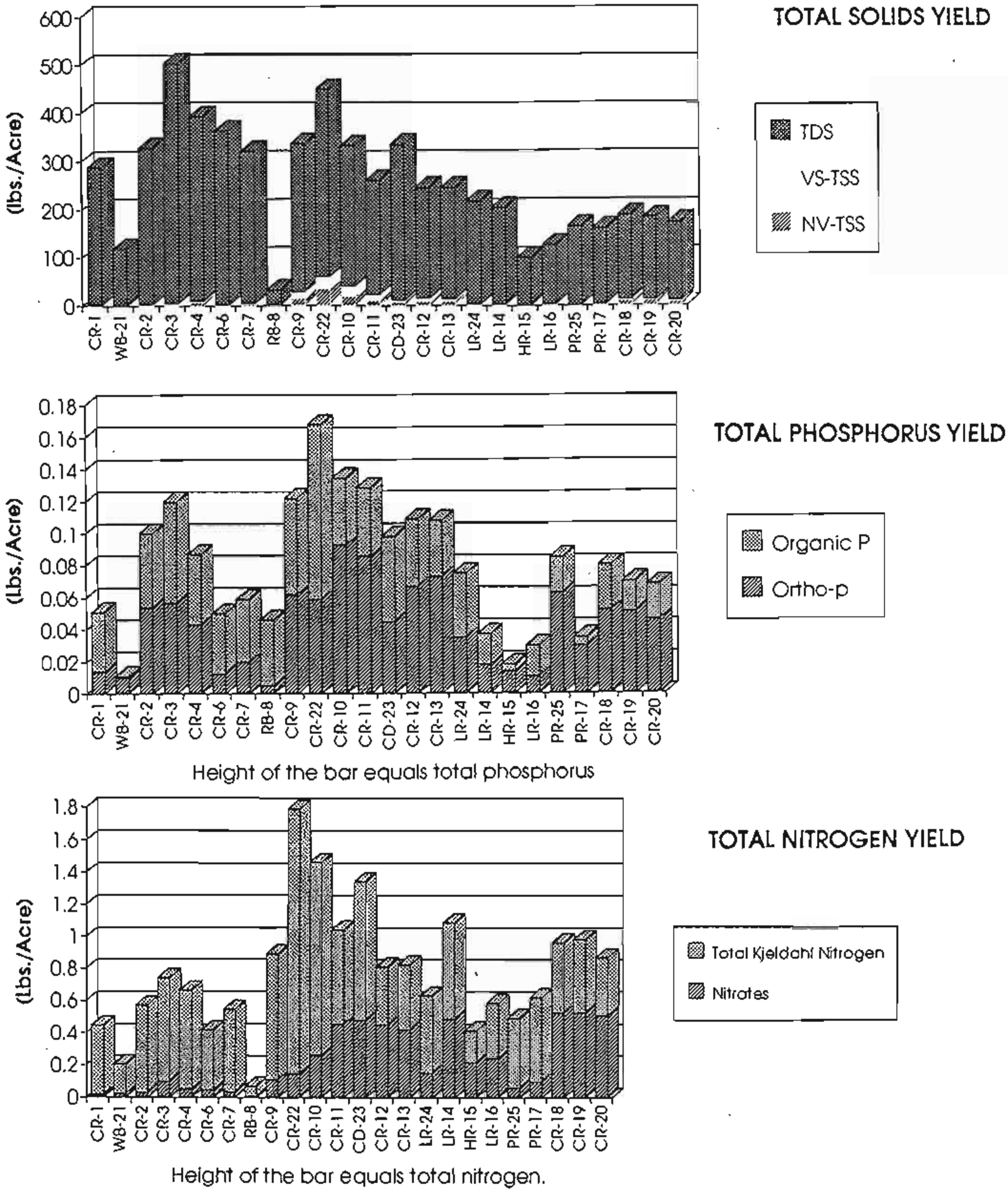
High total solids yields also occur at sample sites CR-9, CR-22, CR-10, CR-11 and CD-23 which are located within the Clearwater River in the channelized reach. Within this region, the total solid yields are predominately in the form of dissolved solids. The drainage area for CR-9, CR-22, CR-10 and CD-23 show high total suspended yields. However, only 10% of the total

Table 5-1. Indicator Pesticides Present in Stream and Sediment Samples

SITE LOCATIONS	MCPA % Samples < MDL	MCPA Values Above MDL (Date)	2,4-D % Samples < MDL	2,4-D Values Above MDL (Date)
Sediment				
CR-1	100%		100%	
CR-2	100%		67%	0.1 ppm (7/8/92)
CR-3	100%		67%	0.01 ppm (5/12/92)
CR-4	100%		67%	.01 ppm (11/17/92)
CR-6	100%		67%	.03 ppm (11/17/92)
CR-7	100%		100%	
RB-8	100%		100%	
CR-9	100%		100%	
CR-10	100%		33%	0.32 ppm (7/8/92); 0.02 ppm (5/12/92)
CR-11	100%		67%	0.01 ppm (5/12/92)
CR-12	100%		100%	
CR-13	100%		33%	0.63 ppm (7/8/92); 0.01 ppm (5/12/92)
LR-14	100%		33%	.03 ppm (11/17/92); 1.3 ppm (7/8/92)
HR-15	100%		67%	.06 ppm (11/17/92)
LR-16	100%		67%	1.5 ppm (7/8/92)
PR-17	100%		100%	
CR-18	100%		67%	1.1 ppm (7/8/92)
CR-19	100%		67%	0.74 ppm (7/8/92)
CR-20	100%		33%	1.44 ppm (7/8/92); 0.03 ppm (5/12/92)
WB-21	100%		67%	0.21 ppm (7/8/92)
CR-22	100%		67%	0.05 ppm (7/8/92)
CD-23	100%		33%	1.03 ppm (7/8/92); 0.03 ppm (5/12/92)
LR-24	100%		33%	0.89 ppm (7/8/92); 0.02 ppm (5/12/92)
PR-25	100%		67%	0.96 ppm (7/8/92)
Water Column				
CR-1	100%		67%	2.45 ppb (7/8/92)
CR-2	100%		67%	1.06 ppb (7/8/92)
CR-3	100%		100%	
CR-4	100%		100%	
CR-6	100%		100%	
CR-7	100%		100%	
RB-8	100%		100%	
CR-9	100%		100%	
CR-10	100%		100%	
CR-11	100%		100%	
CR-12	100%		100%	
CR-13	100%		100%	
LR-14	100%		100%	
HR-15	100%		67%	1.1 ppb (7/8/92)
LR-16	100%		67%	0.5 ppb (11/17/92)
PR-17	100%		100%	
CR-18	100%		100%	
CR-19	100%		100%	
CR-20	100%		100%	
WB-21	100%		100%	
CR-22	100%		100%	
CD-23	100%		67%	2.38 ppb (7/8/92)
LR-24	100%		67%	2.6 ppb (4/27/92)
PR-25	100%		100%	

Note 1: Results reflect limited number of samples collected on April 27, July 8, and November 17, 1992.

Note 2: Phenoxy screen performed on MPCA and 2,4-D; no degradation products recorded or quantified.



HDR Engineering Inc.

Red Lake Watershed District — Dedicated to Water Management

Figure 5-33
Annual Total Solids, Total Phosphorus (as P) and Total Nitrogen (as N) Yeilds for, April 1, 1992-March 31, 1993 by Subwatershed

solids yield is in the form of total suspended solids. The highest yield (60 lb/acre) of total suspended solids occurred at the Kiwosay Outlet (CR-22). As measured by volatile solids, approximately 50% of the total suspended solid yields in this area is in the organic form.

A regional comparison of total solid yields between the Clearwater River watershed and seven watersheds located within the Northern Glaciated Plain ecoregion (Big Stone Lake in Southwest Minnesota) were made (HDR 1992). Based on a comparison of annual total solids yields, the total solids yield occurring within the Clearwater River (259 lbs/acre) is comparable to the average total solids yield (210 lbs/acre) for Big Stone Lake watersheds. In general, land use between the two ecoregions is similar enough to provide a good comparison. However, it is likely that some variation in yields will result due to differences in topography, geology, and climatic factors.

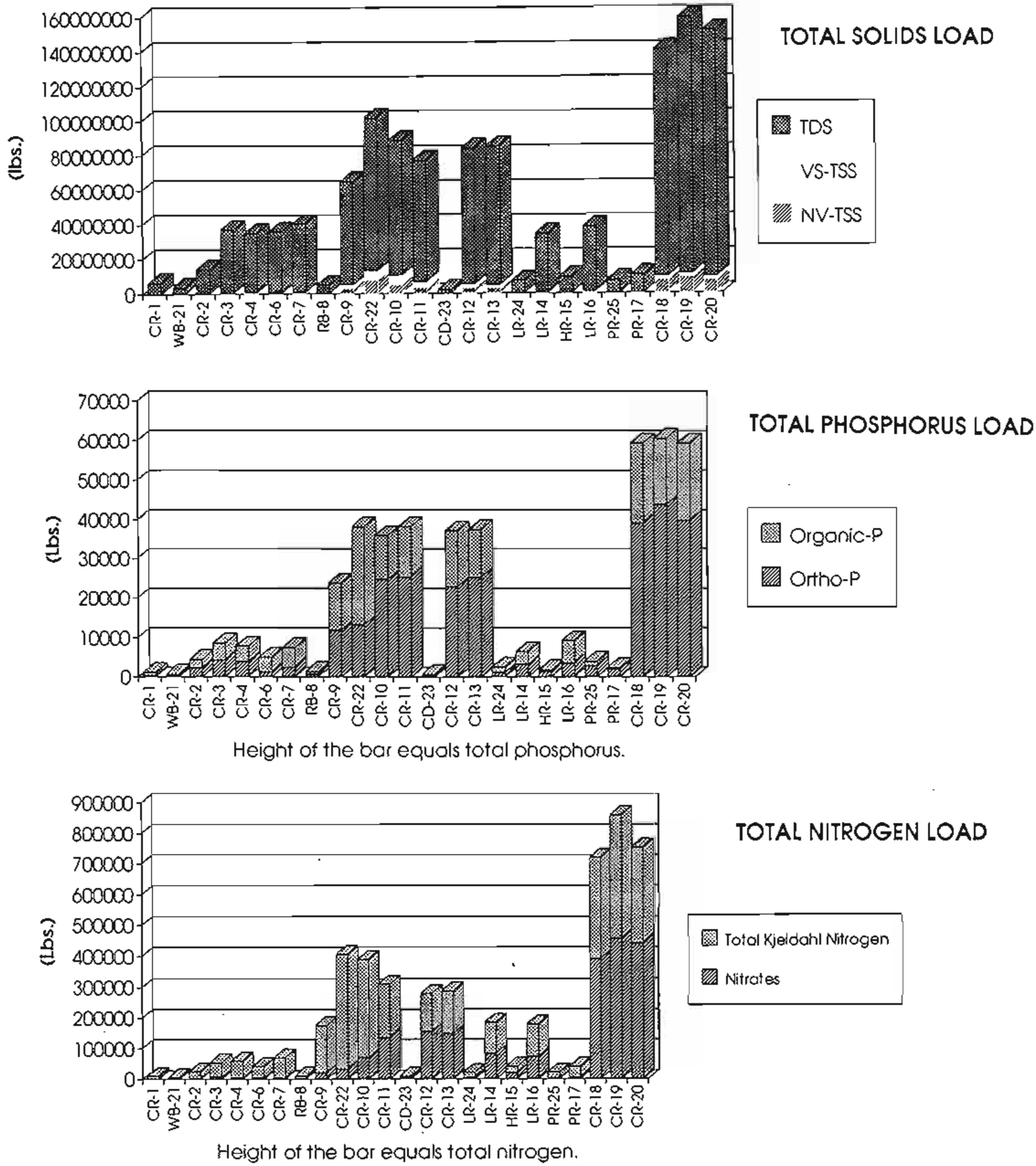
Limited information is available regarding annual yields within the Red River Valley. Estimated yields on a regional scale have been reported in the Souris-Red-Rainy River Basins Comprehensive Study (Souris-Red-Rainy Basin Commission 1972). The estimated sediment yield from areas (>100 square miles) in the Red River Valley is 312 lbs/acre.

Annual total solid loads are greatest at the downstream Clearwater River locations (Figure 5-34), while total suspended solids loads are greatest in the channelized reach. Monthly loads of total solids within the watershed follow a general seasonal trend (Figure 5-35). High monthly loads typically occur during spring runoff (March, April and May) and during summer storm events which typically occur during the months of July, August and September.

5.2.2 Phosphorus

Annual total annual phosphorus yields within the watershed ranged from 0.01-0.17 lbs/acre (Figures 5-33). In general, the highest yields occurred near urban areas and within the channelized portion of the Clearwater River. The lowest total phosphorus yields are found within Walker Brook and Lost River. Yields of less than 0.04 lbs/acre were measured at WB-21, HR-15, PR-17, LR-14 and LR-16.

Total phosphorus yields appear to increase downstream of urbanized areas. Sampling sites which occur immediately downstream of Gonvick (LR-24) and McIntosh (PR-25) have increased phosphorus yields. Greater phosphorus yields also occur in the immediate vicinity of the City

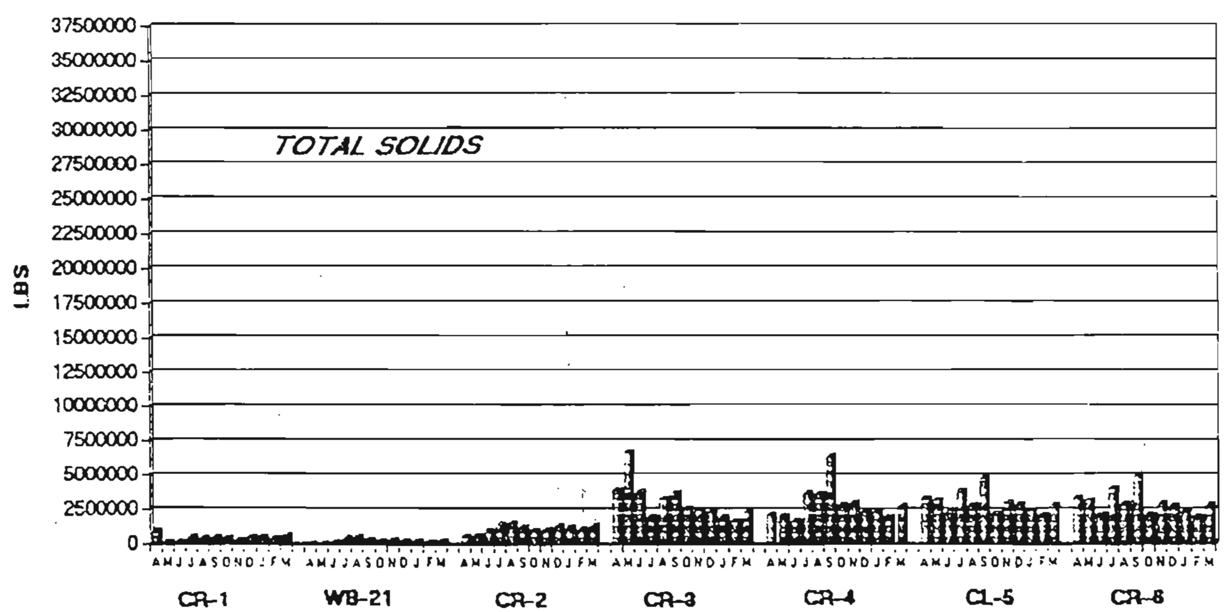


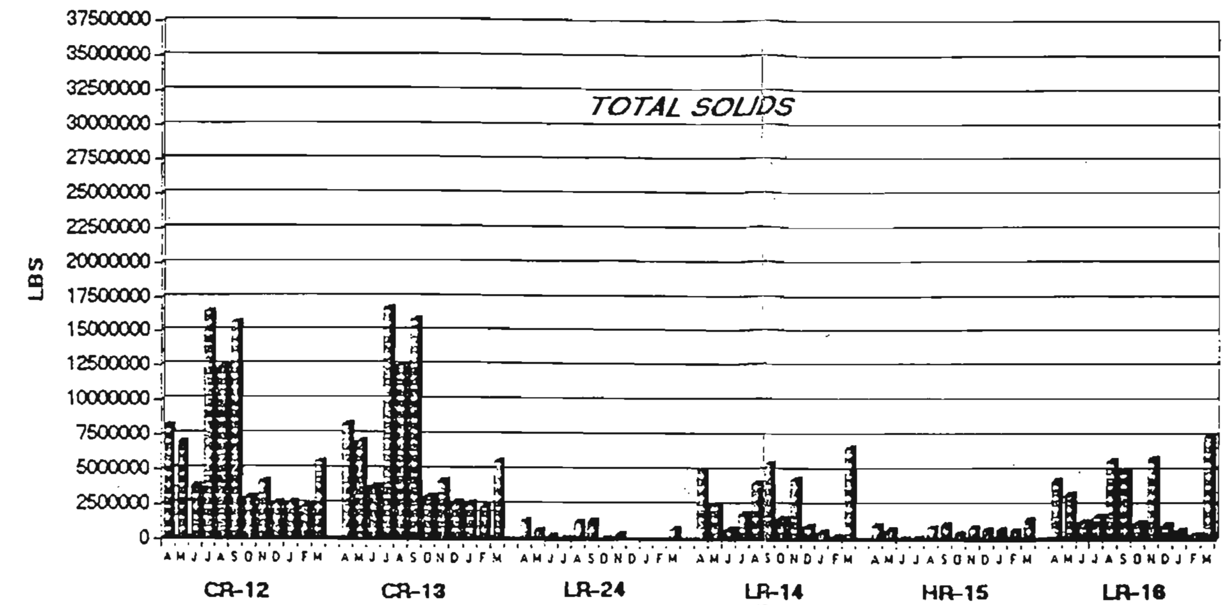
HDR

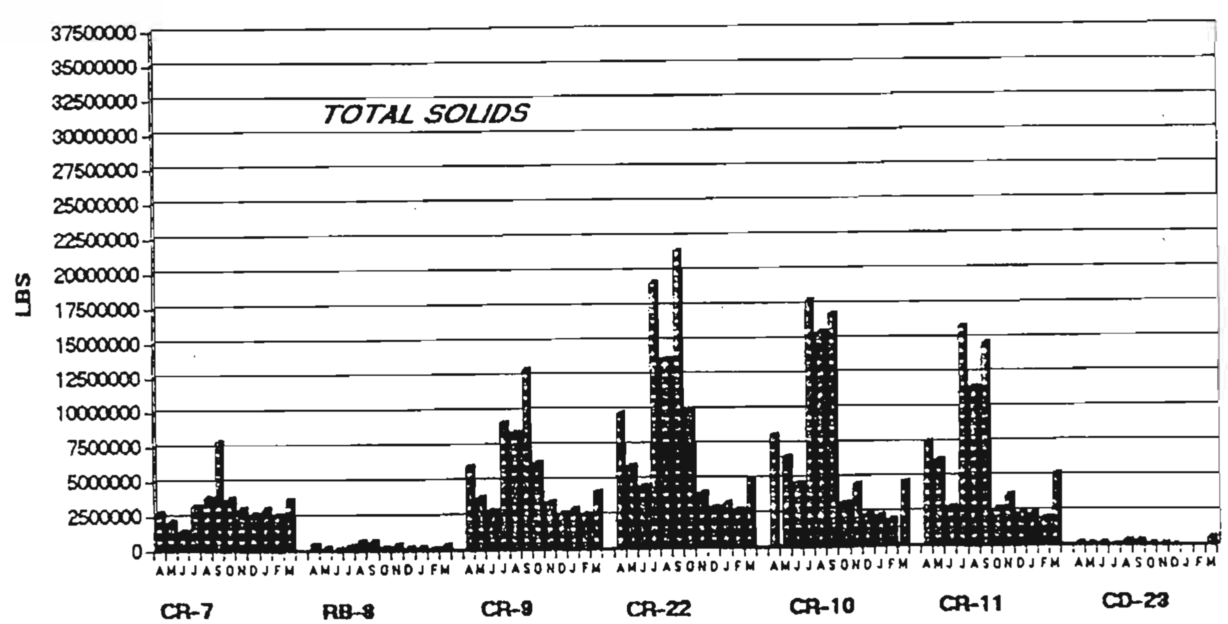
HDR Engineering Inc.

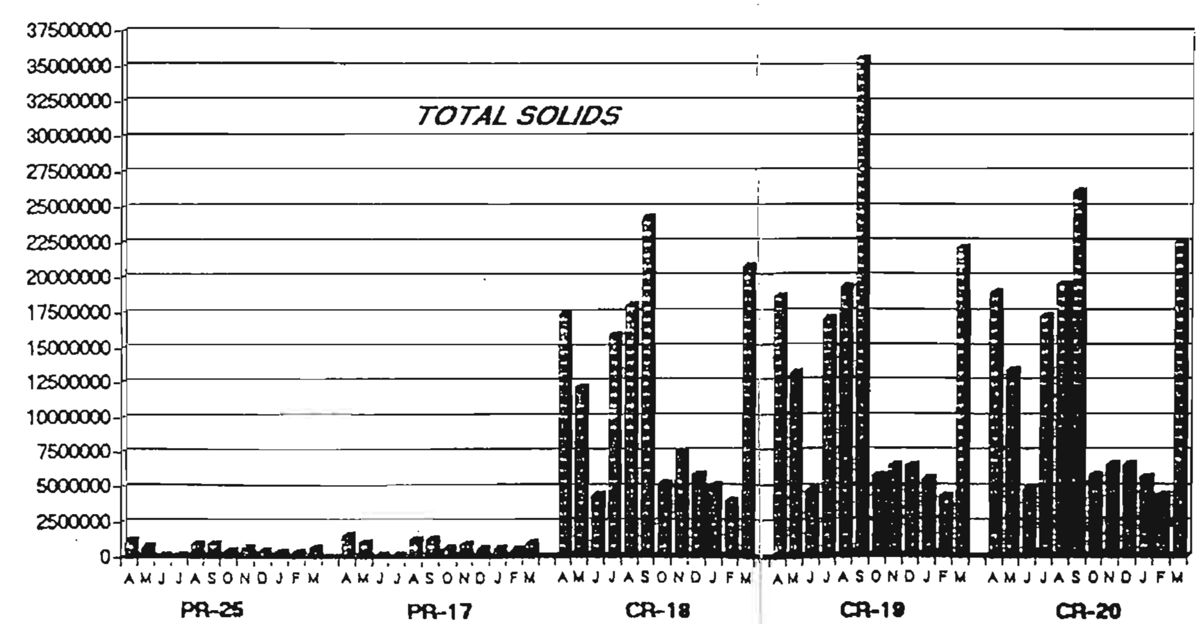
Red Lake Watershed District — Dedicated to Water Management

Figure 5-34
Annual Total Solids, Total Phosphorus (as P) and Total Nitrogen (as N) Loads for, April 1, 1992-March 31, 1993 by Subwatershed









HDR
HDR Engineering Inc.

Red Lake Watershed District
Dedicated to Water Management

Figure 5-35

Monthly Total Solids Load
by Subwatershed
April 1, 1992-March 31, 1993

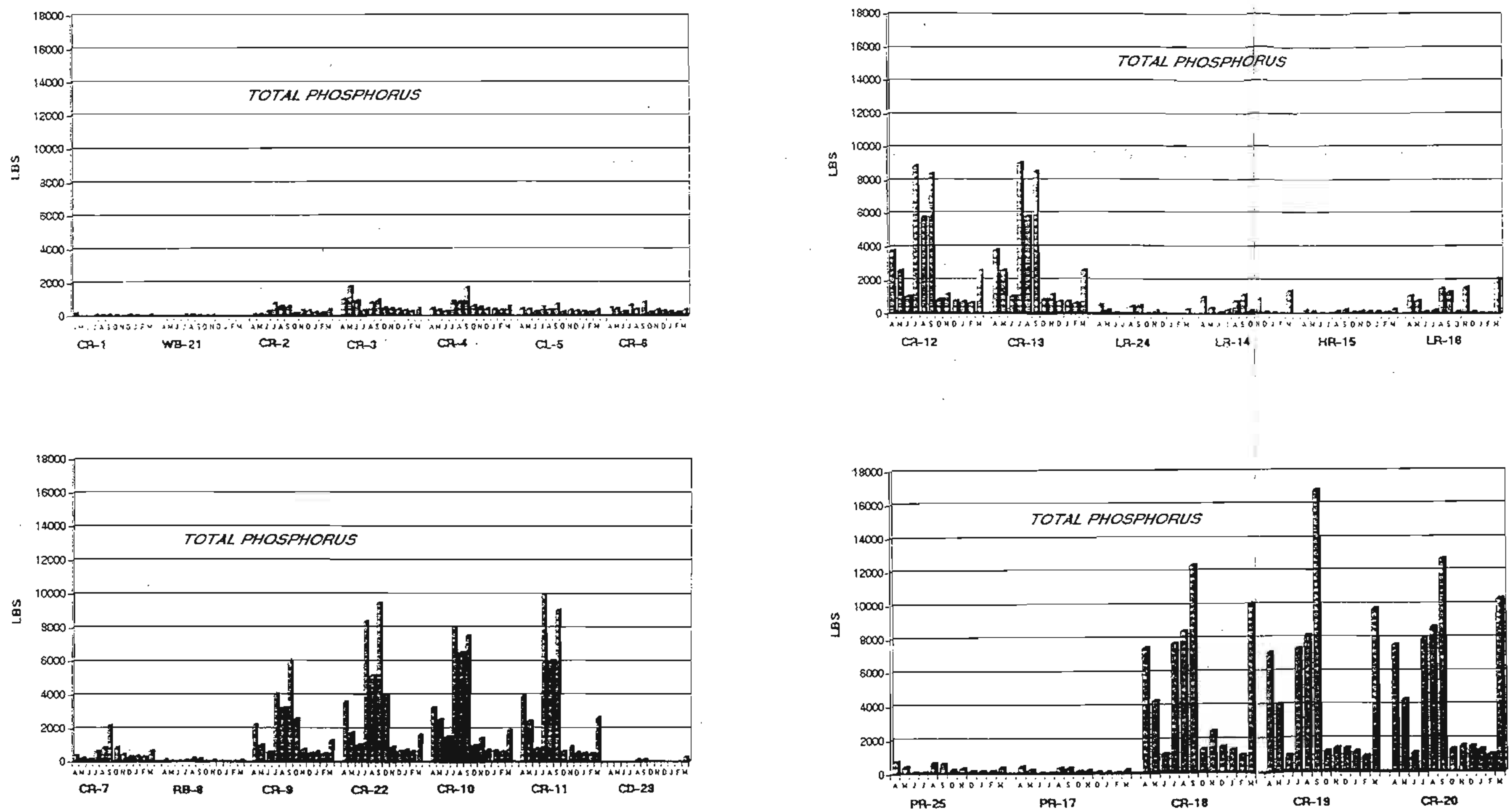
of Plummer (CR-12 and CR-13). The total phosphorus yields associated within these urban areas are primarily in the inorganic form. High inorganic phosphorus yields also occur downstream of Bagley (CR-2, CR-3) and near Red Lake Falls (CR-18, CR-19). These data possibly show the effects of urban influences.

The highest total phosphorus yields (0.12-0.17 lbs/acre) occur on the Clearwater River at sample sites CR-9, CR-22, CR-10, and CR-11, within the channelized reach. Approximately 50% of the total phosphorus yield within this area is inorganic in nature. It is apparent that some characteristic of the soil, agricultural land use, or physical nature of stream channel is causing high phosphorus yields within this section of the Clearwater River. The greatest yield occurred at the Kiwosay Outlet.

Based on data obtained from the Minnesota Lake Eutrophication Analysis Procedure (MINLEAP), annual export coefficients for total phosphorus were obtained for the North Central Hardwood Forest (NCHF), Northern Lakes and Forests (NLF) and Northern Glaciated Plains (NGP) ecoregions. The average total phosphorus yield for the Clearwater watershed (0.072 lbs/acre) was compared to values obtained for the NCHF (0.17 lbs/acre), NLF (0.107 lbs/acre) and NGP (0.677 lbs/acre) ecoregions. Results indicate that the annual phosphorus yield within the Clearwater watershed is considerably lower than the estimated yields for the various ecoregions.

Total phosphorus yields were also compared to the average annual yields from seven watersheds located in the Northern Glaciated Plains (Big Stone Lake in Southwest Minnesota). The average annual yield within these watersheds (0.25 lbs/acre) is significantly higher than the annual yields (0.072 lbs/acre) into the Clearwater watershed. Regional differences in topography, geology and climate may account for some of the observed differences. Annual yields into the Clearwater watershed are also lower than estimated annual yields estimated for the Red River (0.19 lbs/acre) at Emerson, Manitoba (Stoner et al. 1993).

Annual total phosphorus loads were greatest within the channelized reach and near the mouth of the Clearwater River (Figure 5-34). Monthly total phosphorus loads are summarized in Figure 5-36. High loads typically occur in March, April, May and July, August and September. Phosphorus load during the spring results from the runoff of mobilized phosphorus from agricultural sites. High phosphorus loads during the summer are most likely caused by storm runoff.



HDR

HDR Engineering Inc.

Red Lake Watershed District
Dedicated to Water Management

Figure 5-36

Monthly Total Phosphorus (as P)
Load by Subwatershed,
April 1, 1992-March 31, 1993

5.2.3 Nitrogen

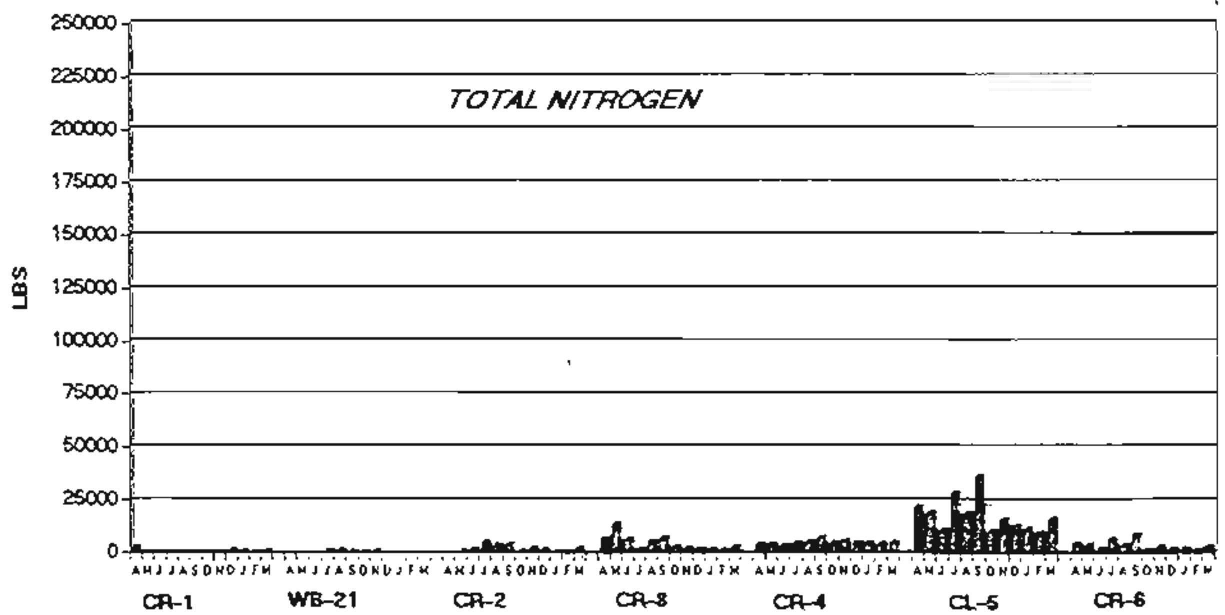
Annual total nitrogen yields within the Clearwater watershed ranged from 0.09-1.8 lbs/acre (Figures 5-33). The lowest total nitrogen yield (0.09 lbs/acre) occurred on Walker Brook. Total nitrogen yields on many sections of the Clearwater River and tributaries are comparable. The total nitrogen yield in the upstream areas is primarily as TKN, while nitrate represents the greatest portion in the downstream areas.

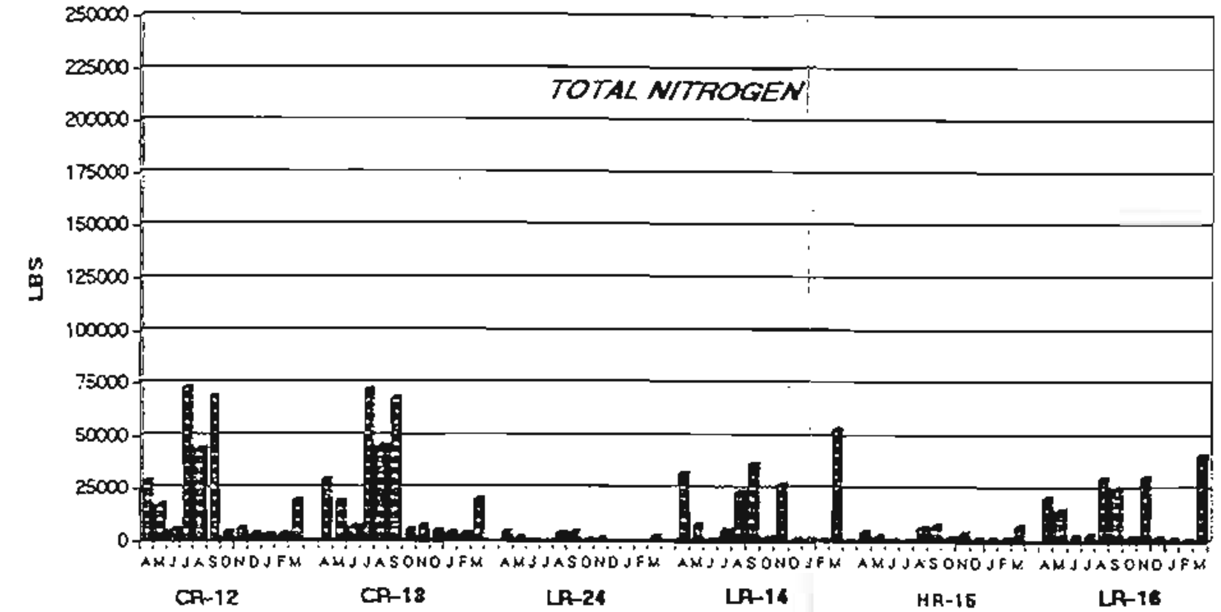
The highest total nitrogen yields (1.0-1.8 lbs/acre) occurred within the channelized reach (CR-9, CR-22, CR-10, CR-11 and CD-23) on the Clearwater River. Like phosphorus, the highest yield occurred at CR-22, which is the Kiwosay Outlet. Although this area has high nitrate yields, the total nitrogen yield is predominately in the form of organic nitrogen.

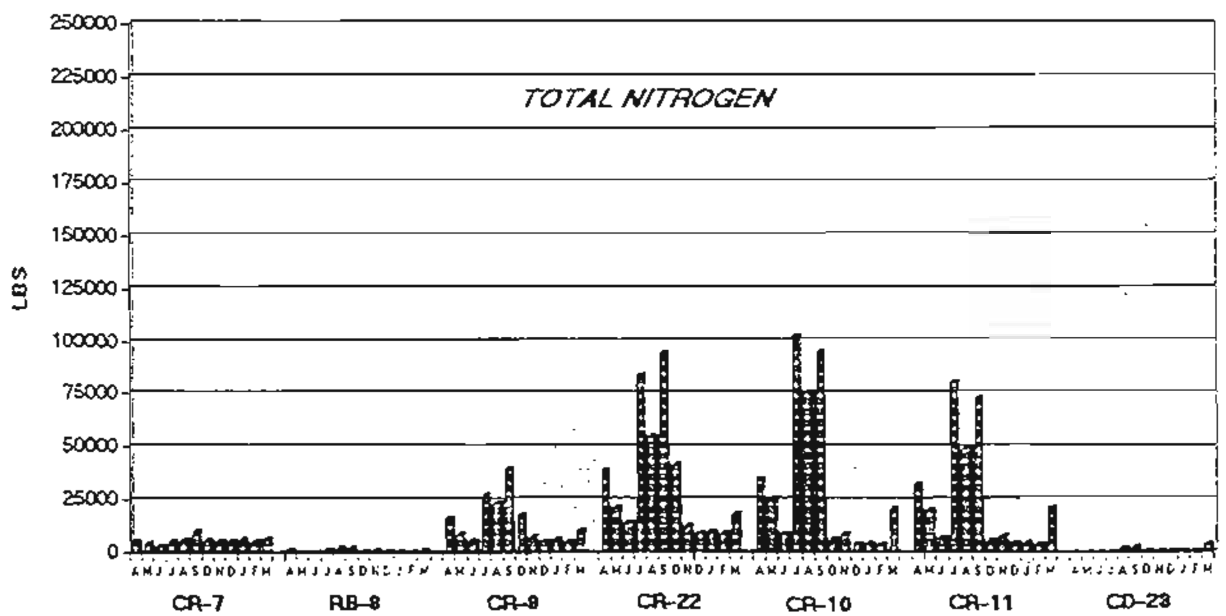
Another region of the Clearwater with high total nitrogen yield is located immediately upstream of Red Lake Falls. Sample sites CR-18, CR-19 and CR-20 have annual yields near 1.0 lbs/acre. These sites have the highest nitrate yields within the watershed, with nitrate-nitrogen accounting for more than 50% of the total nitrogen yield. In addition to high nitrate yields, this area also has high inorganic phosphorus yields. Other nearby watersheds, Plummer (CR-13) and HR-15, also have high nitrate yields which make up approximately 50% of the total nitrogen yield.

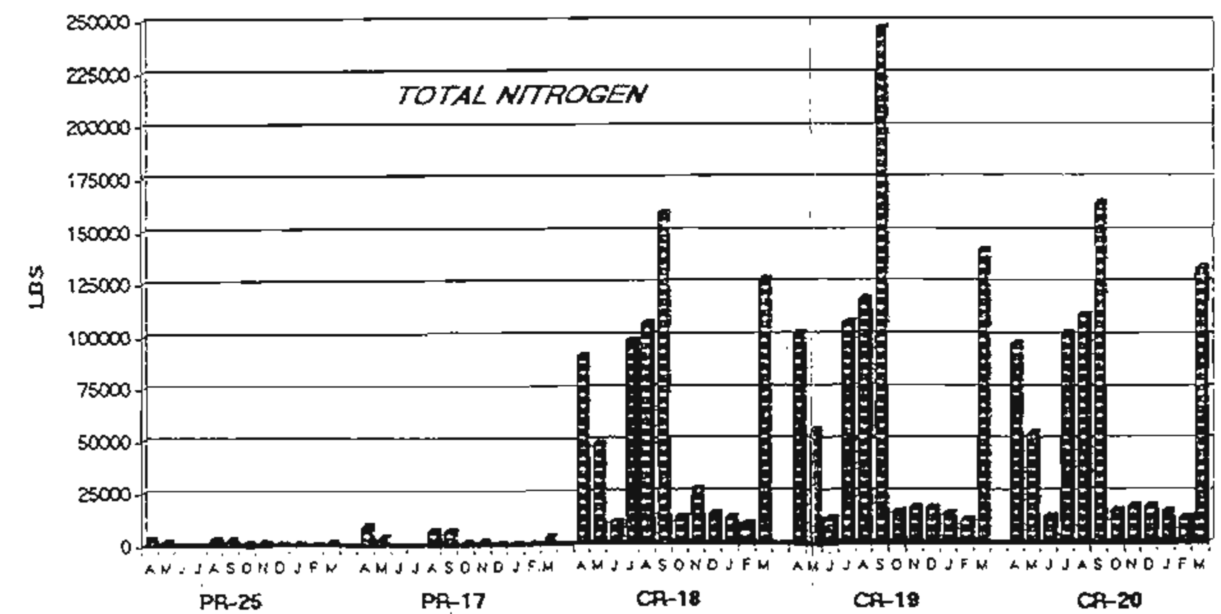
The annual total nitrogen yield (0.78 lbs/acre) within the Clearwater River watershed is comparable to the annual yield (0.83 lbs/acre) obtained from seven watersheds located in the Northern Glaciated Plains, tributary to Big Stone Lake (HDR 1992). The Clearwater River annual yield is also comparable to the estimated average annual nitrogen load (0.64 lbs/acre) to the Red River at Emerson, Manitoba (Stoner et al. 1993).

Annual total nitrogen load occurred below the Kiwosay Outlet and within the channelized reach (Figure 5-23). Monthly total nitrogen loads are summarized in Figure 5-37. The most noticeable seasonality occurs during the periods of March, April, May and July, August and September. The high loads in spring correspond to snowmelt and spring runoff. The increased load during the summer months is probably caused by increased runoff from storms.









HDR Engineering Inc.

Figure 5-37

Monthly Total Nitrogen (as N)
Load by Subwatershed
April 1, 1992-March 31, 1993

5.2.4 Chemical Oxygen Demand

Chemical oxygen demand (COD) is a measure of the oxygen equivalent of the organic matter content. It essentially represents potential "consumption" of oxygen within the receiving water. Within the Clearwater watershed, annual COD yields ranged from 11-74.5 lbs/acre (Figure 5-38). The lowest yields occurred at HR-15 on the Hill River. The highest COD yields, 58-75 lbs/acre, occur at sample sites CR-9, CR-22, CR-10, and CR-11 within the channelized reach. These results correlate to high total suspended solids yields which occur at the same sampling locations. This correlation suggests this region of the Clearwater River is receiving high inputs of organic matter. High COD yields (45 lbs/acre) also occur downstream of Bagley (CR-2, CR-3, CR-4), near Plummer (CR-12, CR-13) and downstream of Gonvik (LR-24).

5.3 Water Quality of Clearwater Lake

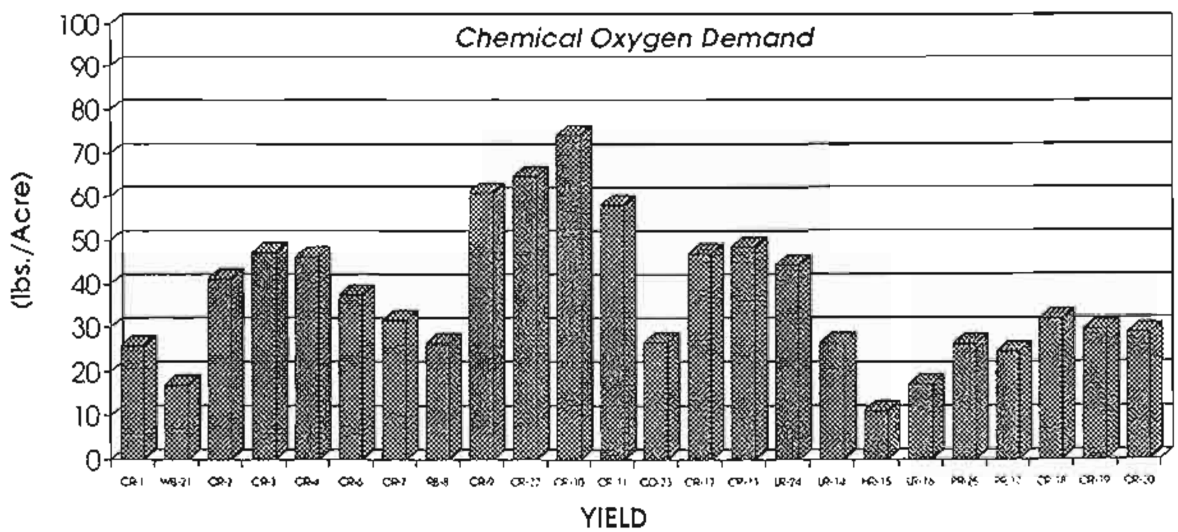
This section discusses the water quality of Clearwater Lake. Although the study did not include a specific detailed analysis of the lake, enough information is available to obtain a reasonable evaluation of the lake's trophic status.

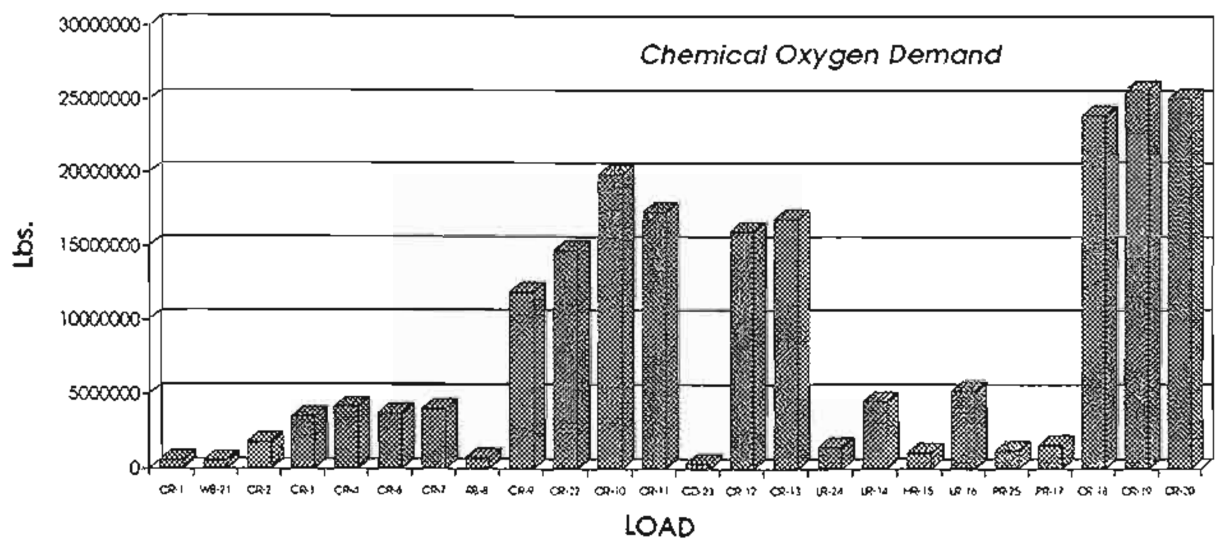
5.3.1 Characterization of Trophic Status

Clearwater Lake is located on the western edge of the Northern Minnesota Wetland (NMW) ecoregion. However, limited data are available concerning "typical" water quality characteristics for lakes occurring within the NMW ecoregion. For comparison purposes, data for lakes occurring within the NCHF ecoregion will be used to assess regional trends in water quality.

Certain "characteristics" of a lake are generally used to judge water quality. These characteristics are the total phosphorus, chlorophyll-a concentrations, and visibility of the secchi disk (an indication of water clarity). Typical values for lakes within the NCHF ecoregion are as follows (numbers in parentheses are 25th and 75th percentiles):

Total Phosphorus	30 µg/l (20-50 µg/l)
Chlorophyll-a	10 µg/l (5-22 µg/l)
Secchi disc	2 m (1.5-3.2 m)



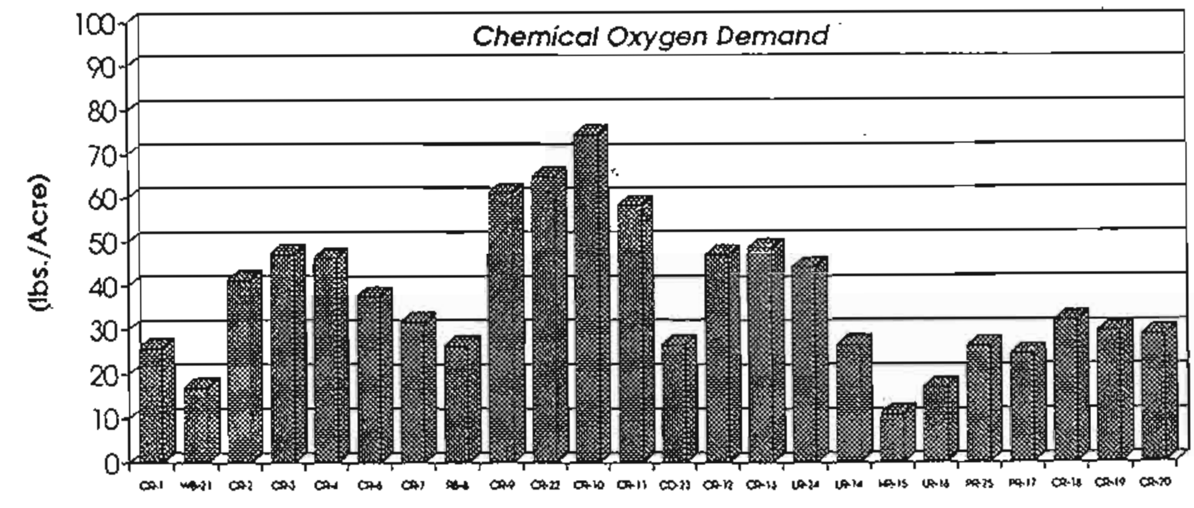


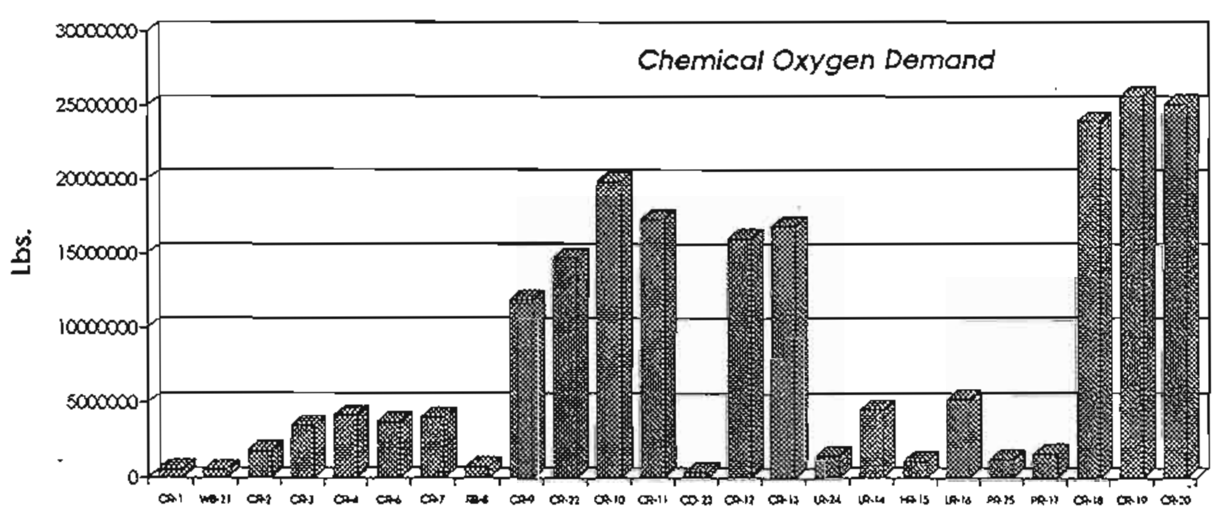
HDR Engineering Inc.

Red Lake Watershed District
Dedicated to Water Management

Figure 5-38

Annual Chemical Oxygen Demand
Yield and Load,
April 1, 1992-March 31, 1993
by Subwatershed





HDR Engineering Inc.

Figure 5-38
Annual Chemical Oxygen Demand
Yield and Load,
April 1, 1992-March 31, 1993
by Subwatershed

A comparison of these results to data compiled on Clearwater Lake, indicate that the trophic status of Clearwater Lake is mesotrophic (see Figure 5-39). Total phosphorus concentrations ranged from 12-47 μg/l with a mean of 29 μg/l. Chlorophyll-a concentrations ranged from 2.3-8.4 μg/l with a mean of 4.5 μg/l. Secchi disc readings ranged from 1.8-5.1 meters with a mean of 3.3. These values fall within the range that is considered "typical" for NCHF lakes. Table 5-2 presents descriptive statistics for the water quality of Clearwater Lake.

5.3.2 Load Retained by Clearwater Lake

5.3.2.1 Phosphorus

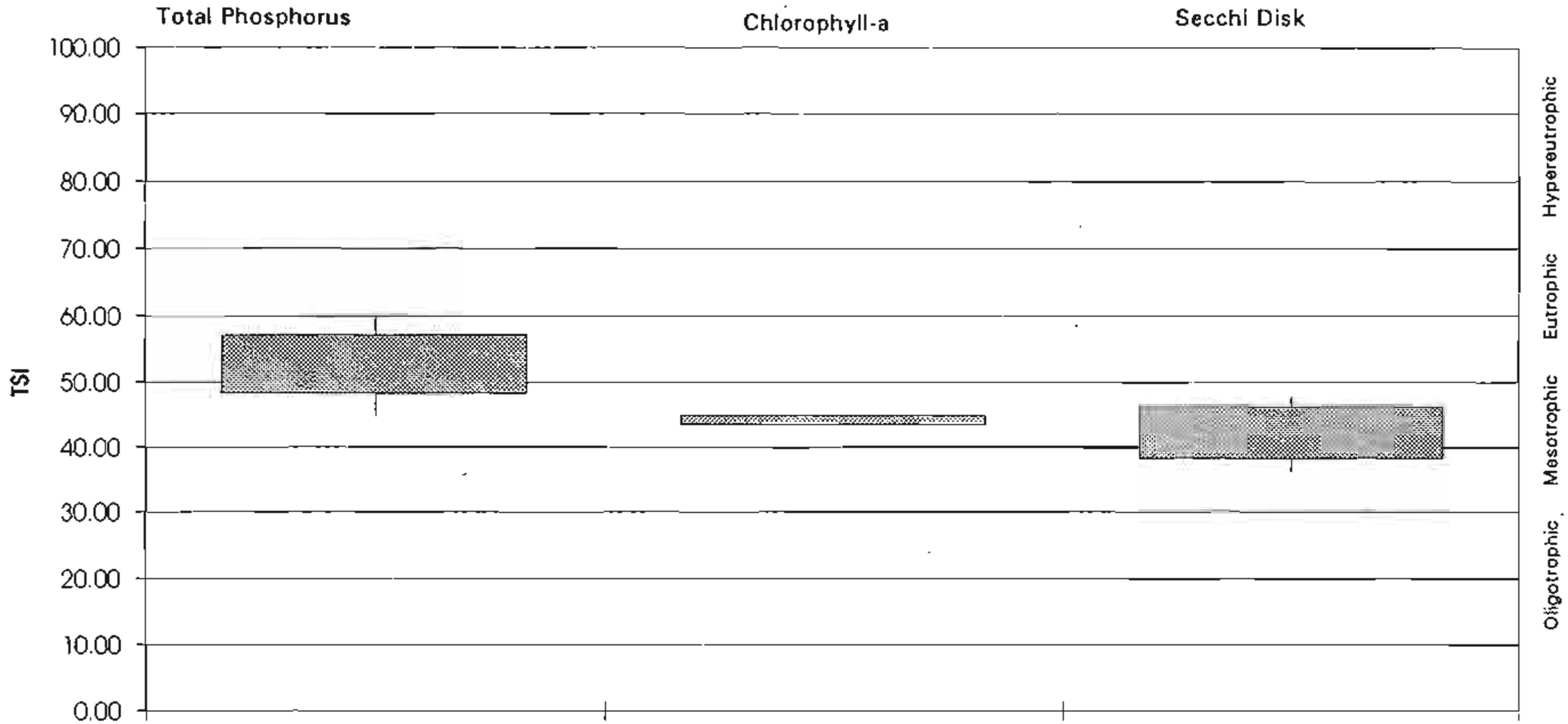
Clearwater Lake is moderately "efficient" at retaining phosphorus entering the lake. The average annual retention of phosphorus is approximately 37%. The total phosphorus load entering the lake is 7,840 lbs compared to 4,972 lbs leaving the lake. The composition of total phosphorus is about equally divided between orthophosphorus (inorganic) and organic phosphorus forms.

5.3.2.2 Nitrogen

The retention of nitrogen within the lake is very similar to that of phosphorus on a percentage basis, but the mass is much larger. The average retention of nitrogen is 31%. The total nitrogen load entering the lake is 60,401 lbs compared to 41,571 lbs leaving the lake. The total nitrogen load is largely comprised of organic nitrogen. This organic matter is likely originating from plant material and soil humus.

5.3.2.3 Solids

In general, solids retention does not occur in Clearwater Lake. The total solid load entering the lake is primarily in the dissolved solid form. Over 96% of the total solids load is made up of dissolved solids. The total solids load entering the lake is 35,674,860 lbs compared to 36,380,579 lbs leaving the lake.



HDR

HDR Engineering Inc.

Red Lake Watershed District
Dedicated to Water Management

Legend

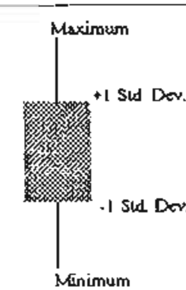


Figure 5-39

Trophic Status of Clearwater Lake Based on Samples Collected May 1992 - September 1992

Table 5-2. Water Quality Summary for Clearwater Lake, April 1, 1992-March 31, 1993

Parameter	Sample Size	Mean	Median	St. Dev.	Minimum	Maximum
Water Temp. (°C)	13	17.32	17.20	2.11	13.7	20.4
pH	13	8.28	8.23	0.17	8.04	8.56
Conductivity (umhos/cm)	13	458.54	450.00	31.67	416	517
Dissolved Oxygen (mg/l)	12	9.86	9.78	1.39	8	12.7
Turbidity (Ntus)	13	0.99	1.10	0.44	0.2	1.7
COD (mg/l)	12	23.58	22.00	6.65	15	37
Color App: (Pt/Co units)	13	23.08	14.00	14.83	5	51
True: (Pt/Co units)	12	13.00	11.50	10.77	0	42
Nitrate (as N) (mg/l)	13	0.02	0.00	0.03	0.0005	0.105
Ammonia (as N) (mg/l)	12	0.01	0.01	0.00	0.005	0.005
Total Kjeldahl Nitrogen (as N) (mg/l)	10	0.96	0.10	1.44	0.05	4.09
Orthophosphate (as P) (mg/l)	11	0.01	0.00	0.01	0.001	0.017
Organic Phosphorus (as P) (mg/l)	11	0.02	0.02	0.01	0.004	0.036
Total Phosphorus (as P) (mg/l)	13	0.03	0.03	0.01	0.012	0.047
Alkalinity (as $CaCO_3$) (mg/l)	13	221.38	219.00	20.20	189	262
Chlorophyll-a (mg/l)	1	0.01	---	---	---	---
Fecal Coliforms (colonies/100 ml)	13	0.15	0.00	0.53	0	2
Total Suspended Solids (mg/l)	13	2.08	1.75	1.23	0.5	5
Volatile Solids (mg/l)	13	1.44	1.50	0.82	0.5	3.25
Secchi Disk (meters)	9	3.34	3.51	1.07	1.83	5.18

5.4 Biological Characteristics of the Clearwater River

This section presents a summary of the biological diversity of the Clearwater River; the fishery, macroinvertebrates and attached algal community (periphyton). It is largely based on the stream survey performed by the MnDNR and periphyton samples scraped from vegetation by RLWD staff during June, July and August. The discussion is divided into three stream reaches corresponding to the MnDNR survey.

5.4.1 Fish Community

5.4.1.1 Reach 1 (River Miles 0.0 to 46.2)

This portion of the stream meanders through a mixed hardwood lined corridor, has few stream-bank alterations and remains natural in appearance. There are numerous and extensive riffle areas starting at mile 25.0. These riffle areas are comprised of large boulder and rock with an average diameter greater than 12 inches. This portion of the stream has ideal gamefish habitat. The gamefish community exhibited the greatest species diversity of the three reaches. Rock bass were the most abundant species sampled followed by the smallmouth bass, walleye and perch, and northern pike. The roughfish community was somewhat diverse; golden redhorse was the most abundant species present followed by the shorthead redhorse, white sucker, quillback, and stonecat, respectively.

Numerous crayfish and other invertebrate species, which serve as an important food source, were sampled at the various riffle areas. The diversity of minnow species within this reach was low. There were two species sampled; the most abundant being the common shiner followed by the hornyhead chub.

As the river enters Red Lake Falls, a sequence of riffle-pool occur within the city limits. Smallmouth bass and walleye were sampled at mile 0.8, which is located in downtown Red Lake Falls. At present, anglers are reporting fewer walleye and northern pike in the Red Lake Falls area. Spring spawning walleyes have been concentrating below the Clearwater dam and some very large fish have been harvested in the mid-1980s.

5.4.1.2 Reach 2 (River Miles 46.2 to 79.2)

The State of Minnesota established a protected minimum flow of 36 cfs as measured at the Plummer gauge, for this reach. The stream channel is very uniform in depth and bottom types and poor water clarity results is little instream vegetation. Large woody debris for fish habitat is limited. Due to low habitat diversity, the gamefish community was nearly nonexistent, with only some small northern pike sampled. The only minnow species identified within this reach of the river was the common shiner. The roughfish community composition was consistent throughout Reach 2. The golden redhorse and the white sucker were the most abundant followed by the shorthead redhorse.

5.4.1.3 Reach 3 (River Miles 79.2 - 145.0)

The headwaters area from near Bagley to the channelized section (mile 145 to 79.2) lies in a natural forest region with minor influences by man. The river flows through three small shallow lakes near Bagley. Within this reach, the stream is slow moving due to the gradient and choked with naturally growing wild rice and beaver dams.

As the stream enters Beltrami County at mile 116.8 it flows through a moderate gradient, boulder strewn stream bed rich in springs. This river reach is classified as a designated trout stream. Brown and rainbow trout are stocked annually due to limited natural reproduction. Various habitat improvement projects have taken place since the 1950s ranging from Hewitt log ramps to stream bank riprapping. Habitat improvement measures focusing on beaver removal and channel narrowing continues to be the major projects proposed for future work.

The minnow community within Reach 3 exhibited the greatest amount of species diversity as compared to Reach 2 or 1. The blacknose dace was the most abundant species followed by the common shiner, blacknose shiner, creek chub, hornyhead chub, and the fathead minnow. White sucker dominated the roughfish community. No redhorse were sampled within this river reach. This reach also contained the only bullheads to be sampled in the river. It should be noted that no roughfish were sampled within the designated trout regions of this reach. The gamefish community consisted of the yellow perch being the most abundant followed by brown trout and bluegills respectively.

Between river mile 113.0 and 99.0 the river flows through a wild and untouched valley that is unique for this part of the state. The river flows through Clearwater Lake starting at mile 99.0.

Just upstream from the lake there are some riffle areas that could be considered important walleye spawning habitat. Future work should be directed at documenting spawning use and evaluating egg deposition and hatching success.

5.4.1.4 Fish Flesh Contaminant Analysis

The MnDNR collected fish samples at four locations (Red Lake Falls, Trail Crossing, Sawmill Station and Plummer) for PCB and mercury analysis. White sucker were collected at all four locations, while northern pike were collected at Plummer. Mercury concentration in parts per million (ppm) for white sucker ranged from 0.140 at Red Lake Falls and Sawmill to 0.072 at Trail Crossing. Mercury concentration for northern pike was detected at 0.22 at Plummer. PCB analysis of northern pike at Plummer indicated a level of 0.044 ppm. The Minnesota Department of Health has issued a 1994 Fish Consumption Advisory for all portions of the Clearwater River.

5.4.2 Macroinvertebrates

Within the Clearwater River several trends relating to the diversity and abundance of macroinvertebrate species are evident. In general, species composition is uniform throughout all river reaches. A list of common invertebrate orders previously identified by the MnDNR as part of the Clearwater River fisheries survey, is presented in Table 5-3.

Within specific regions of the Clearwater River, the lack of habitat such as instream vegetation and areas of transition (e.g., riffle, pool, run) limits the abundance and diversity of certain invertebrate species. As a result, invertebrate populations within the Clearwater River tend to follow a distribution trend which is directly related to the physical characteristics of the stream reach.

The greatest diversity and numbers of invertebrates are found within Reach 1 and 3. These reaches provide invertebrates with suitable cover and substrate required for a balanced lotic system. Results from the fisheries survey indicate that the stable invertebrate communities are capable of sustaining viable fish populations within these areas.

Low invertebrate diversity and numbers occur within Reach 2 due to the lack of suitable habitat structure. One invertebrate order in particular, Malacostraca (crayfish), were determined to be extremely rare. Although only one location was sampled in Reach 2, results are believed to be representative because of the uniform stream geometry found throughout the reach.

Table 5-3. List of Common Invertebrate Orders Found in Clearwater River

Order	Common Name
Odonata	Dragonfly Damselfly
Tripotera	Caddisfly
Hemiptera	Water striders
Ephemeroptera	Mayfly
Diptera	Cranefly Phantom midge Gnats Horsefly
Coleoptera	Whirligig
Malacostraca	Crayfish
Copepoda	Cyclops
Hydracarina	Water mite
Gastropoda	Gyraulus Snail Fingernail clams

5.4.3 Periphyton

Within the Clearwater River, the number of types of periphyton (attached algae) is uniform from downstream to upstream, but the relative abundance varies within the reaches. Diatoms were the most prevalent type of periphytic organism found in the samples. Other organisms present, but found infrequently within samples, include green and blue-green algae along with various desmids, protozoans, rotifers, and nematodes.

The observed differences in the number of types of periphyton between Reach 2 and Reaches 1 and 3, are likely the result of little structural diversity in Reach 2. Within Reach 1 and 3 there is suitable substrate (rocks, logs, aquatic plants, etc.) which can support a diverse periphytic community. By contrast, Reach 2 is deficient in substrate. The general trend of reduced periphytic diversity in Reach 2 is exhibited throughout the various trophic levels.

5.5 Diagnostic Study Summary

Water quality of the Clearwater River and its tributaries are affected by municipal point sources, channelization, wetlands and agriculture. Important observations resulting from the diagnostic summary includes:

- Total solids concentrations, comprised largely of dissolved solids, increase moving downstream from the headwaters of the Lost, Clearwater, Poplar and Hill rivers. This phenomena occurs naturally, but is accelerated in the case of the Clearwater River by the increased density of ditch outlets, increased intensity of agricultural practices, the degraded physical integrity of the channel and municipal and urban discharges (e.g., Bagley area). The one monitored agricultural ditch had the greatest solids concentrations.

- Storm events which caused increased nonpoint source pollution runoff was an important factor influencing water quality, primarily in the lower river reaches. The effect of smaller storm events, evidenced by lower dissolved solids, greater total suspended solids, and greater nutrients, lasts a few days. The effect of larger storms lasted one to two weeks.

- Total suspended solids concentrations compared favorably to water quality of minimally impacted streams in the Northern Minnesota Wetland and North Central hardwood Forest ecoregions. Concentrations within the channelized reach of the Clearwater River were more similar to the Red River Valley ecoregion.

- Municipal point source discharges, specifically from McIntosh, Bagley, and Clearbrook, most affect total phosphorus concentrations. This affect is most readily observable at upstream locations, where "background" concentrations are low.

Measured total phosphorus concentrations in the upstream reaches were below measured concentrations for minimally impacted streams, but were comparable to the North Central Hardwood Forest and Northern Minnesota Wetlands in the mid and lower reaches.

- Municipal wastewater point sources have a less pronounced effect on total nitrogen concentrations, than on total phosphorus. Total nitrogen concentrations increased from upstream to downstream, a natural phenomena. Interestingly, the largest increase in total nitrogen occurred at the Kiwosay outlet, where flow from a large peat wetland enters the Clearwater River. Ammonia was generally not measurable. Nitrate concentrations within the headwaters of the Clearwater River compared favorable with the Northern Minnesota Wetlands ecoregion, but exceeded typical concentrations for the Red River Valley in the lower reaches. Concentrations were elevated in Ruffy Brook, compared to similar headwaters areas.

- Dissolved oxygen concentrations reach critically low values within portions of the Clearwater River, Walker Brook, the Lost River and the Poplar River. Natural low flow and winter ice conditions presumably cause the low concentrations within Walker Brook, although chemical oxygen demand is elevated in this reach. Municipal and urban discharges are the likely cause of the low dissolved oxygen below the Bagley area. Dissolved oxygen also decreases through the channelized reach, as chemical oxygen demand increases, presumably the result of increased agricultural intensity.

- Monitoring locations below municipal point sources discharges showed greater algae concentrations, as evidenced by chlorophyll-a concentrations.

- Fecal coliform bacteria are elevated below the municipal discharges of McIntosh and Gonvick, and within the middle portion of the channelized reaches. Concentrations throughout the watershed seem elevated, at least when compared to a reference concentration of 200 colonies per 100 ml.

- Pesticides, as characterized by the two indicators MCPA and 2,4-D do not present a risk either in the water column or within sediments.

- Clearwater Lake is a mesotrophic trophic lake. The low retention of total phosphorus (37%), as compared to typical retention for lakes (76%), suggests additional sources of nutrients, other than upstream loading. There is reason for concern about increasing cultural eutrophication of Clearwater Lake.

- Greatest yields (lbs/acre) within the watershed for total nitrogen and total phosphorus occur below the Kiwosay outlet, a large peat wetland.

- The largest yields of chemical oxygen demand occurred within the channelized portion of the Clearwater River. Agricultural production and the increased number of ditch outlets presumably affect this reach.

- The greatest loads (lbs) of nutrients and solids occur in two general locations; immediately below Bagley and within the channelized reach. The loads within the channelized reach are considerably greater and of more importance. The high loads within the channelized reach are presumably from the increased density of ditch outlets in this reach and increased intensity in agricultural production. Monitoring locations impacted by point source discharges also show high loads.

- The greatest monthly load for nutrients occurred during the spring runoff months of March, April and May.

- Total solids yields compared favorably with yields for streams tributary to Big Stone Lake, located within the Northern Glaciated Plains ecoregion.

- The biologic community (fish, macroinvertebrates and periphyton) is substantially altered within the channelized reach. This reach exhibits lower species diversity when compared to the upstream and downstream reaches. The lack of physical integrity is the primary factor for lower diversity.

- The study does confirm impairment of the Clearwater River between mile points 135 and 132 and 58 and 47. These areas are anticipated to be of primary concern for implementation measures for the next phase of the study.

6.0 MANAGEMENT PLAN FOR IMPROVING WATER QUALITY

6.1 General

Perhaps the most important purpose of the Clearwater Nonpoint Study, is to develop an effective management plan once water quality degradation is identified. Water quality degradation is generally identified by comparing the concentrations measured during the diagnostic study to "expected" or "the best possible" concentrations. Similarly, subwatershed yields calculated from the monitoring data can be compared to each other and to land use characteristics within the subwatershed. Yields can also be compared to watersheds outside of the study area. Presumable, the manifestation of degraded water quality is impaired use; i.e., the desired uses of the Clearwater River are not being met.

Two methods seem reasonable for determining the "best possible" water quality for the Clearwater River, and establishing numeric water quality goals. The MPCA has identified water quality concentrations, by Ecoregion, for minimally impacted streams. The data presented in Section 5.1, "Water Quality Characteristics" show many Clearwater River monitoring locations, especially within the headwaters, have better water quality than those identified within the ecoregion as "minimally impacted". Limited sample size within the ecoregion for minimally impacted streams may be one reason for this observation.

Perhaps the best possible water quality within the Clearwater River can be established by using the measured concentrations at headwater monitoring locations, not influenced by point source discharges (CR-1 and WB-21). However, it must be realized that these concentrations would likely increase naturally while moving downstream, even without anthropogenic influence. To quantify the magnitude of this increase is difficult, but these concentrations can be used as a point to begin setting numeric water quality "goals" for the Clearwater River, if it is desired to work toward more pristine conditions.

The last, easiest, and most direct approach to identifying water quality degradation and water quality goals, although not necessarily based on achieving the best possible water quality, is to use water quality standards established by the MPCA. These standards are established to ensure swimmable and fishable uses associated with Class 2B waters (see Table 1-1). Based on the diagnostic study, concentrations of dissolved oxygen and possibly fecal coliform bacteria, failed to meet established standards. Therefore, a goal of the management plan is to improve water quality to meet standards. Total suspended solids are also an important index of water quality.

quality. Although a specific concentration goal within the river is difficult to establish, the general goal of decreasing sediment yields from subwatersheds seems reasonable. Nutrients are often associated with sediment, and consistently decrease.

The reasons for degraded water quality within portions of the Clearwater River are multiple and complex. Point source discharges are the primary factors affecting water quality in the upstream reaches of the Clearwater, Poplar River and possibly Ruffy Brook. Walker Brook is most influenced by ice and snow cover. Feedlots, channel scour, bank erosion, and agricultural practices are the primary factors within the middle, channelized portion of the Clearwater River. These factors along with local conditions and tributary inflow, ultimately influence the water quality within the downstream reach of the Clearwater River. The management plan is centered around developing a method of addressing each of the identified factors, evaluating the anticipated improvement in water quality by implementing these methods and providing estimated costs for these methods. Responsibility for selecting specific water quality improvement methods lies with the Technical Steering Committee and is based on an understanding of desired uses discussed at public informational meetings.

The type of monitoring network used during this study is primarily designed to determine spatial and seasonal water quality trends and assess the general quality of water. The network is not specifically designed to assess the affect of loads from individual point or nonpoint sources, within the context of a water quality model. (It is not suited to establishing Total Maximum Daily loads from individual sources). However, the data can be used within the water quality model to "recreate" loads within various reaches of the river using the observed water quality and to generally assess the response of the river when loads are reduced by implementation methods. An example best illustrates the point. The water quality data clearly show an increase in total suspended solids within the channelized portion of the Clearwater River. The water quality data gathered during the study identified that an increase in total suspended solids occurred. But, the data are not sufficiently detailed to estimate what percentage of the increase comes from either point or diffuse sources like bed scour and bank erosion, discharges from commercial rice production, feedlots or drainage ditch outlets. This requires a more intensive, localized monitoring effort.

This management plan is based on "present conditions" within the watershed. Considerable land, as much as 25% within Pennington County, is enrolled in the Conservation Reserve Program. The affect of measures described here may be greatly minimized should this land come back into production.

6.2 Management of Clearwater River Watershed by Stream Reach

From a management perspective, water quality goals need to reflect differences in river characteristics and surrounding land uses. For the purposes of establishing water quality goals and developing a management plan, we divided the Clearwater River into three reaches. These are the same reaches introduced in Section 2.1, "Physical Characteristics of the Clearwater River", and used by the MnDNR while performing their stream survey. These reaches were selected for developing the management plan because water quality, the biotic community, watershed characteristics (e.g., land use) and channel characteristics are clearly unique to each reach.

The management plan is based on a preliminary goal of swimmable and fishable waters for the entire Clearwater River. Table 6-1 shows the preliminary water quality goals. Low dissolved oxygen below Bagley suggests the fishable goal is not met within Reach 1. The low dissolved oxygen within Reach 1 can sufficiently affect the viability of the fishery. Fecal coliform bacteria could potentially impair the swimmable goal in many reaches (e.g., the channelized portion of the Clearwater River, the lower reaches of the Clearwater river above Red Lake Falls, and the upper reaches of the Poplar River). Habitat within the channelized portion of the Clearwater River, likely prohibits the development of a self-sustaining sport fishery.

The need for nutrient goals for lotic systems, is not as obvious as the need for limiting nutrient inputs for lentic systems. Nutrient concentrations within the Clearwater River are lower than initially expected and generally less than the concentrations established by the MPCA for minimally impacted streams. Nutrient load reductions can be expected by reducing total suspended solids loads. Therefore, no nutrient goals were established for the Clearwater River.

The exception is for Clearwater Lake. Nutrient loading to Clearwater Lake should not exceed the present loading rate, in order to ensure the rate of cultural eutrophication does not increase. Clearwater Lake retained 37% of the annual total phosphorus load, compared to typical values exceeding 60%. The low percentage of total phosphorus retained by Clearwater Lake, suggests additional sources along the shoreline of the lake or from within the lake (sediment). These are most likely shoreline development and failing septic systems. The data suggest Clearwater Lake is undergoing cultural eutrophication and further study of the lake is warranted.

Table 6-1. Water Quality Goals for the Clearwater River and Tributaries, Based on the Desired Uses of Swimmable and Fishable Waters

		Water Quality Goal		
Stream Reaches	**Desired Uses**	**Total Suspended Solids**	**Dissolved Oxygen[1]**	**Fecal Coliform Bacteria[1]**
Clearwater River Reaches 1, 2, and 3	Swimming and Fishing	Goal is to reduce yield in subwatersheds to Reach 2	5 mg/l	< 200 organisms per 100 milliliters
Lost River	Swimming and Fishing	None priority given to Clearwater	5 mg/l	< 200 organisms per 100 milliliters
Hill River	Swimming and Fishing	None priority given to Clearwater	5 mg/l	< 200 organisms per 100 milliliters
Poplar River	Swimming and Fishing	None priority given to Clearwater	5 mg/l	< 200 organisms per 100 milliliters

[1] Dissolved oxygen and fecal coliform bacteria goals are related to target load reductions for steady state low flow conditions occurring during period modeled (July 27-August 10, 1992).

6.3 Problem Identification, Corrective Measures and Estimated Costs

This section identifies specific problem areas, identifies needed load reductions, identifies strategies to address these problems, and provides estimated costs for implementing these activities. Estimated costs are for planning purpose only and do not include costs for technical support (e.g., engineering) or administration. Preliminary design and refined cost estimates are necessary prior to construction. Conceptual designs of the various implementation methods are presented in appropriate cases.

6.3.1 Streambank Erosion

Streambank erosion and erosion generally is a sign that sediment transport within a river is not in equilibrium. Erosion protection measures are intended to alter aggradation and degradation. Based on the increase in total suspended sediment concentrations and field observations, sediment transport in the channelized reach is not in equilibrium. Placing physical structures in this reach needs to be done so cautiously.

Streambank erosion surveys of the Lost, Hill and Poplar Rivers are still necessary to determine the extent and severity of erosion on these rivers. Therefore, implementation activities for addressing streambank erosion will concentrate on the Clearwater River. The MnDNR identified a number of locations subject to erosion along the Clearwater River while performing their stream survey (see Figure 2-2). Table 6-2 shows locations of streambank erosion, estimated length of channel eroding and estimated costs for implementing protection. These costs are based on typical unit length estimates, using the previous experience of the RLWD. Because of the large number of locations, further prioritization of these sites is needed to identify the most critical erosion problems and rank them in order of importance for implementation.

A number of erosion protection measures are potentially available, each being site specific. Traditional and "nontraditional" methods are available, with nontraditional methods generally providing habitat and bank protection. Examples of traditional methods include regrading and revegetation and armoring by using properly sized rock riprap and gabions. Nontraditional methods include regrading and revegetation using more endemic species, the use of rock riprap of varying median diameters (e.g., larger boulders and smaller cobble) strategically placed to

Table 6-2. Locations of Streambank Erosion Identified by the Minnesota Department of Natural Resources on the Clearwater River

River Mile	Description of Erosion Problem	Approximate Length (ft)	Estimated Cost[1]
2.5	Bank erosion on outside bend of river	50	1,350
3.5	Erosion on outside bend by house	100	2,700
5.6	High bank - gravel pit road dozed into river	None Available	
6.2	High sand bluff	250-300	8,100
9.8	High degree of bank erosion on left bank	200	5,400
11.3	Erosion resulting from cattle watering	150	4,050
19.7	High sand bank	200	5,400
21.2	Erosion on outside bend near farm pasture	75	2,050
25.5	High bank eroding	150	4,050
28.2	Typical bank erosion	75	2,025
50.9	Bank erosion area	50	1,350
59.8	Bank erosion near rice paddy	75-100	2,700
64.2	Bank erosion near rice paddy	75-100	2,700
116.7	Bank erosion	25	675
	Total	1,525	45,525

[1] Based on unit cost of $27/foot for 12-inches D_{50} riprap (Brent Johnson, RLWD); estimate for planning only.

create habitat and root wad revetment. Figure 6-1 shows conceptual designs for traditional and nontraditional methods. The selection of a specific protection method will occur during implementation based on hydraulic considerations, the need for creating habitat and cost.

In the case of larger bluff areas, redirecting the energy of the stream may be needed. One method to achieve this is the use of log deflectors (Figure 6-2). Wedge dams (Figure 6-2) or "K-dams" may be used within the channel to alter sediment transport and create local pool areas.

Suggested implementation responsibilities for streambank protection are:

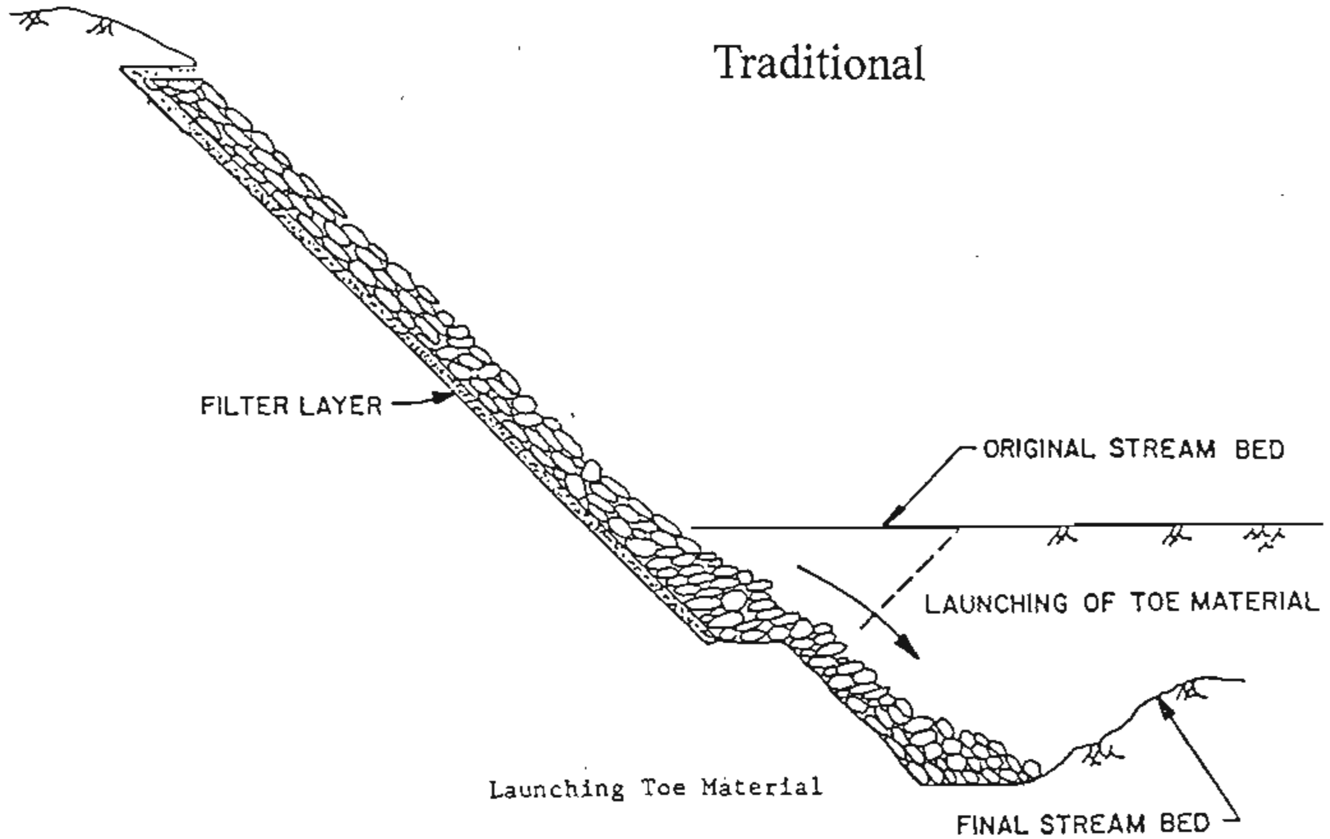
- Hydraulic Design - RLWD
- Habitat Considerations - MnDNR
- Landowner Relations and Easements - SWCDs and RLWD
- Construction Monitoring - SWCDs and RLWD
- Funding - MPCA, MnDNR, BWSR and local match

6.3.2 Nonpoint Sources

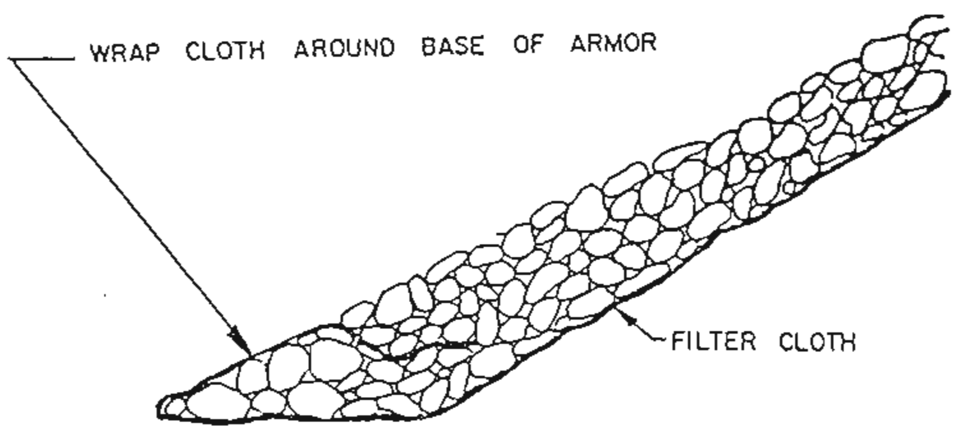
Nonpoint sources are by definition diffuse and generally more difficult to control than point source discharges. These sources are generally considered the result of land use practices. More intensive land use practices like row crop production generally result in greater nonpoint sources of nutrients, sediment and oxygen demanding materials. The annual yield coefficients (mass per area - in our case lbs/acre - year) presented in Section 5.2, "Estimated Loading and Yields" can be used to assess the nonpoint source contribution of the each of the subwatersheds within the Clearwater River basin. Yield coefficients are normalized by drainage area and are a better measure of the influence of specific subwatersheds than loads.

Using annual yields, each of the subwatersheds can be prioritized with regard to their nonpoint source contribution. Subwatersheds were prioritized from "worst" (highest yields) to "best" (lowest yields) by evaluating the magnitude of the chemical oxygen demand, total solids, total phosphorus and total nitrogen annual yield coefficients (see Table 6-3). The annual yield coefficients showed considerable variation among locations. Clearwater River subwatersheds terminating at sampling locations CR-22, CR-10, CR-9, CR-11 and CR-12 consistently had the largest solids, nutrient and COD yields. Therefore, these subwatersheds are selected as the priority subwatersheds for the implementation of nonpoint source BMPs.

Traditional



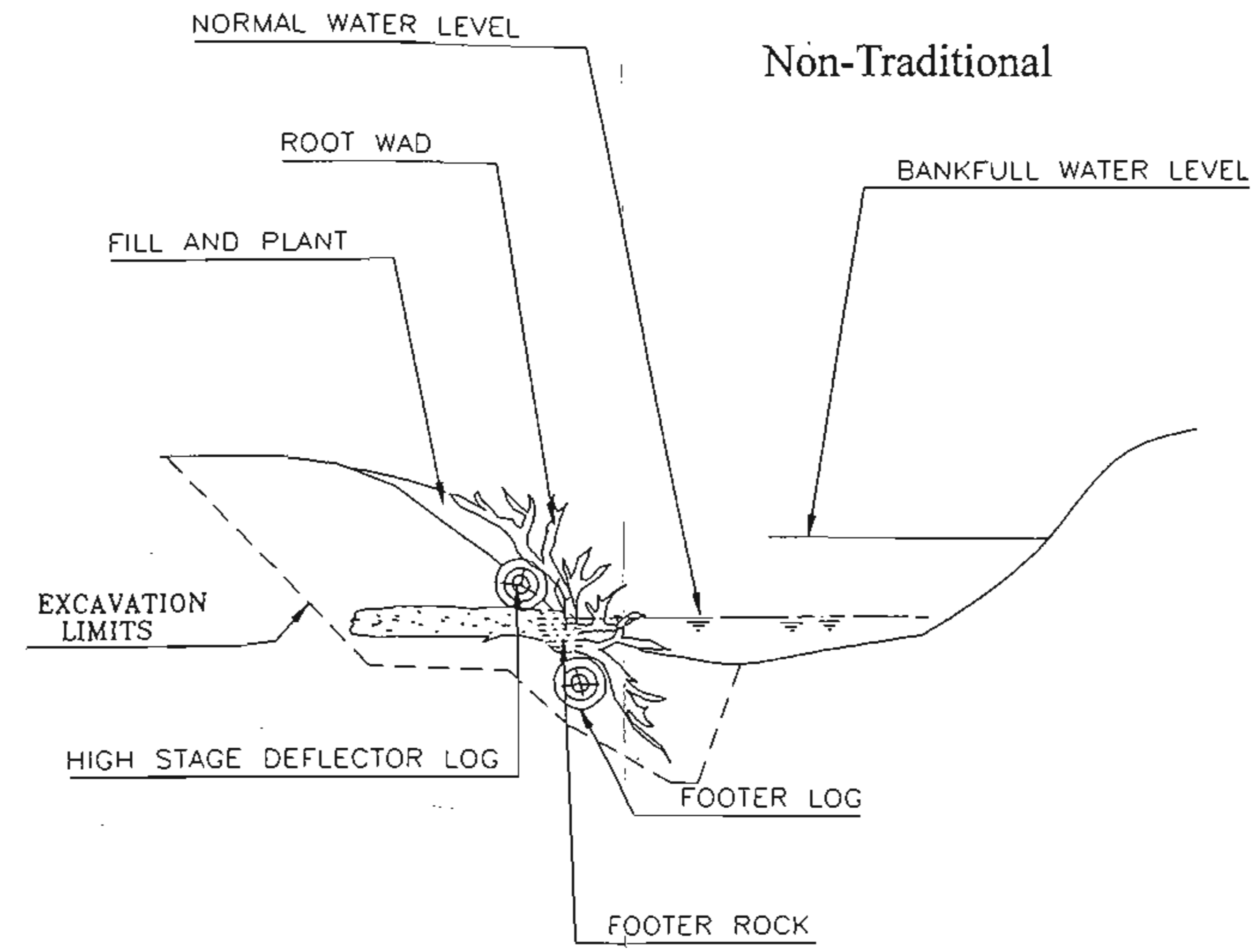
Launching Toe Material



"Dutch Toe"

Source: SCS 1989.

Non-Traditional



ROOT WAD REVETMENT

NTS

Notes:

1. Excavated area will require revegetation after installation.
2. Root wad should not protrude into channel farther than natural bank.

HDR Engineering Inc.

FIGURE 6-1

Conceptual Design of Select Traditional and Nontraditional Methods for Streambank Protection

Table 6-3. Subwatershed Implementation Priority for the Application of Nonpoint Source Best Management Practices

		Total Yield in lbs/acre/yr				
Clearwater River		Chemical Oxygen Demand	Total Solids	Total Suspended Solids	Total Phosphorus	Total Nitrogen
Reach #1	CR-20	28.8	174.1	11.1	0.068	0.87
	CR-19	29.6	183.5	1.3	0.07	0.99
	CR-18	32.1	188.8	13.3	0.08	0.97
	CR-13	48.5	245.6	14.2	0.108	0.83
	CR-12[1]	47	246.2	16.2	0.109	0.82
	CD-23	26.7	334.7	11.6	0.098	1.3
Reach #2	CR-11[1]	58.3	260.5	23.8	0.129	1.05
	CR-10[1]	74.5	331.9	41.1	0.135	1.5
	CR-9[1]	61.1	336.3	27.6	0.122	0.9
	CR-22[1]	64.9	451.3	60.2	0.168	1.8
Reach #3	CR-7	31.7	320.7	5.5	0.059	0.55
	CR-6	37.5	363.2	1.3	0.05	0.37
	CR-4	46.3	392.9	11.3	0.087	0.61
	CR-3	47.3	503.8	6.2	0.053	0.74
	CR-2	41.4	327.8	4.1	0.01	0.57
	CR-1	26	287.8	2.38	0.051	0.45
Tributaries						
Poplar River	PR-17	24.7	161.4	4.3	0.035	0.62
	PR-25	26.4	165.6	1.5	0.085	0.5
Lost River	LR-14	26.7	204.5	3.3	0.037	1.1
	LR-16	17.2	126.6	4.4	0.03	0.59
	LR-24	44.4	217.5	3	0.075	0.62
Hill River	HR-15	11.1	99.6	1.4	10.018	0.41
Ruffy Brook	RB-8	26.6	177.1	0.63	0.046	0.38
Walker Brook	WB-21	17	117.1	1.3	0.001	0.091

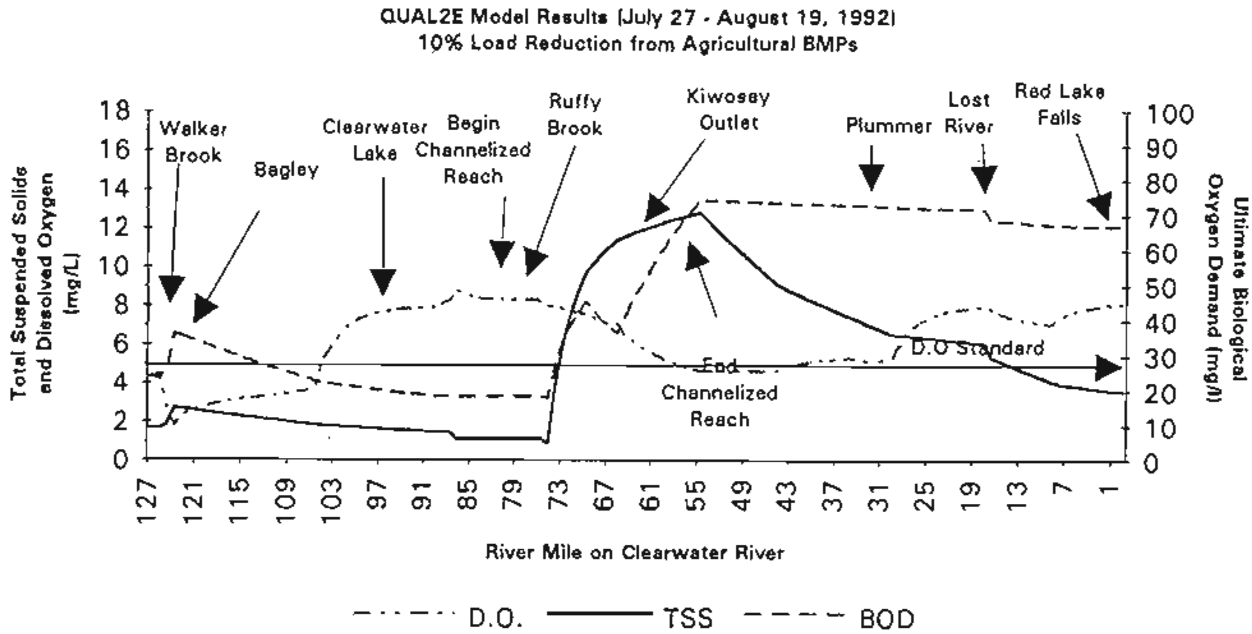
[1] Priority subwatersheds for implementation.

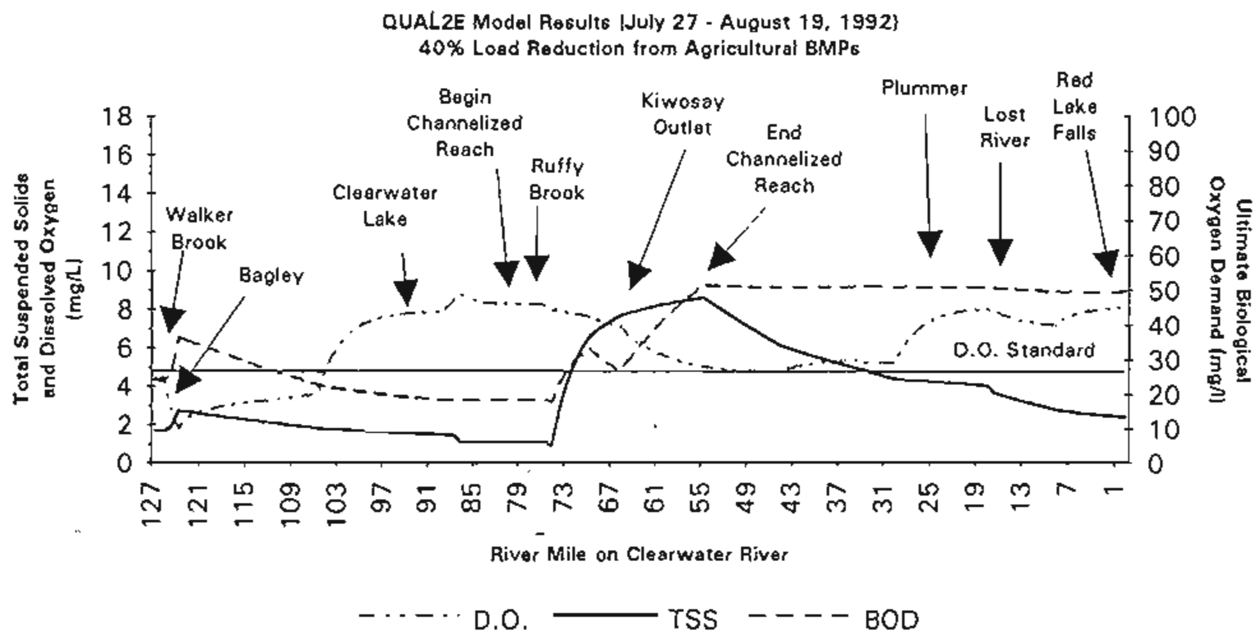
The anticipated improvement in water quality from implementation of BMPs is shown in Figure 6-3. The anticipated improvement is based on the assumption that the percentage of annual load reduction occurring during the low flow period modeled (July 27 - August 10, 1992) is equal to the percentage of the annual load monitored during this period. That is, the load reduction from BMPs on a monthly basis or some shorter time period, is in proportion to the percentage measured for the same period during the study. The challenge is to select a suite of BMP's (see Table 6-4) capable of achieving load reductions. For planning purposes and to enable cost estimation the BMP was assumed to be conservation tillage and, modeling provided the basis for estimating the acreage of land needing conservation tillage to achieve annual load reductions of 10%, 20%, 30%, and 40%.

BMPs are defined as those practices, techniques, or measures determined to be the most effective, practicable means of preventing or reducing sediment and/or pollutants from rural and urban nonpoint sources to a level compatible with achieving water quality goals. A description of these management practices is provided in Table 6-4 and their effect in Table 6-5. The estimated number of acres needing BMPs is based on load reductions associated with "conservation tillage" practices (Table 6-6). The effectiveness of other BMPs which are implemented should be compared relative to minimum tillage with regard to relative load reduction. Areas with large C-factors can be identified within each of these subwatershed using the existing EPPL7 database, as likely areas for the application of BMPs.

The statistical analysis performed to assess the relationship between measured water quality, land use and soils characteristics within varying distances of the Clearwater, Lost, Hill and Poplar Rivers, suggests a distance which most influences water quality. A description of the statistical analysis and the process to determine the most influential distance appears in Appendix E.

The commercial production of wild rice has long been suspected as a reason for degraded water quality within the channelized reach of the Clearwater River (Reach 2). Results from this study do not allow the clear separation of the effects of stream channelization from rice paddy discharge, and drainage ditch outlets. Operational data available from rice producers for 1992 suggest channelization may be at least as important in influencing water quality. Discharge from rice paddies is generally complete by July 25th (Personal communication between P. Imle and M. Deutschman, April 21, 1994). Discharge ceased slightly later than normal during 1992, near





Note: assumes no load reduction in the Bagley area. Locations are approximate.

HDR Engineering Inc.

Red Lake Watershed District — Dedicated to Water Management

Figure 6-3

Anticipated Improvement in Water Quality Within the Clearwater River for Various Percentage Reductions in Annual Load from Priority Subwatersheds

Table 6-4. Identification and Description of Best Management Practices Considered Feasible for Reducing Nonpoint Source Loads Within Priority Subwatersheds of the Clearwater River (EPA 1993)

Best Management Practices	
Conservation Cover	Establishing and maintaining perennial vegetative cover to protect soil and water resources on land retired from agricultural production.
Conservation Tillage	Conservation tillage includes a number of different planting, tilling, and cultivating methods designed to leave a vegetative residue on the soil.
Contour Farming	Farming around the slopes which reduces erosion and increases infiltration. Erosion rates can be reduced up to 50% using this practice.
Cover and Green Manure Crop	A crop of close-growing grasses, legumes, or small grain grown primarily for seasonal protection and soil improvement.
Critical Area Planting	Planting vegetation, such as trees, shrubs, grasses or legumes, on highly erodible or critically eroding areas.
Crop Residue Use	Using plant residues to protect cultivated fields during critical erosion periods.
Diversion	A channel constructed across a slope to collect water and prevent damage to the area below the diversion.
Field Border	A strip of perennial vegetation established at the edge of a field by planting or converting it from trees to herbaceous vegetation of shrubs.
Filter Strip	A strip or area of vegetation intended to remove sediment, organic matter, and other pollutants from runoff and wastewater.
Grade Stabilization Structure	Grade stabilization structures involve pipe outlets or drop spillways and are used to allow water to drop to a lower elevation while protecting the soil from gully erosion or scouring.
Grassed Waterway	A natural or constructed channel that is planted with suitable vegetation to protect the soil from erosion by concentrated storm event flows.

Table 6-4. Identification and Description of Best Management Practices Considered Feasible for Reducing Nonpoint Source Loads Within Priority Subwatersheds of the Clearwater River (EPA 1993) - Continued

Best Management Practices	
Grasses and Legumes in Rotation	Establishing grasses and legumes or a mixture of them and maintaining the stand for a definite number of years as part of a conservation cropping system.
Sediment Basin	Basins constructed to collect and store debris or sediment.
Contour Strip-Cropping	Growing crops in a systematic arrangement of strips or bands on the contour to reduce water erosion.
Field Strip-Cropping	Growing crops in a systematic arrangement of strips across the general slope (not contour) to reduce water erosion.
Terrace	An earthen embankment, a channel, or combination ridge and channel constructed across the slope to intercept runoff.
Tile Intake Buffers	Tile intake buffers are intended to filter sediment and nutrients from cropland runoff prior to being discharged to ditches and streams.
Water and Sediment Control Basin	An earthen embankment or a combination ridge and channel constructed across gullies and watercourses with underground outlets. Effective for preventing gully erosion, trapping sediment and reducing downstream peak flows.
Wetland Development/ Restoration	Wetland development involves creating an artificial wetland or restoring a previously drained wetland. Wetlands act as sediment and nutrient traps, and can also reduce peak flows.
Agricultural Waste/Feedlot Management	An agricultural waste management system is a combination of practices used to properly store manure and other wastes from feedlots until they can be properly applied to cropland. A runoff management system is designed to control polluted runoff from a feedlot.
Pasture Management/ Livestock Exclusion	Livestock exclusion involves the fencing off of areas where grazing would cause erosion of streambanks or allow water quality to be lowered by livestock activity. The quality of pasture land can also be maintained.
Nutrient Management	Using proper rates, placement and timing of fertilizer applications to reduce nitrogen and phosphorus losses from cropland.

Table 6-5. The Relationship Between Various Best Management Practices (BMPs) and Anticipated Benefits of the BMP (EPA 1993)

BMPs	Sediment Reduction	Nutrient Reduction	Flow Stability	Fishery [1] Habitat
Conservation Tillage	X	X	X	X
Contour Farming	X	X	X	X
Strip Cropping	X	X		
Crop Rotation	X	X		X
Terraces	X	X	X	
Diversions				
Grassed Waterways	X	X		X
Grade Stabilization Structures	X		X	
Tile Intake Buffers	X	X	X	X
Water and Sediment Control Basins	X	X	X	X
Wetland Development/ Restoration	X	X	X	X
Agricultural Waste/ Feedlot Management		X		X
Pasture Management/ Livestock Exclusion	X	X		X
Nutrient Management		X		X

[1] Assumed to increase fish habitat by improving water quality.

Table 6-6. Estimated Acreage Needing Minimum Tillage Practices for Select Watersheds[2] to Achieve 10-40% Reduction in Annual Total Solids Load

	Estimated Acreage (Percentage of Drainage Area) Needing Minimum Tillage[1] to Achieve Annual Load Reduction			
Subwatershed	**10%**	**20%**	**30%**	**40%**
CR-10	3,418 (4.7%)	6,836 (9.4%)	10,253 (14.1%)	13,671(18.8%)
CR-11	2,616 (8.7%)	5,231 (17.4%)	7,847 (26.1%)	10,463(34.9%)
CR-12	2,817 (7.5%)	5,634 (15.0%)	8,451 (22.6%)	11,268 (30.1%)
Estimated[2] Cost for Priority Watersheds (CR-9, CR-10, CR-11, CR-12. CR-22)	944,640	1,891,840	2,839,040	3,786,240

[1] Assumed 30% reduction in erosion rate. See Appendix C for assumptions.

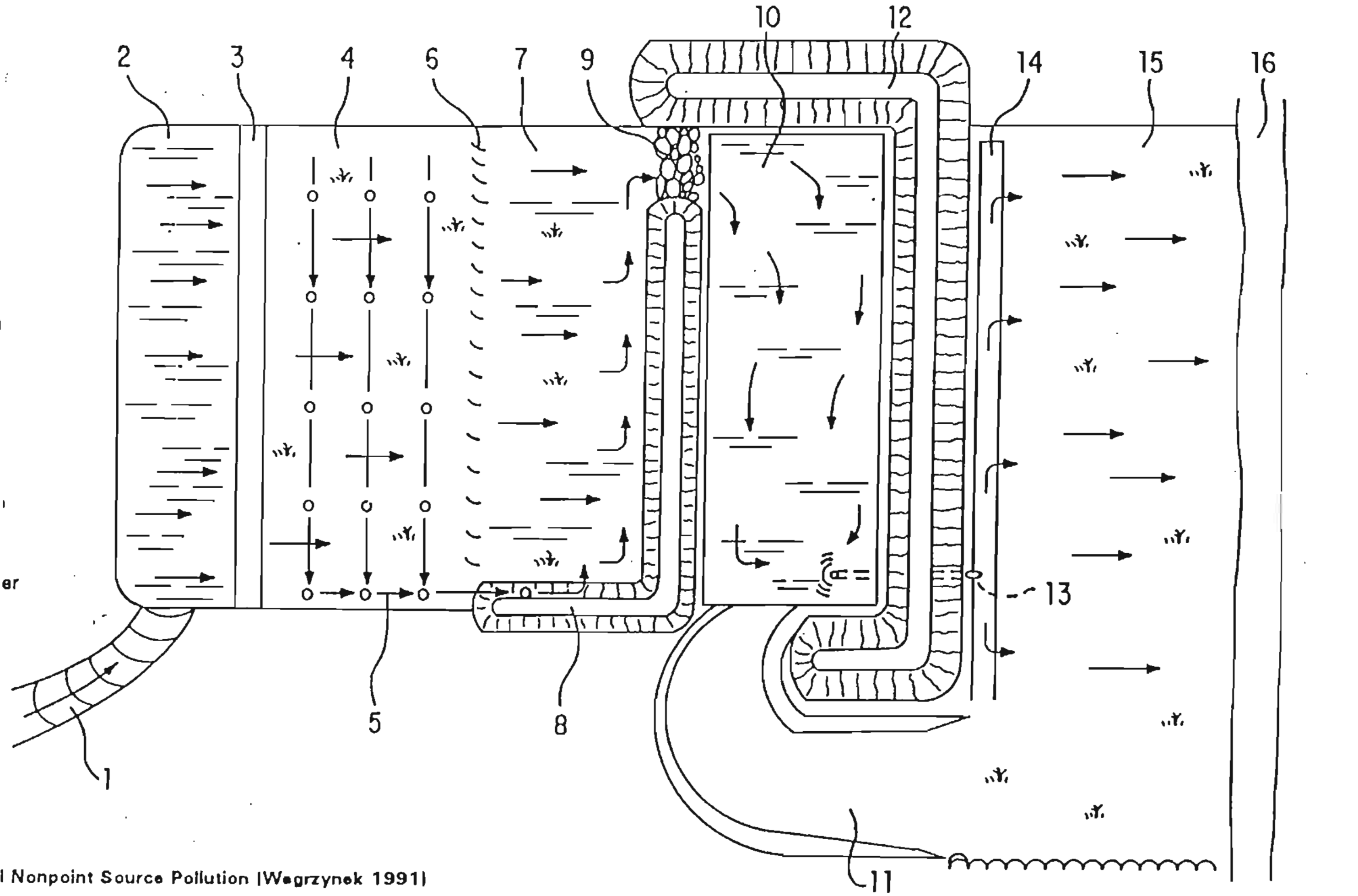
[2] Based on unit cost of $40/acre, one-time payment. Personal Communication between M. Deutschman and D. Thompson, May 13, 1993).

the last day of July, because of the wetter than normal season. Maximum concentrations of total suspended solids and total phosphorus within Reach 2 occurred after completion of this discharge and coincided with a large August storm event. Further intensive monitoring of specific discharges during the July discharge period is needed to quantitatively estimate loads coming from agricultural rice discharges versus channel erosion or other sources like dryland drainage ditches. However, a general increase in the concentrations in total suspended solids and nutrients occurred during early July and coincided with the approximate time discharge began. Nearly 100 cfs entered the Clearwater River during the July 27th - August 10th period, between the upper monitoring locations at Ruffy Brook (RB-8) and Clearwater Lake (CR-7) and the downstream monitoring location below the channelized reach (CR-12). Decreasing water temperature in this same reach moving in the downstream direction suggests groundwater is an important source of water and that not all the water came from rice paddy discharges.

Although the magnitude of the load from rice producers can not be accurately quantified without additional information, rice growers should consider ways of improving water quality during or prior to discharge. The limited amount of water quality data for rice paddies and the large amount of water used suggest the load can be important (see Appendix B). Some producers have in effect already implemented one type of BMP. Discharge from a paddy is typically to a drainage ditch prior to entering the Clearwater River. Risers with stop-logs are present on many of these gravity flow drainage ditches. Some ditches near the outlet are sufficiently wide to encourage sedimentation and are periodically cleaned to remove entrapped sediment.

Improvements to the gravity flow ditch could be made to increase sedimentation. One method is the use of level bottom ditches to encourage standing water within the ditch along with periodic removal of sediment. A second approach is redesign of the drainage ditch to create a shallow shelf adjacent to the deeper main portion of the ditch. These shallower areas can become vegetated by species like cattail and reed canary grass - in essence a biofiltration system. A third approach is to specifically design a system to treat agricultural runoff. Figure 6-4 presents the conceptual design for one type of treatment system. Select features of this type of system can perhaps be used on drainage ditches. These structural measures should be implemented in concert with conservation practices.

The most effective method for developing BMPs for rice producers is to establish a pilot program. Producers could volunteer to become involved in the program. Technical assistance for the design of the BMP would be provided by the RLWD, with cost sharing provided by MPCA, BSWR and local matching funds. The estimated cost to construct one pilot system is $26,140-65,340 (assuming a 3 acre-foot volume and $0.20-0.50 per cubic foot unit cost).



Legend

1 = Controlled Delivery
2 = Sediment Basin
3 = Level Lip Spreader
4 = Primary Grass Filter
5 = Sub-surface Tile Drainage System
6 = Change in Slope
7 = Wetland Area
8 = Training Dike
9 = Outlet
10 = Deep Water Pond
11 = Emergency Spillway
12 = Dike
13 = Outlet Pipe
14 = Spreader Dike
15 = Grass or Woodlands Polishing Filter
16 = Final Outlet

Source: Constructed Wetlands to Control Nonpoint Source Pollution (Wegrzynek 1991)

HDR Engineering Inc.

Red Lake Watershed District — Dedicated to Water Management

Figure 6-4

Conceptual Design for Agricultural Runoff Treatment System

Suggested responsibilities for implementing BMPs are:

- BMP design - SWCDs and SCS
- Estimate of Load Reduction - SCS, MPCA
- Landowner Relation and Easements - SWCDs
- Construction Monitoring - SWCDs
- Funding - MPCA, MnDNR, BWSR, SCS and local match

6.3.3 Point Sources

Point source discharges are one of the most important factors influencing water quality within the Clearwater River basin, especially during low flow conditions. Table 6-7 shows the type of treatment system for point source dischargers located within the Clearwater River basin. Many are lagoon systems designed to discharge during the spring and fall months.

Information gathered during the study provides evidence of the importance of point source discharges. Calibration of the water quality model suggests a large load occurring between the upstream monitoring locations of CR-1 and WB-21 and below Bagley at CR-2. This load is presumed to come from point and nonpoint sources within the City of Bagley. Figure 6-5 shows the effect of reducing the COD load by 50% and 100%.

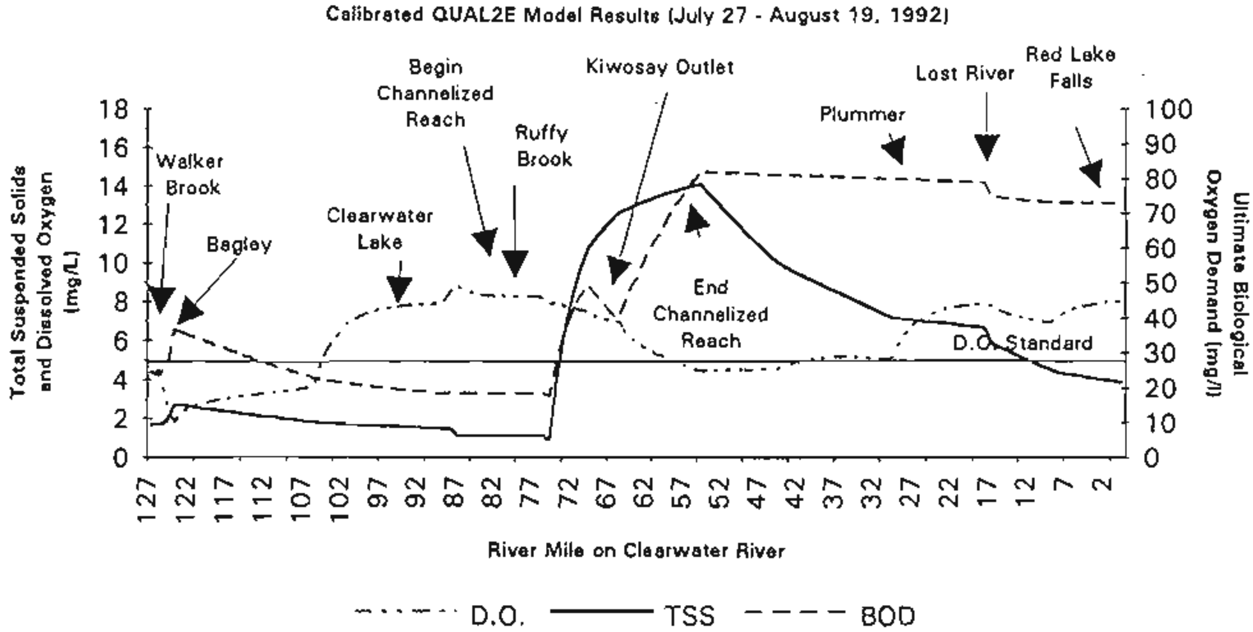
Additional point sources within the watershed influence water quality. The MnDNR identified two storm sewers discharging directly to the Clearwater River at river miles 1.0 and 133.0 during their survey. These locations may be treated by designing storm water retention basins. Typical cost for these basins ranges from $0.20-0.50 per cubic foot of storage (HDR 1993). The MnDNR also identified the discharge of an unknown fluid at river mile 2.3, near Red Lake Falls. Construction debris is present on the banks of the Clearwater River at river mile 1.0 and 31.2 and should be removed.

Regulation of point source discharges is the responsibility of the MPCA through the National Point Discharge Elimination System (NPDES) program. The MPCA should initiate as a part of this management plan an evaluation of the point source discharges within the Clearwater River basin and the effluent limitations needed to ensure water quality standards are met. Evaluation by the MPCA of the importance of the point sources identified by the MnDNR is also needed. The cost estimates have been provided for this effort.

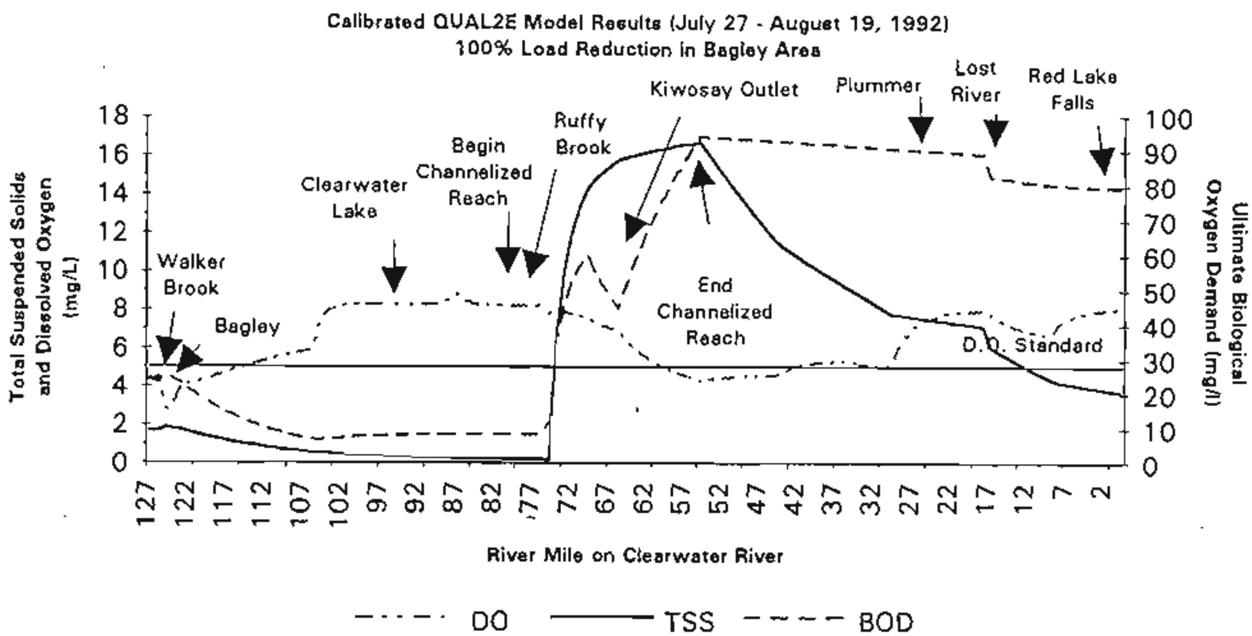
Table 6-7. Wastewater Treatment Facilities for Municipal Dischargers Within the Clearwater River Basin[1]

Location	Type of Treatment System	Year Constructed	1990 Population Served	Final Disposal
Clearbrook	Stab. Ponds	1989	557	Rutty Brook
McIntosh	Stab. Ponds	1973	664	Poplar River
Fosston	Pre-Aer., Stab Pond	1946-65,88	5,529	Poplar River
Gonvick	Activated Sludge, Contact Stabilization, Aerobic Digestion, Final Settling Tank, and Chlorination	1969	302	Lost River
Erskine	Stab. Ponds, Rapid Infiltration Basin	1968,88	422	Land
Plummer	Stab. Pond	1959	277	Clearwater River
Oklee	Stab. Pond	U.C.	441	Lost River
Bagley	Stab. Pond	1970	1,167	Clearwater River

[1] Source: Wastewater Disposal Facilities Inventory, MPCA 1991.



Note: locations are approximate.



Note: D.O. sag near Bagley caused by low headwater D.O. from Walker Brook.

HDR Engineering Inc.

Red Lake Watershed District — Dedicated to Water Management

Figure 6-5

Response of the Clearwater River Associated a 100% Ultimate BOD Load Reduction near Bagley, Minnesota, for the July 27-August 10, 1992 Period

Suggested responsibilities for implementing these point source discharge activities are:

- Evaluation of effluent discharges from Municipal Discharges - MPCA
- Development of stormwater retention basins - MPCA
- Evaluation of unknown fluid at River Mile 2.3 - SWCD
- Clean-up of Construction Debris at River Miles 1.0 and 31.2 - RLWD

6.3.4 Feedlots

This study included an inventory of feedlots using GIS. Based on current estimates, approximately 804 feedlots occur within the watersheds of the Clearwater, Lost, Hill and Poplar Rivers. GIS analysis also showed 26 feedlots within 100 m (300 feet) of a watercourse. Feedlot characteristics such as number of animals or animal waste management practices were not determined. Because of their proximity to the river, the 26 feedlots have been identified as high priority for implementation purposes. These 26 feedlots include those identified by the MnDNR as sites where runoff moves directly to the river.

The presence of a feedlot does not necessarily mean degraded water quality. Therefore, an inspection program is recommended to identify problem feedlots. Activities to be performed during implementation include cataloging each feedlot by assigning a unique identification number, performing an accurate count of the number and type of livestock at each feedlot and determining the type of animal waste practices employed. Based on the number of animals present and proximity to the river, feedlots should be reprioritized for field inspection. The need for corrective measures will then be based on these field inspections. Estimated cost for this program is approximately $20,000 (assuming 16 hours per feedlot and 26 feedlots).

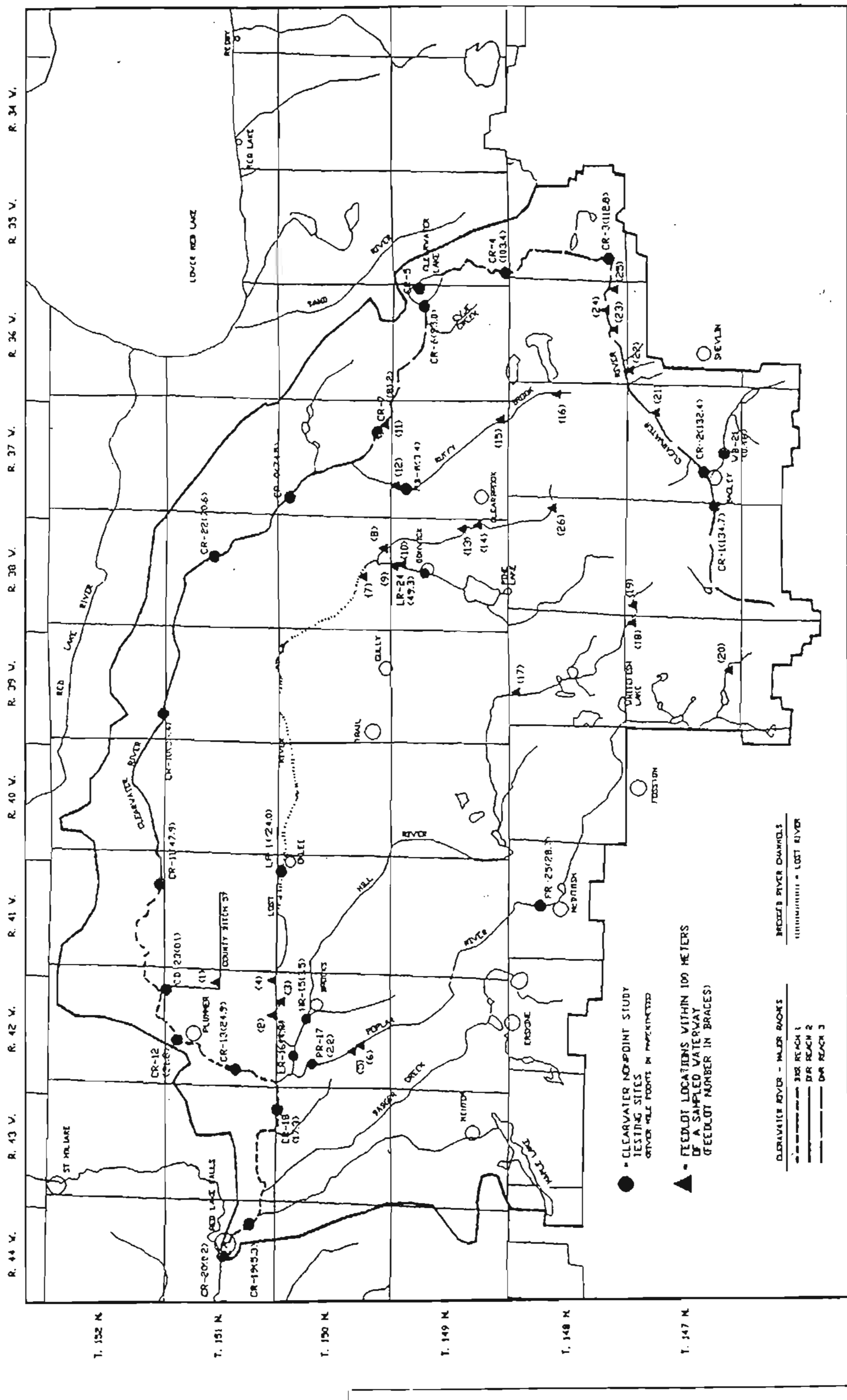
Table 6-8 and the corresponding map on page 6-23A shows preliminary priority for feedlots along the Clearwater River. The goal of the management plan is to inspect ten feedlots per year within each of the counties. Anticipated measures for addressing feedlots include animal exclusion from along the river by fencing and the construction of animal waste management. Each of these activities is to be cost shared with the local land owner at a rate to be established by SWCDs. No cost estimates have been provided for corrective measures.

Table 6-8. Priority Feedlots[1] Within the Clearwater River Basin

Feedlot Number	Feedlot Location (Township, Section, Range)	Distance to Watercourse
1	151N, 13, 42W	100 m
2	151N, 34, 42W	100 m
3	150N, 2, 42W	100 m
4	151N, 36, 42W	100 m
5	150N, 28, 42W	100 m
6	150N, 28, 42W	100 m
7	150N, 28, 38W	100 m
8	150N, 35, 38W	100 m
9	149N, 3, 38W	100 m
10	149N, 3, 38W	100 m
11	150N, 35, 37W	100 m
12	149N, 5, 37W	100 m
13	149N, 24, 38W	100 m
14	149N, 25, 38W	100 m
15	149N, 36, 37W	100 m
16	148N, 13, 37W	100 m
17	148N, 5, 39W	100 m
18	147N, 1, 39W	100 m
19	147N, 6, 38W	100 m
20	147N, 34, 39W	100 m
21	147N, 11, 37W	100 m
22	147N, 5, 36W	100 m
23	148N, 34, 36W	100 m
24	148N, 35, 36W	100 m
25	148N, 36, 36W	100 m
26	148N, 13, 38W	100 m

Note: Cost of inspection program to identify problem feedlots is $20,000 (assuming 16 hours per inspection for 26 feedlots).

[1] All feedlots are within 100 meters of Ruffy Brook and the Lost, Hill, Poplar or Clearwater Rivers.



HDR Engineering Inc.

Red Lake Watershed District
Dedicated to Water Management

Figure 6-6

Location of Priority Feedlots

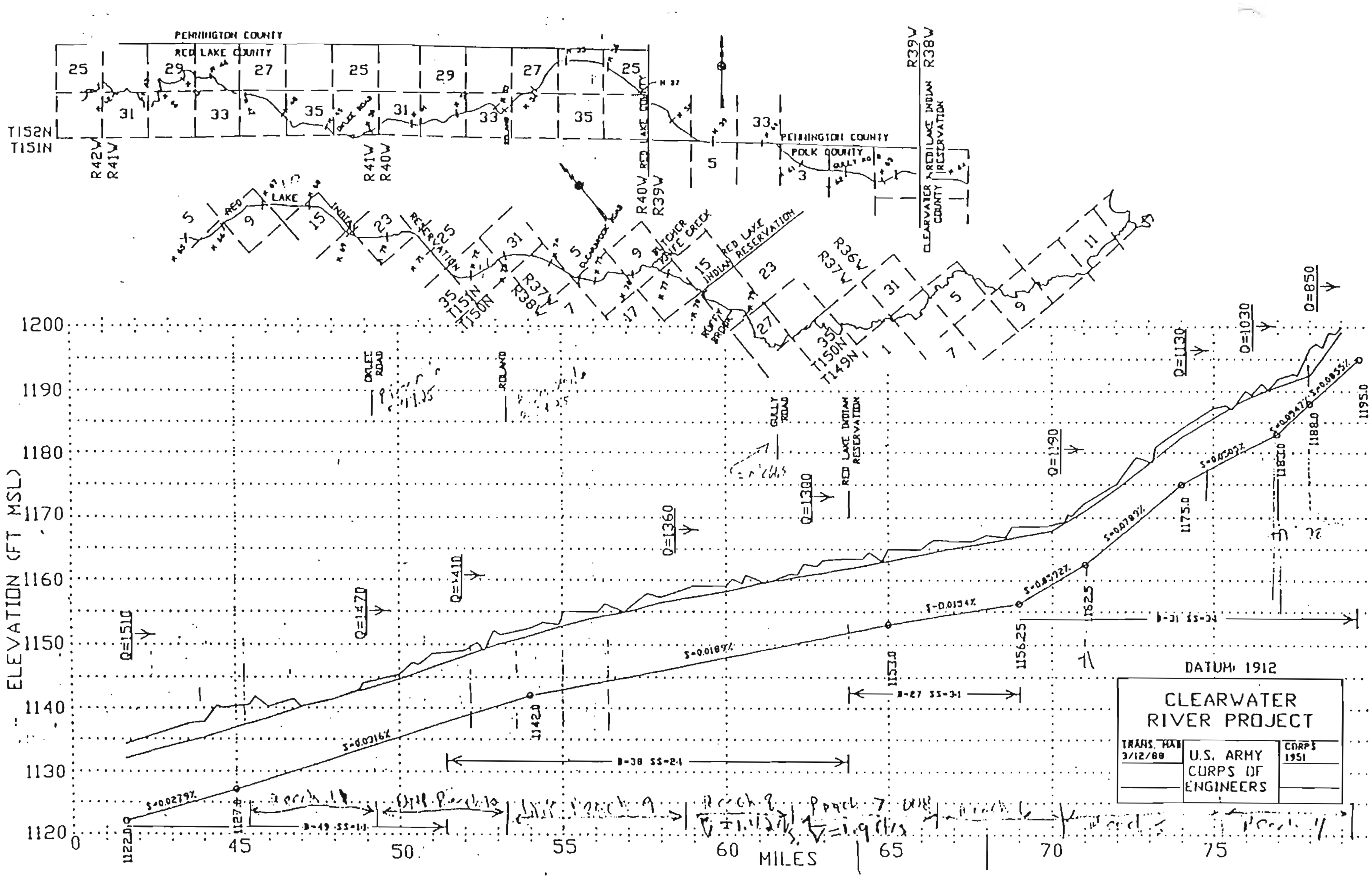
Suggest responsibilities for implementation of feedlot management activities are:

- Cataloging feedlots and determining characteristics within the portion of the county within the Clearwater River basin - SWCDs
- Reprioritizing feedlots for implementation - SWCDs
- Performing field inspections - SWCDs
- Designing Animal Waste Management Units for Manure Management - SWCDs and SCS
- Implement animal exclusion program - SWCD

6.3.5 Rehabilitation of the Channelized Reach

Channelization has affected the water quality of the Clearwater River. Water quality degrades throughout the channelized portion (Reach 2) of the Clearwater River. The influence of the channelized reach continues through the remaining portion of the Clearwater River until the confluence with the Lost River. Various approaches can be used to improve the structural integrity of the channelized reach. The strategy associated with each approach is to provide a mechanism for enhancing sedimentation by altering the velocity distribution within the river and reducing scour. The velocity distribution can be effectively altered by enhancing structural integrity.

Three approaches to improving structural integrity and "rehabilitating" the channelized reach are possible, depending upon the aggressiveness desired. It is generally assumed that greater structural integrity leads to greater biological diversity. Therefore, a viable, reproducing fishery is anticipated only with the more aggressive approaches achieved by creating a floodplain or placing the river within the old channel. A more marginal fishery where the sport fish population is primarily maintained by migration and stocking is anticipated for the least aggressive approach. Figure 6-6 shows the physical characteristics of the existing channelized portion of the Clearwater River. This reach was designed by the COE. Responsibility for the maintenance of the channel is the responsibility of the RWLD under agreement with the COE. An agreement for administrative and maintenance considerations is needed before rehabilitation can proceed.



HDR Engineering Inc.

Figure 6-7
Typical Cross Section and Profile for the Channelized Portion of the Clearwater River - Design Characteristics

Placing "structures" within the channelized reach either for bank stabilization or the creating habitat, has the potential to increase the stage within the channel. Therefore, some preliminary design considerations for stream rehabilitation are needed. Some of these design considerations include:

- Hydraulic analysis to ensure an understanding of the increase in stage and velocity within the channel during flood flows. Stage increases during high flow events should be minimized.

- Hydraulic analysis to understand stage and velocity within the channel during low flow periods, in order to achieve goals for habitat improvement, sedimentation and scour protection.

- Consideration of the use of materials naturally occurring within the area for habitat improvements.

- Comparison to the characteristics of the old channel for the purposes of rehabilitation (e.g., average depth, channel width, channel geometry, width of floodplain).

The best approach for implementing this program is through cost sharing in order to establish pilot or demonstration projects. This approach will not only demonstrate feasibility, but establish more refined estimates of cost. Land owners can be queried to determine potential interest. Willing land owners can be provided with an easement for their land. Technical assistance can be provided by the various agencies.

Establishing a "buffer" riparian area mimicking the endemic species along the river is a likely component of each of the channel rehabilitation options. The planting of deciduous and coniferous trees with an understory of shrubs along the channelized reach can provide shade, thereby reducing water temperature and during higher flows providing fish habitat. This buffer area can also provide water quality benefit by filtration of runoff and sedimentation during high flows.

Ideally, the width of the buffer area would be similar to the natural watercourse. From a practical perspective because of land rights, the width will be less - established by the willingness of land owners. Four components are an essential part of vegetating a buffer area: 1) the limited use of fertilizers will help plants become established; 2) native grass species should be used to establish a sod to bind the soil; 3) jute mesh should be applied over the entire slope to stabilize the area while species become established; and 4) shrub and tree provide shade and protect soil during high flows. Cut dormant stems of willow or cottonwood can be placed

3 feet on center, in a diagonal or if desired in a more random fashion. A detailed plan for developing vegetated buffer areas needs development during the management plan. But typical costs are $250/acre.

The suggest responsibilities for implementing channel rehabilitation are:

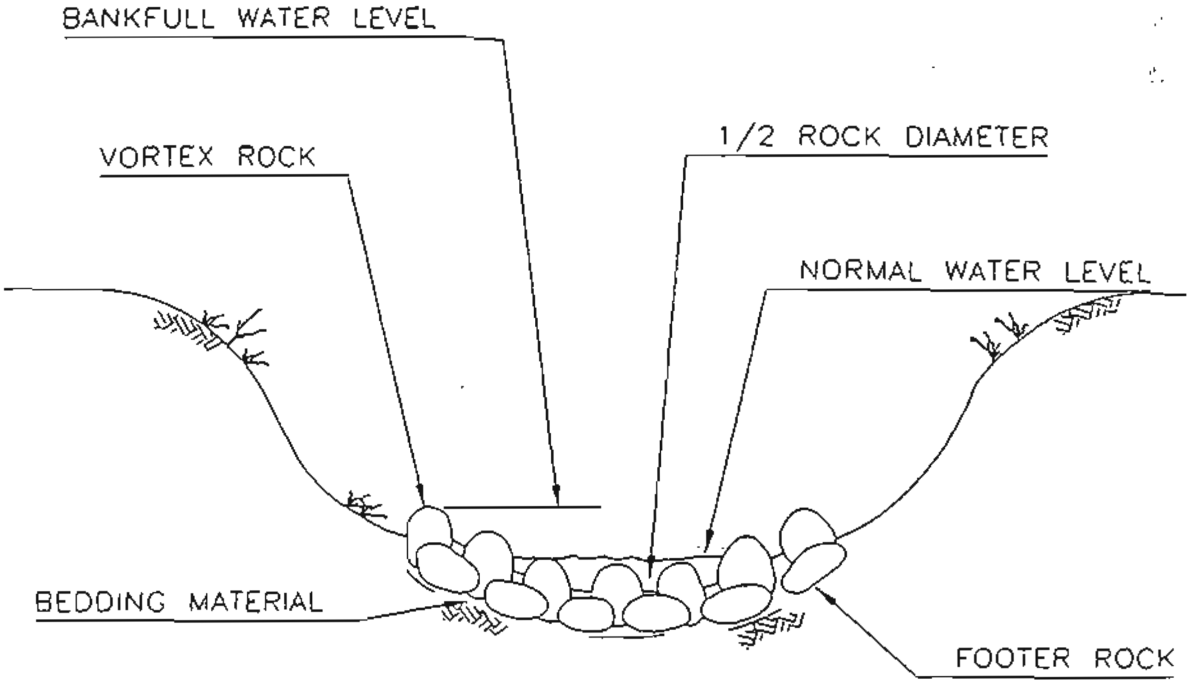
- Hydraulic analysis of various designs - RLWD.
- Administration of land rights - RLWD.
- Mailing of questionnaires to determine land owner interest - SWCDs.
- Design of habitat improvements - MnDNR.
- Develop buffer area vegetation plan - SCS.
- Funding - EPA, MPCA, BWSR, LCMR, and local cost share.
- Conceptual Design Technical Assistance for Rehabilitation - EPA and Private Consultant.

Estimated cost for performing a pilot rehabilitation on ½-mile is $264,000-792,000 (assuming Option 2 - Rehabilitate the Channelized Reach with a Floodplain.

6.3.5.1 <u>Rehabilitate the Channelized Reach - No Floodplain</u>

One approach is to maintain the present trapezoidal cross section of the channelized reach. Structural measures can be used within the trapezoidal channel to decrease scour and enhance sedimentation. These same structures when properly designed and implemented can provide structure suitable for fish habitat.

A large amount of sediment is moved within the Clearwater River through the channelized reach. Items placed incorrectly within the channel can impede this transport and create bars or induce scour. Modifications which deflect the current to provide eddies and holding areas could deflect current into the banks and accelerate bank erosion. Acceptable structures for this type of river tend to result in "smooth" streamlines. Acceptable structures include vortex rock weirs (Figure 6-7), bank keyed root wads (Figure 6-1) or boulders, floating logs or tree cover. Each of these improvement structures can provide protection, supply diversity and improve habitat.



VORTEX ROCK WEIR - CROSS SECTION

Looking Upstream NTS

Note: These structures may not be applicable in all stream types.

HDR Engineering Inc.

Figure 6-8

Vortex Rock Weir used for Channel Stabilization

Rootwad revetment may not be as effective in stabilizing shallow reaches where significant channel icing occurs. The face of the rootwad should be trimmed and back-filled with soil to present a smooth face to flow. This will minimize debris collection.

6.3.5.2 Rehabilitate the Channelized Reach - With Floodplain

The second approach is to create a floodplain along the existing trapezoidal channel (Figure 6-8), while incorporating the revegetation and the structural measures previously discussed. The "ideal" width of the floodplain can be determined based on historical photos of the Clearwater River. Consideration of land owner concerns will likely limit the width of the constructed floodplain to a much smaller width. A preliminary recommendation is a floodplain varying from two to three times the top-width of the channel in a sinuous fashion moving in the downstream direction. The constructed floodplain should be revegetated in the manner previously described.

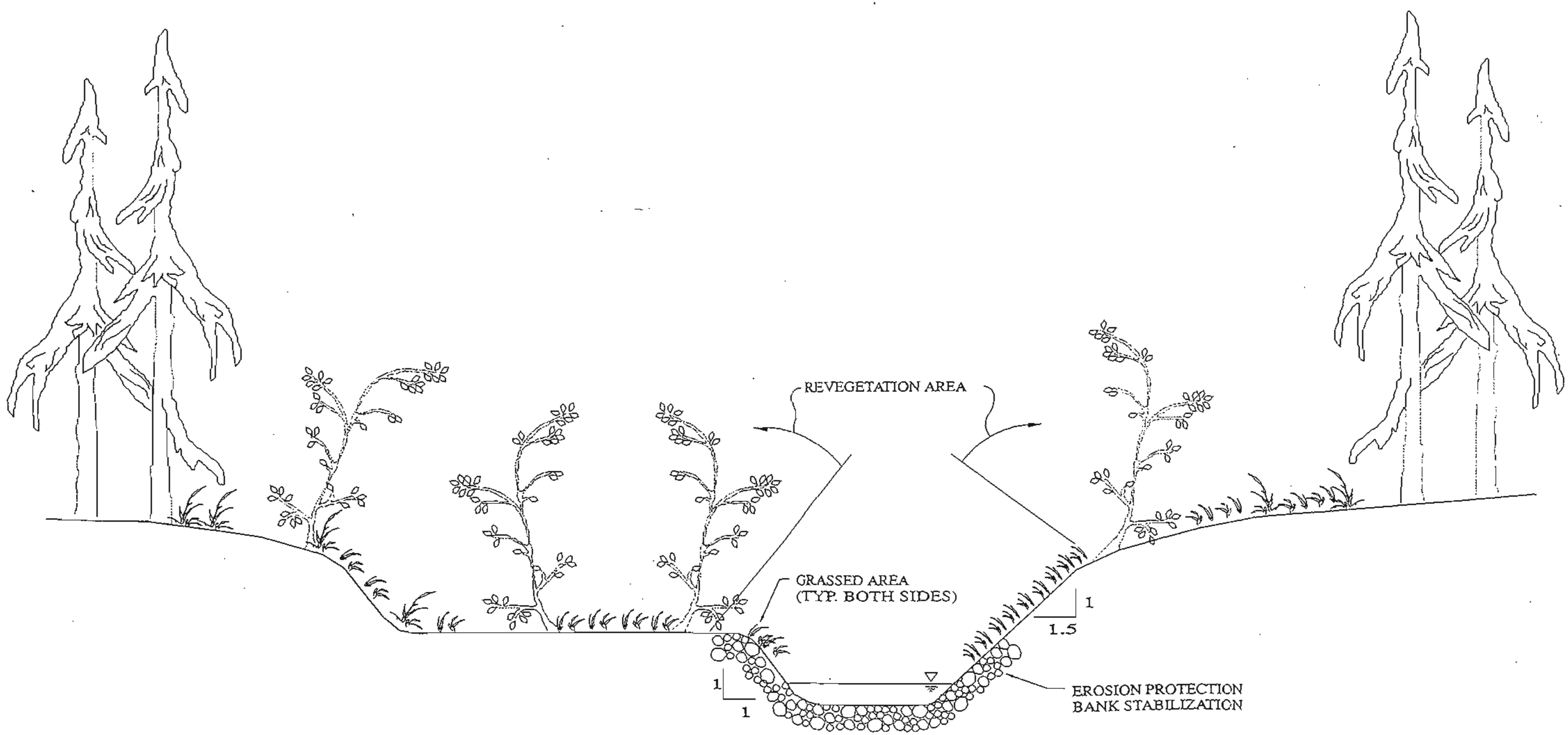
The elevation of the constructed flood plain can be determined based on the desired frequency of flood plain inundation. Ideally, this should be based on the frequency of inundation for the river prior to channelization. An initial recommendation is inundation for a 2 year return period flow. Estimated costs range from $100-300 per lineal foot of constructed flood plain. Assuming a pilot program to rehabilitate a ½-mile reach, the estimate costs range from $266,400-792,000.

6.3.5.3 Reestablish the Old Stream Channel

The final approach is to reestablish flow within the original channel of the Clearwater River. This approach entails diverting flow within the present channelized reach into the original channel. A detailed plan would need to be developed prior to implementation. This approach would likely be the most complex and costly. Many of the old meanders are not farmed and would no longer provide conveyance. The goal would be to match the physical characteristics of the Clearwater River upstream and downstream of the channelized reach. No cost estimate is available for this alternative.

6.4 Fish Passage

The MnDNR identified the dam controlling the elevation of Clearwater Lake as a important barrier preventing fish migration. Two options are available for allowing migration: 1) removal of the structure; and 2) construction of a fish passage structure. Responsibility for implementation of a strategy to allow fish migration is the responsibility of the MnDNR.



HDR
HDR Engineering Inc.

Figure 6-9

Floodplain Conceptual Design Along Existing Trapezoidal Channel

6.5 Education

A good education program is essential to the success of the management program. The primary purpose of an education program is to inform residents and landowners about the ongoing activities and inform them of the importance of these activities.

- Develop education program - headwaters RDC and U of M Extension
- Develop technical materials for program - RLWD and SWCDs
- Implement program - headwaters RDC
- Funding - MPCA, BWSR

An estimated $20,000 is needed to implement an education program.

6.6 Management Plan Summary

The primary factors affecting water quality within the Clearwater River basin can be categorized as:

- Streambank erosion
- Nonpoint source discharges
- Point source discharges
- Feedlots
- Lack of channel integrity

The MnDNR identified 14 locations subject to streambank erosion. The locations contribute to sediment loads. Traditional (rock riprap) methods for stabilizing streambank erosion have an estimated cost of $45,525. A summary of the management activities is provided in Table 6-9.

Using annual yields, each of the twenty five subwatersheds were prioritized with regard to their nonpoint source contribution. Subwatersheds were prioritized from "worst" (highest yields) to "best" (lowest yields) by evaluating the magnitude of the chemical oxygen demand, total solids, total phosphorus and total nitrogen annual yield. Five subwatersheds within the middle reach of the Clearwater River showed the greatest yields and were selected for the application of nonpoint source BMPs. These subwatersheds are CR-22, CR-10, CR-9, CR-11 and CR-12 and consistently had the largest solids, nutrient and COD yields. To achieve annual total solids and

Table 6-9

CLEARWATER RIVER MANAGEMENT PLAN SUMMARY TABLE

Problem	Activity	Implementation Responsibility	Estimated[1] Cost
Streambank Erosion (The MnDNR has identified 14 locations subject to erosion on the Clearwater River.)	Traditional and nontradional stabilization measures	• Hydraulic design - RLWD • Habitat considerations - MnDNR • Landowner relation and easements - SWCDs and RLWD • Construction monitoring - SWCDs • Funding - MPCA, MnDNR, BWSR and local match	\$45,500[2] (Approximate length 1,525 feet)
Nonpoint Source Discharges (High priority watersheds include CR-22, CR-10, CR-9, CR-11 and CR-20.)	Conservation practices	• BMP design - SWCDs and SCS • Estimate of load reduction - SCS, MPCA • Landowner relation and easements - SWCDs • Funding - MPCA, MnDNR, BWSR and local match	Conservation Practices[3] \$944,640 (10% reduction in solids and COD) \$3,786,240 (40% reduction in solids and COD) Construction of Pilot System for Drainage Ditch \$26,100-65,340
Point Source Discharges (Nine point source discharges have been identified within Clearwater River basin.)	Regulation of point source discharges through NPDES program implemented by MPCA.	• Evaluation of effluent discharges from municipal discharges - MPCA • Development of stormwater retention basins - MPCA • Evaluation of unknown fluid at River Mile 2.3 - SWCD • Cleanup of construction debris at River Miles 1.0 and 31.2 - RLWD	Construction of stormwater retention basins (\$0.020-0.050 per cubic foot of storage) No Cost Estimate Provided

Table 6-9

CLEARWATER RIVER MANAGEMENT PLAN SUMMARY TABLE - Continued

Problem	Activity	Implementation Responsibility	Estimated[1] Cost
Feedlots (Based on proximity to river, 27 high priority feedlots have been identified.)	Establish feedlot inspection program with minimum goal of ten feedlot inspections per year. Prioritize feedlots for corrective measures.	• Cataloging feedlots and determining characteristics within the portion of the county within the Clearwater River basin - SWCDs • Reprioritizing feedlots for implementation - SWCDs • Performing field inspections - SWCDs • Designing animal waste management units for manure management - SWCDs and SCS • Implement animal exclusion program - SWCD	Activities to be cost shared with the local landowner at a rate to be established by SWCDs. Inspection Program[4] Estimate is $20,000
Lack of Channel Integrity within channelized portion (Reach 2) of Clearwater River.	• Establishment of riparian buffer area along the river • Structural measures within existing channel (vortex rock weir, rootwad revetment) • Creating floodplain along trapezoidal channel • Diverting flow into old stream channel	• Hydraulic analysis of various designs - RLWD • Administration of land rights - RLWD • Mailing of questionnaires to determine landowner interest - SWCDs • Design of habitat improvements - MnDNR • Develop buffer area vegetation plan - SCS • Funding - EPA, MPCA, BWSR, LCMR, and local cost share • Conceptual design technical assistance for rehabilitation - EPA and private consultant	Revegetation of riparian area along river ($235/acre) Creating Floodplain (Option 2) Pilot Project for ½-mile $266,400-792,000
Disseminate Information	Develop Education Program	• Develop Program - Headwaters RDC • Prepare Technical Information - SWCDs and RLWD • Implement Program - Headwaters RDC and U of M Extension • Funding - MPCA, BWSR	$20,000

Total Estimated Cost
$1,322,640-4,729,080

[1] Costs are for planning purposes only and to be used during Phase II application.

[2] Based on unit cost of $27 per lineal foot for "traditional" rock riprap.

[3] Estimate is for conservation tillage practices assuming $40/acre. Other practices could be used.

[4] Estimate assumes 16 hours per feedlot for 27 inspections.

oxygen demanding load reductions of 10%, 20%, 30% and 40% using conservative tillage practices an estimated 7%, 14%, 21% and 28% of the subwatershed area respectively, requires treatment. This treatment is in addition to the set-aside (Conservation Reserve Program) acres already present within the watershed. The estimated cost for treatment at the 10% level is $944,640 compared to $3,786,240 at the 40% level. Treatment at the 40% level should ensure meeting 5 mg/l dissolved oxygen.

The commercial production of wild rice has long been suspected as a reason for degraded water quality within the channelized reach of the Clearwater River (Reach 2). Results from this study do not allow the clear separation of the effects of stream channelization from rice paddy discharge, and drainage ditch outlets. Operational data available from rice producers for 1992 suggest channelization may be at least as important in influencing water quality. Although the magnitude of the load from rice producers can not be accurately quantified without additional information, rice growers should consider ways of improving water quality during or prior to discharge. Improvements to the gravity flow ditch could be made to increase sedimentation. Other methods include the use of level bottom ditches to encourage standing water within the ditch along with periodic removal of sediment, redesign of the drainage ditch to create a biofiltration system, and the use of specially designed systems to treat agricultural runoff. Estimated cost for a demonstration project ranges from $26,140-65,340, depending upon the volume of water to be treated.

Nine point sources are present within the Clearwater River basin. These are having a marked impact on water quality within the Clearwater River and tributaries to the Clearwater. Responsibility for addressing point source discharges lies with the MPCA.

Based on GIS analysis using 1992 land use data, an estimated 804 feedlots are present within the watersheds of the Clearwater, Lost, Hill and Poplar Rivers. GIS analysis showed 26 feedlots within 100 m (300 feet) of a watercourse. Feedlot characteristics such as number of animals or animal waste management practices were not determined. Because of their proximity to the river, the 26 feedlots have been identified as high priority for implementation purposes. The goal of the management plan is to inspect 10 feedlots per year within each of the counties, and assess the need for corrective measures. Anticipated measures for addressing feedlots include animal exclusion from along the river by fencing and the construction of animal waste management. Estimated cost for the inspection program is $20,000.

Channelization has affected the water quality of the Clearwater River. Water quality degrades throughout the channelized portion of the Clearwater River. The influence of the channelized reach continues through the remaining portion of the Clearwater River until the confluence with the Lost River. Various approaches can be used to improve the structural integrity of the channelized reach. The strategy associated with each approach is to provide a mechanism for enhancing sedimentation by altering the velocity distribution within the river and reducing scour. The velocity distribution can be effectively altered by enhancing structural integrity.

Three approaches to improving structural integrity and "rehabilitating" the channelized reach are possible, depending upon the aggressiveness desired. Each of these approaches includes establishing a vegetated buffer area along the river - a riparian zone. Approaches to rehabilitate channel integrity include structural measures within the existing trapezoidal channel, creating a floodplain along the trapezoidal channel and diverting flow into the old stream channel. Estimated costs for revegetation of the riparian area average $235/acre. Estimated cost for a demonstration project intended to rehabilitate ½-mile of channelized river ranges from $264,000-792,000. Detailed plans are needed prior to rehabilitation to establish rehabilitation goals, estimate costs accurately and prepare design plans and specifications.

An education program will be initiated during implementation of the management plan. The purpose is to inform area residents and project participants about project activities and assist with understanding the need for these activities.

The estimated cost, excluding administration and technical support (e.g., engineering) ranges from $1,322,640-4,729,080. The estimated cost range represents differing levels of aggressiveness for improving water quality.

7.0 ADDITIONAL RECOMMENDATIONS

Additional recommendations resulting from the study include:

- An intensive water quality and flow monitoring program should be performed during the low flow period, for a one week period. The purpose would be to intensively sample specific sources to understand their importance. Sampling performed at specific point source discharge outlets (e.g., lagoon, rice paddy discharge, ditch outlets) allows separation of their magnitude and allows considerable refinement of the water quality model. The sampling program should include a determination of sediment sources and sinks within the channelized reach.

- One local agency should be established for administering and coordinating the management plan and responsibilities assigned for various tasks. All project water quality and flow data should be maintained by RLWD. Geographic Information System data should be maintained by Clearwater SWCD. Activities related to education are the responsibility of the Headwaters ROC.

8.0 REFERENCES

Bemidji State University, 1973. Environmental Biological Aspects of Water Management Alternative in the Red Lake River Subbasin Minnesota.

HDR Engineering, Inc., 1993. Evaluation of Water Quality Models - Clearwater Nonpoint Source Project. A Technical Memorandum.

HDR Engineering, Inc., 1993. Longyear Lake Management Plan, Phase I Diagnostic/Feasibility Report.

HDR Engineering, Inc., 1992. Restoration of Big Stone Lake, Evaluation of Effectiveness of Lake Management Measures. EPA Clean Lakes Phase II Final Report.

Karr J.R. et al., 1986. Assessing Biological Integrity in Running Waters: A Method and its Rational. Ill. Nat. Hist. Sun. Spec. Publication 5.

Minnesota Department of Natural Resources, 1991. Clearwater River Time of Travel.

Minnesota Department of Natural Resources, 1988. Clearwater River Population Assessment.

Minnesota Pollution Control Agency, 1993. Selected Water Quality Characteristics of Minnesota's Seven Ecoregions.

Minnesota Pollution Control Agency, 1991. Wastewater Disposal Facilities Inventory.

Minnesota Pollution Control Agency, 1990a. Minnesota Water Quality Water Years 1988-1989. The 1990 Report to the Congress of the United States.

Minnesota Pollution Control Agency, 1990b. Minnesota Lake Water Quality Assessment Report: A Practical Guide for Lake Managers.

Minnesota Pollution Control Agency, 1989. Water Quality Monitoring for the Clean Water Partnership.

Minnesota Pollution Control Agency, 1988a. Appendices to Minnesota Nonpoint Source Pollution Assessment Report.

Minnesota Pollution Control Agency, 1988b. List of All Impacted Water Bodies. 304(L) Long, Medium (MINI) and Short Lists, pp. 1-4.

Minnesota Pollution Control Agency, 1979. Wild Rice Water Quality Management Planning.

Minnesota Pollution Control Agency, 1977. Report on the Water Quality of the Clearwater River in Clearwater, Polk, Pennington and Red Lake Counties.

Red Lake Watershed District, 1992a. Red Lake Watershed District Clearwater Nonpoint Study Monitoring Plan.

Red Lake Watershed District, 1992b. Quality Assurance Manual Red Lake Watershed District Surface Water Quality Monitoring Plan.

Red Lake Watershed District, University of Minnesota, Crookston and the International Coalition for Land and Water Stewardship, 1990. Clearwater Project: Pesticides and Land Use.

Red Lake Watershed District, 1988. Ten Year Updated Overall Plan.

Souris-Red-Rainy Basin Commission, 1972. Souris-Red-Rainy Basins Comprehensive Study. Volume 1-8.

Stoner, J.D. et al., 1993. Red River of the North Basin, Minnesota, North Dakota, and South Dakota. Journal of the American Water Resources Association. Water Resources Bulletin. Volume 29, No. 4.

Tornes, L.H. and Bringham, M.E., 1994. Water Resources Investigations Report: Nutrients, Suspended Sediment, and Pesticides in Waters of the Red River of the North Basin, Minnesota, North Dakota, and South Dakota, 1970-1990. Water Resources Investigations Report 93-4231.

U.S. Department of Agriculture, 1992. Stream Habitat Improvement Handbook. Technical Publication R8-TP16.

U.S. Department of Agriculture Soil Conservation Service, 1993. Conservation Management Systems. Technical Guide: Section III. USDA Soil Conservation Service, St. Paul, Minnesota.

U.S. Department of Agriculture Soil Conservation Service, 1989. Loose Riprap Protection, Minnesota Technical Release 3. U.S. Department of Agriculture, 101 pages.

U.S. Army Corps of Engineers, 1987. Empirical Methods for Predicting Eutrophication in Impoundments, by William W. Walker, Jr. Technical Report E-81-9, Report 4, Phase III: Applications Manual.

U.S. Army Corps of Engineers, 1975. Final Environmental Impact Statement Operation and Maintenance Activities. Red Lake and C.W. Rivers Project, Minnesota.

U.S. Environmental Protection Agency, 1993. EPA Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters.

U.S. Geological Survey, 1988. Water Resources Data Minnesota Water Year 1988.

U.S. Geological Survey, 1986. Suspended Sediment in Minnesota Streams, by L.H Thorns. Water-Resources Investigations Report 93-4312.

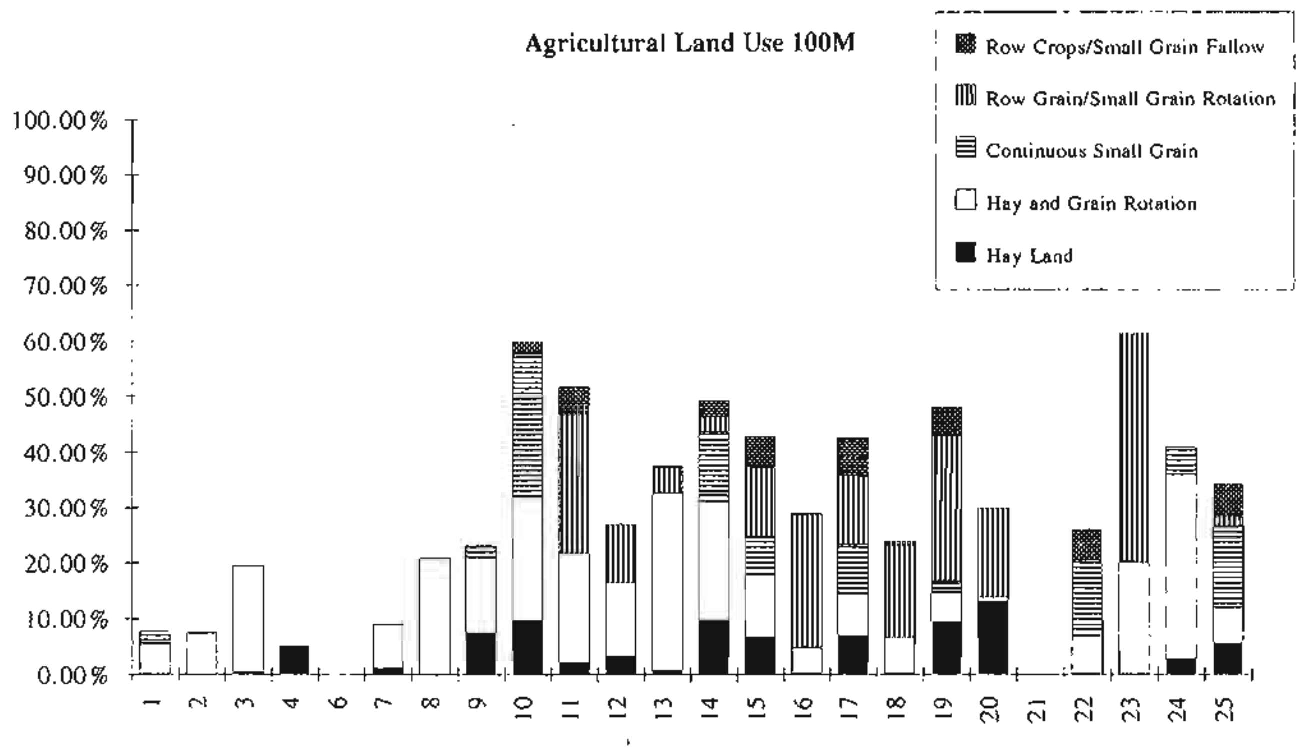
Walker, W.W., Jr., 1986. "Empirical Methods for Predicting Eutrophication in Impoundments; Report 4, Phase III: Applications Manual," Technical Report E-81-9.

Wischmeirer, W.H. and Smith, D.D., 1978. Predicting Rainfall Erosion Losses - Guide to Conservation Planning. USDA Ag Handbook No. 537. U.S. Supt. of Doc., Washington, D.C.

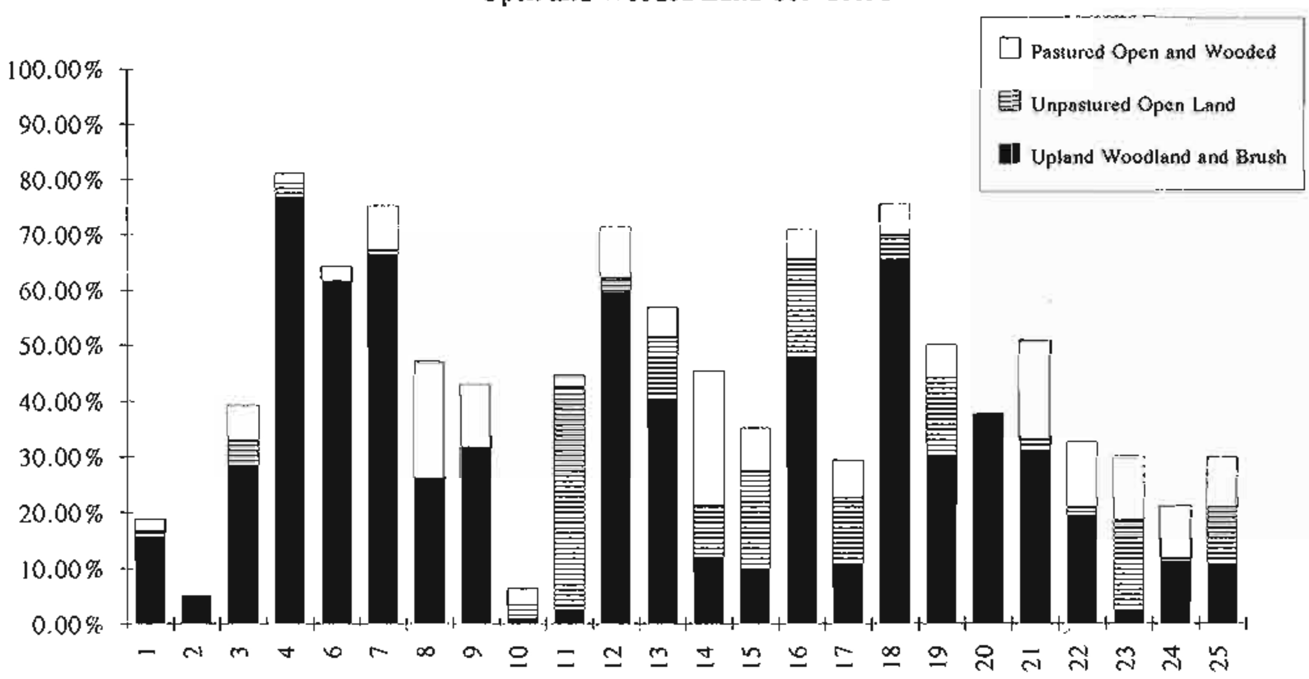
Young, R.A. et al., 1987. AGNPS, Agricultural Non-Point Source Pollution Model. A Watershed Analysis Tool. Conservation Research Dept. 35, 80 pp., Agri. Res. Serv., USDA Washington, D.C. 77 pp.

Appendix A

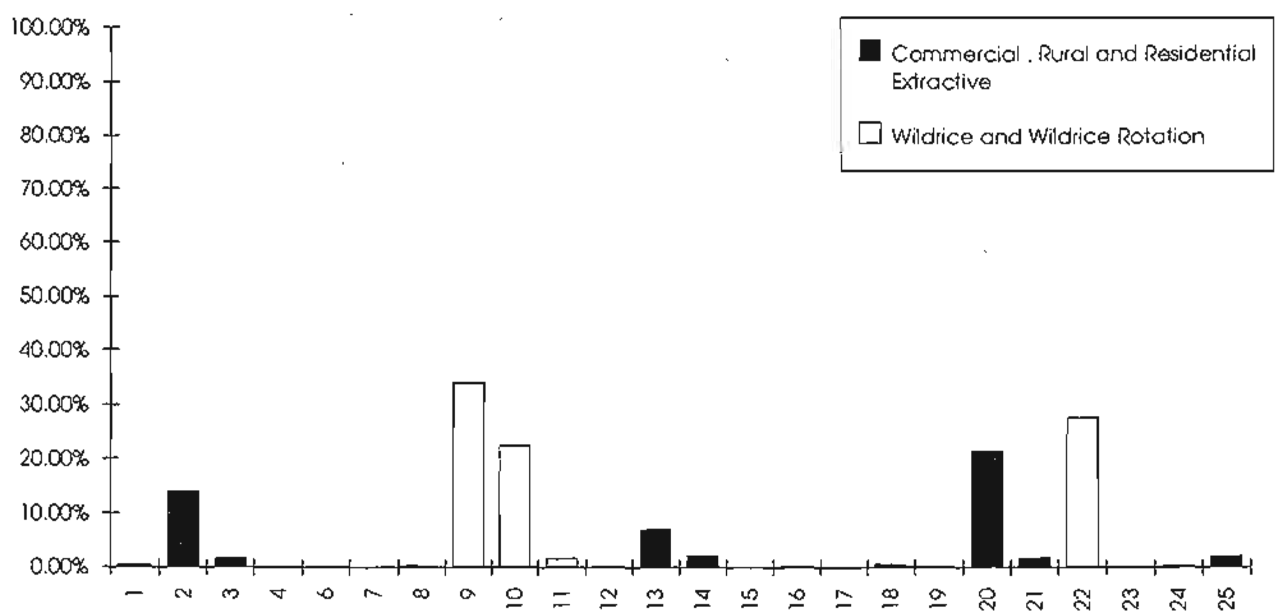
CLEARWATER RIVER LAND USE


Agricultural Land Use 100M
Row Crops/Small Grain Fallow
Row Grain/Small Grain Rotation
Continuous Small Grain
Hay and Grain Rotation
Hay Land
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
1
2
3
4
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25

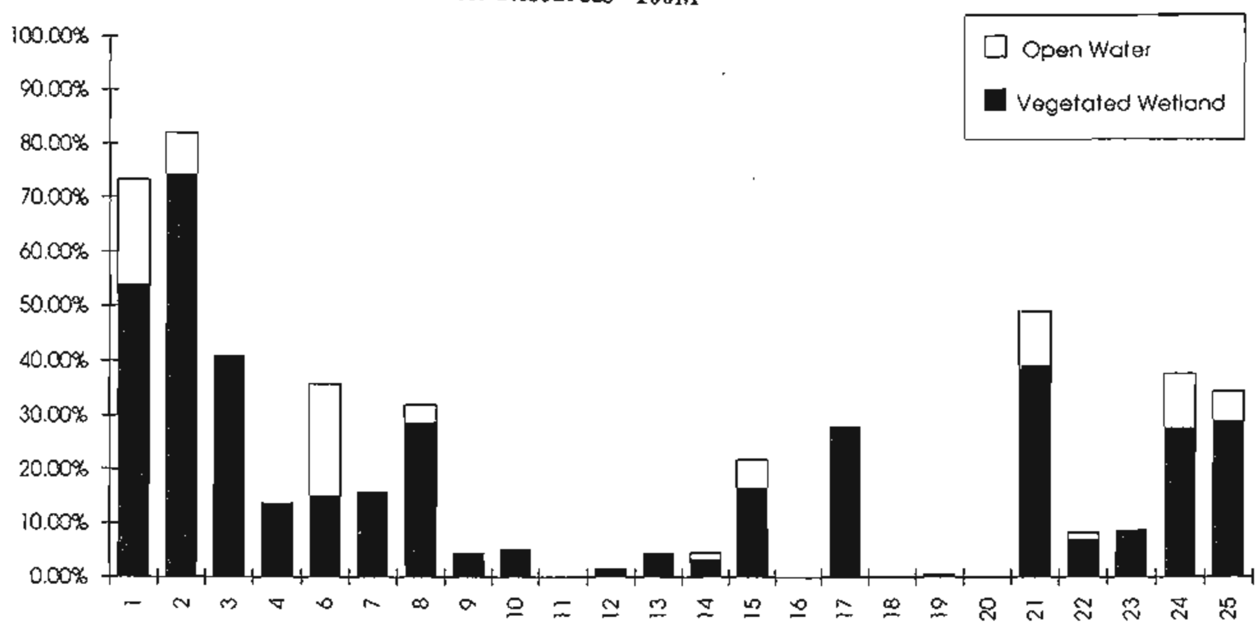
Open and Wooded Land Use 100M



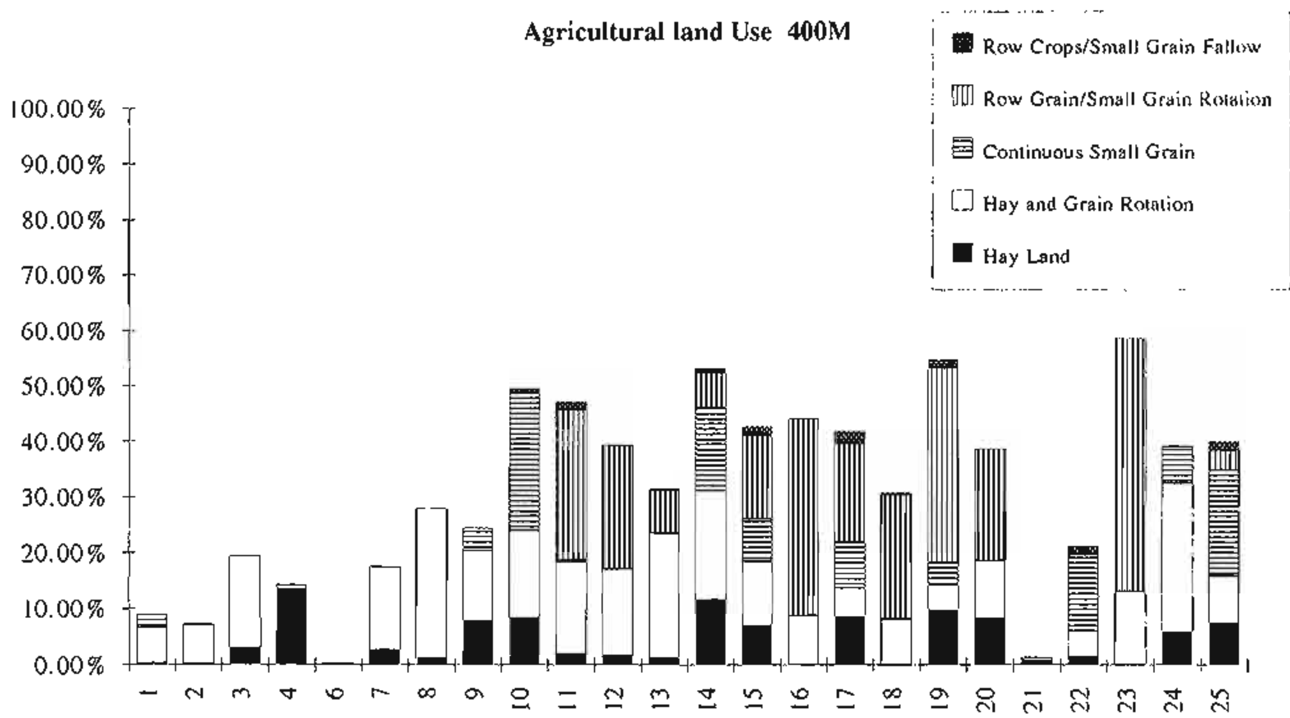
Commercial and Residential Land Use 100M

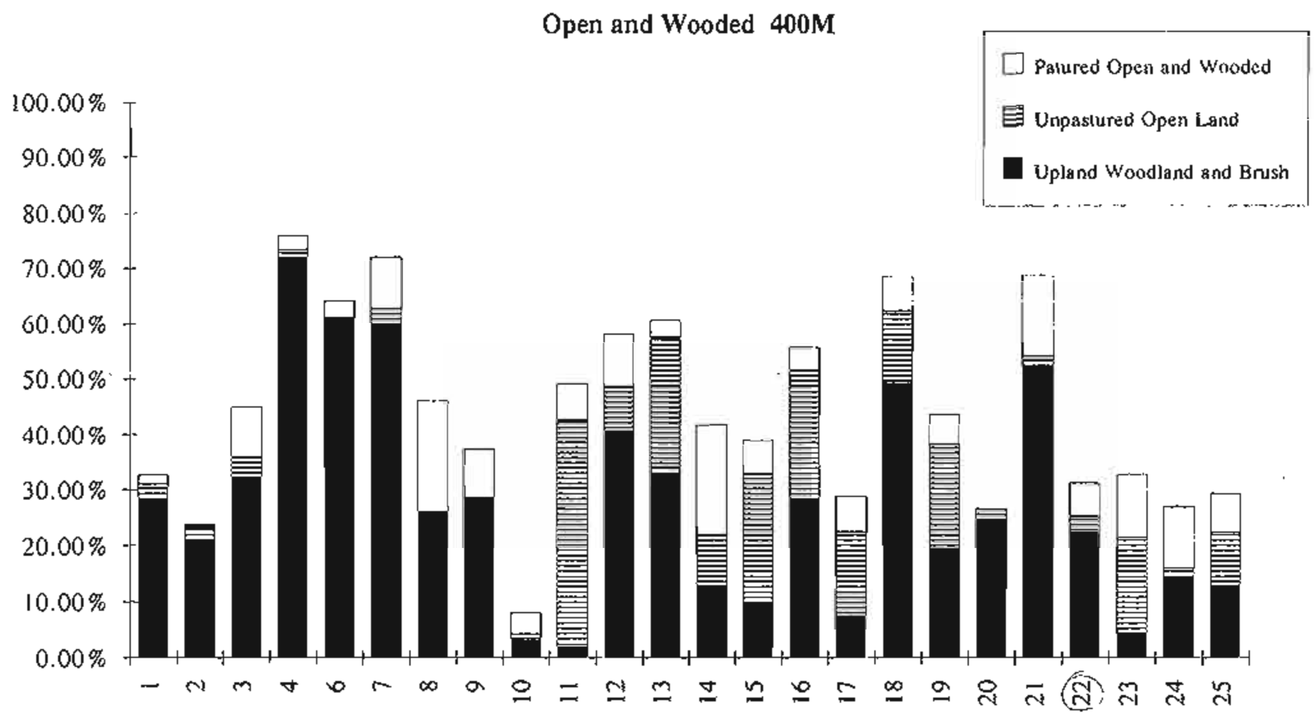


Water Resources 100M



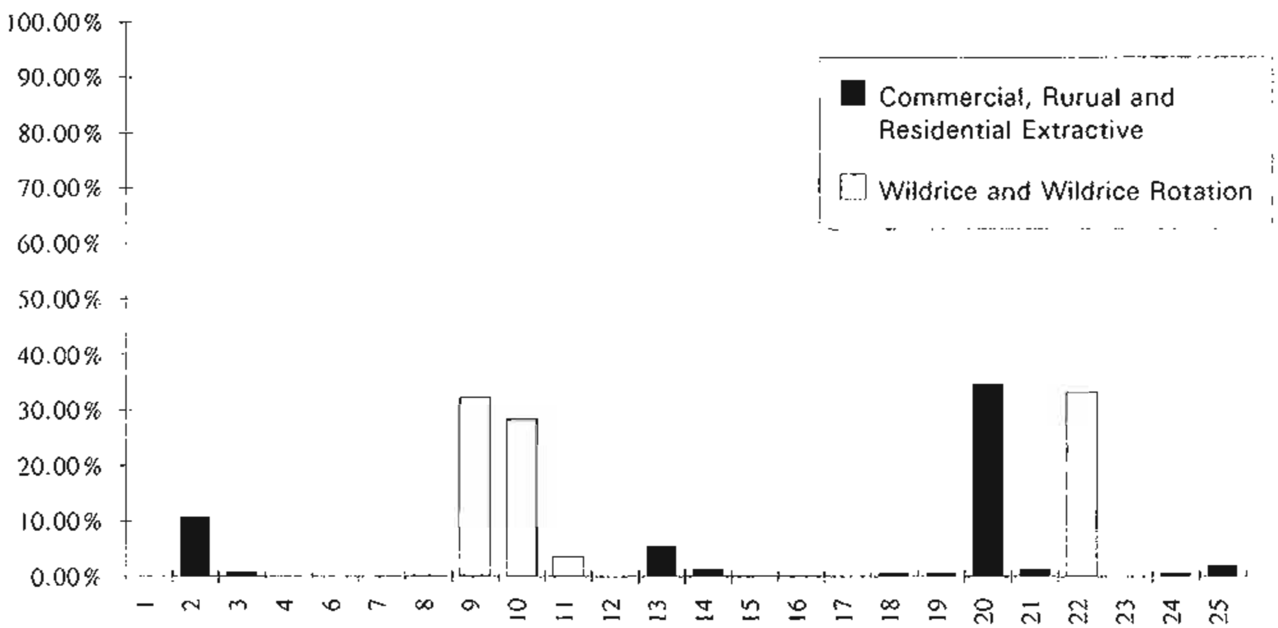
Agricultural land Use 400M

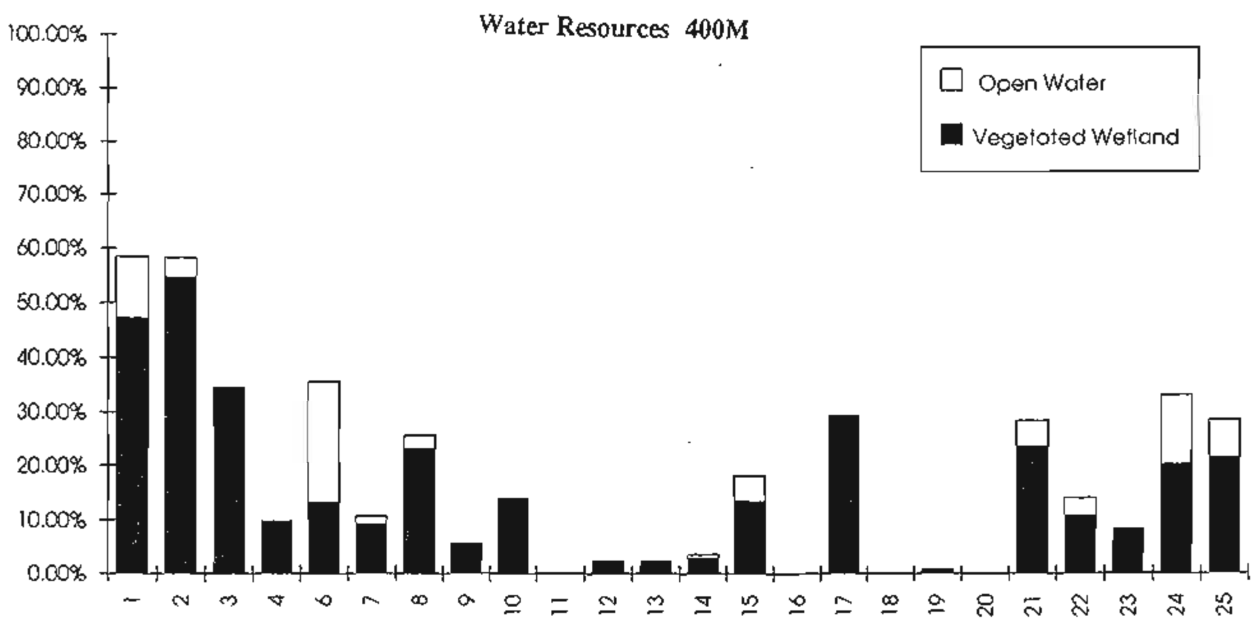




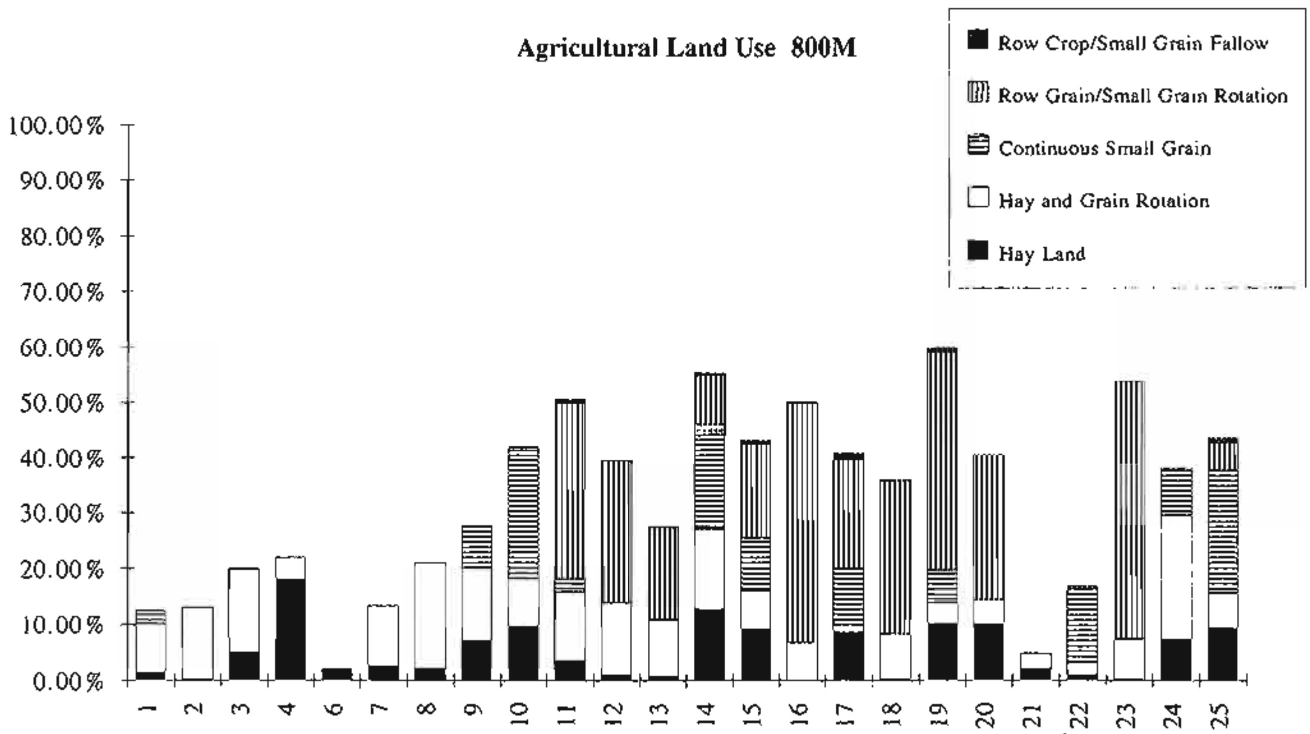
Open and Wooded 400M
Patured Open and Wooded
Unpastured Open Land
Upland Woodland and Brush
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
1
2
3
4
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25

Commercial and Residential Land Use 400M

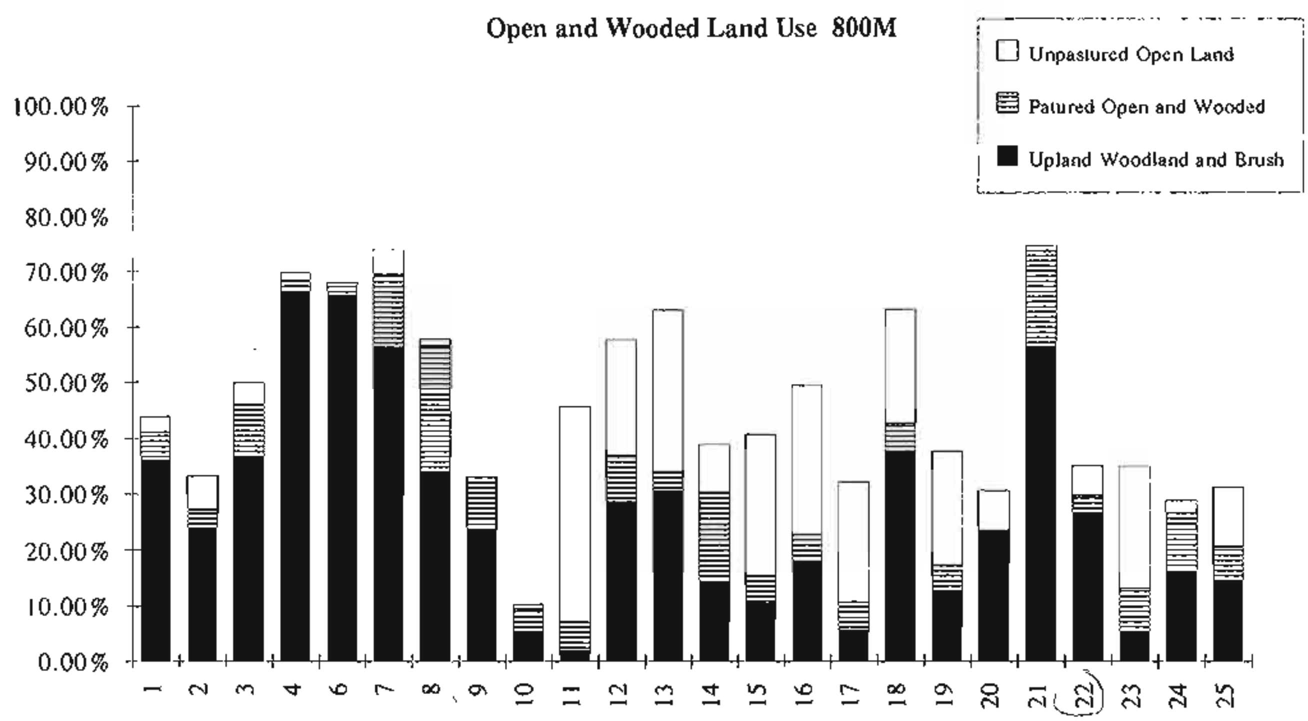




Water Resources 400M
Open Water
Vegetated Wetland
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
1
2
3
4
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25

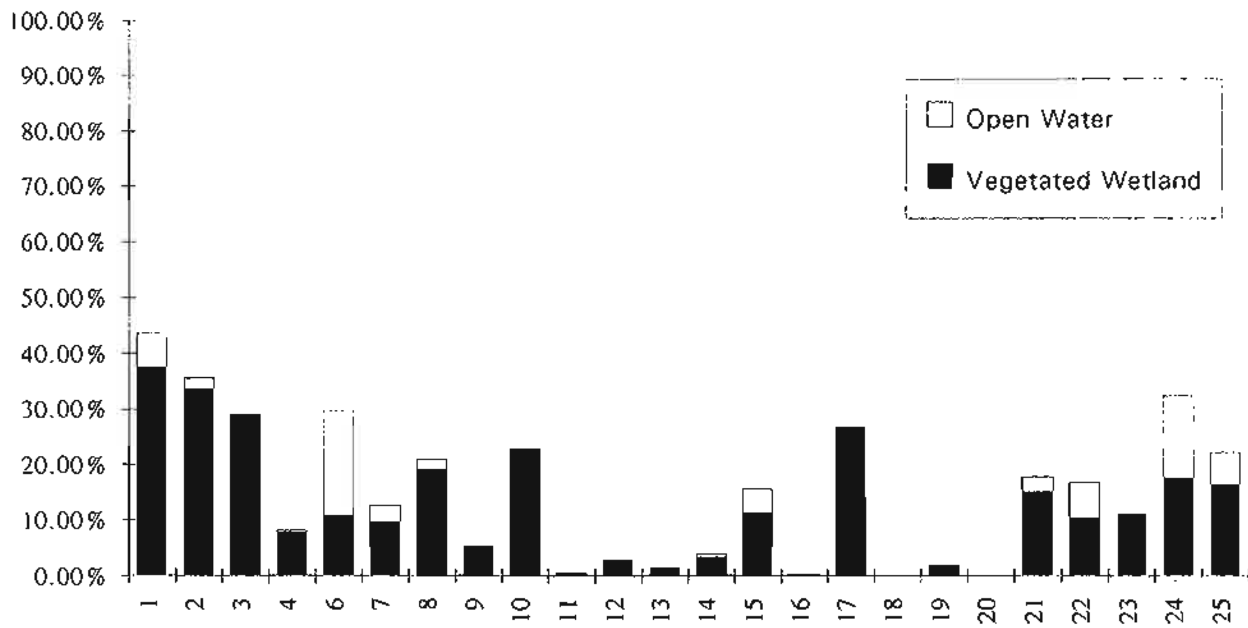


Agricultural Land Use 800M
Row Crop/Small Grain Fallow
Row Grain/Small Grain Rotation
Continuous Small Grain
Hay and Grain Rotation
Hay Land
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
1
2
3
4
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25

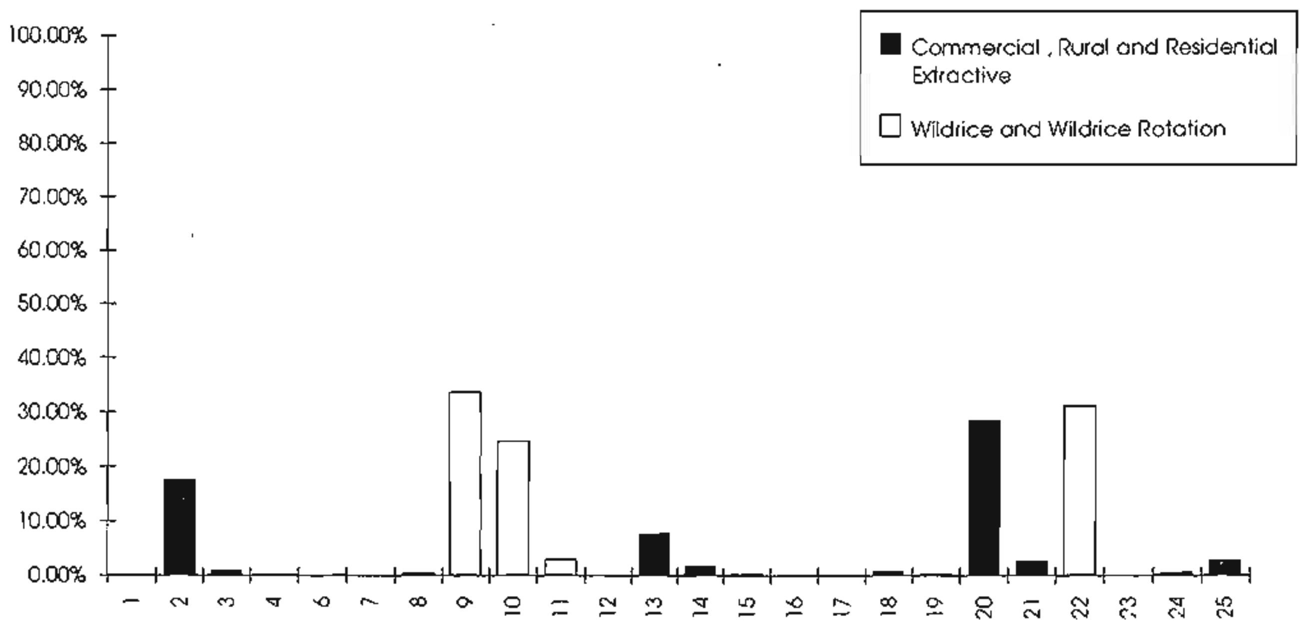


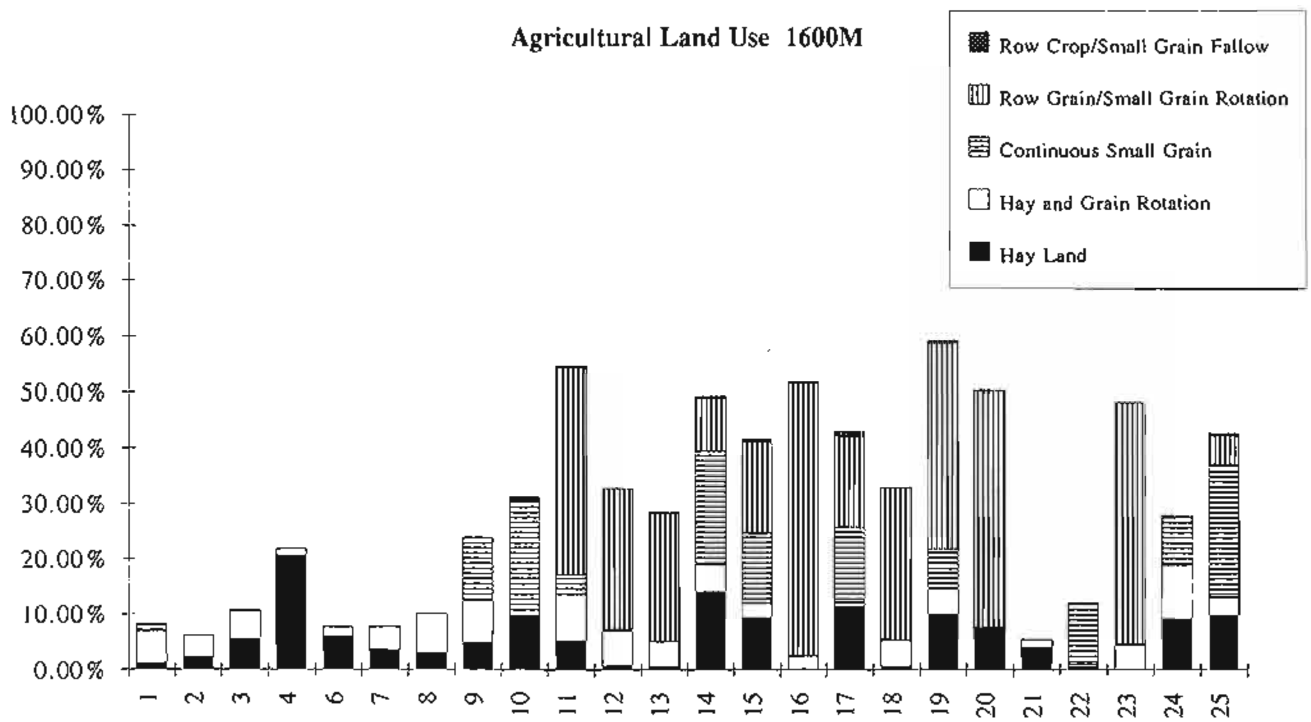
Open and Wooded Land Use 800M
Unpastured Open Land
Patured Open and Wooded
Upland Woodland and Brush
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
1
2
3
4
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25

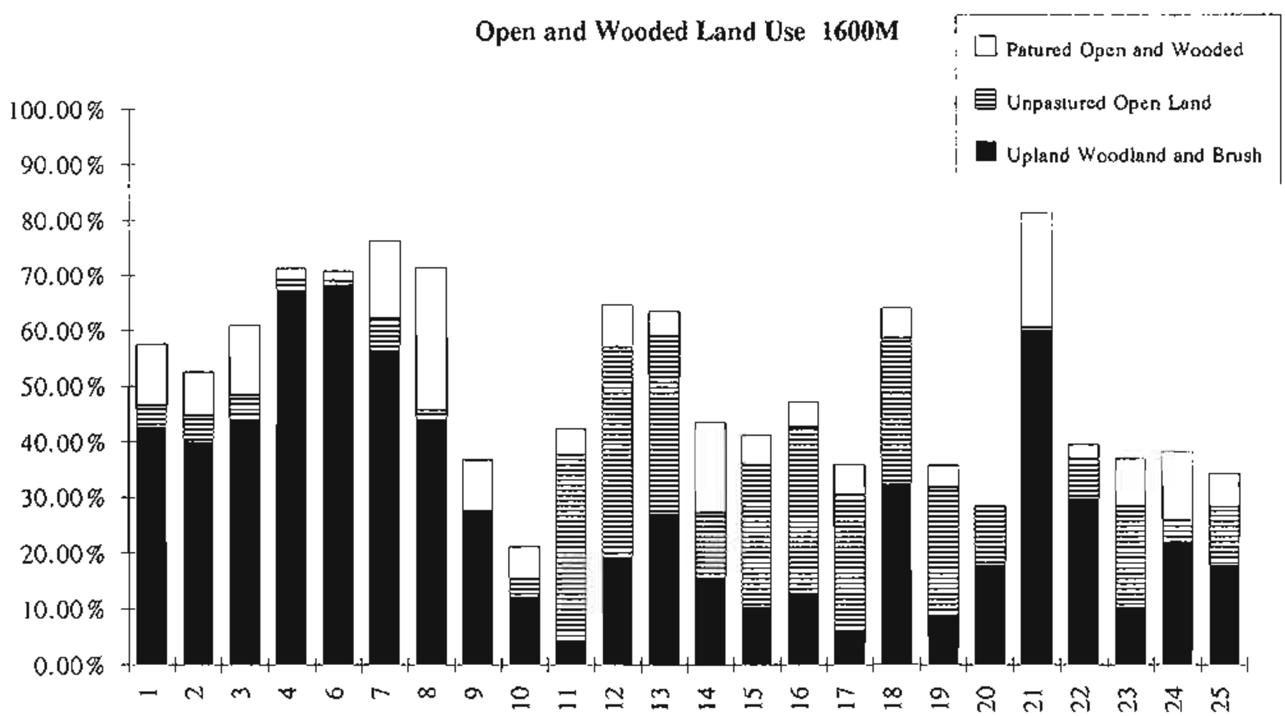
Water Resources 800M



Commerial and Residential Land Use 800M

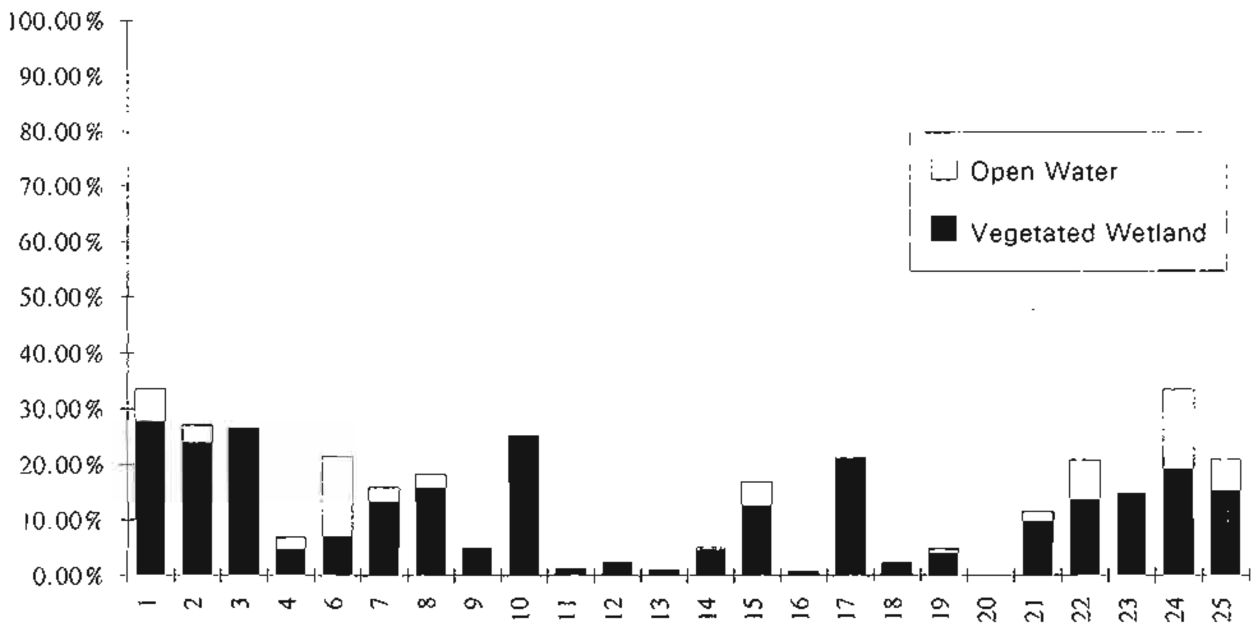



Agricultural Land Use 1600M
Row Crop/Small Grain Fallow
Row Grain/Small Grain Rotation
Continuous Small Grain
Hay and Grain Rotation
Hay Land
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
1
2
3
4
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25

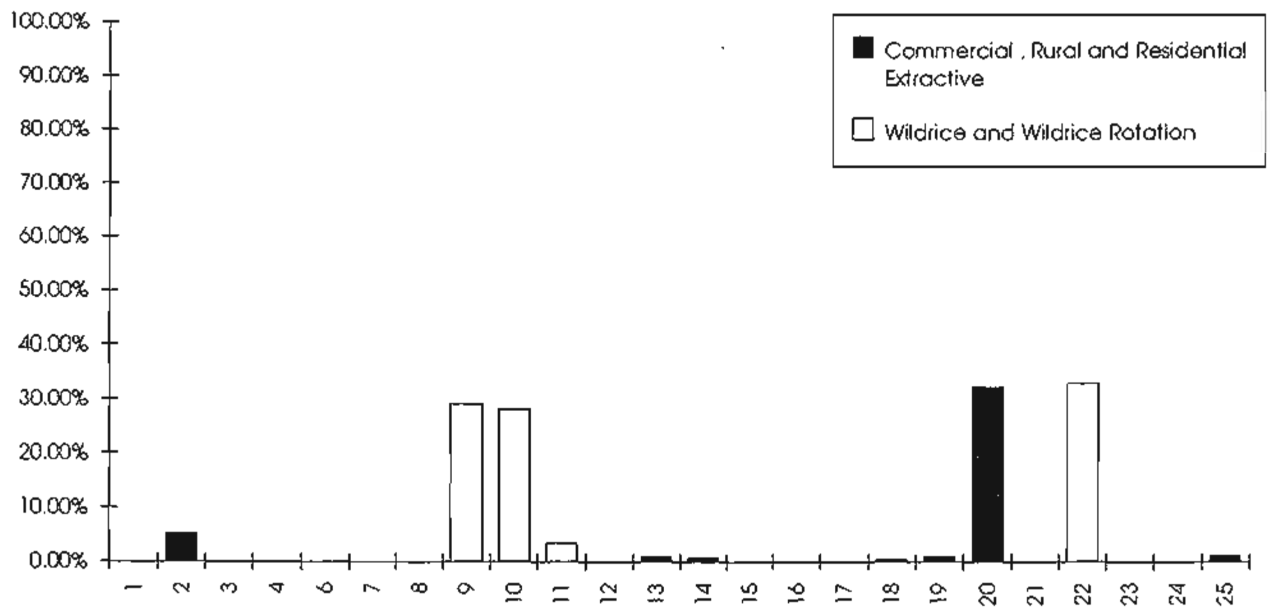


Open and Wooded Land Use 1600M
Patured Open and Wooded
Unpastured Open Land
Upland Woodland and Brush
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
1
2
3
4
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25

Water Resources 1600M



Commercial and Residential Land Use 1600M



Appendix B

QUAL2E MODEL INPUT DATA AND CALIBRATION

* * * QUAL-2E STREAM QUALITY ROUTING MODEL * * *
Version 3.14 January 1992

$$$ (PROBLEM TITLES) $$$

CARD TYPE		QUAL-2E PROGRAM TITLES
TITLE01		SIMULATION FOR JULY 27 THROUGH AUGUST 10, 1993
TITLE02		CLEARWATER RIVER, MINNESOTA (CALIBRATED 5/2/94)
TITLE03	NO	CONSERVATIVE MINERAL I IN
TITLE04	NO	CONSERVATIVE MINERAL II IN
TITLE05	NO	CONSERVATIVE MINERAL III IN
TITLE06	YES	TEMPERATURE
TITLE07	YES	BIOCHEMICAL OXYGEN DEMAND
TITLE08	YES	ALGAE AS CHL-A IN UG/L
TITLE09	YES	PHOSPHORUS CYCLE AS P IN MG/L
TITLE10		(ORGANIC-P, DISSOLVED-P)
TITLE11	YES	NITROGEN CYCLE AS N IN MG/L
TITLE12		(ORGANIC-N, AMMONIA-N, NITRITE-N, NITRATE-N)
TITLE13	YES	DISSOLVED OXYGEN IN MG/L
TITLE14	YES	FECAL COLIFORMS IN NO./100 ML
TITLE15	YES	ARBITRARY NON-CONSERVATIVE TSOL MG/L
ENDTITLE		

$$$ DATA TYPE 1 (CONTROL DATA) $$$

CARD TYPE		CARD TYPE	
LIST DATA INPUT	0.00000		0.00000
NO WRITE OPTIONAL SUMMARY	0.00000		0.00000
NO FLOW AUGMENTATION	0.00000		0.00000
STEADY STATE	0.00000		0.00000
NO TRAPEZOIDAL X-SECTIONS	0.00000		0.00000
PRINT LCD/SOLAR DATA	0.00000		0.00000
PLOT DO AND BOD	0.00000		0.00000
FIXED DNSTM COND (YES=1)=	1.00000	5D-ULT BOD CONV K COEF =	0.23000
INPUT METRIC (YES=1) =	0.00000	OUTPUT METRIC (YES=1) =	0.00000
NUMBER OF REACHES =	28.00000	NUMBER OF JUNCTIONS =	5.00000
NUM OF HEADWATERS =	6.00000	NUMBER OF POINT LOADS =	4.00000
TIME STEP (HOURS) =	0.00000	LNTH COMP ELEMENT (DX)=	1.00000
MAXIMUM ITERATIONS =	30.00000	TIME INC. FOR RPT2 (HRS)=	0.00000
LATITUDE OF BASIN (DEG) =	47.00000	LONGITUDE OF BASIN (DEG)=	96.00000
STANDARD MERIDIAN (DEG) =	81.00000	DAY OF YEAR START TIME =	240.00000
EVAP. COEFF. (AE) =	0.00103	EVAP. COEFF. (BE) =	0.00016
ELEV. OF BASIN (ELEV) =	1100.00000	DUST ATTENUATION COEF. =	0.06000
ENDATA1	0.00000		0.00000

$$$ DATA TYPE 1A (ALGAE PRODUCTION AND NITROGEN OXIDATION CONSTANTS) $$$

CARD TYPE		CARD TYPE	
O UPTAKE BY NH3 OXID(MG O/MG N)=	3.4300	O UPTAKE BY NO2 OXID(MG O/MG N)=	1.1400
O PROD BY ALGAE (MG O/MG A) =	1.6000	O UPTAKE BY ALGAE (MG O/MG A) =	2.0000
N CONTENT OF ALGAE (MG N/MG A) =	0.0850	P CONTENT OF ALGAE (MG P/MG A) =	0.0140
ALG MAX SPEC GROWTH RATE(1/DAY)=	4.0000	ALGAE RESPIRATION RATE (1/DAY) =	0.0500
N HALF SATURATION CONST (MG/L) =	0.2000	P HALF SATURATION CONST (MG/L)=	0.0400
LIN ALG SHADE CO (1/FT-UGCHA/L=)	0.0008	NLIN SHADE(1/FT-(UGCHA/L)**2/3)=	0.0000
LIGHT FUNCTION OPTION (LFNOPT) =	3.0000	LIGHT SAT'N COEF (BTU/FT2-MIN) =	0.1100
DAILY AVERAGING OPTION (LAVOPT)=	3.0000	TOTAL DAILY SOLAR RADTN (INT) =	0.9200
NUMBER OF DAYLIGHT HOURS (DLH) =	13.3000	TOTAL DAILY SOLR RAD (BTU/FT-2)=	1527.1000
ALGY GROWTH CALC OPTION(LGROPT)=	2.0000	ALGAL PREF FOR NH3-N (PREFN) =	0.8000
ALG/TEMP SOLR RAD FACTOR(TFACT)=	0.4400	NITRIFICATION INHIBITION COEF =	10.0000
ENDATA1A	0.0000		0.0000

$$$ DATA TYPE 1B (TEMPERATURE CORRECTION CONSTANTS FOR RATE COEFFICIENTS) $$$

CARD TYPE	RATE CODE	THETA VALUE	
THETA(1)	BOD DECA	1.047	DFLT
THETA(2)	BOD SETT	1.024	DFLT
THETA(3)	OXY TRAN	1.024	DFLT
THETA(4)	SOD RATE	1.060	DFLT
THETA(5)	ORGN DEC	1.047	DFLT
THETA(6)	ORGN SET	1.024	DFLT
THETA(7)	NH3 DECA	1.083	DFLT
THETA(8)	NH3 SRCE	1.074	DFLT
THETA(9)	NO2 DECA	1.047	DFLT
THETA(10)	PORG DEC	1.047	DFLT
THETA(11)	PORG SET	1.024	DFLT
THETA(12)	DISP SRC	1.074	DFLT
THETA(13)	ALG GROW	1.047	DFLT
THETA(14)	ALG RESP	1.047	DFLT
THETA(15)	ALG SETT	1.024	DFLT

THETA(16)	COLI DEC	1.047	DFLT
THETA(17)	ANC DECA	1.000	DFLT
THETA(18)	ANC SETT	1.024	DFLT
THETA(19)	ANC SRCE	1.000	DFLT
ENDATA1B			

$$$ DATA TYPE 2 (REACH IDENTIFICATION) $$$

CARD TYPE	REACH ORDER AND IDENT			R. MI/KM		R. MI/KM
STREAM REACH	1.0	RCH=CW. RIVER HEAD	FROM	135.7	TO	133.4
STREAM REACH	2.0	RCH=WALKER BROOK	FROM	1.0	TO	0.0
STREAM REACH	3.0	RCH=CW RIVER SW BAG	FROM	133.4	TO	131.4
STREAM REACH	4.0	RCH=CWR E. BAG-PINEW	FROM	131.4	TO	112.8
STREAM REACH	5.0	RCH=S3 TO CLWTER LK	FROM	112.8	TO	96.0
STREAM REACH	6.0	RCH=CLEARWATER LAKE	FROM	96.0	TO	94.0
STREAM REACH	7.0	RCH=CLWR LK-CR11	FROM	94.0	TO	81.2
STREAM REACH	8.0	RCH=CR11-RUFFY BROOK	FROM	81.2	TO	80.0
STREAM REACH	9.0	RCH=RUFFY BRK TRIB	FROM	3.4	TO	0.0
STREAM REACH	10.0	RCH=RFFY BRK - CR#5	FROM	80.0	TO	74.5
STREAM REACH	11.0	RCH=CR#5 - SITE 22	FROM	74.5	TO	69.6
STREAM REACH	12.0	RCH=S22 - TRAIL RD	FROM	69.6	TO	58.4
STREAM REACH	13.0	RCH=TRL RD-LINDER BR	FROM	58.4	TO	47.9
STREAM REACH	14.0	RCH=LINDER BR-CD#57	FROM	47.9	TO	37.0
STREAM REACH	15.0	RCH=CD#57-PLUMMER	FROM	37.0	TO	31.8
STREAM REACH	16.0	RCH=PLUMMER-S13	FROM	31.8	TO	24.9
STREAM REACH	17.0	RCH=S13-LOST RIVER	FROM	24.9	TO	18.0
STREAM REACH	18.0	RCH=LR GONVICK-MI37	FROM	49.3	TO	37.0
STREAM REACH	19.0	RCH=MI 37-OKLEE	FROM	37.0	TO	24.0
STREAM REACH	20.0	RCH=OKLEE-HILL R.	FROM	24.0	TO	4.2
STREAM REACH	21.0	RCH=HE S15-LOST R	FROM	3.5	TO	0.0
STREAM REACH	22.0	RCH=LR/HR - POP. R.	FROM	4.2	TO	2.2
STREAM REACH	23.0	RCH=PR MCINTS-MI20	FROM	28.7	TO	20.0
STREAM REACH	24.0	RCH=PR MI20-MI10	FROM	20.0	TO	10.0
STREAM REACH	25.0	RCH=PR MI10-LOST R	FROM	10.0	TO	0.0
STREAM REACH	26.0	RCH=PR/LR-C.W. RIVER	FROM	2.2	TO	0.0
STREAM REACH	27.0	RCH=CWR MI18-MI9	FROM	18.0	TO	9.0
STREAM REACH	28.0	RCH=CWR MI9-RDLK. FL	FROM	9.0	TO	0.0
ENDATA2	0.0			0.0		0.0

$$$ DATA TYPE 3 (TARGET LEVEL DO AND FLOW AUGMENTATION SOURCES) $$$

CARD TYPE	REACH	AVAIL HDWS	TARGET	ORDER OF AVAIL SOURCES					
ENDATA3	0.	0.	0.0	0.	0.	0.	0.	0.	0.

$$$ DATA TYPE 4 (COMPUTATIONAL REACH FLAG FIELD) $$$

CARD TYPE	REACH	ELEMENTS/REACH	COMPUTATIONAL FLAGS
FLAG FIELD	1.	2.	1.3.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	2.	1.	1.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	3.	2.	4.6.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	4.	18.	2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.0.0.
FLAG FIELD	5.	16.	2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.0.0.0.0.
FLAG FIELD	6.	2.	2.2.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	7.	12.	2.2.2.2.2.2.2.2.2.2.2.2.0.0.0.0.0.0.0.0.
FLAG FIELD	8.	1.	3.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	9.	3.	1.2.2.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	10.	5.	4.2.2.2.2.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	11.	4.	2.2.2.2.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	12.	11.	2.2.2.2.2.2.2.2.2.2.2.0.0.0.0.0.0.0.0.0.
FLAG FIELD	13.	10.	2.2.2.2.2.2.2.2.2.2.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	14.	10.	2.2.2.2.2.2.2.2.2.2.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	15.	5.	6.2.2.2.6.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	16.	6.	2.2.2.2.2.2.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	17.	6.	2.2.2.2.2.3.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	18.	12.	1.2.2.2.2.2.2.2.2.2.2.2.0.0.0.0.0.0.0.0.
FLAG FIELD	19.	13.	2.2.2.2.2.2.2.2.2.2.2.2.2.0.0.0.0.0.0.0.
FLAG FIELD	20.	19.	6.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.3.0.
FLAG FIELD	21.	3.	1.2.2.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	22.	2.	4.3.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	23.	8.	1.2.2.2.2.2.2.2.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	24.	10.	2.2.2.2.2.2.2.2.2.2.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	25.	10.	2.2.2.2.2.2.2.2.2.2.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	26.	2.	4.2.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	27.	9.	4.2.2.2.2.2.2.2.2.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	28.	9.	2.2.2.2.2.2.2.2.5.0.0.0.0.0.0.0.0.0.0.0.
ENDATA4	0.	0.	0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.

$$$ DATA TYPE 5 (HYDRAULIC DATA FOR DETERMINING VELOCITY AND DEPTH) $$$

CARD TYPE	REACH	COEF-DSPN	COEFQV	EXPOQV	COEFQH	EXPOQH	CMANN

HYDRAULICS	1.	300.00	0.038	0.711	1.377	0.275	0.040
HYDRAULICS	2.	300.00	0.017	0.948	3.741	0.070	0.040
HYDRAULICS	3.	300.00	0.038	0.711	1.377	0.275	0.040
HYDRAULICS	4.	300.00	0.019	0.690	1.592	0.292	0.040
HYDRAULICS	5.	300.00	0.072	0.579	0.348	0.479	0.040
HYDRAULICS	6.	300.00	0.001	0.010	8.500	0.010	0.040
HYDRAULICS	7.	300.00	0.109	0.533	0.278	0.374	0.040
HYDRAULICS	8.	300.00	0.040	0.757	0.887	0.147	0.040
HYDRAULICS	9.	300.00	0.237	0.500	0.337	0.362	0.040
HYDRAULICS	10.	300.00	0.315	0.339	0.122	0.598	0.040
HYDRAULICS	11.	300.00	0.315	0.339	0.122	0.598	0.040
HYDRAULICS	12.	300.00	0.142	0.406	0.243	0.440	0.040
HYDRAULICS	13.	300.00	0.142	0.406	0.243	0.440	0.040
HYDRAULICS	14.	300.00	0.106	0.525	0.089	0.630	0.040
HYDRAULICS	15.	300.00	0.028	0.760	0.138	0.524	0.040
HYDRAULICS	16.	300.00	0.028	0.760	0.138	0.524	0.040
HYDRAULICS	17.	300.00	0.028	0.760	0.138	0.524	0.040
HYDRAULICS	18.	300.00	0.025	0.766	1.746	0.214	0.040
HYDRAULICS	19.	300.00	0.025	0.766	1.746	0.214	0.040
HYDRAULICS	20.	300.00	0.025	0.766	1.746	0.214	0.040
HYDRAULICS	21.	300.00	0.111	0.547	0.532	0.315	0.040
HYDRAULICS	22.	300.00	0.062	0.470	0.153	0.576	0.040
HYDRAULICS	23.	300.00	0.098	0.594	0.708	0.287	0.040
HYDRAULICS	24.	300.00	0.098	0.594	0.708	0.287	0.040
HYDRAULICS	25.	300.00	0.098	0.594	0.708	0.287	0.040
HYDRAULICS	26.	300.00	0.062	0.470	0.153	0.576	0.040
HYDRAULICS	27.	300.00	0.007	0.848	1.552	0.105	0.040
HYDRAULICS	28.	300.00	0.085	0.550	0.227	0.399	0.040
ENDATA5	0.	0.00	0.000	0.000	0.000	0.000	0.000

$$$ DATA TYPE 5A (STEADY STATE TEMPERATURE AND CLIMATOLOGY DATA) $$$

CARD TYPE	REACH	ELEVATION	DUST COEF	CLOUD COVER	DRY BULB TEMP	WET BULB TEMP	ATM PRESSURE	WIND	SOLAR RAD ATTENUATION
TEMP/LCD	1.	1100.00	0.06	0.70	65.00	60.00	30.00	10.00	1.00
TEMP/LCD	2.	1100.00	0.06	0.70	65.00	60.00	30.00	10.00	1.00
TEMP/LCD	3.	1100.00	0.06	0.70	65.00	60.00	30.00	10.00	1.00
TEMP/LCD	4.	1100.00	0.06	0.70	65.00	60.00	30.00	10.00	1.00
TEMP/LCD	5.	1100.00	0.06	0.70	65.00	60.00	30.00	10.00	1.00
TEMP/LCD	6.	1100.00	0.06	0.70	65.00	60.00	30.00	10.00	1.00
TEMP/LCD	7.	1100.00	0.06	0.70	65.00	60.00	30.00	10.00	1.00
TEMP/LCD	8.	1100.00	0.06	0.70	65.00	60.00	30.00	10.00	1.00
TEMP/LCD	9.	1100.00	0.06	0.70	65.00	60.00	30.00	10.00	1.00
TEMP/LCD	10.	1100.00	0.06	0.70	65.00	60.00	30.00	10.00	1.00
TEMP/LCD	11.	1100.00	0.06	0.70	65.00	60.00	30.00	10.00	1.00
TEMP/LCD	12.	1100.00	0.06	0.70	65.00	60.00	30.00	10.00	1.00
TEMP/LCD	13.	1100.00	0.06	0.70	65.00	60.00	30.00	10.00	1.00
TEMP/LCD	14.	1100.00	0.06	0.70	65.00	60.00	30.00	10.00	1.00
TEMP/LCD	15.	1100.00	0.06	0.70	65.00	60.00	30.00	10.00	1.00
TEMP/LCD	16.	1100.00	0.06	0.70	65.00	60.00	30.00	10.00	1.00
TEMP/LCD	17.	1100.00	0.06	0.70	65.00	60.00	30.00	10.00	1.00
TEMP/LCD	18.	1100.00	0.06	0.70	65.00	60.00	30.00	10.00	1.00
TEMP/LCD	19.	1100.00	0.06	0.70	65.00	60.00	30.00	10.00	1.00
TEMP/LCD	20.	1100.00	0.06	0.70	65.00	60.00	30.00	10.00	1.00
TEMP/LCD	21.	1100.00	0.06	0.70	65.00	60.00	30.00	10.00	1.00
TEMP/LCD	22.	1100.00	0.06	0.70	65.00	60.00	30.00	10.00	1.00
TEMP/LCD	23.	1100.00	0.06	0.70	65.00	60.00	30.00	10.00	1.00
TEMP/LCD	24.	1100.00	0.06	0.70	65.00	60.00	30.00	10.00	1.00
TEMP/LCD	25.	1100.00	0.06	0.70	65.00	60.00	30.00	10.00	1.00
TEMP/LCD	26.	1100.00	0.06	0.70	65.00	60.00	30.00	10.00	1.00
TEMP/LCD	27.	1100.00	0.06	0.70	65.00	60.00	30.00	10.00	1.00
TEMP/LCD	28.	1100.00	0.06	0.70	65.00	60.00	30.00	10.00	1.00
ENDATA5A	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 6 (REACTION COEFFICIENTS FOR DEOXYGENATION AND REAERATION) $$$

CARD TYPE	REACH	K1	K3	SOD RATE	K2OPT	K2	COEQK2 OR TSIV COEF OR FOR OPT 8	EXPQK2 SLOPE FOR OPT 8
REACT COEF	1.	0.10	0.00	0.300	3.	0.00	0.000	0.00000
REACT COEF	2.	0.10	0.00	0.300	3.	0.00	0.000	0.00000
REACT COEF	3.	0.10	0.00	0.300	3.	0.00	0.000	0.00000
REACT COEF	4.	0.10	0.00	0.100	3.	0.00	0.000	0.00000
REACT COEF	5.	0.10	0.00	0.100	3.	0.00	0.000	0.00000
REACT COEF	6.	0.00	0.00	0.200	3.	0.00	0.000	0.00000
REACT COEF	7.	0.00	0.00	0.200	3.	0.00	0.000	0.00000
REACT COEF	8.	0.00	0.00	0.100	3.	0.00	0.000	0.00000
REACT COEF	9.	0.10	0.00	0.300	3.	0.00	0.000	0.00000
REACT COEF	10.	0.10	0.00	0.200	3.	0.00	0.000	0.00000
REACT COEF	11.	0.10	0.00	0.500	3.	0.00	0.000	0.00000

REACT COEF	12.	0.10	0.00	0.800	3.	0.00	0.000	0.00000
REACT COEF	13.	0.02	0.00	1.000	3.	0.00	0.000	0.00000
REACT COEF	14.	0.02	0.00	1.000	3.	0.00	0.000	0.00000
REACT COEF	15.	0.02	0.00	1.000	3.	0.00	0.000	0.00000
REACT COEF	16.	0.02	0.00	0.200	3.	0.00	0.000	0.00000
REACT COEF	17.	0.02	0.00	0.200	3.	0.00	0.000	0.00000
REACT COEF	18.	0.05	0.00	0.100	3.	0.00	0.000	0.00000
REACT COEF	19.	0.05	0.00	0.100	3.	0.00	0.000	0.00000
REACT COEF	20.	0.05	0.00	0.100	3.	0.00	0.000	0.00000
REACT COEF	21.	0.10	0.00	0.200	3.	0.00	0.000	0.00000
REACT COEF	22.	0.10	0.00	0.200	3.	0.00	0.000	0.00000
REACT COEF	23.	0.02	0.00	0.100	3.	0.00	0.000	0.00000
REACT COEF	24.	0.02	0.00	0.100	3.	0.00	0.000	0.00000
REACT COEF	25.	0.02	0.00	0.100	3.	0.00	0.000	0.00000
REACT COEF	26.	0.02	0.00	0.200	3.	0.00	0.000	0.00000
REACT COEF	27.	0.02	0.00	0.200	3.	0.00	0.000	0.00000
REACT COEF	28.	0.02	0.00	0.200	3.	0.00	0.000	0.00000
ENDATA6	0.	0.00	0.00	0.000	0.	0.00	0.000	0.00000

$$$ DATA TYPE 6A (NITROGEN AND PHOSPHORUS CONSTANTS) $$$

CARD TYPE	REACH	CKNH2	SETNH2	CKNH3	SNH3	CKNO2	CKPORG	SETPORG	SPO4
N AND P COEF	1.	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00
N AND P COEF	2.	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00
N AND P COEF	3.	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00
N AND P COEF	4.	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00
N AND P COEF	5.	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00
N AND P COEF	6.	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00
N AND P COEF	7.	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00
N AND P COEF	8.	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00
N AND P COEF	9.	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00
N AND P COEF	10.	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00
N AND P COEF	11.	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00
N AND P COEF	12.	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00
N AND P COEF	13.	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00
N AND P COEF	14.	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00
N AND P COEF	15.	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00
N AND P COEF	16.	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00
N AND P COEF	17.	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00
N AND P COEF	18.	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00
N AND P COEF	19.	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00
N AND P COEF	20.	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00
N AND P COEF	21.	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00
N AND P COEF	22.	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00
N AND P COEF	23.	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00
N AND P COEF	24.	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00
N AND P COEF	25.	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00
N AND P COEF	26.	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00
N AND P COEF	27.	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00
N AND P COEF	28.	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00
ENDATA6A	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 6B (ALGAE/OTHER COEFFICIENTS) $$$

CARD TYPE	REACH	ALPHAO	ALGSET	EXCOEF	CK5 CKCOLI	CKANC	SETANC	SRCANC
ALG/OTHER COEF	1.	50.00	0.00	0.25	0.10	0.00	0.08	0.00
ALG/OTHER COEF	2.	50.00	0.00	0.25	0.10	0.00	0.08	0.00
ALG/OTHER COEF	3.	50.00	0.00	0.25	0.10	0.00	0.08	0.00
ALG/OTHER COEF	4.	50.00	0.00	0.25	0.00	0.00	0.08	0.00
ALG/OTHER COEF	5.	50.00	0.00	0.25	0.10	0.00	0.01	0.00
ALG/OTHER COEF	6.	50.00	0.00	0.05	0.50	0.00	0.00	0.00
ALG/OTHER COEF	7.	50.00	0.00	0.25	0.10	0.00	0.01	0.00
ALG/OTHER COEF	8.	50.00	0.00	0.25	0.10	0.00	0.08	0.00
ALG/OTHER COEF	9.	50.00	0.00	0.25	0.10	0.00	0.08	0.00
ALG/OTHER COEF	10.	50.00	0.00	0.25	0.01	0.00	0.01	0.00
ALG/OTHER COEF	11.	50.00	0.00	0.25	0.01	0.00	0.03	0.00
ALG/OTHER COEF	12.	50.00	0.00	0.25	0.01	0.00	0.03	0.00
ALG/OTHER COEF	13.	50.00	0.00	0.25	0.05	0.00	0.60	0.00
ALG/OTHER COEF	14.	50.00	0.00	0.25	0.30	0.00	0.40	0.00
ALG/OTHER COEF	15.	50.00	0.00	0.25	0.30	0.00	0.40	0.00
ALG/OTHER COEF	16.	50.00	0.00	0.25	1.30	0.00	0.08	0.00
ALG/OTHER COEF	17.	50.00	0.00	0.25	1.30	0.00	0.08	0.00
ALG/OTHER COEF	18.	50.00	0.00	0.25	0.05	0.00	0.00	0.00
ALG/OTHER COEF	19.	50.00	0.00	0.25	0.05	0.00	0.00	0.00
ALG/OTHER COEF	20.	50.00	0.00	0.25	0.05	0.00	0.00	0.00
ALG/OTHER COEF	21.	50.00	0.00	0.25	0.05	0.00	0.08	0.00
ALG/OTHER COEF	22.	50.00	0.00	0.25	0.05	0.00	0.08	0.00
ALG/OTHER COEF	23.	50.00	0.00	0.25	0.10	0.00	0.01	0.00
ALG/OTHER COEF	24.	50.00	0.00	0.25	0.10	0.00	0.01	0.00

ALG/OTHER COEF	25.	50.00	0.00	0.25	0.10	0.00	0.01	0.00
ALG/OTHER COEF	26.	50.00	0.00	0.25	0.05	0.00	0.00	0.00
ALG/OTHER COEF	27.	50.00	0.00	0.25	0.60	0.00	0.25	0.00
ALG/OTHER COEF	28.	50.00	0.00	0.25	0.60	0.00	0.25	0.00
ENDATA6B	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 7 (INITIAL CONDITIONS) $$$

CARD TYPE	REACH	TEMP	D.O.	BOD	CM-1	CM-2	CM-3	ANC	COLI
INITIAL COND-1	1.	60.00	5.00	15.00	0.00	0.00	0.00	0.00	20.00
INITIAL COND-1	2.	60.00	5.00	15.00	0.00	0.00	0.00	0.00	20.00
INITIAL COND-1	3.	60.00	4.00	15.00	0.00	0.00	0.00	0.00	20.00
INITIAL COND-1	4.	60.00	3.00	15.00	0.00	0.00	0.00	0.00	20.00
INITIAL COND-1	5.	60.00	5.00	15.00	0.00	0.00	0.00	0.00	20.00
INITIAL COND-1	6.	60.00	2.00	20.00	0.00	0.00	0.00	0.00	200.00
INITIAL COND-1	7.	60.00	0.00	20.00	0.00	0.00	0.00	0.00	200.00
INITIAL COND-1	8.	60.00	0.00	20.00	0.00	0.00	0.00	0.00	200.00
INITIAL COND-1	9.	65.00	0.00	20.00	0.00	0.00	0.00	0.00	200.00
INITIAL COND-1	10.	65.00	0.00	20.00	0.00	0.00	0.00	0.00	200.00
INITIAL COND-1	11.	65.00	0.00	20.00	0.00	0.00	0.00	0.00	200.00
INITIAL COND-1	12.	65.00	0.00	20.00	0.00	0.00	0.00	0.00	200.00
INITIAL COND-1	13.	65.00	0.00	20.00	0.00	0.00	0.00	0.00	200.00
INITIAL COND-1	14.	65.00	0.00	40.00	0.00	0.00	0.00	0.00	200.00
INITIAL COND-1	15.	65.00	0.00	40.00	0.00	0.00	0.00	0.00	200.00
INITIAL COND-1	16.	65.00	0.00	40.00	0.00	0.00	0.00	0.00	200.00
INITIAL COND-1	17.	65.00	0.00	40.00	0.00	0.00	0.00	0.00	500.00
INITIAL COND-1	18.	70.00	0.00	40.00	0.00	0.00	0.00	0.00	500.00
INITIAL COND-1	19.	70.00	0.00	40.00	0.00	0.00	0.00	0.00	500.00
INITIAL COND-1	20.	70.00	0.00	40.00	0.00	0.00	0.00	0.00	500.00
INITIAL COND-1	21.	70.00	0.00	80.00	0.00	0.00	0.00	0.00	500.00
INITIAL COND-1	22.	70.00	0.00	80.00	0.00	0.00	0.00	0.00	500.00
INITIAL COND-1	23.	70.00	0.00	80.00	0.00	0.00	0.00	0.00	500.00
INITIAL COND-1	24.	70.00	0.00	80.00	0.00	0.00	0.00	0.00	500.00
INITIAL COND-1	25.	70.00	0.00	80.00	0.00	0.00	0.00	0.00	500.00
INITIAL COND-1	26.	70.00	0.00	80.00	0.00	0.00	0.00	0.00	1000.00
INITIAL COND-1	27.	70.00	0.00	80.00	0.00	0.00	0.00	0.00	1000.00
INITIAL COND-1	28.	70.00	0.00	80.00	0.00	0.00	0.00	0.00	1000.00
ENDATA7	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 7A (INITIAL CONDITIONS FOR CHOROPHYLL A, NITROGEN, AND PHOSPHORUS) $$$

CARD TYPE	REACH	CHL-A	ORG-N	NH3-N	NO2-N	NO3-N	ORG-P	DIS-P
INITIAL COND-2	1.	5.00	0.05	0.00	0.00	0.00	0.05	0.05
INITIAL COND-2	2.	5.00	0.05	0.00	0.00	0.00	0.05	0.05
INITIAL COND-2	3.	5.00	0.05	0.00	0.00	0.00	0.05	0.05
INITIAL COND-2	4.	5.00	0.05	0.00	0.00	0.00	0.05	0.05
INITIAL COND-2	5.	5.00	0.05	0.00	0.00	0.00	0.05	0.05
INITIAL COND-2	6.	5.00	0.05	0.00	0.00	0.00	0.05	0.05
INITIAL COND-2	7.	5.00	0.05	0.00	0.00	0.00	0.05	0.05
INITIAL COND-2	8.	0.00	0.05	0.00	0.00	0.00	0.05	0.05
INITIAL COND-2	9.	0.00	0.05	0.00	0.00	0.00	0.05	0.05
INITIAL COND-2	10.	0.00	0.05	0.00	0.00	0.00	0.05	0.05
INITIAL COND-2	11.	0.00	0.05	0.00	0.00	0.00	0.05	0.05
INITIAL COND-2	12.	0.00	0.05	0.00	0.00	0.00	0.05	0.05
INITIAL COND-2	13.	0.00	0.05	0.00	0.00	0.00	0.05	0.05
INITIAL COND-2	14.	0.00	0.05	0.00	0.00	0.00	0.05	0.05
INITIAL COND-2	15.	0.00	0.05	0.00	0.00	0.00	0.05	0.05
INITIAL COND-2	16.	0.00	0.05	0.00	0.00	0.00	0.05	0.05
INITIAL COND-2	17.	0.00	0.05	0.00	0.00	0.00	0.05	0.05
INITIAL COND-2	18.	0.00	0.05	0.00	0.00	0.00	0.05	0.05
INITIAL COND-2	19.	0.00	0.05	0.00	0.00	0.00	0.05	0.05
INITIAL COND-2	20.	0.00	0.05	0.00	0.00	0.00	0.05	0.05
INITIAL COND-2	21.	0.00	0.05	0.00	0.00	0.00	0.05	0.05
INITIAL COND-2	22.	0.00	0.05	0.00	0.00	0.00	0.05	0.05
INITIAL COND-2	23.	0.00	0.05	0.00	0.00	0.00	0.05	0.05
INITIAL COND-2	24.	0.00	0.05	0.00	0.00	0.00	0.05	0.05
INITIAL COND-2	25.	0.00	0.05	0.00	0.00	0.00	0.05	0.05
INITIAL COND-2	26.	0.00	0.05	0.00	0.00	0.00	0.05	0.05
INITIAL COND-2	27.	0.00	0.05	0.00	0.00	0.00	0.05	0.05
INITIAL COND-2	28.	0.00	0.05	0.00	0.00	0.00	0.05	0.05
ENDATA7A	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 8 (INCREMENTAL INFLOW CONDITIONS) $$$

CARD TYPE	REACH	FLOW	TEMP	D.O.	BOD	CM-1	CM-2	CM-3	ANC	COLI
INCR INFLOW-1	1.	0.000	52.00	4.00	15.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	2.	0.000	52.00	4.00	15.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	3.	0.000	52.00	4.00	15.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	4.	1.000	52.00	4.00	15.00	0.00	0.00	0.00	0.00	300.00
INCR INFLOW-1	5.	7.000	52.00	4.00	15.00	0.00	0.00	0.00	0.00	800.00

INCR INFLOW-1	6.	0.000	52.00	4.00	15.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	7.	-7.000	70.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	8.	10.000	52.00	4.00	15.00	0.00	0.00	0.00	0.00	1000.00
INCR INFLOW-1	9.	0.000	52.00	4.00	15.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	10.	50.000	65.90	6.00	80.00	0.00	0.00	0.00	20.00	150.00
INCR INFLOW-1	11.	25.000	65.90	6.00	5.00	0.00	0.00	0.00	20.00	190.00
INCR INFLOW-1	12.	39.000	65.90	6.00	230.00	0.00	0.00	0.00	20.00	800.00
INCR INFLOW-1	13.	-44.000	70.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	14.	2.800	52.00	4.00	80.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	15.	1.200	52.00	4.00	80.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	16.	1.000	52.00	4.00	80.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	17.	1.000	52.00	4.00	90.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	18.	7.000	52.00	4.00	100.00	0.00	0.00	0.00	1.00	325.00
INCR INFLOW-1	19.	7.000	52.00	4.00	100.00	0.00	0.00	0.00	1.00	250.00
INCR INFLOW-1	20.	0.000	52.00	4.00	80.00	0.00	0.00	0.00	1.00	0.00
INCR INFLOW-1	21.	0.000	52.00	4.00	35.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	22.	0.000	52.00	4.00	15.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	23.	0.000	52.00	4.00	80.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	24.	0.000	52.00	4.00	80.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	25.	0.000	52.00	4.00	80.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	26.	0.000	52.00	4.00	80.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	27.	-14.000	70.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	28.	2.000	52.00	4.00	80.00	0.00	0.00	0.00	0.00	0.00
ENDATA8	0.	0.000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 8A (INCREMENTAL INFLOW CONDITIONS FOR CHLOROPHYLL A, NITROGEN, AND PHOSPHORUS) $$$

CARD TYPE	REACH	CHL-A	ORG-N	NH3-N	NO2-N	NO3-N	ORG-P	DIS-P
INCR INFLOW-2	1.	0.00	0.00	0.00	0.00	0.00	0.00	0.01
INCR INFLOW-2	2.	0.00	0.00	0.00	0.00	0.00	0.00	0.01
INCR INFLOW-2	3.	0.00	0.00	0.00	0.00	0.00	0.00	0.01
INCR INFLOW-2	4.	0.00	0.00	0.00	0.00	0.00	0.00	0.01
INCR INFLOW-2	5.	0.00	0.00	0.00	0.00	0.00	0.00	0.01
INCR INFLOW-2	6.	0.00	0.00	0.00	0.00	0.00	0.00	0.01
INCR INFLOW-2	7.	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-2	8.	0.00	0.00	0.00	0.00	0.00	0.02	0.04
INCR INFLOW-2	9.	0.00	0.05	0.00	0.00	0.02	0.07	0.04
INCR INFLOW-2	10.	0.00	0.56	0.00	0.00	0.02	0.12	0.04
INCR INFLOW-2	11.	0.00	0.38	0.00	0.00	0.50	0.22	0.13
INCR INFLOW-2	12.	0.00	0.57	0.00	0.00	0.25	0.22	0.08
INCR INFLOW-2	13.	0.00	0.38	0.00	0.00	0.55	0.21	0.80
INCR INFLOW-2	14.	0.00	0.38	0.00	0.00	0.25	0.19	0.04
INCR INFLOW-2	15.	0.00	0.56	0.00	0.00	0.25	0.19	0.04
INCR INFLOW-2	16.	0.00	0.18	0.00	0.00	0.57	0.16	0.05
INCR INFLOW-2	17.	0.00	0.18	0.00	0.00	0.57	0.16	0.05
INCR INFLOW-2	18.	0.00	0.05	0.00	0.00	0.01	0.00	0.03
INCR INFLOW-2	19.	0.00	0.18	0.00	0.00	0.01	0.00	0.03
INCR INFLOW-2	20.	0.00	0.18	0.00	0.00	0.02	0.00	0.03
INCR INFLOW-2	21.	0.00	0.05	0.00	0.00	0.01	0.08	0.04
INCR INFLOW-2	22.	0.00	0.05	0.00	0.00	0.00	0.00	0.01
INCR INFLOW-2	23.	0.00	0.87	0.00	0.00	0.02	0.09	0.03
INCR INFLOW-2	24.	0.00	1.30	0.00	0.00	0.02	0.09	0.03
INCR INFLOW-2	25.	0.00	1.64	0.00	0.00	0.02	0.09	0.03
INCR INFLOW-2	26.	0.00	0.00	0.00	0.00	0.00	0.00	0.01
INCR INFLOW-2	27.	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-2	28.	0.00	0.00	0.00	0.00	0.00	0.00	0.01
ENDATA8A	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 9 (STREAM JUNCTIONS) $$$

CARD TYPE	JUNCTION ORDER AND IDENT		UPSTRM	JUNCTION	TRIB
STREAM JUNCTION	1.	JNC=CLWATER/WALKER B	2.	4.	3.
STREAM JUNCTION	2.	JNC=RUFFY/CLWATER	54.	58.	57.
STREAM JUNCTION	3.	JNC=HILL/LOST RIVERS	158.	162.	161.
STREAM JUNCTION	4.	JNC=POPLAR/LOST RIVE	163.	192.	191.
STREAM JUNCTION	5.	JNC=LOST/CLWTER RIVE	114.	194.	193.
ENDATA9	0.		0.	0.	0.

$$$ DATA TYPE 10 (HEADWATER SOURCES) $$$

CARD TYPE	HDWTR ORDER	NAME	FLOW	TEMP	D.O.	BOD	CM-1	CM-2	CM-3
HEADWTR-1	1.	SW CWR	7.00	55.00	3.90	25.00	0.00	0.00	0.00
HEADWTR-1	2.	WALKER BROOK	1.00	53.00	1.50	60.00	0.00	0.00	0.00
HEADWTR-1	3.	RUFFY BROOK	1.00	55.00	6.60	43.00	0.00	0.00	0.00
HEADWTR-1	4.	LOST R	3.00	55.00	7.00	48.00	0.00	0.00	0.00
HEADWTR-1	5.	HILL RIVER	1.00	59.00	8.95	35.00	0.00	0.00	0.00
HEADWTR-1	6.	POPLAR RIVER	1.00	60.70	2.00	80.00	0.00	0.00	0.00
ENDATA10	0.		0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 10A (HEADWATER CONDITIONS FOR CHLOROPHYLL, NITROGEN, PHOSPHORUS, COLIFORM AND SELECTED NON-CONSERVATIVE CONSTITUENT) $$$

CARD TYPE	HDWTR ORDER	ANC	COLI	CHL-A	ORG-N	NH3-N	NO2-N	NO3-N	ORG-P	DIS-P
HEADWTR-2	1.	1.75	20.00	5.00	0.05	0.00	0.00	0.01	0.03	0.01
HEADWTR-2	2.	4.65	11.00	5.00	0.05	0.00	0.00	0.01	0.04	0.02
HEADWTR-2	3.	3.40	633.00	5.00	0.05	0.00	0.00	0.02	0.04	0.07
HEADWTR-2	4.	2.15	325.00	5.20	0.05	0.00	0.00	0.00	0.03	0.03
HEADWTR-2	5.	2.40	253.00	5.00	0.05	0.00	0.00	0.01	0.04	0.08
HEADWTR-2	6.	5.15	3695.00	5.20	0.87	0.00	0.00	0.01	0.05	0.09
ENDATA10A	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 11 (POINT SOURCE / POINT SOURCE CHARACTERISTICS) $$$

CARD TYPE	POINT LOAD ORDER	NAME	EFF	FLOW	TEMP	D.O.	BOD	CM-1	CM-2	CM-3
POINTLD-1	1.	BAGELY	0.00	27.00	55.00	1.00	40.00	0.00	0.00	0.00
POINTLD-1	2.	OKLEE	0.00	0.00	55.00	0.00	0.00	0.00	0.00	0.00
POINTLD-1	3.	PLUMMER	0.00	0.00	55.00	0.00	0.00	0.00	0.00	0.00
POINTLD-1	4.	CO #57	0.00	0.00	55.00	0.00	0.00	0.00	0.00	0.00
ENDATA11	0.		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 11A (POINT SOURCE CHARACTERISTICS - CHLOROPHYLL A, NITROGEN, PHOSPHORUS, COLIFORMS AND SELECTED NON-CONSERVATIVE CONSTITUENT) $$$

CARD TYPE	POINT LOAD ORDER	ANC	COLI	CHL-A	ORG-N	NH3-N	NO2-N	NO3-N	ORG-P	DIS-P
POINTLD-2	1.	3.00	275.00	0.00	0.00	0.00	0.00	0.03	0.03	0.03
POINTLD-2	2.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
POINTLD-2	3.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
POINTLD-2	4.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ENDATA11A	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 12 (DAM CHARACTERISTICS) $$$

	DAM	RCH	ELE	ADAM	BDAM	FDAM	HDAM
ENDATA12	0.	0.	0.	0.00	0.00	0.00	0.00

$$$ DATA TYPE 13 (DOWNSTREAM BOUNDARY CONDITIONS-1) $$$

CARD TYPE	TEMP	D.O.	BOD	CM-1	CM-2	CM-3	ANC	COLI
DOWNSTREAM BOUNDARY-1	70.40	10.30	74.50	0.00	0.00	0.00	3.80	38.00
ENDATA13								

$$$ DATA TYPE 13A (DOWNSTREAM BOUNDARY CONDITIONS-2) $$$

CARD TYPE	CHL-A	ORG-N	NH3-N	NO2-N	NH3-N	ORG-P	DIS-P
DOWNSTREAM BOUNDARY-2	0.00	0.33	0.00	0.00	0.27	0.06	0.11
ENDATA13A							

STEADY STATE TEMPERATURE SIMULATION; CONVERGENCE SUMMARY:

ITERATION	NUMBER OF NONCONVERGENT ELEMENTS
1	114
2	0

SUMMARY OF VALUES FOR STEADY STATE TEMPERATURE CALCULATIONS (SUBROUTINE HEATER):

DAILY NET SOLAR RADIATION = 1527.079 BTU/FT-2 (414.404 LANGLEYS)
NUMBER OF DAYLIGHT HOURS = 13.3

HOURLY VALUES OF SOLAR RADIATION (BTU/FT-2)

1	0.00	9	80.28	17	121.24
2	0.00	10	118.97	18	82.83
3	0.00	11	151.64	19	41.79
4	0.00	12	175.31	20	5.63
5	0.00	13	187.89	21	0.00
6	0.00	14	188.28	22	0.00
7	4.18	15	176.44	23	0.00
8	39.19	16	153.42	24	0.00

STEADY STATE ALGAE/NUTRIENT/DISSOLVED OXYGEN SIMULATION; CONVERGENCE SUMMARY:

VARIABLE	ITERATION	NUMBER OF NONCONVERGENT ELEMENTS
ALGAE GROWTH RATE	1	211
ALGAE GROWTH RATE	2	211
ALGAE GROWTH RATE	3	210
ALGAE GROWTH RATE	4	209
ALGAE GROWTH RATE	5	185
ALGAE GROWTH RATE	6	104
ALGAE GROWTH RATE	7	4
ALGAE GROWTH RATE	8	0
ALGAE GROWTH RATE	9	0

SUMMARY OF CONDITIONS FOR ALGAL GROWTH RATE SIMULATION:

1. LIGHT AVERAGING OPTION. LAVOPT= 3

   METHOD: AVERAGE OF HOURLY SOLAR VALUES

   SOURCE OF SOLAR VALUES: SUBROUTINE HEATER (SS TEMP)
   DAILY NET SOLAR RADIATION: 1527.079 BTU/FT-2 (414.404 LANGLEYS)
   NUMBER OF DAYLIGHT HOURS: 13.3
   PHOTOSYNTHETIC ACTIVE FRACTION OF SOLAR RADIATION (TFACT): 0.44
   MEAN SOLAR RADIATION ADJUSTMENT FACTOR (AFACT): N/A

   HOURLY VALUES OF SOLAR RADIATION (LANGLEYS)

1	0.00	9	21.79	17	32.90
2	0.00	10	32.28	18	22.48
3	0.00	11	41.15	19	11.34
4	0.00	12	47.57	20	1.53
5	0.00	13	50.99	21	0.00
6	0:00	14	51.09	22	0.00
7	1.13	15	47.88	23	0.00
8	10.64	16	41.63	24	0.00

2. LIGHT FUNCTION OPTION: LFNOPT= 3

   STEELE FUNCTION, WITH IMAX = 0.030 LANGLEYS/MIN

3. GROWTH ATTENUATION OPTION FOR NUTRIENTS. LGROPT= 2

   MINIMUM OF NITROGEN, PHOSPHORUS: FL*MIN(FN,FP)

***** STEADY STATE SIMULATION *****

** HYDRAULICS SUMMARY **

ELE ORD	RCH NUM	ELE NUM	BEGIN LOC MILE	END LOC MILE	FLOW CFS	POINT SRCE CFS	INCR FLOW CFS	VEL FPS	TRVL TIME DAY	DEPTH FT	WIDTH FT	VOLUME K-FT-3	BOTTOM AREA K-FT-2	X-SECT AREA FT-2	DSPRSN COEF FT-2/S
1	1	1	135.70	134.70	7.00	0.00	0.00	0.152	0.403	2.352	19.636	243.83	128.51	46.18	14.17
2	1	2	134.70	133.70	7.00	0.00	0.00	0.152	0.403	2.352	19.636	243.83	128.51	46.18	14.17
3	2	1	1.00	0.00	1.00	0.00	0.00	0.017	3.681	3.741	16.103	318.07	124.53	60.24	2.28
4	3	1	133.40	132.40	8.00	0.00	0.00	0.167	0.367	2.440	19.673	253.42	129.64	48.00	16.06
5	3	2	132.40	131.40	35.00	27.00	0.00	0.476	0.128	3.661	20.083	388.23	144.70	73.53	64.32
6	4	1	131.40	130.40	35.06	0.00	0.06	0.216	0.282	4.498	36.004	855.06	237.60	161.94	34.72
7	4	2	130.40	129.40	35.11	0.00	0.06	0.217	0.282	4.500	36.005	855.48	237.63	162.02	34.77
8	4	3	129.40	128.40	35.17	0.00	0.06	0.217	0.282	4.502	36.006	855.90	237.65	162.10	34.82
9	4	4	128.40	127.40	35.22	0.00	0.06	0.217	0.281	4.504	36.007	856.32	237.68	162.18	34.88
10	4	5	127.40	126.40	35.28	0.00	0.06	0.217	0.281	4.506	36.008	856.73	237.71	162.26	34.93
11	4	6	126.40	125.40	35.33	0.00	0.06	0.218	0.281	4.508	36.009	857.15	237.74	162.34	34.98
12	4	7	125.40	124.40	35.39	0.00	0.06	0.218	0.280	4.510	36.010	857.57	237.76	162.42	35.03
13	4	8	124.40	123.40	35.44	0.00	0.06	0.218	0.280	4.512	36.011	857.99	237.79	162.50	35.08
14	4	9	123.40	122.40	35.50	0.00	0.06	0.218	0.280	4.515	36.012	858.40	237.82	162.58	35.13
15	4	10	122.40	121.40	35.56	0.00	0.06	0.219	0.280	4.517	36.013	858.82	237.84	162.66	35.18
16	4	11	121.40	120.40	35.61	0.00	0.06	0.219	0.279	4.519	36.014	859.24	237.87	162.73	35.23
17	4	12	120.40	119.40	35.67	0.00	0.06	0.219	0.279	4.521	36.015	859.65	237.90	162.81	35.29
18	4	13	119.40	118.40	35.72	0.00	0.06	0.219	0.279	4.523	36.016	860.07	237.93	162.89	35.34
19	4	14	118.40	117.40	35.78	0.00	0.06	0.220	0.278	4.525	36.017	860.48	237.95	162.97	35.39
20	4	15	117.40	116.40	35.83	0.00	0.06	0.220	0.278	4.527	36.018	860.89	237.98	163.05	35.44
21	4	16	116.40	115.40	35.89	0.00	0.06	0.220	0.278	4.529	36.019	861.31	238.01	163.13	35.49
22	4	17	115.40	114.40	35.94	0.00	0.06	0.220	0.277	4.531	36.020	861.72	238.03	163.20	35.54
	4	18	114.40	113.40	36.00	0.00	0.06	0.220	0.277	4.533	36.021	862.13	238.06	163.28	35.59
24	5	1	112.80	111.80	36.44	0.00	0.44	0.577	0.106	1.948	32.398	333.21	191.63	63.11	46.12
25	5	2	111.80	110.80	36.88	0.00	0.44	0.581	0.105	1.959	32.376	334.89	191.63	63.43	46.66
26	5	3	110.80	109.80	37.31	0.00	0.44	0.585	0.104	1.970	32.353	336.55	191.63	63.74	47.21
27	5	4	109.80	108.80	37.75	0.00	0.44	0.589	0.104	1.981	32.332	338.21	191.63	64.05	47.75
28	5	5	108.80	107.80	38.19	0.00	0.44	0.593	0.103	1.992	32.310	339.85	191.63	64.37	48.29
29	5	6	107.80	106.80	38.63	0.00	0.44	0.597	0.102	2.003	32.289	341.49	191.64	64.68	48.83
30	5	7	106.80	105.80	39.06	0.00	0.44	0.601	0.102	2.014	32.268	343.11	191.64	64.98	49.37
31	5	8	105.80	104.80	39.50	0.00	0.44	0.605	0.101	2.025	32.247	344.72	191.64	65.29	49.91
32	5	9	104.80	103.80	39.94	0.00	0.44	0.609	0.100	2.035	32.226	346.32	191.65	65.59	50.45
33	5	10	103.80	102.80	40.38	0.00	0.44	0.613	0.100	2.046	32.206	347.92	191.65	65.89	50.99
34	5	11	102.80	101.80	40.81	0.00	0.44	0.617	0.099	2.057	32.186	349.50	191.66	66.19	51.53
35	5	12	101.80	100.80	41.25	0.00	0.44	0.620	0.099	2.067	32.166	351.07	191.66	66.49	52.07
36	5	13	100.80	99.80	41.69	0.00	0.44	0.624	0.098	2.078	32.146	352.63	191.67	66.79	52.61
37	5	14	99.80	98.80	42.13	0.00	0.44	0.628	0.097	2.088	32.127	354.19	191.68	67.08	53.15
38	5	15	98.80	97.80	42.56	0.00	0.44	0.632	0.097	2.098	32.107	355.73	191.69	67.37	53.69

***** STEADY STATE SIMULATION *****

** HYDRAULICS SUMMARY **

ELE ORD	RCH NUM	ELE NUM	BEGIN LOC MILE	END LOC MILE	FLOW CFS	POINT SRCE CFS	INCR FLOW CFS	VEL FPS	TRVL TIME DAY	DEPTH FT	WIDTH FT	VOLUME K-FT-3	BOTTOM AREA K-FT-2	X-SECT AREA FT-2	DSPRSN COEF FT-2/S
39	5	16	97.80	96.80	43.00	0.00	0.44	0.635	0.096	2.109	32.088	357.27	191.69	67.66	54.23
40	6	1	96.00	95.00	43.00	0.00	0.00	0.001	58.855	8.826	4692.242	218659.30	24868.24	41412.75	0.29
41	6	2	95.00	94.00	43.00	0.00	0.00	0.001	58.855	8.826	4692.242	218659.30	24868.24	41412.75	0.29
42	7	1	94.00	93.00	42.42	0.00	-0.58	0.803	0.076	1.129	46.762	278.78	258.83	52.80	40.75
43	7	2	93.00	92.00	41.83	0.00	-0.58	0.797	0.077	1.123	46.701	276.99	258.45	52.46	40.27
44	7	3	92.00	91.00	41.25	0.00	-0.58	0.791	0.077	1.117	46.640	275.18	258.06	52.12	39.80
45	7	4	91.00	90.00	40.67	0.00	-0.58	0.786	0.078	1.111	46.579	273.35	257.67	51.77	39.32
46	7	5	90.00	89.00	40.08	0.00	-0.58	0.779	0.078	1.105	46.516	271.51	257.28	51.42	38.84
47	7	6	89.00	88.00	39.50	0.00	-0.58	0.773	0.079	1.099	46.453	269.66	256.88	51.07	38.37
48	7	7	88.00	87.00	38.92	0.00	-0.58	0.767	0.080	1.093	46.389	267.79	256.48	50.72	37.89
49	7	8	87.00	86.00	38.33	0.00	-0.58	0.761	0.080	1.087	46.324	265.91	256.07	50.36	37.41
50	7	9	86.00	85.00	37.75	0.00	-0.58	0.755	0.081	1.081	46.257	264.01	255.65	50.00	36.93
51	7	10	85.00	84.00	37.17	0.00	-0.58	0.749	0.082	1.075	46.191	262.10	255.23	49.64	36.44
52	7	11	84.00	83.00	36.58	0.00	-0.58	0.742	0.082	1.068	46.123	260.17	254.81	49.28	35.96
53	7	12	83.00	82.00	36.00	0.00	-0.58	0.736	0.083	1.062	46.054	258.23	254.38	48.91	35.48
54	8	1	81.20	80.20	46.00	0.00	10.00	0.722	0.085	1.557	40.909	336.36	232.44	63.70	47.87
55	9	1	3.40	2.40	1.00	0.00	0.00	0.237	0.258	0.337	12.521	22.28	69.67	4.22	4.39
56	9	2	2.40	1.40	1.00	0.00	0.00	0.237	0.258	0.337	12.521	22.28	69.67	4.22	4.39
57	9	3	1.40	0.40	1.00	0.00	0.00	0.237	0.258	0.337	12.521	22.28	69.67	4.22	4.39
	10	1	80.00	79.00	57.00	0.00	10.00	1.240	0.049	1.369	33.570	242.64	191.70	45.95	73.86
59	10	2	79.00	78.00	67.00	0.00	10.00	1.310	0.047	1.508	33.913	270.00	194.99	51.14	84.56
60	10	3	78.00	77.00	77.00	0.00	10.00	1.374	0.044	1.639	34.212	296.00	197.94	56.06	95.00
61	10	4	77.00	76.00	87.00	0.00	10.00	1.432	0.043	1.763	34.476	320.88	200.65	60.77	105.23
62	10	5	76.00	75.00	97.00	0.00	10.00	1.485	0.041	1.881	34.713	344.81	203.15	65.30	115.26
63	11	1	74.50	73.50	103.25	0.00	6.25	1.517	0.040	1.953	34.850	359.34	204.63	68.06	121.45
64	11	2	73.50	72.50	109.50	0.00	6.25	1.548	0.039	2.023	34.979	373.57	206.05	70.75	127.57
65	11	3	72.50	71.50	115.75	0.00	6.25	1.577	0.039	2.091	35.102	387.53	207.42	73.40	133.64
66	11	4	71.50	70.50	122.00	0.00	6.25	1.605	0.038	2.158	35.218	401.24	208.74	75.99	139.65
67	12	1	69.60	68.60	125.55	0.00	3.55	1.010	0.060	2.037	60.999	656.20	343.59	124.28	83.77
68	12	2	68.60	67.60	129.09	0.00	3.55	1.022	0.060	2.063	61.261	667.14	345.24	126.35	85.60
69	12	3	67.60	66.60	132.64	0.00	3.55	1.033	0.059	2.087	61.517	677.96	346.85	128.40	87.41
70	12	4	66.60	65.60	136.18	0.00	3.55	1.044	0.059	2.112	61.767	688.67	348.43	130.43	89.21

***** STEADY STATE SIMULATION *****

** HYDRAULICS SUMMARY **

ELE ORD	RCH NUM	ELE NUM	BEGIN LOC MILE	END LOC MILE	FLOW CFS	POINT SRCE CFS	INCR FLOW CFS	VEL FPS	TRVL TIME DAY	DEPTH FT	WIDTH FT	VOLUME K-FT-3	BOTTOM AREA K-FT-2	X-SECT AREA FT-2	DSPRSN COEF FT-2/S
71	12	5	65.60	64.60	139.73	0.00	3.55	1.055	0.058	2.136	62.012	699.27	349.98	132.44	90.99
72	12	6	64.60	63.60	143.27	0.00	3.55	1.066	0.057	2.159	62.252	709.75	351.49	134.42	92.77
73	12	7	63.60	62.60	146.82	0.00	3.55	1.076	0.057	2.183	62.487	720.13	352.98	136.39	94.54
74	12	8	62.60	61.60	150.36	0.00	3.55	1.087	0.056	2.206	62.717	730.41	354.44	138.34	96.30
75	12	9	61.60	60.60	153.91	0.00	3.55	1.097	0.056	2.228	62.943	740.59	355.87	140.26	98.05
76	12	10	60.60	59.60	157.45	0.00	3.55	1.107	0.055	2.251	63.164	750.68	357.27	142.17	99.79
77	12	11	59.60	58.60	161.00	0.00	3.55	1.118	0.055	2.273	63.381	760.68	358.65	144.07	101.52
78	13	1	58.40	57.40	156.60	0.00	-4.40	1.105	0.055	2.246	63.111	748.26	356.94	141.72	99.37
79	13	2	57.40	56.40	152.20	0.00	-4.40	1.092	0.056	2.218	62.834	735.70	355.18	139.34	97.21
80	13	3	56.40	55.40	147.80	0.00	-4.40	1.079	0.057	2.189	62.551	722.99	353.39	136.93	95.03
81	13	4	55.40	54.40	143.40	0.00	-4.40	1.066	0.057	2.160	62.261	710.13	351.55	134.49	92.84
82	13	5	54.40	53.40	139.00	0.00	-4.40	1.053	0.058	2.131	61.963	697.10	349.66	132.03	90.63
83	13	6	53.40	52.40	134.60	0.00	-4.40	1.039	0.059	2.101	61.656	683.91	347.73	129.53	88.40
84	13	7	52.40	51.40	130.20	0.00	-4.40	1.025	0.060	2.070	61.342	670.54	345.75	127.00	86.16
85	13	8	51.40	50.40	125.80	0.00	-4.40	1.011	0.060	2.039	61.018	656.99	343.71	124.43	83.91
86	13	9	50.40	49.40	121.40	0.00	-4.40	0.997	0.061	2.008	60.684	643.24	341.61	121.83	81.63
87	13	10	49.40	48.40	117.00	0.00	-4.40	0.982	0.062	1.975	60.340	629.29	339.45	119.18	79.33
88	14	1	47.90	46.90	117.28	0.00	0.28	1.293	0.047	1.791	50.649	478.86	286.34	90.69	96.30
89	14	2	46.90	45.90	117.56	0.00	0.28	1.295	0.047	1.793	50.631	479.40	286.27	90.80	96.55
90	14	3	45.90	44.90	117.84	0.00	0.28	1.296	0.047	1.796	50.612	479.95	286.20	90.90	96.79
91	14	4	44.90	43.90	118.12	0.00	0.28	1.298	0.047	1.799	50.593	480.49	286.13	91.00	97.03
92	14	5	43.90	42.90	118.40	0.00	0.28	1.300	0.047	1.801	50.575	481.03	286.06	91.10	97.27
93	14	6	42.90	41.90	118.68	0.00	0.28	1.301	0.047	1.804	50.556	481.57	285.99	91.21	97.51
94	14	7	41.90	40.90	118.96	0.00	0.28	1.303	0.047	1.807	50.538	482.11	285.92	91.31	97.75
	14	8	40.90	39.90	119.24	0.00	0.28	1.304	0.047	1.809	50.519	482.65	285.85	91.41	97.99
	14	9	39.90	38.90	119.52	0.00	0.28	1.306	0.047	1.812	50.501	483.18	285.78	91.51	98.24
97	14	10	38.90	37.90	119.80	0.00	0.28	1.308	0.047	1.815	50.483	483.72	285.71	91.61	98.48
98	15	1	37.00	36.00	120.04	0.00	0.24	1.065	0.057	1.696	66.441	595.00	368.72	112.69	75.83
99	15	2	36.00	35.00	120.28	0.00	0.24	1.067	0.057	1.698	66.403	595.28	368.54	112.74	76.01
100	15	3	35.00	34.00	120.52	0.00	0.24	1.068	0.057	1.700	66.365	595.57	368.36	112.80	76.19
101	15	4	34.00	33.00	120.76	0.00	0.24	1.070	0.057	1.701	66.328	595.85	368.18	112.85	76.37
102	15	5	33.00	32.00	121.00	0.00	0.24	1.072	0.057	1.703	66.291	596.13	368.00	112.90	76.55
103	16	1	31.80	30.80	121.17	0.00	0.17	1.073	0.057	1.704	66.265	596.33	367.88	112.94	76.68
104	16	2	30.80	29.80	121.33	0.00	0.17	1.074	0.057	1.706	66.239	596.53	367.75	112.98	76.80
105	16	3	29.80	28.80	121.50	0.00	0.17	1.075	0.057	1.707	66.213	596.73	367.63	113.02	76.93
106	16	4	28.80	27.80	121.67	0.00	0.17	1.076	0.057	1.708	66.187	596.92	367.51	113.05	77.06
107	16	5	27.80	26.80	121.83	0.00	0.17	1.077	0.057	1.709	66.161	597.12	367.38	113.09	77.18
108	16	6	26.80	25.80	122.00	0.00	0.17	1.078	0.057	1.711	66.136	597.31	367.26	113.13	77.31

***** STEADY STATE SIMULATION *****

** HYDRAULICS SUMMARY **

ELE ORD	RCH NUM	ELE NUM	BEGIN LOC MILE	END LOC MILE	FLOW CFS	POINT SRCE CFS	INCR FLOW CFS	VEL FPS	TRVL TIME DAY	DEPTH FT	WIDTH FT	VOLUME K-FT-3	BOTTOM AREA K-FT-2	X-SECT AREA FT-2	DSPRSN COEF FT-2/S
109	17	1	24.90	23.90	122.17	0.00	0.17	1.080	0.057	1.712	66.110	597.51	367.14	113.16	77.44
110	17	2	23.90	22.90	122.33	0.00	0.17	1.081	0.057	1.713	66.085	597.70	367.02	113.20	77.56
111	17	3	22.90	21.90	122.50	0.00	0.17	1.082	0.056	1.714	66.059	597.90	366.89	113.24	77.69
112	17	4	21.90	20.90	122.67	0.00	0.17	1.083	0.056	1.715	66.034	598.10	366.77	113.28	77.82
113	17	5	20.90	19.90	122.83	0.00	0.17	1.084	0.056	1.717	66.008	598.29	366.65	113.31	77.94
114	17	6	19.90	18.90	123.00	0.00	0.17	1.085	0.056	1.718	65.983	598.48	366.53	113.35	78.07
115	18	1	49.30	48.30	3.58	0.00	0.58	0.066	0.920	2.294	23.502	284.71	148.32	53.92	6.08
116	18	2	48.30	47.30	4.17	0.00	0.58	0.075	0.819	2.370	23.573	294.93	149.49	55.86	7.02
117	18	3	47.30	46.30	4.75	0.00	0.58	0.082	0.741	2.437	23.635	304.12	150.53	57.60	7.94
118	18	4	46.30	45.30	5.33	0.00	0.58	0.090	0.678	2.498	23.689	312.47	151.46	59.18	8.86
119	18	5	45.30	44.30	5.92	0.00	0.58	0.098	0.626	2.554	23.739	320.15	152.31	60.64	9.77
120	18	6	44.30	43.30	6.50	0.00	0.58	0.105	0.583	2.606	23.783	327.28	153.10	61.98	10.68
121	18	7	43.30	42.30	7.08	0.00	0.58	0.112	0.546	2.655	23.824	333.93	153.82	63.24	11.58
122	18	8	42.30	41.30	7.67	0.00	0.58	0.119	0.514	2.700	23.862	340.17	154.50	64.43	12.48
123	18	9	41.30	40.30	8.25	0.00	0.58	0.126	0.485	2.743	23.897	346.05	155.14	65.54	13.37
124	18	10	40.30	39.30	8.83	0.00	0.58	0.133	0.461	2.783	23.930	351.63	155.74	66.60	14.26
125	18	11	39.30	38.30	9.42	0.00	0.58	0.139	0.439	2.821	23.960	356.93	156.30	67.60	15.15
126	18	12	38.30	37.30	10.00	0.00	0.58	0.146	0.419	2.858	23.989	361.99	156.84	68.56	16.04
127	19	1	37.00	36.00	10.54	0.00	0.54	0.152	0.402	2.890	24.014	366.46	157.32	69.40	16.85
128	19	2	36.00	35.00	11.08	0.00	0.54	0.158	0.387	2.921	24.038	370.76	157.77	70.22	17.66
129	19	3	35.00	34.00	11.62	0.00	0.54	0.164	0.374	2.951	24.061	374.90	158.20	71.00	18.47
130	19	4	34.00	33.00	12.15	0.00	0.54	0.169	0.361	2.980	24.083	378.89	158.62	71.76	19.28
131	19	5	33.00	32.00	12.69	0.00	0.54	0.175	0.349	3.007	24.104	382.76	159.03	72.49	20.08
132	19	6	32.00	31.00	13.23	0.00	0.54	0.181	0.338	3.034	24.124	386.50	159.42	73.20	20.89
	19	7	31.00	30.00	13.77	0.00	0.54	0.186	0.328	3.060	24.143	390.12	159.79	73.89	21.69
	19	8	30.00	29.00	14.31	0.00	0.54	0.192	0.318	3.086	24.162	393.64	160.16	74.55	22.49
135	19	9	29.00	28.00	14.85	0.00	0.54	0.197	0.310	3.110	24.180	397.06	160.51	75.20	23.29
136	19	10	28.00	27.00	15.38	0.00	0.54	0.203	0.301	3.134	24.197	400.38	160.85	75.83	24.08
137	19	11	27.00	26.00	15.92	0.00	0.54	0.208	0.293	3.157	24.213	403.62	161.19	76.44	24.88
138	19	12	26.00	25.00	16.46	0.00	0.54	0.214	0.286	3.180	24.230	406.77	161.51	77.04	25.67
139	19	13	25.00	24.00	17.00	0.00	0.54	0.219	0.279	3.202	24.245	409.84	161.82	77.62	26.47
140	20	1	24.00	23.00	17.00	0.00	0.00	0.219	0.279	3.202	24.245	409.84	161.82	77.62	26.47
141	20	2	23.00	22.00	17.00	0.00	0.00	0.219	0.279	3.202	24.245	409.84	161.82	77.62	26.47
142	20	3	22.00	21.00	17.00	0.00	0.00	0.219	0.279	3.202	24.245	409.84	161.82	77.62	26.47
143	20	4	21.00	20.00	17.00	0.00	0.00	0.219	0.279	3.202	24.245	409.84	161.82	77.62	26.47
144	20	5	20.00	19.00	17.00	0.00	0.00	0.219	0.279	3.202	24.245	409.84	161.82	77.62	26.47
145	20	6	19.00	18.00	17.00	0.00	0.00	0.219	0.279	3.202	24.245	409.84	161.82	77.62	26.47
146	20	7	18.00	17.00	17.00	0.00	0.00	0.219	0.279	3.202	24.245	409.84	161.82	77.62	26.47
147	20	8	17.00	16.00	17.00	0.00	0.00	0.219	0.279	3.202	24.245	409.84	161.82	77.62	26.47
148	20	9	16.00	15.00	17.00	0.00	0.00	0.219	0.279	3.202	24.245	409.84	161.82	77.62	26.47

***** STEADY STATE SIMULATION *****

** HYDRAULICS SUMMARY **

ELE ORD	RCH NUM	ELE NUM	BEGIN LOC MILE	END LOC MILE	FLOW CFS	POINT SRCE CFS	INCR FLOW CFS	VEL FPS	TRVL TIME DAY	DEPTH FT	WIDTH FT	VOLUME K-FT-3	BOTTOM AREA K-FT-2	X-SECT AREA FT-2	DSPRSN COEF FT-2/S
149	20	10	15.00	14.00	17.00	0.00	0.00	0.219	0.279	3.202	24.245	409.84	161.82	77.62	26.47
150	20	11	14.00	13.00	17.00	0.00	0.00	0.219	0.279	3.202	24.245	409.84	161.82	77.62	26.47
151	20	12	13.00	12.00	17.00	0.00	0.00	0.219	0.279	3.202	24.245	409.84	161.82	77.62	26.47
152	20	13	12.00	11.00	17.00	0.00	0.00	0.219	0.279	3.202	24.245	409.84	161.82	77.62	26.47
153	20	14	11.00	10.00	17.00	0.00	0.00	0.219	0.279	3.202	24.245	409.84	161.82	77.62	26.47
154	20	15	10.00	9.00	17.00	0.00	0.00	0.219	0.279	3.202	24.245	409.84	161.82	77.62	26.47
155	20	16	9.00	8.00	17.00	0.00	0.00	0.219	0.279	3.202	24.245	409.84	161.82	77.62	26.47
156	20	17	8.00	7.00	17.00	0.00	0.00	0.219	0.279	3.202	24.245	409.84	161.82	77.62	26.47
157	20	18	7.00	6.00	17.00	0.00	0.00	0.219	0.279	3.202	24.245	409.84	161.82	77.62	26.47
158	20	19	6.00	5.00	17.00	0.00	0.00	0.219	0.279	3.202	24.245	409.84	161.82	77.62	26.47
159	21	1	3.50	2.50	1.00	0.00	0.00	0.111	0.551	0.532	16.934	47.57	95.03	9.01	3.01
160	21	2	2.50	1.50	1.00	0.00	0.00	0.111	0.551	0.532	16.934	47.57	95.03	9.01	3.01
161	21	3	1.50	0.50	1.00	0.00	0.00	0.111	0.551	0.532	16.934	47.57	95.03	9.01	3.01
162	22	1	4.20	3.20	18.00	0.00	0.00	0.241	0.253	0.809	92.294	394.04	495.85	74.63	9.26
163	22	2	3.20	2.20	18.00	0.00	0.00	0.241	0.253	0.809	92.294	394.04	495.85	74.63	9.26
164	23	1	28.70	27.70	1.00	0.00	0.00	0.098	0.624	0.708	14.413	53.88	83.57	10.20	3.37
165	23	2	27.70	26.70	1.00	0.00	0.00	0.098	0.624	0.708	14.413	53.88	83.57	10.20	3.37
166	23	3	26.70	25.70	1.00	0.00	0.00	0.098	0.624	0.708	14.413	53.88	83.57	10.20	3.37
167	23	4	25.70	24.70	1.00	0.00	0.00	0.098	0.624	0.708	14.413	53.88	83.57	10.20	3.37
168	23	5	24.70	23.70	1.00	0.00	0.00	0.098	0.624	0.708	14.413	53.88	83.57	10.20	3.37
169	23	6	23.70	22.70	1.00	0.00	0.00	0.098	0.624	0.708	14.413	53.88	83.57	10.20	3.37
170	23	7	22.70	21.70	1.00	0.00	0.00	0.098	0.624	0.708	14.413	53.88	83.57	10.20	3.37
	23	8	21.70	20.70	1.00	0.00	0.00	0.098	0.624	0.708	14.413	53.88	83.57	10.20	3.37
172	24	1	20.00	19.00	1.00	0.00	0.00	0.098	0.624	0.708	14.413	53.88	83.57	10.20	3.37
173	24	2	19.00	18.00	1.00	0.00	0.00	0.098	0.624	0.708	14.413	53.88	83.57	10.20	3.37
174	24	3	18.00	17.00	1.00	0.00	0.00	0.098	0.624	0.708	14.413	53.88	83.57	10.20	3.37
175	24	4	17.00	16.00	1.00	0.00	0.00	0.098	0.624	0.708	14.413	53.88	83.57	10.20	3.37
176	24	5	16.00	15.00	1.00	0.00	0.00	0.098	0.624	0.708	14.413	53.88	83.57	10.20	3.37
177	24	6	15.00	14.00	1.00	0.00	0.00	0.098	0.624	0.708	14.413	53.88	83.57	10.20	3.37
178	24	7	14.00	13.00	1.00	0.00	0.00	0.098	0.624	0.708	14.413	53.88	83.57	10.20	3.37
179	24	8	13.00	12.00	1.00	0.00	0.00	0.098	0.624	0.708	14.413	53.88	83.57	10.20	3.37
180	24	9	12.00	11.00	1.00	0.00	0.00	0.098	0.624	0.708	14.413	53.88	83.57	10.20	3.37
181	24	10	11.00	10.00	1.00	0.00	0.00	0.098	0.624	0.708	14.413	53.88	83.57	10.20	3.37
182	25	1	10.00	9.00	1.00	0.00	0.00	0.098	0.624	0.708	14.413	53.88	83.57	10.20	3.37
183	25	2	9.00	8.00	1.00	0.00	0.00	0.098	0.624	0.708	14.413	53.88	83.57	10.20	3.37
184	25	3	8.00	7.00	1.00	0.00	0.00	0.098	0.624	0.708	14.413	53.88	83.57	10.20	3.37

***** STEADY STATE SIMULATION *****

** HYDRAULICS SUMMARY **

ELE ORD	RCH NUM	ELE NUM	BEGIN LOC MILE	END LOC MILE	FLOW CFS	POINT SRCE CFS	INCR FLOW CFS	VEL FPS	TRVL TIME DAY	DEPTH FT	WIDTH FT	VOLUME K-FT-3	BOTTOM AREA K-FT-2	X-SECT AREA FT-2	DSPRSN COEF FT-2/S
185	25	4	7.00	6.00	1.00	0.00	0.00	0.098	0.624	0.708	14.413	53.88	83.57	10.20	3.37
186	25	5	6.00	5.00	1.00	0.00	0.00	0.098	0.624	0.708	14.413	53.88	83.57	10.20	3.37
187	25	6	5.00	4.00	1.00	0.00	0.00	0.098	0.624	0.708	14.413	53.88	83.57	10.20	3.37
188	25	7	4.00	3.00	1.00	0.00	0.00	0.098	0.624	0.708	14.413	53.88	83.57	10.20	3.37
189	25	8	3.00	2.00	1.00	0.00	0.00	0.098	0.624	0.708	14.413	53.88	83.57	10.20	3.37
190	25	9	2.00	1.00	1.00	0.00	0.00	0.098	0.624	0.708	14.413	53.88	83.57	10.20	3.37
191	25	10	1.00	0.00	1.00	0.00	0.00	0.098	0.624	0.708	14.413	53.88	83.57	10.20	3.37
192	26	1	2.20	1.20	19.00	0.00	0.00	0.247	0.247	0.834	92.065	405.49	494.91	76.80	9.75
193	26	2	1.20	0.20	19.00	0.00	0.00	0.247	0.247	0.834	92.065	405.49	494.91	76.80	9.75
194	27	1	18.00	17.00	140.44	0.00	-1.56	0.464	0.132	2.608	116.130	1599.40	640.71	302.92	47.24
195	27	2	17.00	16.00	138.89	0.00	-1.56	0.459	0.133	2.605	116.069	1596.69	640.36	302.40	46.75
196	27	3	16.00	15.00	137.33	0.00	-1.56	0.455	0.134	2.602	116.007	1593.96	640.00	301.89	46.26
197	27	4	15.00	14.00	135.78	0.00	-1.56	0.451	0.136	2.599	115.945	1591.20	639.64	301.36	45.77
198	27	5	14.00	13.00	134.22	0.00	-1.56	0.446	0.137	2.596	115.883	1588.42	639.27	300.84	45.28
199	27	6	13.00	12.00	132.67	0.00	-1.56	0.442	0.138	2.593	115.819	1585.61	638.91	300.30	44.78
200	27	7	12.00	11.00	131.11	0.00	-1.56	0.437	0.140	2.590	115.755	1582.77	638.53	299.77	44.29
201	27	8	11.00	10.00	129.56	0.00	-1.56	0.433	0.141	2.586	115.690	1579.90	638.16	299.22	43.80
202	27	9	10.00	9.00	128.00	0.00	-1.56	0.429	0.143	2.583	115.624	1577.00	637.77	298.67	43.31
203	28	1	9.00	8.00	128.22	0.00	0.22	1.227	0.050	1.574	66.384	551.82	367.13	104.51	82.08
204	28	2	8.00	7.00	128.44	0.00	0.22	1.228	0.050	1.575	66.390	552.25	367.17	104.59	82.20
205	28	3	7.00	6.00	128.67	0.00	0.22	1.229	0.050	1.577	66.395	552.68	367.22	104.67	82.33
206	28	4	6.00	5.00	128.89	0.00	0.22	1.230	0.050	1.578	66.401	553.11	367.26	104.76	82.46
[illegible]	28	5	5.00	4.00	129.11	0.00	0.22	1.232	0.050	1.579	66.407	553.54	367.30	104.84	82.58
[illegible]	28	6	4.00	3.00	129.33	0.00	0.22	1.233	0.050	1.580	66.413	553.97	367.34	104.92	82.71
209	28	7	3.00	2.00	129.56	0.00	0.22	1.234	0.050	1.581	66.419	554.40	367.38	105.00	82.83
210	28	8	2.00	1.00	129.78	0.00	0.22	1.235	0.049	1.582	66.425	554.82	367.43	105.08	82.96
211	28	9	1.00	0.00	130.00	0.00	0.22	1.236	0.049	1.583	66.430	555.25	367.47	105.16	83.08

***** STEADY STATE SIMULATION *****

** REACTION COEFFICIENT SUMMARY **

RCH NUM	ELE NUM	DO SAT MG/L	K2 OPT	OXYGN REAIR 1/DAY	BOD DECAY 1/DAY	BOD SETT 1/DAY	SOD RATE G/F2D	ORGN DECAY 1/DAY	ORGN SETT 1/DAY	NH3 DECAY 1/DAY	NH3 SRCE MG/F2D	NO2 DECAY 1/DAY	ORGP DECAY 1/DAY	ORGP SETT 1/DAY	DISP SRCE MG/F2D	COLI DECAY 1/DAY	ANC DECAY 1/DAY	ANC SETT 1/DAY	ANC SRCE MG/F2D
5	16	9.13	3	3.38	0.10	0.00	0.10	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00	0.10	0.00	0.01	0.00
6	1	9.03	3	1.72	0.00	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.51	0.00	0.00	0.00
6	2	8.98	3	0.02	0.00	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.52	0.00	0.00	0.00
7	1	8.97	3	4.95	0.00	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
7	2	8.97	3	9.90	0.00	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
7	3	8.97	3	9.94	0.00	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
7	4	8.97	3	9.98	0.00	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
7	5	8.97	3	10.02	0.00	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
7	6	8.97	3	10.07	0.00	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
7	7	8.97	3	10.11	0.00	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
7	8	8.97	3	10.15	0.00	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
7	9	8.97	3	10.20	0.00	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
7	10	8.97	3	10.25	0.00	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
7	11	8.97	3	10.29	0.00	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
7	12	8.97	3	10.34	0.00	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
8	1	9.31	3	7.72	0.00	0.00	0.09	0.05	0.05	0.18	0.00	0.19	0.10	0.10	0.00	0.10	0.00	0.08	0.00
9	1	9.55	3	30.58	0.09	0.00	0.26	0.05	0.05	0.17	0.00	0.18	0.09	0.09	0.00	0.09	0.00	0.08	0.00
9	2	9.18	3	32.00	0.10	0.00	0.29	0.05	0.05	0.19	0.00	0.20	0.10	0.10	0.00	0.10	0.00	0.08	0.00
9	3	9.05	3	32.56	0.10	0.00	0.31	0.05	0.05	0.21	0.00	0.20	0.10	0.10	0.00	0.10	0.00	0.08	0.00
	1	9.29	3	13.69	0.10	0.00	0.19	0.05	0.05	0.19	0.00	0.19	0.10	0.10	0.00	0.01	0.00	0.01	0.00
10	2	9.28	3	8.35	0.10	0.00	0.19	0.05	0.05	0.19	0.00	0.19	0.10	0.10	0.00	0.01	0.00	0.01	0.00
10	3	9.27	3	7.49	0.10	0.00	0.19	0.05	0.05	0.19	0.00	0.19	0.10	0.10	0.00	0.01	0.00	0.01	0.00
10	4	9.26	3	6.81	0.10	0.00	0.19	0.05	0.05	0.19	0.00	0.19	0.10	0.10	0.00	0.01	0.00	0.01	0.00
10	5	9.25	3	6.27	0.10	0.00	0.19	0.05	0.05	0.19	0.00	0.19	0.10	0.10	0.00	0.01	0.00	0.01	0.00
11	1	9.25	3	5.89	0.10	0.00	0.48	0.05	0.05	0.19	0.00	0.19	0.10	0.10	0.00	0.01	0.00	0.03	0.00
11	2	9.24	3	5.64	0.10	0.00	0.48	0.05	0.05	0.19	0.00	0.19	0.10	0.10	0.00	0.01	0.00	0.03	0.00
11	3	9.23	3	5.41	0.10	0.00	0.48	0.05	0.05	0.19	0.00	0.19	0.10	0.10	0.00	0.01	0.00	0.03	0.00
11	4	9.23	3	5.21	0.10	0.00	0.48	0.05	0.05	0.19	0.00	0.19	0.10	0.10	0.00	0.01	0.00	0.03	0.00
12	1	9.22	3	4.77	0.10	0.00	0.78	0.05	0.05	0.19	0.00	0.20	0.10	0.10	0.00	0.01	0.00	0.03	0.00
12	2	9.21	3	4.40	0.10	0.00	0.78	0.05	0.05	0.19	0.00	0.20	0.10	0.10	0.00	0.01	0.00	0.03	0.00
12	3	9.20	3	4.35	0.10	0.00	0.78	0.05	0.05	0.19	0.00	0.20	0.10	0.10	0.00	0.01	0.00	0.03	0.00
12	4	9.19	3	4.31	0.10	0.00	0.78	0.05	0.05	0.19	0.00	0.20	0.10	0.10	0.00	0.01	0.00	0.03	0.00

***** STEADY STATE SIMULATION *****

** REACTION COEFFICIENT SUMMARY **

RCH NUM	ELE NUM	DO SAT MG/L	K2 OPT	OXYGN REAIR 1/DAY	BOD DECAY 1/DAY	BOD SETT 1/DAY	SOD RATE G/F2D	ORGN DECAY 1/DAY	ORGN SETT 1/DAY	NH3 DECAY 1/DAY	NH3 SRCE MG/F2D	NO2 DECAY 1/DAY	ORGP DECAY 1/DAY	ORGP SETT 1/DAY	DISP SRCE MG/F2D	COLI DECAY 1/DAY	ANC DECAY 1/DAY	ANC SETT 1/DAY	ANC SRCE MG/F2D
12	5	9.18	3	4.26	0.10	0.00	0.79	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00	0.01	0.00	0.03	0.00
12	6	9.17	3	4.21	0.10	0.00	0.79	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00	0.01	0.00	0.03	0.00
12	7	9.17	3	4.17	0.10	0.00	0.79	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00	0.01	0.00	0.03	0.00
12	8	9.16	3	4.13	0.10	0.00	0.79	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00	0.01	0.00	0.03	0.00
12	9	9.15	3	4.09	0.10	0.00	0.79	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00	0.01	0.00	0.03	0.00
12	10	9.15	3	4.05	0.10	0.00	0.79	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00	0.01	0.00	0.03	0.00
12	11	9.14	3	4.01	0.10	0.00	0.79	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00	0.01	0.00	0.03	0.00
13	1	9.13	3	4.02	0.02	0.00	1.00	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00	0.05	0.00	0.60	0.00
13	2	9.13	3	4.07	0.02	0.00	1.00	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00	0.05	0.00	0.60	0.00
13	3	9.12	3	4.13	0.02	0.00	1.00	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00	0.05	0.00	0.60	0.00
13	4	9.11	3	4.19	0.02	0.00	1.00	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00	0.05	0.00	0.60	0.00
13	5	9.10	3	4.26	0.02	0.00	1.01	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00	0.05	0.00	0.60	0.00
13	6	9.10	3	4.32	0.02	0.00	1.01	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00	0.05	0.00	0.60	0.00
13	7	9.09	3	4.39	0.02	0.00	1.01	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00	0.05	0.00	0.60	0.00
13	8	9.08	3	4.46	0.02	0.00	1.01	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00	0.05	0.00	0.60	0.00
13	9	9.08	3	4.54	0.02	0.00	1.02	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00	0.05	0.00	0.60	0.00
13	10	9.07	3	4.62	0.02	0.00	1.02	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00	0.05	0.00	0.60	0.00
14	1	9.07	3	5.43	0.02	0.00	1.02	0.05	0.05	0.21	0.00	0.20	0.10	0.10	0.00	0.30	0.00	0.40	0.00
14	2	9.07	3	6.19	0.02	0.00	1.02	0.05	0.05	0.21	0.00	0.20	0.10	0.10	0.00	0.30	0.00	0.40	0.00
14	3	9.06	3	6.18	0.02	0.00	1.02	0.05	0.05	0.21	0.00	0.20	0.10	0.10	0.00	0.30	0.00	0.40	0.00
14	4	9.06	3	6.17	0.02	0.00	1.02	0.05	0.05	0.21	0.00	0.20	0.10	0.10	0.00	0.30	0.00	0.40	0.00
14	5	9.06	3	6.17	0.02	0.00	1.02	0.05	0.05	0.21	0.00	0.20	0.10	0.10	0.00	0.30	0.00	0.40	0.00
14	6	9.06	3	6.16	0.02	0.00	1.02	0.05	0.05	0.21	0.00	0.20	0.10	0.10	0.00	0.30	0.00	0.40	0.00
14	7	9.06	3	6.15	0.02	0.00	1.02	0.05	0.05	0.21	0.00	0.20	0.10	0.10	0.00	0.30	0.00	0.40	0.00
	8	9.06	3	6.14	0.02	0.00	1.02	0.05	0.05	0.21	0.00	0.20	0.10	0.10	0.00	0.30	0.00	0.40	0.00
	9	9.06	3	6.13	0.02	0.00	1.02	0.05	0.05	0.21	0.00	0.20	0.10	0.10	0.00	0.31	0.00	0.40	0.00
14	10	9.06	3	6.12	0.02	0.00	1.02	0.05	0.05	0.21	0.00	0.20	0.10	0.10	0.00	0.31	0.00	0.40	0.00
15	1	9.05	3	6.11	0.02	0.00	1.02	0.05	0.05	0.21	0.00	0.20	0.10	0.10	0.00	0.31	0.00	0.40	0.00
15	2	9.05	3	6.11	0.02	0.00	1.02	0.05	0.05	0.21	0.00	0.20	0.10	0.10	0.00	0.31	0.00	0.40	0.00
15	3	9.05	3	6.11	0.02	0.00	1.02	0.05	0.05	0.21	0.00	0.20	0.10	0.10	0.00	0.31	0.00	0.40	0.00
15	4	9.05	3	6.10	0.02	0.00	1.02	0.05	0.05	0.21	0.00	0.20	0.10	0.10	0.00	0.31	0.00	0.40	0.00
15	5	9.05	3	6.10	0.02	0.00	1.03	0.05	0.05	0.21	0.00	0.20	0.10	0.10	0.00	0.31	0.00	0.40	0.00
16	1	9.04	3	6.10	0.02	0.00	0.21	0.05	0.05	0.21	0.00	0.20	0.10	0.10	0.00	1.33	0.00	0.08	0.00
16	2	9.04	3	6.10	0.02	0.00	0.21	0.05	0.05	0.21	0.00	0.20	0.10	0.10	0.00	1.33	0.00	0.08	0.00
16	3	9.04	3	6.10	0.02	0.00	0.21	0.05	0.05	0.21	0.00	0.20	0.10	0.10	0.00	1.33	0.00	0.08	0.00
16	4	9.04	3	6.09	0.02	0.00	0.21	0.05	0.05	0.21	0.00	0.20	0.10	0.10	0.00	1.33	0.00	0.08	0.00
16	5	9.03	3	6.09	0.02	0.00	0.21	0.05	0.05	0.21	0.00	0.20	0.10	0.10	0.00	1.33	0.00	0.08	0.00
16	6	9.03	3	6.09	0.02	0.00	0.21	0.05	0.05	0.21	0.00	0.20	0.10	0.10	0.00	1.33	0.00	0.08	0.00

***** STEADY STATE SIMULATION *****

** REACTION COEFFICIENT SUMMARY **

RCH NUM	ELE NUM	DO SAT MG/L	K2 OPT	OXYGN REAIR 1/DAY	BOD DECAY 1/DAY	BOD SETT 1/DAY	SOD RATE G/F2D	ORGN DECAY 1/DAY	ORGN SETT 1/DAY	NH3 DECAY 1/DAY	NH3 SRCE MG/F2D	NO2 DECAY 1/DAY	ORGP DECAY 1/DAY	ORGP SETT 1/DAY	DISP SRCE MG/F2D	COLI DECAY 1/DAY	ANC DECAY 1/DAY	ANC SETT 1/DAY	ANC SRCE MG/F2D
17	1	9.03	3	6.09	0.02	0.00	0.21	0.05	0.05	0.21	0.00	0.20	0.10	0.10	0.00	1.33	0.00	0.08	0.00
17	2	9.03	3	6.09	0.02	0.00	0.21	0.05	0.05	0.21	0.00	0.20	0.10	0.10	0.00	1.33	0.00	0.08	0.00
17	3	9.03	3	6.08	0.02	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	1.33	0.00	0.08	0.00
17	4	9.03	3	6.08	0.02	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	1.33	0.00	0.08	0.00
17	5	9.02	3	6.08	0.02	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	1.33	0.00	0.08	0.00
17	6	9.02	3	6.08	0.02	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	1.33	0.00	0.08	0.00
18	1	9.85	3	0.88	0.04	0.00	0.08	0.04	0.05	0.15	0.00	0.17	0.08	0.09	0.00	0.04	0.00	0.00	0.00
18	2	9.54	3	0.92	0.05	0.00	0.09	0.05	0.05	0.17	0.00	0.18	0.09	0.09	0.00	0.05	0.00	0.00	0.00
18	3	9.40	3	0.94	0.05	0.00	0.09	0.05	0.05	0.18	0.00	0.19	0.09	0.10	0.00	0.05	0.00	0.00	0.00
18	4	9.34	3	0.96	0.05	0.00	0.09	0.05	0.05	0.18	0.00	0.19	0.09	0.10	0.00	0.05	0.00	0.00	0.00
18	5	9.30	3	0.97	0.05	0.00	0.09	0.05	0.05	0.19	0.00	0.19	0.10	0.10	0.00	0.05	0.00	0.00	0.00
18	6	9.28	3	0.97	0.05	0.00	0.10	0.05	0.05	0.19	0.00	0.19	0.10	0.10	0.00	0.05	0.00	0.00	0.00
18	7	9.27	3	0.98	0.05	0.00	0.10	0.05	0.05	0.19	0.00	0.19	0.10	0.10	0.00	0.05	0.00	0.00	0.00
18	8	9.26	3	0.99	0.05	0.00	0.10	0.05	0.05	0.19	0.00	0.19	0.10	0.10	0.00	0.05	0.00	0.00	0.00
18	9	9.26	3	0.99	0.05	0.00	0.10	0.05	0.05	0.19	0.00	0.19	0.10	0.10	0.00	0.05	0.00	0.00	0.00
18	10	9.25	3	1.00	0.05	0.00	0.10	0.05	0.05	0.19	0.00	0.19	0.10	0.10	0.00	0.05	0.00	0.00	0.00
18	11	9.25	3	1.00	0.05	0.00	0.10	0.05	0.05	0.19	0.00	0.19	0.10	0.10	0.00	0.05	0.00	0.00	0.00
18	12	9.25	3	1.01	0.05	0.00	0.10	0.05	0.05	0.19	0.00	0.19	0.10	0.10	0.00	0.05	0.00	0.00	0.00
19	1	9.25	3	1.01	0.05	0.00	0.10	0.05	0.05	0.19	0.00	0.19	0.10	0.10	0.00	0.05	0.00	0.00	0.00
19	2	9.24	3	1.01	0.05	0.00	0.10	0.05	0.05	0.19	0.00	0.19	0.10	0.10	0.00	0.05	0.00	0.00	0.00
19	3	9.24	3	1.02	0.05	0.00	0.10	0.05	0.05	0.19	0.00	0.19	0.10	0.10	0.00	0.05	0.00	0.00	0.00
19	4	9.24	3	1.02	0.05	0.00	0.10	0.05	0.05	0.19	0.00	0.19	0.10	0.10	0.00	0.05	0.00	0.00	0.00
19	5	9.23	3	1.02	0.05	0.00	0.10	0.05	0.05	0.19	0.00	0.19	0.10	0.10	0.00	0.05	0.00	0.00	0.00
19	6	9.23	3	1.03	0.05	0.00	0.10	0.05	0.05	0.19	0.00	0.19	0.10	0.10	0.00	0.05	0.00	0.00	0.00
	7	9.23	3	1.03	0.05	0.00	0.10	0.05	0.05	0.19	0.00	0.19	0.10	0.10	0.00	0.05	0.00	0.00	0.00
	8	9.23	3	1.03	0.05	0.00	0.10	0.05	0.05	0.19	0.00	0.19	0.10	0.10	0.00	0.05	0.00	0.00	0.00
19	9	9.23	3	1.03	0.05	0.00	0.10	0.05	0.05	0.19	0.00	0.19	0.10	0.10	0.00	0.05	0.00	0.00	0.00
19	10	9.23	3	1.04	0.05	0.00	0.10	0.05	0.05	0.19	0.00	0.19	0.10	0.10	0.00	0.05	0.00	0.00	0.00
19	11	9.23	3	1.04	0.05	0.00	0.10	0.05	0.05	0.19	0.00	0.19	0.10	0.10	0.00	0.05	0.00	0.00	0.00
19	12	9.23	3	1.04	0.05	0.00	0.10	0.05	0.05	0.19	0.00	0.19	0.10	0.10	0.00	0.05	0.00	0.00	0.00
19	13	9.23	3	1.04	0.05	0.00	0.10	0.05	0.05	0.19	0.00	0.19	0.10	0.10	0.00	0.05	0.00	0.00	0.00
20	1	9.19	3	1.05	0.05	0.00	0.10	0.05	0.05	0.19	0.00	0.20	0.10	0.10	0.00	0.05	0.00	0.00	0.00
20	2	9.15	3	1.05	0.05	0.00	0.10	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00	0.05	0.00	0.00	0.00
20	3	9.12	3	1.06	0.05	0.00	0.10	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00	0.05	0.00	0.00	0.00
20	4	9.10	3	1.06	0.05	0.00	0.10	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00	0.05	0.00	0.00	0.00
20	5	9.08	3	1.06	0.05	0.00	0.10	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00	0.05	0.00	0.00	0.00
20	6	9.06	3	1.07	0.05	0.00	0.10	0.05	0.05	0.21	0.00	0.20	0.10	0.10	0.00	0.05	0.00	0.00	0.00
20	7	9.05	3	1.07	0.05	0.00	0.10	0.05	0.05	0.21	0.00	0.20	0.10	0.10	0.00	0.05	0.00	0.00	0.00
20	8	9.04	3	1.07	0.05	0.00	0.10	0.05	0.05	0.21	0.00	0.20	0.10	0.10	0.00	0.05	0.00	0.00	0.00
20	9	9.03	3	1.07	0.05	0.00	0.10	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.05	0.00	0.00	0.00

***** STEADY STATE SIMULATION *****

** REACTION COEFFICIENT SUMMARY **

RCH NUM	ELE NUM	DO SAT MG/L	K2 OPT	OXYGN REAIR 1/DAY	BOD DECAY 1/DAY	BOD SETT 1/DAY	SOD RATE G/F2D	ORGN DECAY 1/DAY	ORGN SETT 1/DAY	NH3 DECAY 1/DAY	NH3 SRCE MG/F2D	NO2 DECAY 1/DAY	ORGP DECAY 1/DAY	ORGP SETT 1/DAY	DISP SRCE MG/F2D	COLI DECAY 1/DAY	ANC DECAY 1/DAY	ANC SETT 1/DAY	ANC SRCE MG/F2D
20	10	9.02	3	1.07	0.05	0.00	0.10	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.05	0.00	0.00	0.00
20	11	9.01	3	1.07	0.05	0.00	0.10	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.05	0.00	0.00	0.00
20	12	9.00	3	1.08	0.05	0.00	0.10	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.05	0.00	0.00	0.00
20	13	9.00	3	1.08	0.05	0.00	0.10	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.05	0.00	0.00	0.00
20	14	9.00	3	1.08	0.05	0.00	0.10	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.05	0.00	0.00	0.00
20	15	8.99	3	1.08	0.05	0.00	0.10	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.05	0.00	0.00	0.00
20	16	8.99	3	1.08	0.05	0.00	0.10	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.05	0.00	0.00	0.00
20	17	8.99	3	1.08	0.05	0.00	0.10	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.05	0.00	0.00	0.00
20	18	8.98	3	1.08	0.05	0.00	0.10	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.05	0.00	0.00	0.00
20	19	8.98	3	1.08	0.05	0.00	0.10	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.05	0.00	0.00	0.00
21	1	9.30	3	10.87	0.10	0.00	0.19	0.05	0.05	0.19	0.00	0.19	0.10	0.10	0.00	0.05	0.00	0.08	0.00
21	2	9.07	3	11.20	0.10	0.00	0.20	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00	0.05	0.00	0.08	0.00
21	3	9.00	3	11.31	0.10	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.05	0.00	0.08	0.00
22	1	8.98	3	7.57	0.10	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.05	0.00	0.08	0.00
22	2	8.98	3	8.93	0.10	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.05	0.00	0.08	0.00
23	1	9.28	3	6.67	0.02	0.00	0.10	0.05	0.05	0.19	0.00	0.19	0.10	0.10	0.00	0.10	0.00	0.01	0.00
23	2	9.08	3	6.85	0.02	0.00	0.10	0.05	0.05	0.20	0.00	0.20	0.10	0.10	0.00	0.10	0.00	0.01	0.00
23	3	9.01	3	6.91	0.02	0.00	0.10	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
23	4	8.98	3	6.94	0.02	0.00	0.10	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
23	5	8.98	3	6.94	0.02	0.00	0.10	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
23	6	8.97	3	6.95	0.02	0.00	0.11	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
23	7	8.97	3	6.95	0.02	0.00	0.11	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
	8	8.97	3	6.95	0.02	0.00	0.11	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
24	1	8.97	3	6.95	0.02	0.00	0.11	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
24	2	8.97	3	6.95	0.02	0.00	0.11	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
24	3	8.97	3	6.95	0.02	0.00	0.11	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
24	4	8.97	3	6.95	0.02	0.00	0.11	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
24	5	8.97	3	6.95	0.02	0.00	0.11	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
24	6	8.97	3	6.95	0.02	0.00	0.11	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
24	7	8.97	3	6.95	0.02	0.00	0.11	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
24	8	8.97	3	6.95	0.02	0.00	0.11	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
24	9	8.97	3	6.95	0.02	0.00	0.11	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
24	10	8.97	3	6.95	0.02	0.00	0.11	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
25	1	8.97	3	6.95	0.02	0.00	0.11	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
25	2	8.97	3	6.95	0.02	0.00	0.11	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
25	3	8.97	3	6.95	0.02	0.00	0.11	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00

***** STEADY STATE SIMULATION *****

** REACTION COEFFICIENT SUMMARY **

RCH NUM	ELE NUM	DO SAT MG/L	K2 OPT	OXYGN REAIR 1/DAY	BOD DECAY 1/DAY	BOD SETT 1/DAY	SOD RATE G/F2D	ORGN DECAY 1/DAY	ORGN SETT 1/DAY	NH3 DECAY 1/DAY	NH3 SRCE MG/F2D	NO2 DECAY 1/DAY	ORGP DECAY 1/DAY	ORGP SETT 1/DAY	DISP SRCE MG/F2D	COLI DECAY 1/DAY	ANC DECAY 1/DAY	ANC SETT 1/DAY	ANC SRCE MG/F2D
25	4	8.97	3	6.95	0.02	0.00	0.11	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
25	5	8.97	3	6.95	0.02	0.00	0.11	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
25	6	8.97	3	6.95	0.02	0.00	0.11	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
25	7	8.97	3	6.95	0.02	0.00	0.11	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
25	8	8.97	3	6.95	0.02	0.00	0.11	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
25	9	8.97	3	6.95	0.02	0.00	0.11	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
25	10	8.97	3	6.95	0.02	0.00	0.11	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.10	0.00	0.01	0.00
26	1	8.98	3	8.28	0.02	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.05	0.00	0.00	0.00
26	2	8.97	3	8.63	0.02	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.05	0.00	0.00	0.00
27	1	9.01	3	4.73	0.02	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.62	0.00	0.25	0.00
27	2	9.01	3	2.12	0.02	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.62	0.00	0.25	0.00
27	3	9.01	3	2.12	0.02	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.62	0.00	0.25	0.00
27	4	9.00	3	2.11	0.02	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.62	0.00	0.25	0.00
27	5	9.00	3	2.11	0.02	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.62	0.00	0.25	0.00
27	6	9.00	3	2.10	0.02	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.62	0.00	0.25	0.00
27	7	8.99	3	2.10	0.02	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.62	0.00	0.25	0.00
27	8	8.99	3	2.09	0.02	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.62	0.00	0.25	0.00
27	9	8.99	3	2.08	0.02	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.62	0.00	0.25	0.00
28	1	8.99	3	4.74	0.02	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.62	0.00	0.25	0.00
28	2	8.99	3	7.39	0.02	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.62	0.00	0.25	0.00
28	3	8.99	3	7.39	0.02	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.62	0.00	0.25	0.00
28	4	9.00	3	7.38	0.02	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.62	0.00	0.25	0.00
	5	9.00	3	7.38	0.02	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.62	0.00	0.25	0.00
	6	9.00	3	7.37	0.02	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.62	0.00	0.25	0.00
28	7	9.00	3	7.37	0.02	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.62	0.00	0.25	0.00
28	8	9.00	3	7.36	0.02	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.62	0.00	0.25	0.00
28	9	9.00	3	7.36	0.02	0.00	0.21	0.05	0.05	0.21	0.00	0.21	0.10	0.10	0.00	0.62	0.00	0.25	0.00

***** STEADY STATE SIMULATION *****

** WATER QUALITY VARIABLES **

RCH NUM	ELE NUM	TEMP DEG-F	CM-1	CM-2	CM-3	DO MG/L	BOD MG/L	ORGN MG/L	NH3N MG/L	NO2N MG/L	NO3N MG/L	SUM-N MG/L	ORGP MG/L	DIS-P MG/L	SUM-P MG/L	COLI #/100ML	ANC TSOL MG/L	CHLA UG/L
1	1	58.73	0.00	0.00	0.00	4.35	24.23	0.05	0.01	0.00	0.01	0.07	0.02	0.01	0.03	19.38	1.70	4.98
1	2	61.54	0.00	0.00	0.00	4.46	23.48	0.05	0.01	0.00	0.01	0.06	0.02	0.01	0.03	18.78	1.66	4.96
2	1	64.06	0.00	0.00	0.00	0.00	44.93	0.04	0.01	0.00	0.01	0.06	0.02	0.02	0.05	8.53	3.62	5.00
3	1	63.52	0.00	0.00	0.00	2.76	25.49	0.04	0.01	0.00	0.01	0.06	0.02	0.01	0.03	20.51	1.86	4.87
3	2	57.82	0.00	0.00	0.00	1.80	36.32	0.01	0.00	0.00	0.03	0.04	0.03	0.03	0.05	214.06	2.71	1.14
4	1	58.88	0.00	0.00	0.00	2.35	35.71	0.01	0.00	0.00	0.03	0.04	0.03	0.03	0.05	214.19	2.67	1.14
4	2	60.08	0.00	0.00	0.00	2.53	34.87	0.01	0.00	0.00	0.03	0.04	0.03	0.03	0.05	214.33	2.61	1.15
4	3	61.14	0.00	0.00	0.00	2.68	34.04	0.01	0.00	0.00	0.03	0.04	0.02	0.03	0.05	214.46	2.56	1.15
4	4	62.09	0.00	0.00	0.00	2.79	33.20	0.01	0.00	0.00	0.03	0.04	0.02	0.03	0.05	214.60	2.50	1.16
4	5	62.93	0.00	0.00	0.00	2.89	32.38	0.01	0.00	0.00	0.03	0.04	0.02	0.03	0.05	214.73	2.45	1.17
4	6	63.67	0.00	0.00	0.00	2.96	31.56	0.01	0.00	0.00	0.03	0.04	0.02	0.03	0.05	214.87	2.39	1.17
4	7	64.34	0.00	0.00	0.00	3.03	30.75	0.01	0.00	0.00	0.03	0.04	0.02	0.03	0.05	215.00	2.34	1.18
4	8	64.93	0.00	0.00	0.00	3.09	29.95	0.01	0.00	0.00	0.03	0.04	0.02	0.03	0.05	215.14	2.29	1.19
4	9	65.45	0.00	0.00	0.00	3.14	29.16	0.01	0.00	0.00	0.03	0.04	0.02	0.03	0.05	215.27	2.23	1.20
4	10	65.91	0.00	0.00	0.00	3.19	28.38	0.01	0.00	0.00	0.03	0.04	0.02	0.03	0.05	215.40	2.18	1.20
4	11	66.31	0.00	0.00	0.00	3.23	27.63	0.01	0.00	0.00	0.03	0.04	0.02	0.03	0.05	215.53	2.13	1.21
4	12	66.67	0.00	0.00	0.00	3.28	26.88	0.01	0.00	0.00	0.03	0.04	0.01	0.03	0.05	215.66	2.08	1.22
4	13	66.98	0.00	0.00	0.00	3.33	26.15	0.01	0.00	0.00	0.03	0.04	0.01	0.03	0.05	215.79	2.04	1.23
4	14	67.25	0.00	0.00	0.00	3.39	25.44	0.01	0.00	0.00	0.03	0.04	0.01	0.03	0.05	215.93	1.99	1.24
4	15	67.50	0.00	0.00	0.00	3.44	24.75	0.01	0.00	0.00	0.03	0.03	0.01	0.03	0.05	216.06	1.94	1.25
4	16	67.71	0.00	0.00	0.00	3.49	24.07	0.01	0.00	0.00	0.03	0.03	0.01	0.03	0.04	216.19	1.90	1.26
4	17	67.90	0.00	0.00	0.00	3.55	23.41	0.01	0.00	0.00	0.03	0.03	0.01	0.03	0.04	216.32	1.85	1.26
	18	68.06	0.00	0.00	0.00	3.64	22.77	0.01	0.00	0.00	0.03	0.03	0.01	0.03	0.04	216.53	1.81	1.27
5	1	68.05	0.00	0.00	0.00	4.76	22.25	0.01	0.00	0.00	0.02	0.03	0.01	0.03	0.04	219.43	1.79	1.26
5	2	68.03	0.00	0.00	0.00	5.63	21.94	0.01	0.00	0.00	0.02	0.03	0.01	0.03	0.04	223.96	1.76	1.24
5	3	68.02	0.00	0.00	0.00	6.25	21.63	0.01	0.00	0.00	0.02	0.03	0.01	0.03	0.04	228.34	1.74	1.23
5	4	68.00	0.00	0.00	0.00	6.69	21.33	0.01	0.00	0.00	0.02	0.03	0.01	0.03	0.04	232.55	1.72	1.22
5	5	67.99	0.00	0.00	0.00	7.01	21.04	0.01	0.00	0.00	0.02	0.03	0.01	0.03	0.04	236.62	1.70	1.20
5	6	67.98	0.00	0.00	0.00	7.24	20.76	0.01	0.00	0.00	0.02	0.03	0.01	0.03	0.04	240.55	1.68	1.19
5	7	67.97	0.00	0.00	0.00	7.41	20.49	0.01	0.00	0.00	0.02	0.03	0.01	0.03	0.04	244.34	1.66	1.18
5	8	67.96	0.00	0.00	0.00	7.53	20.23	0.01	0.00	0.00	0.02	0.03	0.01	0.03	0.04	247.99	1.64	1.17
5	9	67.95	0.00	0.00	0.00	7.62	19.97	0.01	0.00	0.00	0.02	0.03	0.01	0.03	0.04	251.52	1.62	1.15
5	10	67.94	0.00	0.00	0.00	7.69	19.72	0.01	0.00	0.00	0.02	0.03	0.01	0.03	0.04	254.93	1.60	1.14
5	11	67.94	0.00	0.00	0.00	7.74	19.48	0.01	0.00	0.00	0.02	0.03	0.01	0.03	0.04	258.23	1.58	1.13
5	12	67.93	0.00	0.00	0.00	7.78	19.24	0.01	0.00	0.00	0.02	0.03	0.01	0.03	0.04	261.41	1.56	1.12
5	13	67.92	0.00	0.00	0.00	7.81	19.01	0.01	0.00	0.00	0.02	0.03	0.01	0.03	0.04	264.48	1.54	1.11
5	14	67.92	0.00	0.00	0.00	7.83	18.79	0.01	0.00	0.00	0.02	0.03	0.01	0.03	0.04	267.45	1.52	1.09
5	15	67.92	0.00	0.00	0.00	7.85	18.57	0.01	0.00	0.00	0.02	0.03	0.01	0.03	0.04	270.27	1.51	1.08

***** STEADY STATE SIMULATION *****

** WATER QUALITY VARIABLES **

RCH NUM	ELE NUM	TEMP DEG-F	CM-1	CM-2	CM-3	DO MG/L	BOD MG/L	ORGN MG/L	NH3N MG/L	NO2N MG/L	NO3N MG/L	SUM-N MG/L	ORGP MG/L	DIS-P MG/L	SUM-P MG/L	COLI #/100ML	ANC TSOL MG/L	CHLA UG/L
5	16	67.93	0.00	0.00	0.00	7.87	18.36	0.01	0.00	0.00	0.02	0.03	0.01	0.03	0.04	269.95	1.49	1.07
6	1	68.98	0.00	0.00	0.00	8.04	18.36	0.00	0.00	0.00	0.02	0.03	0.00	0.03	0.04	76.21	1.49	1.08
6	2	69.49	0.00	0.00	0.00	0.00	18.36	0.00	0.00	0.00	0.02	0.03	0.00	0.03	0.03	2.54	1.47	1.05
7	1	69.52	0.00	0.00	0.00	8.79	18.36	0.00	0.00	0.00	0.02	0.02	0.00	0.03	0.03	0.63	1.14	0.92
7	2	69.52	0.00	0.00	0.00	8.57	18.36	0.00	0.00	0.00	0.02	0.02	0.00	0.03	0.03	0.63	1.14	0.92
7	3	69.52	0.00	0.00	0.00	8.44	18.36	0.00	0.00	0.00	0.02	0.02	0.00	0.03	0.03	0.62	1.14	0.92
7	4	69.52	0.00	0.00	0.00	8.37	18.36	0.00	0.00	0.00	0.02	0.02	0.00	0.03	0.03	0.62	1.14	0.92
7	5	69.52	0.00	0.00	0.00	8.33	18.36	0.00	0.00	0.00	0.02	0.02	0.00	0.03	0.03	0.61	1.13	0.92
7	6	69.52	0.00	0.00	0.00	8.30	18.36	0.00	0.00	0.00	0.02	0.02	0.00	0.03	0.03	0.61	1.13	0.92
7	7	69.52	0.00	0.00	0.00	8.29	18.36	0.00	0.00	0.00	0.02	0.02	0.00	0.03	0.03	0.60	1.13	0.92
7	8	69.52	0.00	0.00	0.00	8.28	18.36	0.00	0.00	0.00	0.02	0.02	0.00	0.03	0.03	0.60	1.13	0.92
7	9	69.52	0.00	0.00	0.00	8.28	18.36	0.00	0.00	0.00	0.02	0.02	0.00	0.03	0.03	0.59	1.13	0.92
7	10	69.52	0.00	0.00	0.00	8.27	18.36	0.00	0.00	0.00	0.02	0.02	0.00	0.03	0.03	0.59	1.13	0.92
7	11	69.52	0.00	0.00	0.00	8.27	18.36	0.00	0.00	0.00	0.02	0.02	0.00	0.03	0.03	0.60	1.13	0.92
7	12	69.50	0.00	0.00	0.00	8.27	18.36	0.00	0.00	0.00	0.02	0.02	0.00	0.03	0.03	2.49	1.13	0.92
8	1	66.14	0.00	0.00	0.00	7.94	17.76	0.00	0.00	0.00	0.02	0.02	0.01	0.03	0.04	215.98	0.92	0.72
9	1	63.97	0.00	0.00	0.00	8.26	42.02	0.05	0.01	0.00	0.02	0.08	0.04	0.07	0.11	618.61	3.33	5.00
9	2	67.42	0.00	0.00	0.00	8.06	40.98	0.05	0.01	0.00	0.02	0.07	0.04	0.07	0.11	603.28	3.27	4.99
9	3	68.72	0.00	0.00	0.00	7.90	39.90	0.05	0.01	0.00	0.02	0.07	0.04	0.07	0.11	586.61	3.21	4.97
	1	66.38	0.00	0.00	0.00	7.96	28.96	0.10	0.00	0.00	0.02	0.12	0.03	0.04	0.06	210.98	4.30	0.67
10	2	66.51	0.00	0.00	0.00	7.82	36.41	0.17	0.00	0.00	0.02	0.19	0.04	0.04	0.08	201.81	6.64	0.57
10	3	66.60	0.00	0.00	0.00	7.71	41.89	0.22	0.00	0.00	0.02	0.24	0.05	0.04	0.09	195.01	8.37	0.50
10	4	66.67	0.00	0.00	0.00	7.61	46.08	0.26	0.00	0.00	0.02	0.28	0.06	0.04	0.10	189.77	9.70	0.44
10	5	66.72	0.00	0.00	0.00	7.52	49.31	0.29	0.00	0.00	0.02	0.31	0.06	0.04	0.10	185.65	10.75	0.39
11	1	66.79	0.00	0.00	0.00	7.31	46.45	0.29	0.00	0.00	0.05	0.34	0.07	0.04	0.12	185.85	11.30	0.37
11	2	66.85	0.00	0.00	0.00	7.16	43.92	0.30	0.00	0.00	0.08	0.37	0.08	0.05	0.13	186.01	11.78	0.35
11	3	66.90	0.00	0.00	0.00	7.04	41.67	0.30	0.00	0.00	0.10	0.40	0.09	0.05	0.14	186.16	12.21	0.33
11	4	66.95	0.00	0.00	0.00	6.94	39.76	0.30	0.00	0.00	0.12	0.42	0.09	0.06	0.15	186.56	12.59	0.32
12	1	67.04	0.00	0.00	0.00	6.48	44.87	0.31	0.00	0.00	0.12	0.43	0.10	0.06	0.16	203.63	12.78	0.31
12	2	67.16	0.00	0.00	0.00	6.13	49.66	0.31	0.00	0.00	0.13	0.44	0.10	0.06	0.16	219.88	12.96	0.30
12	3	67.26	0.00	0.00	0.00	5.84	54.17	0.32	0.01	0.00	0.13	0.45	0.10	0.06	0.16	235.24	13.12	0.30
12	4	67.36	0.00	0.00	0.00	5.59	58.41	0.32	0.01	0.00	0.13	0.46	0.10	0.06	0.17	249.79	13.28	0.29

***** STEADY STATE SIMULATION *****

** WATER QUALITY VARIABLES **

RCH NUM	ELE NUM	TEMP DEG-F	CM-1	CM-2	CM-3	DO MG/L	BOD MG/L	ORGN MG/L	NH3N MG/L	NO2N MG/L	NO3N MG/L	SUM-N MG/L	ORGP MG/L	DIS-P MG/L	SUM-P MG/L	COLI #/100ML	ANC TSOL MG/L	CHLA UG/L
12	5	67.44	0.00	0.00	0.00	5.37	62.41	0.33	0.01	0.00	0.14	0.47	0.11	0.06	0.17	263.60	13.43	0.29
12	6	67.52	0.00	0.00	0.00	5.18	66.18	0.33	0.01	0.00	0.14	0.48	0.11	0.07	0.17	276.71	13.56	0.28
12	7	67.58	0.00	0.00	0.00	5.01	69.75	0.34	0.01	0.00	0.14	0.49	0.11	0.07	0.18	289.18	13.70	0.28
12	8	67.65	0.00	0.00	0.00	4.86	73.12	0.34	0.01	0.00	0.14	0.49	0.11	0.07	0.18	301.05	13.82	0.28
12	9	67.70	0.00	0.00	0.00	4.72	76.31	0.34	0.01	0.00	0.15	0.50	0.11	0.07	0.18	312.37	13.94	0.27
12	10	67.76	0.00	0.00	0.00	4.59	79.34	0.35	0.01	0.00	0.15	0.51	0.11	0.07	0.18	323.17	14.05	0.27
12	11	67.80	0.00	0.00	0.00	4.47	82.16	0.35	0.01	0.00	0.15	0.51	0.11	0.07	0.18	333.30	14.15	0.27
13	1	67.89	0.00	0.00	0.00	4.49	82.07	0.35	0.01	0.00	0.15	0.51	0.11	0.07	0.18	332.40	13.71	0.27
13	2	67.97	0.00	0.00	0.00	4.51	81.98	0.34	0.01	0.00	0.15	0.51	0.11	0.07	0.18	331.49	13.27	0.27
13	3	68.05	0.00	0.00	0.00	4.52	81.89	0.34	0.01	0.00	0.15	0.51	0.11	0.07	0.18	330.58	12.84	0.27
13	4	68.13	0.00	0.00	0.00	4.53	81.80	0.34	0.01	0.00	0.15	0.51	0.11	0.07	0.18	329.65	12.43	0.28
13	5	68.20	0.00	0.00	0.00	4.53	81.71	0.34	0.01	0.00	0.15	0.51	0.11	0.07	0.18	328.71	12.02	0.28
13	6	68.27	0.00	0.00	0.00	4.54	81.61	0.34	0.02	0.00	0.15	0.51	0.11	0.07	0.18	327.76	11.61	0.28
13	7	68.35	0.00	0.00	0.00	4.54	81.52	0.34	0.02	0.00	0.15	0.50	0.11	0.07	0.18	326.80	11.22	0.28
13	8	68.41	0.00	0.00	0.00	4.55	81.42	0.33	0.02	0.00	0.15	0.50	0.10	0.08	0.18	325.83	10.84	0.29
13	9	68.48	0.00	0.00	0.00	4.55	81.32	0.33	0.02	0.00	0.15	0.50	0.10	0.08	0.18	324.85	10.46	0.29
13	10	68.54	0.00	0.00	0.00	4.55	81.22	0.33	0.02	0.00	0.15	0.50	0.10	0.08	0.18	323.78	10.09	0.29
14	1	68.56	0.00	0.00	0.00	4.73	81.13	0.33	0.02	0.00	0.15	0.50	0.10	0.08	0.18	317.71	9.85	0.30
14	2	68.58	0.00	0.00	0.00	4.86	81.05	0.33	0.02	0.00	0.15	0.50	0.10	0.08	0.18	312.47	9.64	0.30
14	3	68.59	0.00	0.00	0.00	4.96	80.97	0.32	0.02	0.00	0.15	0.50	0.10	0.08	0.18	307.32	9.44	0.30
14	4	68.60	0.00	0.00	0.00	5.04	80.89	0.32	0.02	0.00	0.15	0.50	0.10	0.08	0.18	302.26	9.24	0.30
14	5	68.61	0.00	0.00	0.00	5.10	80.81	0.32	0.02	0.00	0.15	0.50	0.10	0.08	0.18	297.29	9.05	0.30
14	6	68.63	0.00	0.00	0.00	5.15	80.73	0.32	0.02	0.00	0.15	0.50	0.10	0.08	0.18	292.40	8.86	0.30
14	7	68.64	0.00	0.00	0.00	5.18	80.65	0.32	0.02	0.00	0.15	0.50	0.10	0.08	0.18	287.60	8.67	0.31
	8	68.65	0.00	0.00	0.00	5.21	80.57	0.32	0.02	0.00	0.15	0.50	0.10	0.08	0.18	282.89	8.49	0.31
	9	68.65	0.00	0.00	0.00	5.23	80.50	0.32	0.02	0.00	0.15	0.50	0.10	0.08	0.18	278.26	8.32	0.31
14	10	68.66	0.00	0.00	0.00	5.24	80.42	0.31	0.02	0.00	0.15	0.50	0.09	0.08	0.17	273.70	8.14	0.31
15	1	68.68	0.00	0.00	0.00	5.12	80.33	0.31	0.02	0.00	0.15	0.50	0.09	0.08	0.17	268.90	7.96	0.31
15	2	68.71	0.00	0.00	0.00	5.12	80.24	0.31	0.02	0.00	0.15	0.50	0.09	0.08	0.17	263.75	7.77	0.32
15	3	68.73	0.00	0.00	0.00	5.11	80.14	0.31	0.03	0.00	0.15	0.50	0.09	0.08	0.17	258.71	7.58	0.32
15	4	68.75	0.00	0.00	0.00	5.11	80.05	0.31	0.03	0.01	0.15	0.50	0.09	0.08	0.17	253.76	7.39	0.32
15	5	68.78	0.00	0.00	0.00	5.12	79.96	0.31	0.03	0.01	0.15	0.50	0.09	0.08	0.17	248.74	7.21	0.32
16	1	68.80	0.00	0.00	0.00	5.87	79.86	0.31	0.03	0.01	0.16	0.49	0.09	0.08	0.17	230.96	7.17	0.33
16	2	68.83	0.00	0.00	0.00	6.42	79.77	0.30	0.03	0.01	0.16	0.49	0.09	0.08	0.17	214.46	7.13	0.33
16	3	68.85	0.00	0.00	0.00	6.83	79.68	0.30	0.03	0.01	0.16	0.49	0.09	0.08	0.17	199.14	7.08	0.33
16	4	68.88	0.00	0.00	0.00	7.14	79.59	0.30	0.03	0.01	0.16	0.49	0.09	0.08	0.17	184.92	7.04	0.34
16	5	68.90	0.00	0.00	0.00	7.36	79.50	0.30	0.03	0.01	0.16	0.49	0.09	0.08	0.17	171.73	7.00	0.34
16	6	68.92	0.00	0.00	0.00	7.53	79.41	0.30	0.03	0.01	0.16	0.49	0.08	0.09	0.17	159.48	6.96	0.34

***** STEADY STATE SIMULATION *****

** WATER QUALITY VARIABLES **

RCH NUM	ELE NUM	TEMP DEG-F	CM-1	CM-2	CM-3	DO MG/L	BOD MG/L	ORGN MG/L	NH3N MG/L	NO2N MG/L	NO3N MG/L	SUM-N MG/L	ORGP MG/L	DIS-P MG/L	SUM-P MG/L	COLI #/100ML	ANC TSOL MG/L	CHLA UG/L
17	1	68.94	0.00	0.00	0.00	7.65	79.33	0.30	0.03	0.01	0.16	0.49	0.08	0.09	0.17	148.11	6.92	0.35
17	2	68.95	0.00	0.00	0.00	7.74	79.25	0.29	0.03	0.01	0.16	0.49	0.08	0.09	0.17	137.56	6.88	0.35
17	3	68.97	0.00	0.00	0.00	7.81	79.17	0.29	0.03	0.01	0.16	0.49	0.08	0.09	0.17	127.77	6.84	0.35
17	4	68.99	0.00	0.00	0.00	7.86	79.10	0.29	0.03	0.01	0.16	0.49	0.08	0.09	0.17	118.67	6.79	0.36
17	5	69.00	0.00	0.00	0.00	7.90	79.02	0.29	0.03	0.01	0.16	0.49	0.08	0.09	0.17	110.24	6.75	0.36
17	6	69.01	0.00	0.00	0.00	7.92	78.89	0.29	0.03	0.01	0.16	0.49	0.08	0.09	0.17	102.58	6.70	0.37
18	1	61.28	0.00	0.00	0.00	6.07	54.38	0.05	0.01	0.00	0.00	0.05	0.02	0.03	0.05	313.13	1.96	4.25
18	2	64.00	0.00	0.00	0.00	5.41	58.63	0.04	0.01	0.00	0.00	0.05	0.02	0.03	0.05	303.77	1.83	3.58
18	3	65.28	0.00	0.00	0.00	4.98	61.60	0.04	0.01	0.00	0.00	0.05	0.01	0.03	0.05	296.30	1.72	3.09
18	4	65.92	0.00	0.00	0.00	4.72	63.77	0.04	0.01	0.00	0.01	0.05	0.01	0.03	0.04	290.24	1.64	2.71
18	5	66.26	0.00	0.00	0.00	4.55	65.40	0.04	0.01	0.00	0.01	0.05	0.01	0.03	0.04	285.23	1.58	2.41
18	6	66.45	0.00	0.00	0.00	4.45	66.66	0.04	0.01	0.00	0.01	0.05	0.01	0.03	0.04	281.02	1.53	2.17
18	7	66.57	0.00	0.00	0.00	4.39	67.64	0.04	0.01	0.00	0.01	0.05	0.01	0.03	0.04	277.42	1.48	1.97
18	8	66.64	0.00	0.00	0.00	4.35	68.42	0.04	0.01	0.00	0.01	0.05	0.01	0.03	0.04	274.30	1.44	1.80
18	9	66.68	0.00	0.00	0.00	4.33	69.04	0.04	0.01	0.00	0.01	0.05	0.00	0.03	0.04	271.57	1.41	1.66
18	10	66.71	0.00	0.00	0.00	4.33	69.55	0.04	0.01	0.00	0.01	0.05	0.00	0.03	0.04	269.15	1.38	1.54
18	11	66.73	0.00	0.00	0.00	4.33	69.96	0.03	0.01	0.00	0.01	0.05	0.00	0.03	0.04	266.98	1.36	1.44
18	12	66.75	0.00	0.00	0.00	4.33	70.29	0.03	0.01	0.00	0.01	0.05	0.00	0.03	0.04	264.95	1.34	1.35
19	1	66.80	0.00	0.00	0.00	4.34	70.44	0.04	0.01	0.00	0.01	0.06	0.00	0.03	0.04	259.16	1.32	1.27
19	2	66.85	0.00	0.00	0.00	4.35	70.56	0.05	0.01	0.00	0.01	0.06	0.00	0.03	0.03	253.97	1.31	1.20
19	3	66.88	0.00	0.00	0.00	4.36	70.65	0.05	0.01	0.00	0.01	0.07	0.00	0.03	0.03	249.30	1.29	1.14
19	4	66.90	0.00	0.00	0.00	4.38	70.72	0.05	0.01	0.00	0.01	0.07	0.00	0.03	0.03	245.06	1.28	1.09
19	5	66.92	0.00	0.00	0.00	4.39	70.76	0.06	0.01	0.00	0.01	0.08	0.00	0.03	0.03	241.20	1.27	1.04
19	6	66.93	0.00	0.00	0.00	4.40	70.79	0.06	0.01	0.00	0.01	0.08	0.00	0.03	0.03	237.67	1.25	0.99
	7	66.94	0.00	0.00	0.00	4.42	70.81	0.06	0.01	0.00	0.01	0.08	0.00	0.03	0.03	234.43	1.24	0.95
	8	66.95	0.00	0.00	0.00	4.44	70.82	0.07	0.01	0.00	0.01	0.09	0.00	0.03	0.03	231.45	1.23	0.92
19	9	66.95	0.00	0.00	0.00	4.45	70.81	0.07	0.01	0.00	0.01	0.09	0.00	0.03	0.03	228.69	1.23	0.88
19	10	66.96	0.00	0.00	0.00	4.47	70.80	0.07	0.01	0.00	0.01	0.09	0.00	0.03	0.03	226.13	1.22	0.85
19	11	66.96	0.00	0.00	0.00	4.48	70.78	0.07	0.01	0.00	0.01	0.09	0.00	0.03	0.03	223.76	1.21	0.82
19	12	66.97	0.00	0.00	0.00	4.50	70.75	0.07	0.01	0.00	0.01	0.10	0.00	0.03	0.03	221.55	1.20	0.80
19	13	66.98	0.00	0.00	0.00	4.51	70.70	0.07	0.01	0.00	0.01	0.10	0.00	0.03	0.03	219.45	1.20	0.77
20	1	67.38	0.00	0.00	0.00	4.54	69.74	0.07	0.01	0.00	0.01	0.10	0.00	0.03	0.03	216.48	1.20	0.77
20	2	67.72	0.00	0.00	0.00	4.55	68.79	0.07	0.01	0.00	0.01	0.10	0.00	0.03	0.03	213.52	1.19	0.77
20	3	68.00	0.00	0.00	0.00	4.56	67.84	0.07	0.01	0.00	0.01	0.09	0.00	0.03	0.03	210.59	1.19	0.77
20	4	68.24	0.00	0.00	0.00	4.57	66.91	0.07	0.01	0.00	0.01	0.09	0.00	0.03	0.03	207.67	1.19	0.78
20	5	68.44	0.00	0.00	0.00	4.58	65.98	0.06	0.01	0.01	0.01	0.09	0.00	0.03	0.03	204.78	1.19	0.78
20	6	68.61	0.00	0.00	0.00	4.59	65.05	0.06	0.01	0.01	0.01	0.09	0.00	0.03	0.03	201.92	1.19	0.78
20	7	68.75	0.00	0.00	0.00	4.60	64.14	0.06	0.01	0.01	0.01	0.09	0.00	0.03	0.03	199.09	1.19	0.78
20	8	68.87	0.00	0.00	0.00	4.62	63.24	0.06	0.01	0.01	0.01	0.09	0.00	0.03	0.03	196.29	1.19	0.79
20	9	68.98	0.00	0.00	0.00	4.63	62.35	0.06	0.01	0.01	0.01	0.09	0.00	0.03	0.03	193.52	1.19	0.79

***** STEADY STATE SIMULATION *****

** WATER QUALITY VARIABLES **

RCH NUM	ELE NUM	TEMP DEG-F	CM-1	CM-2	CM-3	DO MG/L	BOD MG/L	ORGN MG/L	NH3N MG/L	NO2N MG/L	NO3N MG/L	SUM-N MG/L	ORGP MG/L	DIS-P MG/L	SUM-P MG/L	COLI #/100ML	ANC TSOL MG/L	CHLA UG/L
20	10	69.06	0.00	0.00	0.00	4.66	61.47	0.06	0.01	0.01	0.01	0.09	0.00	0.03	0.03	190.79	1.19	0.79
20	11	69.13	0.00	0.00	0.00	4.68	60.60	0.05	0.01	0.01	0.01	0.09	0.00	0.03	0.03	188.09	1.19	0.80
20	12	69.20	0.00	0.00	0.00	4.70	59.74	0.05	0.01	0.01	0.02	0.09	0.00	0.03	0.03	185.42	1.19	0.80
20	13	69.25	0.00	0.00	0.00	4.73	58.89	0.05	0.01	0.01	0.02	0.09	0.00	0.03	0.03	182.79	1.19	0.80
20	14	69.29	0.00	0.00	0.00	4.76	58.05	0.05	0.01	0.01	0.02	0.09	0.00	0.03	0.03	180.19	1.19	0.81
20	15	69.33	0.00	0.00	0.00	4.79	57.23	0.05	0.01	0.01	0.02	0.09	0.00	0.03	0.03	177.63	1.19	0.81
20	16	69.36	0.00	0.00	0.00	4.82	56.41	0.05	0.01	0.01	0.02	0.08	0.00	0.03	0.03	175.10	1.19	0.82
20	17	69.38	0.00	0.00	0.00	4.85	55.61	0.05	0.01	0.01	0.02	0.08	0.00	0.03	0.03	172.61	1.19	0.82
20	18	69.41	0.00	0.00	0.00	4.88	54.82	0.05	0.01	0.01	0.02	0.08	0.00	0.03	0.03	170.15	1.19	0.83
20	19	69.42	0.00	0.00	0.00	4.93	54.00	0.04	0.01	0.01	0.02	0.08	0.00	0.03	0.03	167.82	1.19	0.84
21	1	66.25	0.00	0.00	0.00	7.95	33.25	0.05	0.01	0.00	0.01	0.06	0.04	0.09	0.12	246.51	2.30	4.95
21	2	68.50	0.00	0.00	0.00	7.57	31.49	0.05	0.01	0.00	0.01	0.06	0.04	0.09	0.12	239.82	2.20	4.90
21	3	69.21	0.00	0.00	0.00	7.45	29.92	0.04	0.01	0.00	0.01	0.06	0.03	0.09	0.12	232.92	2.11	4.83
22	1	69.44	0.00	0.00	0.00	5.93	51.67	0.04	0.01	0.01	0.02	0.08	0.00	0.04	0.04	169.90	1.22	1.07
22	2	69.47	0.00	0.00	0.00	6.91	50.36	0.04	0.01	0.01	0.02	0.08	0.00	0.04	0.04	167.88	1.20	1.09
23	1	66.46	0.00	0.00	0.00	7.05	79.05	0.82	0.03	0.00	0.01	0.86	0.04	0.09	0.14	3486.00	5.12	5.25
23	2	68.46	0.00	0.00	0.00	7.84	78.07	0.77	0.04	0.01	0.01	0.84	0.04	0.10	0.13	3279.15	5.09	5.40
23	3	69.15	0.00	0.00	0.00	7.93	77.08	0.73	0.06	0.01	0.01	0.81	0.04	0.10	0.13	3081.33	5.05	5.63
23	4	69.40	0.00	0.00	0.00	7.93	76.09	0.68	0.07	0.02	0.02	0.79	0.03	0.10	0.13	2894.36	5.02	5.93
23	5	69.48	0.00	0.00	0.00	7.92	75.12	0.64	0.08	0.03	0.02	0.77	0.03	0.10	0.13	2718.39	4.99	6.31
23	6	69.51	0.00	0.00	0.00	7.92	74.16	0.60	0.09	0.04	0.02	0.75	0.02	0.10	0.13	2553.01	4.96	6.76
23	7	69.52	0.00	0.00	0.00	7.92	73.21	0.57	0.09	0.04	0.03	0.73	0.02	0.10	0.13	2397.65	4.93	7.29
	8	69.52	0.00	0.00	0.00	7.92	72.27	0.53	0.10	0.05	0.04	0.71	0.02	0.10	0.12	2251.73	4.90	7.89
24	1	69.52	0.00	0.00	0.00	7.92	71.35	0.50	0.10	0.05	0.04	0.70	0.02	0.11	0.12	2114.69	4.87	8.59
24	2	69.52	0.00	0.00	0.00	7.93	70.43	0.47	0.10	0.06	0.05	0.68	0.02	0.11	0.12	1985.99	4.84	9.39
24	3	69.52	0.00	0.00	0.00	7.93	69.53	0.44	0.10	0.06	0.06	0.66	0.01	0.11	0.12	1865.12	4.80	10.31
24	4	69.52	0.00	0.00	0.00	7.93	68.64	0.42	0.10	0.07	0.07	0.65	0.01	0.11	0.12	1751.60	4.77	11.35
24	5	69.52	0.00	0.00	0.00	7.94	67.76	0.39	0.09	0.07	0.08	0.63	0.01	0.11	0.12	1645.00	4.74	12.54
24	6	69.52	0.00	0.00	0.00	7.94	66.90	0.37	0.09	0.07	0.08	0.62	0.01	0.11	0.12	1544.88	4.71	13.89
24	7	69.52	0.00	0.00	0.00	7.94	66.04	0.35	0.09	0.08	0.09	0.61	0.01	0.11	0.12	1450.86	4.68	15.42
24	8	69.52	0.00	0.00	0.00	7.95	65.20	0.33	0.08	0.08	0.10	0.59	0.01	0.11	0.12	1362.55	4.65	17.17
24	9	69.52	0.00	0.00	0.00	7.95	64.36	0.31	0.08	0.08	0.11	0.58	0.01	0.11	0.11	1279.63	4.63	19.15
24	10	69.52	0.00	0.00	0.00	7.96	63.54	0.29	0.08	0.08	0.12	0.57	0.01	0.11	0.11	1201.75	4.60	21.41
25	1	69.52	0.00	0.00	0.00	7.96	62.72	0.28	0.07	0.08	0.13	0.55	0.01	0.11	0.11	1128.61	4.57	23.96
25	2	69.52	0.00	0.00	0.00	7.97	61.92	0.26	0.07	0.08	0.14	0.54	0.01	0.11	0.11	1059.92	4.54	26.85
25	3	69.52	0.00	0.00	0.00	7.97	61.13	0.25	0.06	0.07	0.14	0.53	0.01	0.10	0.11	995.41	4.51	30.12

***** STEADY STATE SIMULATION *****

** WATER QUALITY VARIABLES **

RCH NUM	ELE NUM	TEMP DEG-F	CM-1	CM-2	CM-3	DO MG/L	BOD MG/L	ORGN MG/L	NH3N MG/L	NO2N MG/L	NO3N MG/L	SUM-N MG/L	ORGP MG/L	DIS-P MG/L	SUM-P MG/L	COLI #/100ML	ANC TSOL MG/L	CHLA UG/L
25	4	69.52	0.00	0.00	0.00	7.98	60.35	0.23	0.06	0.07	0.15	0.51	0.00	0.10	0.11	934.83	4.48	33.81
25	5	69.52	0.00	0.00	0.00	7.98	59.57	0.22	0.05	0.07	0.15	0.50	0.00	0.10	0.11	877.93	4.45	37.96
25	6	69.52	0.00	0.00	0.00	7.99	58.81	0.21	0.05	0.07	0.16	0.48	0.00	0.10	0.11	824.50	4.42	42.61
25	7	69.52	0.00	0.00	0.00	8.00	58.06	0.20	0.04	0.07	0.16	0.47	0.00	0.10	0.10	774.32	4.40	47.80
25	8	69.52	0.00	0.00	0.00	8.00	57.32	0.19	0.04	0.06	0.16	0.45	0.00	0.10	0.10	727.19	4.37	53.56
25	9	69.52	0.00	0.00	0.00	8.01	56.58	0.18	0.03	0.06	0.16	0.44	0.00	0.10	0.10	682.92	4.34	59.90
25	10	69.52	0.00	0.00	0.00	8.02	55.83	0.17	0.03	0.06	0.16	0.42	0.00	0.09	0.10	638.88	4.29	66.32
26	1	69.49	0.00	0.00	0.00	7.16	50.48	0.05	0.01	0.01	0.03	0.10	0.00	0.04	0.04	191.62	1.37	4.64
26	2	69.50	0.00	0.00	0.00	7.60	50.40	0.05	0.01	0.01	0.03	0.10	0.00	0.04	0.04	188.63	1.40	4.64
27	1	69.11	0.00	0.00	0.00	7.79	74.98	0.25	0.03	0.01	0.14	0.44	0.07	0.08	0.15	109.29	5.89	0.95
27	2	69.15	0.00	0.00	0.00	7.60	74.78	0.25	0.03	0.01	0.14	0.43	0.07	0.08	0.15	101.08	5.70	0.98
27	3	69.19	0.00	0.00	0.00	7.44	74.58	0.25	0.03	0.01	0.14	0.43	0.06	0.08	0.15	93.41	5.52	1.00
27	4	69.22	0.00	0.00	0.00	7.31	74.37	0.24	0.03	0.01	0.15	0.43	0.06	0.08	0.15	86.25	5.33	1.03
27	5	69.25	0.00	0.00	0.00	7.21	74.16	0.24	0.03	0.01	0.15	0.43	0.06	0.09	0.15	79.58	5.16	1.06
27	6	69.28	0.00	0.00	0.00	7.13	73.95	0.24	0.03	0.01	0.15	0.43	0.06	0.09	0.15	73.37	4.98	1.09
27	7	69.30	0.00	0.00	0.00	7.07	73.74	0.23	0.03	0.01	0.15	0.43	0.06	0.09	0.14	67.58	4.81	1.13
27	8	69.33	0.00	0.00	0.00	7.01	73.53	0.23	0.03	0.01	0.15	0.42	0.06	0.09	0.14	62.20	4.65	1.16
27	9	69.35	0.00	0.00	0.00	6.97	73.32	0.23	0.04	0.01	0.15	0.42	0.05	0.09	0.14	57.22	4.49	1.19
28	1	69.33	0.00	0.00	0.00	7.33	73.18	0.22	0.04	0.01	0.15	0.42	0.05	0.09	0.14	53.91	4.37	1.21
28	2	69.32	0.00	0.00	0.00	7.54	73.12	0.22	0.04	0.01	0.15	0.42	0.05	0.09	0.14	52.21	4.31	1.22
28	3	69.30	0.00	0.00	0.00	7.69	73.06	0.22	0.04	0.01	0.15	0.42	0.05	0.09	0.14	50.56	4.25	1.23
28	4	69.29	0.00	0.00	0.00	7.80	72.99	0.22	0.04	0.02	0.15	0.42	0.05	0.09	0.14	48.96	4.19	1.24
	5	69.28	0.00	0.00	0.00	7.88	72.93	0.22	0.04	0.02	0.15	0.42	0.05	0.09	0.14	47.42	4.13	1.25
	6	69.26	0.00	0.00	0.00	7.94	72.87	0.22	0.04	0.02	0.15	0.41	0.05	0.09	0.14	45.93	4.07	1.26
28	7	69.25	0.00	0.00	0.00	7.99	72.81	0.21	0.04	0.02	0.15	0.41	0.05	0.09	0.14	44.49	4.01	1.26
28	8	69.24	0.00	0.00	0.00	8.02	72.74	0.21	0.04	0.02	0.15	0.41	0.05	0.09	0.14	43.09	3.96	1.27
28	9	69.25	0.00	0.00	0.00	8.07	72.71	0.21	0.04	0.02	0.15	0.41	0.05	0.09	0.14	41.71	3.90	1.27

END OF SYSTEM BOUNDARY CONCENTRATIONS

		70.40	0.00	0.00	0.00	10.30	74.50	0.33	0.00	0.00	0.27	0.60	0.06	0.11	0.16	38.00	3.80	0.00

***** STEADY STATE SIMULATION *****

** ALGAE DATA **

ELE ORD	RCH NUM	ELE NUM	CHLA UG/L	ALGY GRWTH 1/DAY	ALGY RESP 1/DAY	ALGY SETT FT/DA	A P/R RATIO *	NET P-R MG/L-D	NH3 PREF *	NH3-N FRACT N-UPTKE *	LIGHT EXTCO 1/FT	ALGAE GROWTH RATE ATTEN FACTORS LIGHT *	NITRGN *	PHSPRS *
1	1	1	4.98	0.03	0.04	0.00	0.59	0.00	0.80	0.68	0.25	0.13	0.07	0.20
2	1	2	4.96	0.03	0.04	0.00	0.60	0.00	0.80	0.70	0.25	0.13	0.07	0.21
3	2	1	5.00	0.05	0.05	0.00	0.81	0.00	0.80	0.69	0.25	0.15	0.08	0.36
4	3	1	4.87	0.04	0.04	0.00	0.64	0.00	0.80	0.69	0.25	0.13	0.08	0.25
5	3	2	1.14	0.06	0.04	0.00	1.15	0.00	0.80	0.18	0.25	0.15	0.12	0.40
6	4	1	1.14	0.06	0.04	0.00	1.29	0.00	0.80	0.19	0.25	0.17	0.12	0.40
7	4	2	1.15	0.07	0.04	0.00	1.29	0.00	0.80	0.19	0.25	0.17	0.12	0.40
8	4	3	1.15	0.07	0.04	0.00	1.29	0.00	0.80	0.20	0.25	0.17	0.12	0.41
9	4	4	1.16	0.07	0.04	0.00	1.29	0.00	0.80	0.20	0.25	0.17	0.12	0.41
10	4	5	1.17	0.07	0.04	0.00	1.29	0.00	0.80	0.20	0.25	0.17	0.12	0.42
11	4	6	1.17	0.07	0.04	0.00	1.29	0.00	0.80	0.21	0.25	0.17	0.12	0.42
12	4	7	1.18	0.07	0.05	0.00	1.29	0.00	0.80	0.21	0.25	0.17	0.12	0.43
13	4	8	1.19	0.07	0.05	0.00	1.29	0.00	0.80	0.21	0.25	0.17	0.12	0.43
14	4	9	1.20	0.08	0.05	0.00	1.29	0.00	0.80	0.21	0.25	0.17	0.12	0.43
15	4	10	1.20	0.08	0.05	0.00	1.29	0.00	0.80	0.21	0.25	0.17	0.12	0.44
16	4	11	1.21	0.08	0.05	0.00	1.29	0.00	0.80	0.21	0.25	0.17	0.12	0.44
17	4	12	1.22	0.08	0.05	0.00	1.29	0.00	0.80	0.21	0.25	0.17	0.12	0.44
18	4	13	1.23	0.08	0.05	0.00	1.29	0.00	0.80	0.21	0.25	0.17	0.12	0.44
19	4	14	1.24	0.08	0.05	0.00	1.29	0.00	0.80	0.21	0.25	0.17	0.12	0.45
20	4	15	1.25	0.08	0.05	0.00	1.29	0.00	0.80	0.21	0.25	0.17	0.12	0.45
21	4	16	1.26	0.08	0.05	0.00	1.29	0.00	0.80	0.21	0.25	0.17	0.12	0.45
	4	17	1.26	0.08	0.05	0.00	1.29	0.00	0.80	0.21	0.25	0.17	0.12	0.45
	4	18	1.27	0.08	0.05	0.00	1.29	0.00	0.80	0.21	0.25	0.17	0.12	0.46
24	5	1	1.26	0.06	0.05	0.00	0.91	0.00	0.80	0.21	0.25	0.12	0.12	0.45
25	5	2	1.24	0.06	0.05	0.00	0.90	0.00	0.80	0.21	0.25	0.12	0.12	0.45
26	5	3	1.23	0.06	0.05	0.00	0.90	0.00	0.80	0.21	0.25	0.12	0.12	0.45
27	5	4	1.22	0.06	0.05	0.00	0.89	0.00	0.80	0.21	0.25	0.12	0.11	0.45
28	5	5	1.20	0.06	0.05	0.00	0.88	0.00	0.80	0.21	0.25	0.12	0.11	0.45
29	5	6	1.19	0.05	0.05	0.00	0.88	0.00	0.80	0.20	0.25	0.12	0.11	0.45
30	5	7	1.18	0.05	0.05	0.00	0.87	0.00	0.80	0.20	0.25	0.12	0.11	0.45
31	5	8	1.17	0.05	0.05	0.00	0.87	0.00	0.80	0.20	0.25	0.12	0.11	0.45
32	5	9	1.15	0.05	0.05	0.00	0.86	0.00	0.80	0.20	0.25	0.12	0.11	0.44
33	5	10	1.14	0.05	0.05	0.00	0.86	0.00	0.80	0.20	0.25	0.12	0.11	0.44
34	5	11	1.13	0.05	0.05	0.00	0.85	0.00	0.80	0.20	0.25	0.12	0.11	0.44
35	5	12	1.12	0.05	0.05	0.00	0.85	0.00	0.80	0.20	0.25	0.12	0.11	0.44
36	5	13	1.11	0.05	0.05	0.00	0.84	0.00	0.80	0.20	0.25	0.12	0.11	0.44
37	5	14	1.09	0.05	0.05	0.00	0.84	0.00	0.80	0.20	0.25	0.12	0.11	0.44
38	5	15	1.08	0.05	0.05	0.00	0.83	0.00	0.80	0.20	0.25	0.12	0.11	0.44

***** STEADY STATE SIMULATION *****

** ALGAE DATA **

ELE ORD	RCH NUM	ELE NUM	CHLA UG/L	ALGY GRWTH 1/DAY	ALGY RESP 1/DAY	ALGY SETT FT/DA	A P/R RATIO *	NET P-R MG/L-D	NH3 PREF *	NH3-N FRACT N-UPTKE *	LIGHT EXTCO 1/FT	ALGAE GROWTH RATE ATTEN FACTORS LIGHT *	NITRGN *	PHSPRS *
39	5	16	1.07	0.05	0.05	0.00	0.83	0.00	0.80	0.20	0.25	0.12	0.10	0.44
40	6	1	1.08	0.05	0.05	0.00	0.81	0.00	0.80	0.17	0.05	0.12	0.11	0.45
41	6	2	1.05	0.05	0.05	0.00	0.80	0.00	0.80	0.06	0.05	0.12	0.10	0.46
42	7	1	0.92	0.05	0.05	0.00	0.73	0.00	0.80	0.04	0.25	0.11	0.10	0.46
43	7	2	0.92	0.05	0.05	0.00	0.72	0.00	0.80	0.04	0.25	0.11	0.10	0.46
44	7	3	0.92	0.05	0.05	0.00	0.72	0.00	0.80	0.04	0.25	0.11	0.10	0.46
45	7	4	0.92	0.05	0.05	0.00	0.72	0.00	0.80	0.04	0.25	0.11	0.10	0.46
46	7	5	0.92	0.05	0.05	0.00	0.72	0.00	0.80	0.04	0.25	0.11	0.10	0.46
47	7	6	0.92	0.05	0.05	0.00	0.72	0.00	0.80	0.04	0.25	0.11	0.10	0.46
48	7	7	0.92	0.05	0.05	0.00	0.72	0.00	0.80	0.04	0.25	0.11	0.10	0.46
49	7	8	0.92	0.05	0.05	0.00	0.72	0.00	0.80	0.04	0.25	0.11	0.10	0.46
50	7	9	0.92	0.05	0.05	0.00	0.72	0.00	0.80	0.04	0.25	0.11	0.10	0.46
51	7	10	0.92	0.05	0.05	0.00	0.72	0.00	0.80	0.04	0.25	0.11	0.10	0.46
52	7	11	0.92	0.05	0.05	0.00	0.72	0.00	0.80	0.04	0.25	0.11	0.10	0.46
53	7	12	0.92	0.05	0.05	0.00	0.72	0.00	0.80	0.04	0.25	0.11	0.10	0.46
54	8	1	0.72	0.04	0.05	0.00	0.64	0.00	0.80	0.04	0.25	0.12	0.09	0.46
55	9	1	5.00	0.04	0.05	0.00	0.74	0.00	0.80	0.51	0.25	0.10	0.11	0.63
56	9	2	4.99	0.05	0.05	0.00	0.75	0.00	0.80	0.53	0.25	0.10	0.11	0.63
57	9	3	4.97	0.05	0.05	0.00	0.76	0.00	0.80	0.54	0.25	0.10	0.11	0.63
58	10	1	0.67	0.04	0.05	0.00	0.66	0.00	0.80	0.09	0.25	0.11	0.09	0.47
59	10	2	0.57	0.04	0.05	0.00	0.69	0.00	0.80	0.13	0.25	0.12	0.09	0.48
60	10	3	0.50	0.04	0.05	0.00	0.73	0.00	0.80	0.18	0.25	0.12	0.10	0.48
61	10	4	0.44	0.05	0.05	0.00	0.76	0.00	0.80	0.22	0.25	0.12	0.10	0.49
62	10	5	0.39	0.05	0.05	0.00	0.80	0.00	0.80	0.26	0.25	0.12	0.10	0.49
63	11	1	0.37	0.10	0.05	0.00	1.62	0.00	0.80	0.15	0.25	0.12	0.21	0.53
64	11	2	0.35	0.13	0.05	0.00	2.21	0.00	0.80	0.12	0.25	0.12	0.28	0.55
65	11	3	0.33	0.16	0.05	0.00	2.66	0.00	0.80	0.11	0.25	0.12	0.34	0.58
66	11	4	0.32	0.18	0.05	0.00	3.02	0.00	0.80	0.10	0.25	0.12	0.38	0.59
67	12	1	0.31	0.19	0.05	0.00	3.04	0.00	0.80	0.12	0.25	0.12	0.39	0.60
68	12	2	0.30	0.19	0.05	0.00	3.11	0.00	0.80	0.13	0.25	0.12	0.40	0.60
69	12	3	0.30	0.19	0.05	0.00	3.18	0.00	0.80	0.15	0.25	0.12	0.40	0.61
70	12	4	0.29	0.20	0.05	0.00	3.24	0.00	0.80	0.16	0.25	0.12	0.41	0.61

***** STEADY STATE SIMULATION *****

** ALGAE DATA **

ELE ORD	RCH NUM	ELE NUM	CHLA UG/L	ALGY GRWTH 1/DAY	ALGY RESP 1/DAY	ALGY SETT FT/DA	A P/R RATIO *	NET P-R MG/L-D	NH3 PREF *	NH3-N FRACT N-UPTKE *	LIGHT EXTCO 1/FT	ALGAE GROWTH RATE ATTEN FACTORS LIGHT *	NITRGN *	PHSPRS *
71	12	5	0.29	0.20	0.05	0.00	3.30	0.00	0.80	0.17	0.25	0.12	0.42	0.62
72	12	6	0.28	0.21	0.05	0.00	3.36	0.00	0.80	0.18	0.25	0.12	0.42	0.62
73	12	7	0.28	0.21	0.05	0.00	3.41	0.00	0.80	0.19	0.25	0.12	0.43	0.62
74	12	8	0.28	0.21	0.05	0.00	3.46	0.00	0.80	0.20	0.25	0.12	0.43	0.63
75	12	9	0.27	0.22	0.05	0.00	3.51	0.00	0.80	0.21	0.25	0.13	0.44	0.63
76	12	10	0.27	0.22	0.05	0.00	3.56	0.00	0.80	0.21	0.25	0.13	0.44	0.63
77	12	11	0.27	0.22	0.05	0.00	3.60	0.00	0.80	0.22	0.25	0.13	0.45	0.64
78	13	1	0.27	0.22	0.05	0.00	3.60	0.00	0.80	0.23	0.25	0.13	0.45	0.64
79	13	2	0.27	0.22	0.05	0.00	3.60	0.00	0.80	0.25	0.25	0.13	0.45	0.64
80	13	3	0.27	0.22	0.05	0.00	3.60	0.00	0.80	0.26	0.25	0.12	0.45	0.64
81	13	4	0.28	0.23	0.05	0.00	3.59	0.00	0.80	0.27	0.25	0.12	0.45	0.65
82	13	5	0.28	0.23	0.05	0.00	3.59	0.00	0.80	0.28	0.25	0.12	0.45	0.65
83	13	6	0.28	0.23	0.05	0.00	3.59	0.00	0.80	0.29	0.25	0.12	0.45	0.65
84	13	7	0.28	0.23	0.05	0.00	3.58	0.00	0.80	0.30	0.25	0.12	0.46	0.65
85	13	8	0.29	0.23	0.05	0.00	3.58	0.00	0.80	0.31	0.25	0.12	0.46	0.65
86	13	9	0.29	0.23	0.05	0.00	3.58	0.00	0.80	0.32	0.25	0.12	0.46	0.65
87	13	10	0.29	0.23	0.05	0.00	3.57	0.00	0.80	0.33	0.25	0.12	0.46	0.66
88	14	1	0.30	0.22	0.05	0.00	3.51	0.00	0.80	0.34	0.25	0.12	0.46	0.66
89	14	2	0.30	0.22	0.05	0.00	3.52	0.00	0.80	0.34	0.25	0.12	0.46	0.66
90	14	3	0.30	0.22	0.05	0.00	3.53	0.00	0.80	0.35	0.25	0.12	0.46	0.66
91	14	4	0.30	0.22	0.05	0.00	3.54	0.00	0.80	0.35	0.25	0.12	0.46	0.66
92	14	5	0.30	0.23	0.05	0.00	3.55	0.00	0.80	0.36	0.25	0.12	0.46	0.66
93	14	6	0.30	0.23	0.05	0.00	3.56	0.00	0.80	0.37	0.25	0.12	0.47	0.66
	14	7	0.31	0.23	0.05	0.00	3.57	0.00	0.80	0.37	0.25	0.12	0.47	0.66
	14	8	0.31	0.23	0.05	0.00	3.57	0.00	0.80	0.37	0.25	0.12	0.47	0.67
96	14	9	0.31	0.23	0.05	0.00	3.58	0.00	0.80	0.38	0.25	0.12	0.47	0.67
97	14	10	0.31	0.23	0.05	0.00	3.59	0.00	0.80	0.38	0.25	0.12	0.47	0.67
98	15	1	0.31	0.23	0.05	0.00	3.55	0.00	0.80	0.39	0.25	0.12	0.47	0.67
99	15	2	0.32	0.23	0.05	0.00	3.56	0.00	0.80	0.39	0.25	0.12	0.47	0.67
100	15	3	0.32	0.23	0.05	0.00	3.57	0.00	0.80	0.40	0.25	0.12	0.47	0.67
101	15	4	0.32	0.23	0.05	0.00	3.58	0.00	0.80	0.40	0.25	0.12	0.47	0.67
102	15	5	0.32	0.23	0.05	0.00	3.59	0.00	0.80	0.41	0.25	0.12	0.48	0.67
103	16	1	0.33	0.23	0.05	0.00	3.60	0.00	0.80	0.41	0.25	0.12	0.48	0.68
104	16	2	0.33	0.23	0.05	0.00	3.61	0.00	0.80	0.41	0.25	0.12	0.48	0.68
105	16	3	0.33	0.23	0.05	0.00	3.63	0.00	0.80	0.42	0.25	0.12	0.48	0.68
106	16	4	0.34	0.23	0.05	0.00	3.64	0.00	0.80	0.42	0.25	0.12	0.48	0.68
107	16	5	0.34	0.23	0.05	0.00	3.65	0.00	0.80	0.42	0.25	0.12	0.48	0.68
108	16	6	0.34	0.23	0.05	0.00	3.66	0.00	0.80	0.43	0.25	0.12	0.48	0.68

***** STEADY STATE SIMULATION *****

** ALGAE DATA **

ELE ORD	RCH NUM	ELE NUM	CHLA UG/L	ALGY GRWTH 1/DAY	ALGY RESP 1/DAY	ALGY SETT FT/DA	A P/R RATIO *	NET P-R MG/L-D	NH3 PREF *	NH3-N FRACT N-UPTKE *	LIGHT EXTCO 1/FT	ALGAE GROWTH RATE ATTEN FACTORS LIGHT *	NITRGN *	PHSPRS *
109	17	1	0.35	0.24	0.05	0.00	3.67	0.00	0.80	0.43	0.25	0.12	0.49	0.68
110	17	2	0.35	0.24	0.05	0.00	3.68	0.00	0.80	0.43	0.25	0.12	0.49	0.68
111	17	3	0.35	0.24	0.05	0.00	3.70	0.00	0.80	0.43	0.25	0.12	0.49	0.68
112	17	4	0.36	0.24	0.05	0.00	3.71	0.00	0.80	0.44	0.25	0.12	0.49	0.69
113	17	5	0.36	0.24	0.05	0.00	3.72	0.00	0.80	0.44	0.25	0.12	0.49	0.69
114	17	6	0.37	0.24	0.05	0.00	3.73	0.00	0.80	0.44	0.25	0.12	0.49	0.69
115	18	1	4.25	0.01	0.04	0.00	0.27	-0.01	0.80	0.92	0.25	0.13	0.03	0.43
116	18	2	3.58	0.02	0.05	0.00	0.33	0.00	0.80	0.87	0.25	0.13	0.04	0.44
117	18	3	3.09	0.02	0.05	0.00	0.38	0.00	0.80	0.83	0.25	0.13	0.05	0.45
118	18	4	2.71	0.02	0.05	0.00	0.41	0.00	0.80	0.80	0.25	0.13	0.05	0.45
119	18	5	2.41	0.03	0.05	0.00	0.44	0.00	0.80	0.78	0.25	0.13	0.05	0.45
120	18	6	2.17	0.03	0.05	0.00	0.47	0.00	0.80	0.76	0.25	0.13	0.06	0.45
121	18	7	1.97	0.03	0.05	0.00	0.49	0.00	0.80	0.75	0.25	0.13	0.06	0.45
122	18	8	1.80	0.03	0.05	0.00	0.51	0.00	0.80	0.74	0.25	0.13	0.06	0.45
123	18	9	1.66	0.03	0.05	0.00	0.52	0.00	0.80	0.72	0.25	0.13	0.06	0.45
124	18	10	1.54	0.03	0.05	0.00	0.54	0.00	0.80	0.71	0.25	0.13	0.06	0.45
125	18	11	1.44	0.03	0.05	0.00	0.55	0.00	0.80	0.70	0.25	0.14	0.06	0.45
126	18	12	1.35	0.03	0.05	0.00	0.56	0.00	0.80	0.70	0.25	0.14	0.06	0.45
127	19	1	1.27	0.04	0.05	0.00	0.58	0.00	0.80	0.70	0.25	0.14	0.07	0.45
128	19	2	1.20	0.04	0.05	0.00	0.60	0.00	0.80	0.70	0.25	0.14	0.07	0.45
129	19	3	1.14	0.04	0.05	0.00	0.62	0.00	0.80	0.70	0.25	0.14	0.07	0.45
130	19	4	1.09	0.04	0.05	0.00	0.64	0.00	0.80	0.71	0.25	0.14	0.07	0.45
131	19	5	1.04	0.04	0.05	0.00	0.66	0.00	0.80	0.71	0.25	0.14	0.07	0.45
	19	6	0.99	0.04	0.05	0.00	0.68	0.00	0.80	0.72	0.25	0.14	0.08	0.45
	19	7	0.95	0.04	0.05	0.00	0.70	0.00	0.80	0.72	0.25	0.14	0.08	0.45
134	19	8	0.92	0.04	0.05	0.00	0.72	0.00	0.80	0.73	0.25	0.14	0.08	0.45
135	19	9	0.88	0.05	0.05	0.00	0.74	0.00	0.80	0.73	0.25	0.14	0.08	0.45
136	19	10	0.85	0.05	0.05	0.00	0.76	0.00	0.80	0.74	0.25	0.14	0.08	0.45
137	19	11	0.82	0.05	0.05	0.00	0.78	0.00	0.80	0.74	0.25	0.14	0.09	0.45
138	19	12	0.80	0.05	0.05	0.00	0.80	0.00	0.80	0.75	0.25	0.14	0.09	0.45
139	19	13	0.77	0.05	0.05	0.00	0.82	0.00	0.80	0.75	0.25	0.14	0.09	0.45
140	20	1	0.77	0.05	0.05	0.00	0.85	0.00	0.80	0.76	0.25	0.14	0.09	0.45
141	20	2	0.77	0.05	0.05	0.00	0.87	0.00	0.80	0.76	0.25	0.14	0.10	0.45
142	20	3	0.77	0.06	0.05	0.00	0.90	0.00	0.80	0.76	0.25	0.14	0.10	0.45
143	20	4	0.78	0.06	0.05	0.00	0.92	0.00	0.80	0.77	0.25	0.14	0.10	0.45
144	20	5	0.78	0.06	0.05	0.00	0.94	0.00	0.80	0.77	0.25	0.14	0.10	0.45
145	20	6	0.78	0.06	0.05	0.00	0.96	0.00	0.80	0.77	0.25	0.14	0.11	0.45
146	20	7	0.78	0.06	0.05	0.00	0.98	0.00	0.80	0.77	0.25	0.14	0.11	0.45
147	20	8	0.79	0.06	0.05	0.00	1.00	0.00	0.80	0.77	0.25	0.14	0.11	0.45
148	20	9	0.79	0.07	0.05	0.00	1.02	0.00	0.80	0.76	0.25	0.14	0.11	0.45

***** STEADY STATE SIMULATION *****

** ALGAE DATA **

ELE ORD	RCH NUM	ELE NUM	CHLA UG/L	ALGY GRWTH 1/DAY	ALGY RESP 1/DAY	ALGY SETT FT/DA	A P/R RATIO *	NET P-R MG/L-D	NH3 PREF *	NH3-N FRACT N-UPTKE *	LIGHT EXTCO 1/FT	ALGAE GROWTH RATE ATTEN FACTORS LIGHT *	NITRGN *	PHSPRS *
149	20	10	0.79	0.07	0.05	0.00	1.04	0.00	0.80	0.76	0.25	0.14	0.11	0.45
150	20	11	0.80	0.07	0.05	0.00	1.06	0.00	0.80	0.76	0.25	0.14	0.12	0.45
151	20	12	0.80	0.07	0.05	0.00	1.07	0.00	0.80	0.75	0.25	0.14	0.12	0.45
152	20	13	0.80	0.07	0.05	0.00	1.09	0.00	0.80	0.75	0.25	0.14	0.12	0.45
153	20	14	0.81	0.07	0.05	0.00	1.10	0.00	0.80	0.74	0.25	0.14	0.12	0.45
154	20	15	0.81	0.07	0.05	0.00	1.12	0.00	0.80	0.74	0.25	0.14	0.12	0.45
155	20	16	0.82	0.07	0.05	0.00	1.14	0.00	0.80	0.73	0.25	0.14	0.13	0.45
156	20	17	0.82	0.07	0.05	0.00	1.15	0.00	0.80	0.73	0.25	0.14	0.13	0.45
157	20	18	0.83	0.08	0.05	0.00	1.17	0.00	0.80	0.72	0.25	0.14	0.13	0.45
158	20	19	0.84	0.08	0.05	0.00	1.18	0.00	0.80	0.71	0.25	0.14	0.13	0.45
159	21	1	4.95	0.03	0.05	0.00	0.49	0.00	0.80	0.69	0.25	0.11	0.07	0.68
160	21	2	4.90	0.03	0.05	0.00	0.51	0.00	0.80	0.70	0.25	0.11	0.08	0.69
161	21	3	4.83	0.03	0.05	0.00	0.53	0.00	0.80	0.71	0.25	0.11	0.08	0.69
162	22	1	1.07	0.06	0.05	0.00	0.88	0.00	0.80	0.71	0.25	0.11	0.13	0.47
163	22	2	1.09	0.06	0.05	0.00	0.90	0.00	0.80	0.70	0.25	0.11	0.13	0.47
164	23	1	5.25	0.06	0.05	0.00	1.06	0.00	0.80	0.91	0.25	0.11	0.15	0.70
165	23	2	5.40	0.09	0.05	0.00	1.49	0.01	0.80	0.94	0.25	0.11	0.22	0.70
166	23	3	5.63	0.12	0.05	0.00	1.82	0.01	0.80	0.95	0.25	0.11	0.27	0.71
167	23	4	5.93	0.13	0.05	0.00	2.07	0.01	0.80	0.95	0.25	0.11	0.30	0.71
168	23	5	6.31	0.15	0.05	0.00	2.27	0.02	0.80	0.94	0.25	0.11	0.33	0.72
169	23	6	6.76	0.16	0.05	0.00	2.44	0.02	0.80	0.94	0.26	0.11	0.36	0.72
	23	7	7.29	0.17	0.05	0.00	2.58	0.02	0.80	0.93	0.26	0.11	0.38	0.72
	23	8	7.89	0.18	0.05	0.00	2.70	0.03	0.80	0.91	0.26	0.11	0.40	0.72
172	24	1	8.59	0.18	0.05	0.00	2.81	0.03	0.80	0.90	0.26	0.11	0.41	0.72
173	24	2	9.39	0.19	0.05	0.00	2.90	0.04	0.80	0.89	0.26	0.11	0.42	0.73
174	24	3	10.31	0.19	0.05	0.00	2.99	0.04	0.80	0.87	0.26	0.11	0.44	0.73
175	24	4	11.35	0.20	0.05	0.00	3.06	0.05	0.80	0.85	0.26	0.11	0.45	0.73
176	24	5	12.54	0.20	0.05	0.00	3.13	0.06	0.80	0.83	0.26	0.11	0.46	0.73
177	24	6	13.89	0.21	0.05	0.00	3.20	0.06	0.80	0.81	0.26	0.11	0.47	0.73
178	24	7	15.42	0.21	0.05	0.00	3.26	0.07	0.80	0.79	0.26	0.11	0.48	0.73
179	24	8	17.17	0.21	0.05	0.00	3.31	0.08	0.80	0.77	0.26	0.11	0.48	0.73
180	24	9	19.15	0.22	0.05	0.00	3.35	0.09	0.80	0.74	0.26	0.11	0.49	0.73
181	24	10	21.41	0.22	0.05	0.00	3.39	0.11	0.80	0.72	0.27	0.11	0.50	0.73
182	25	1	23.96	0.22	0.05	0.00	3.43	0.12	0.80	0.69	0.27	0.11	0.50	0.73
183	25	2	26.85	0.22	0.05	0.00	3.46	0.14	0.80	0.66	0.27	0.11	0.50	0.72
184	25	3	30.12	0.23	0.05	0.00	3.48	0.16	0.80	0.63	0.27	0.11	0.51	0.72

***** STEADY STATE SIMULATION *****

** ALGAE DATA **

ELE ORD	RCH NUM	ELE NUM	CHLA UG/L	ALGY GRWTH 1/DAY	ALGY RESP 1/DAY	ALGY SETT FT/DA	A P/R RATIO *	NET P-R MG/L-D	NH3 PREF *	NH3-N FRACT N-UPTKE *	LIGHT EXTCO 1/FT	ALGAE GROWTH RATE ATTEN FACTORS LIGHT *	NITRGN *	PHSPRS *
185	25	4	33.81	0.23	0.05	0.00	3.49	0.18	0.80	0.60	0.28	0.11	0.51	0.72
186	25	5	37.96	0.23	0.05	0.00	3.50	0.20	0.80	0.57	0.28	0.11	0.51	0.72
187	25	6	42.61	0.23	0.05	0.00	3.49	0.22	0.80	0.54	0.28	0.11	0.51	0.72
188	25	7	47.80	0.23	0.05	0.00	3.48	0.25	0.80	0.51	0.29	0.11	0.50	0.71
189	25	8	53.56	0.22	0.05	0.00	3.45	0.27	0.80	0.48	0.29	0.11	0.50	0.71
190	25	9	59.90	0.22	0.05	0.00	3.41	0.30	0.80	0.44	0.29	0.11	0.49	0.70
191	25	10	66.32	0.22	0.05	0.00	3.35	0.32	0.80	0.41	0.30	0.11	0.48	0.70
192	26	1	4.64	0.07	0.05	0.00	1.12	0.00	0.80	0.64	0.25	0.11	0.16	0.49
193	26	2	4.64	0.08	0.05	0.00	1.16	0.00	0.80	0.63	0.25	0.11	0.17	0.49
194	27	1	0.95	0.25	0.05	0.00	3.91	0.01	0.80	0.45	0.25	0.13	0.47	0.67
195	27	2	0.98	0.25	0.05	0.00	3.93	0.01	0.80	0.46	0.25	0.13	0.47	0.67
196	27	3	1.00	0.25	0.05	0.00	3.94	0.01	0.80	0.46	0.25	0.13	0.47	0.68
197	27	4	1.03	0.25	0.05	0.00	3.95	0.01	0.80	0.47	0.25	0.13	0.47	0.68
198	27	5	1.06	0.26	0.05	0.00	3.96	0.01	0.80	0.47	0.25	0.13	0.47	0.68
199	27	6	1.09	0.26	0.05	0.00	3.97	0.01	0.80	0.48	0.25	0.13	0.47	0.68
200	27	7	1.13	0.26	0.05	0.00	3.98	0.01	0.80	0.48	0.25	0.13	0.47	0.68
201	27	8	1.16	0.26	0.05	0.00	3.99	0.01	0.80	0.49	0.25	0.13	0.48	0.69
202	27	9	1.19	0.26	0.05	0.00	3.99	0.01	0.80	0.49	0.25	0.13	0.48	0.69
203	28	1	1.21	0.23	0.05	0.00	3.55	0.01	0.80	0.49	0.25	0.12	0.48	0.69
204	28	2	1.22	0.23	0.05	0.00	3.55	0.01	0.80	0.49	0.25	0.12	0.48	0.69
205	28	3	1.23	0.23	0.05	0.00	3.55	0.01	0.80	0.49	0.25	0.12	0.48	0.69
	28	4	1.24	0.23	0.05	0.00	3.55	0.01	0.80	0.50	0.25	0.12	0.48	0.69
	28	5	1.25	0.23	0.05	0.00	3.56	0.01	0.80	0.50	0.25	0.12	0.48	0.69
208	28	6	1.26	0.23	0.05	0.00	3.56	0.01	0.80	0.50	0.25	0.12	0.48	0.69
209	28	7	1.26	0.23	0.05	0.00	3.56	0.01	0.80	0.50	0.25	0.12	0.48	0.69
210	28	8	1.27	0.23	0.05	0.00	3.56	0.01	0.80	0.50	0.25	0.12	0.48	0.69
211	28	9	1.27	0.23	0.05	0.00	3.57	0.01	0.80	0.49	0.25	0.12	0.48	0.69

***** STEADY STATE SIMULATION *****

** DISSOLVED OXYGEN DATA **

ELE ORD	RCH NUM	ELE NUM	TEMP DEG-F	DO SAT MG/L	DO MG/L	DO DEF MG/L	DAM INPUT MG/L	NIT INHIB FACT	COMPONENTS OF DISSOLVED OXYGEN MASS BALANCE (MG/L-DAY) F-FNCTN INPUT	OXYGN REAIR	C-BOD	SOD	NET P-R	NH3-N	NO2-N
1	1	1	58.73	10.15	4.35	5.80	0.00	1.00	9.67	7.18	-1.91	-3.34	0.00	0.00	0.00
2	1	2	61.54	9.82	4.46	5.36	0.00	1.00	0.00	6.88	-1.99	-3.65	0.00	0.00	0.00
3	2	1	64.06	9.54	0.00	9.54	0.00	1.00	0.41	2.09	-4.06	-2.49	0.00	0.00	0.00
4	3	1	63.52	9.60	2.76	6.83	0.00	1.00	0.00	7.09	-2.27	-3.76	0.00	0.00	0.00
5	3	2	57.82	10.26	1.80	8.46	0.00	1.00	6.01	9.86	-2.80	-2.08	0.00	0.00	0.00
6	4	1	58.88	10.13	2.35	7.78	0.00	1.00	0.02	6.58	-2.83	-0.58	0.00	0.00	0.00
7	4	2	60.08	9.99	2.53	7.46	0.00	1.00	0.02	4.24	-2.85	-0.61	0.00	0.00	0.00
8	4	3	61.14	9.86	2.68	7.19	0.00	1.00	0.02	4.15	-2.86	-0.63	0.00	0.00	0.00
9	4	4	62.09	9.76	2.79	6.96	0.00	1.00	0.02	4.07	-2.86	-0.65	0.00	0.00	0.00
10	4	5	62.93	9.66	2.89	6.78	0.00	1.00	0.02	4.00	-2.84	-0.66	0.00	0.00	0.00
11	4	6	63.67	9.58	2.96	6.62	0.00	1.00	0.02	3.95	-2.83	-0.68	0.00	0.00	0.00
12	4	7	64.34	9.51	3.03	6.48	0.00	1.00	0.02	3.90	-2.80	-0.70	0.00	0.00	0.00
13	4	8	64.93	9.44	3.09	6.36	0.00	1.00	0.02	3.86	-2.77	-0.71	0.00	0.00	0.00
14	4	9	65.45	9.39	3.14	6.25	0.00	1.00	0.02	3.82	-2.73	-0.72	0.00	0.00	0.00
15	4	10	65.91	9.34	3.19	6.15	0.00	1.00	0.02	3.78	-2.69	-0.73	0.00	0.00	0.00
16	4	11	66.31	9.30	3.23	6.06	0.00	1.00	0.02	3.74	-2.65	-0.74	0.00	0.00	0.00
17	4	12	66.67	9.26	3.28	5.98	0.00	1.00	0.02	3.71	-2.60	-0.75	0.00	0.00	0.00
18	4	13	66.98	9.23	3.33	5.89	0.00	1.00	0.02	3.67	-2.55	-0.76	0.00	0.00	0.00
19	4	14	67.25	9.20	3.39	5.81	0.00	1.00	0.02	3.63	-2.50	-0.76	0.00	0.00	0.00
20	4	15	67.50	9.17	3.44	5.74	0.00	1.00	0.02	3.59	-2.44	-0.77	0.00	0.00	0.00
21	4	16	67.71	9.15	3.49	5.66	0.00	1.00	0.02	3.56	-2.39	-0.77	0.00	0.00	0.00
	4	17	67.90	9.13	3.55	5.58	0.00	1.00	0.02	3.51	-2.33	-0.78	0.00	0.00	0.00
	4	18	68.06	9.12	3.64	5.48	0.00	1.00	0.02	3.46	-2.28	-0.78	0.00	0.00	0.00
24	5	1	68.05	9.12	4.76	4.35	0.00	1.00	0.45	9.26	-2.23	-1.82	0.00	0.00	0.00
25	5	2	68.03	9.12	5.63	3.49	0.00	1.00	0.45	12.61	-2.20	-1.80	0.00	0.00	0.00
26	5	3	68.02	9.12	6.25	2.87	0.00	1.00	0.45	10.33	-2.16	-1.79	0.00	0.00	0.00
27	5	4	68.00	9.12	6.69	2.43	0.00	1.00	0.45	8.69	-2.13	-1.78	0.00	0.00	0.00
28	5	5	67.99	9.12	7.01	2.11	0.00	1.00	0.44	7.52	-2.10	-1.77	0.00	0.00	0.00
29	5	6	67.98	9.13	7.24	1.88	0.00	1.00	0.44	6.67	-2.08	-1.76	0.00	0.00	0.00
30	5	7	67.97	9.13	7.41	1.72	0.00	1.00	0.44	6.05	-2.05	-1.75	0.00	0.00	0.00
31	5	8	67.96	9.13	7.53	1.59	0.00	1.00	0.44	5.59	-2.02	-1.74	0.00	0.00	0.00
32	5	9	67.95	9.13	7.62	1.50	0.00	1.00	0.44	5.25	-1.99	-1.73	0.00	0.00	0.00
33	5	10	67.94	9.13	7.69	1.44	0.00	1.00	0.43	4.99	-1.97	-1.72	0.00	0.00	0.00
34	5	11	67.94	9.13	7.74	1.39	0.00	1.00	0.43	4.80	-1.94	-1.71	0.00	0.00	0.00
35	5	12	67.93	9.13	7.78	1.35	0.00	1.00	0.43	4.64	-1.92	-1.70	0.00	0.00	0.00
36	5	13	67.92	9.13	7.81	1.32	0.00	1.00	0.43	4.53	-1.90	-1.70	0.00	0.00	0.00
37	5	14	67.92	9.13	7.83	1.30	0.00	1.00	0.43	4.43	-1.87	-1.69	0.00	0.00	0.00
38	5	15	67.92	9.13	7.85	1.28	0.00	1.00	0.43	4.35	-1.85	-1.68	0.00	0.00	0.00

***** STEADY STATE SIMULATION *****

** DISSOLVED OXYGEN DATA **

ELE ORD	RCH NUM	ELE NUM	TEMP DEG-F	DO SAT MG/L	DO MG/L	DO DEF MG/L	DAM INPUT MG/L	NIT INHIB FACT	COMPONENTS OF DISSOLVED OXYGEN MASS BALANCE (MG/L-DAY) F-FNCTN INPUT	OXYGN REAIR	C-BOD	SOD	NET P-R	NH3-N	NO2-N
39	5	16	67.93	9.13	7.87	1.27	0.00	1.00	0.42	4.28	-1.83	-1.67	0.00	0.00	0.00
40	6	1	68.98	9.03	8.04	0.99	0.00	1.00	0.00	1.70	0.00	-0.83	0.00	0.00	0.00
41	6	2	69.49	8.98	0.00	8.98	0.00	1.00	0.00	0.15	0.00	-0.84	0.00	0.00	0.00
42	7	1	69.52	8.97	8.79	0.18	0.00	1.00	-1.59	0.90	0.00	-6.57	0.00	0.00	0.00
43	7	2	69.52	8.97	8.57	0.40	0.00	1.00	-1.56	3.98	0.00	-6.61	0.00	0.00	0.00
44	7	3	69.52	8.97	8.44	0.53	0.00	1.00	-1.55	5.26	0.00	-6.64	0.00	0.00	0.00
45	7	4	69.52	8.97	8.37	0.60	0.00	1.00	-1.54	6.02	0.00	-6.68	0.00	0.00	0.00
46	7	5	69.52	8.97	8.33	0.65	0.00	1.00	-1.55	6.47	0.00	-6.71	0.00	0.00	0.00
47	7	6	69.52	8.97	8.30	0.67	0.00	1.00	-1.55	6.74	0.00	-6.75	0.00	0.00	0.00
48	7	7	69.52	8.97	8.29	0.68	0.00	1.00	-1.56	6.91	0.00	-6.79	0.00	0.00	0.00
49	7	8	69.52	8.97	8.28	0.69	0.00	1.00	-1.57	7.02	0.00	-6.83	0.00	0.00	0.00
50	7	9	69.52	8.97	8.28	0.70	0.00	1.00	-1.58	7.10	0.00	-6.86	0.00	0.00	0.00
51	7	10	69.52	8.97	8.27	0.70	0.00	1.00	-1.59	7.17	0.00	-6.90	0.00	0.00	0.00
52	7	11	69.52	8.97	8.27	0.70	0.00	1.00	-1.60	7.22	0.00	-6.95	0.00	0.00	0.00
53	7	12	69.50	8.97	8.27	0.71	0.00	1.00	-1.61	7.30	0.00	-6.98	0.00	0.00	0.00
54	8	1	66.14	9.31	7.94	1.37	0.00	1.00	10.27	10.60	0.00	-2.14	0.00	0.00	0.00
55	9	1	63.97	9.55	8.26	1.29	0.00	1.00	25.60	39.35	-3.79	-27.59	0.00	0.00	0.00
56	9	2	67.42	9.18	8.06	1.12	0.00	1.00	0.00	35.81	-4.04	-30.85	0.00	0.00	0.00
57	9	3	68.72	9.05	7.90	1.15	0.00	1.00	0.00	37.38	-4.06	-32.18	0.00	0.00	0.00
58	10	1	66.38	9.29	7.96	1.33	0.00	1.00	21.37	18.15	-2.78	-4.90	0.00	0.00	0.00
59	10	2	66.51	9.28	7.82	1.45	0.00	1.00	19.20	12.11	-3.50	-4.46	0.00	0.00	0.00
60	10	3	66.60	9.27	7.71	1.56	0.00	1.00	17.51	11.65	-4.04	-4.12	0.00	0.00	0.00
61	10	4	66.67	9.26	7.61	1.65	0.00	1.00	16.16	11.23	-4.45	-3.84	0.00	0.00	0.00
62	10	5	66.72	9.25	7.52	1.73	0.00	1.00	15.03	10.86	-4.77	-3.60	0.00	0.00	0.00
63	11	1	66.79	9.25	7.31	1.93	0.00	1.00	9.02	11.40	-4.50	-8.69	0.00	0.00	0.00
64	11	2	66.85	9.24	7.16	2.08	0.00	1.00	8.67	11.75	-4.27	-8.41	0.00	0.00	0.00
65	11	3	66.90	9.23	7.04	2.20	0.00	1.00	8.36	11.89	-4.05	-8.15	0.00	0.00	0.00
66	11	4	66.95	9.23	6.94	2.29	0.00	1.00	8.07	11.92	-3.87	-7.91	0.00	0.00	0.00
67	12	1	67.04	9.22	6.48	2.74	0.00	1.00	2.80	13.08	-4.38	-13.44	0.00	0.00	0.00
68	12	2	67.16	9.21	6.13	3.08	0.00	1.00	2.75	13.55	-4.86	-13.33	0.00	0.00	0.00
69	12	3	67.26	9.20	5.84	3.36	0.00	1.00	2.71	14.63	-5.32	-13.22	0.00	0.00	0.00
70	12	4	67.36	9.19	5.59	3.60	0.00	1.00	2.67	15.50	-5.75	-13.10	0.00	0.00	0.00

***** STEADY STATE SIMULATION *****

** DISSOLVED OXYGEN DATA **

ELE ORD	RCH NUM	ELE NUM	TEMP DEG-F	DO SAT MG/L	DO MG/L	DO DEF MG/L	DAM INPUT MG/L	NIT INHIB FACT	F-FNCTN INPUT	OXYGN REAIR	C-BOD	SOD	NET P-R	NH3-N	NO2-N
									COMPONENTS OF DISSOLVED OXYGEN MASS BALANCE (MG/L-DAY)						
71	12	5	67.44	9.18	5.37	3.81	0.00	1.00	2.63	16.21	-6.15	-12.99	0.00	0.00	0.00
72	12	6	67.52	9.17	5.18	3.99	0.00	1.00	2.59	16.81	-6.54	-12.88	0.00	-0.01	0.00
73	12	7	67.58	9.17	5.01	4.15	0.00	1.00	2.55	17.31	-6.90	-12.77	0.00	-0.01	0.00
74	12	8	67.65	9.16	4.86	4.30	0.00	1.00	2.52	17.75	-7.25	-12.66	0.00	-0.01	0.00
75	12	9	67.70	9.15	4.72	4.43	0.00	1.00	2.48	18.12	-7.57	-12.56	0.00	-0.01	0.00
76	12	10	67.76	9.15	4.59	4.56	0.00	1.00	2.45	18.44	-7.88	-12.45	0.00	-0.01	0.00
77	12	11	67.80	9.14	4.47	4.67	0.00	1.00	2.42	18.72	-8.18	-12.35	0.00	-0.01	0.00
78	13	1	67.89	9.13	4.49	4.64	0.00	1.00	-2.28	18.65	-1.64	-15.67	0.00	-0.01	0.00
79	13	2	67.97	9.13	4.51	4.62	0.00	1.00	-2.33	18.82	-1.64	-15.91	0.00	-0.01	0.00
80	13	3	68.05	9.12	4.52	4.60	0.00	1.00	-2.38	19.01	-1.64	-16.16	0.00	-0.01	0.00
81	13	4	68.13	9.11	4.53	4.58	0.00	1.00	-2.42	19.22	-1.64	-16.42	0.00	-0.01	0.00
82	13	5	68.20	9.10	4.53	4.57	0.00	1.00	-2.47	19.45	-1.64	-16.68	0.00	-0.01	0.00
83	13	6	68.27	9.10	4.54	4.56	0.00	1.00	-2.52	19.70	-1.64	-16.96	0.00	-0.01	0.00
84	13	7	68.35	9.09	4.54	4.55	0.00	1.00	-2.58	19.96	-1.64	-17.25	0.00	-0.01	0.00
85	13	8	68.41	9.08	4.55	4.54	0.00	1.00	-2.63	20.25	-1.65	-17.55	0.00	-0.01	0.00
86	13	9	68.48	9.08	4.55	4.53	0.00	1.00	-2.69	20.55	-1.65	-17.87	0.00	-0.01	0.00
87	13	10	68.54	9.07	4.55	4.52	0.00	1.00	-2.75	20.87	-1.65	-18.20	0.00	-0.01	0.00
88	14	1	68.56	9.07	4.73	4.34	0.00	1.00	0.20	23.54	-1.65	-20.09	0.00	-0.01	0.00
89	14	2	68.58	9.07	4.86	4.20	0.00	1.00	0.20	26.03	-1.65	-20.06	0.00	-0.01	0.00
90	14	3	68.59	9.06	4.96	4.10	0.00	1.00	0.20	25.35	-1.64	-20.04	0.00	-0.01	0.00
91	14	4	68.60	9.06	5.04	4.02	0.00	1.00	0.20	24.83	-1.64	-20.02	0.00	-0.01	0.00
92	14	5	68.61	9.06	5.10	3.96	0.00	1.00	0.20	24.42	-1.64	-20.00	0.00	-0.02	0.00
93	14	6	68.63	9.06	5.15	3.91	0.00	1.00	0.20	24.10	-1.64	-19.98	0.00	-0.02	0.00
[illegible]	14	7	68.64	9.06	5.18	3.88	0.00	1.00	0.20	23.85	-1.64	-19.95	0.00	-0.02	0.00
[illegible]	14	8	68.65	9.06	5.21	3.85	0.00	1.00	0.20	23.65	-1.64	-19.93	0.00	-0.02	0.00
96	14	9	68.65	9.06	5.23	3.83	0.00	1.00	0.20	23.49	-1.64	-19.91	0.00	-0.02	0.00
97	14	10	68.66	9.06	5.24	3.82	0.00	1.00	0.20	23.37	-1.64	-19.88	0.00	-0.02	0.00
98	15	1	68.68	9.05	5.12	3.94	0.00	1.00	0.14	24.06	-1.63	-21.29	0.00	-0.02	0.00
99	15	2	68.71	9.05	5.12	3.94	0.00	1.00	0.14	24.04	-1.63	-21.28	0.00	-0.02	0.00
100	15	3	68.73	9.05	5.11	3.94	0.00	1.00	0.14	24.03	-1.63	-21.28	0.00	-0.02	0.00
101	15	4	68.75	9.05	5.11	3.94	0.00	1.00	0.14	24.02	-1.63	-21.27	0.00	-0.02	0.00
102	15	5	68.78	9.05	5.12	3.93	0.00	1.00	0.14	23.97	-1.63	-21.26	0.00	-0.02	0.00
103	16	1	68.80	9.04	5.87	3.18	0.00	1.00	0.10	19.37	-1.63	-4.25	0.00	-0.02	0.00
104	16	2	68.83	9.04	6.42	2.62	0.00	1.00	0.10	15.96	-1.63	-4.25	0.00	-0.02	0.00
105	16	3	68.85	9.04	6.83	2.20	0.00	1.00	0.10	13.44	-1.63	-4.25	0.00	-0.02	0.00
106	16	4	68.88	9.04	7.14	1.90	0.00	1.00	0.10	11.57	-1.63	-4.25	0.00	-0.02	0.00
107	16	5	68.90	9.03	7.36	1.67	0.00	1.00	0.10	10.18	-1.63	-4.25	0.00	-0.02	0.00
108	16	6	68.92	9.03	7.53	1.50	0.00	1.00	0.10	9.15	-1.63	-4.25	0.00	-0.02	0.00

***** STEADY STATE SIMULATION *****

** DISSOLVED OXYGEN DATA **

ELE ORD	RCH NUM	ELE NUM	TEMP DEG-F	DO SAT MG/L	DO MG/L	DO DEF MG/L	DAM INPUT MG/L	NIT INHIB FACT	F-FNCTN INPUT	OXYGN REAIR	C-BOD	SOD	NET P-R	NH3-N	NO2-N
									COMPONENTS OF DISSOLVED OXYGEN MASS BALANCE (MG/L-DAY)						
109	17	1	68.94	9.03	7.65	1.38	0.00	1.00	0.10	8.39	-1.62	-4.25	0.00	-0.02	0.00
110	17	2	68.95	9.03	7.74	1.29	0.00	1.00	0.10	7.82	-1.62	-4.25	0.00	-0.02	0.00
111	17	3	68.97	9.03	7.81	1.22	0.00	1.00	0.10	7.40	-1.62	-4.25	0.00	-0.02	0.00
112	17	4	68.99	9.03	7.86	1.17	0.00	1.00	0.10	7.09	-1.62	-4.25	0.00	-0.02	0.00
113	17	5	69.00	9.02	7.90	1.13	0.00	1.00	0.10	6.86	-1.62	-4.25	0.00	-0.02	0.00
114	17	6	69.01	9.02	7.92	1.10	0.00	1.00	0.10	6.69	-1.62	-4.25	0.00	-0.02	0.00
115	18	1	61.28	9.85	6.07	3.77	0.00	1.00	7.08	3.32	-2.29	-1.24	-0.01	0.00	0.00
116	18	2	64.00	9.54	5.41	4.13	0.00	1.00	0.68	3.79	-2.65	-1.31	0.00	0.00	0.00
117	18	3	65.28	9.40	4.98	4.42	0.00	1.00	0.66	4.16	-2.87	-1.33	0.00	0.00	0.00
118	18	4	65.92	9.34	4.72	4.62	0.00	1.00	0.65	4.41	-3.02	-1.32	0.00	0.00	0.00
119	18	5	66.26	9.30	4.55	4.75	0.00	1.00	0.63	4.59	-3.13	-1.31	0.00	0.00	0.00
120	18	6	66.45	9.28	4.45	4.83	0.00	1.00	0.62	4.71	-3.20	-1.29	0.00	0.00	0.00
121	18	7	66.57	9.27	4.39	4.88	0.00	1.00	0.60	4.79	-3.26	-1.27	0.00	0.00	0.00
122	18	8	66.64	9.26	4.35	4.91	0.00	1.00	0.59	4.85	-3.30	-1.25	0.00	0.00	0.00
123	18	9	66.68	9.26	4.33	4.92	0.00	1.00	0.58	4.89	-3.34	-1.23	0.00	0.00	0.00
124	18	10	66.71	9.25	4.33	4.93	0.00	1.00	0.57	4.91	-3.36	-1.22	0.00	0.00	0.00
125	18	11	66.73	9.25	4.33	4.93	0.00	1.00	0.56	4.93	-3.39	-1.20	0.00	0.00	0.00
126	18	12	66.75	9.25	4.33	4.92	0.00	1.00	0.56	4.95	-3.40	-1.19	0.00	0.00	0.00
127	19	1	66.80	9.25	4.34	4.90	0.00	1.00	0.51	4.95	-3.42	-1.18	0.00	0.00	0.00
128	19	2	66.85	9.24	4.35	4.89	0.00	1.00	0.50	4.96	-3.43	-1.16	0.00	0.00	0.00
129	19	3	66.88	9.24	4.36	4.87	0.00	1.00	0.50	4.96	-3.43	-1.15	0.00	0.00	0.00
130	19	4	66.90	9.24	4.38	4.86	0.00	1.00	0.49	4.96	-3.44	-1.14	0.00	0.00	0.00
131	19	5	66.92	9.23	4.39	4.84	0.00	1.00	0.49	4.96	-3.44	-1.13	0.00	0.00	0.00
[illegible]	19	6	66.93	9.23	4.40	4.83	0.00	1.00	0.48	4.96	-3.44	-1.12	0.00	0.00	0.00
[illegible]	19	7	66.94	9.23	4.42	4.81	0.00	1.00	0.48	4.95	-3.45	-1.11	0.00	0.00	0.00
134	19	8	66.95	9.23	4.44	4.79	0.00	1.00	0.47	4.95	-3.45	-1.11	0.00	0.00	0.00
135	19	9	66.95	9.23	4.45	4.78	0.00	1.00	0.47	4.94	-3.45	-1.10	0.00	0.00	0.00
136	19	10	66.96	9.23	4.47	4.76	0.00	1.00	0.46	4.94	-3.45	-1.09	0.00	-0.01	0.00
137	19	11	66.96	9.23	4.48	4.75	0.00	1.00	0.46	4.93	-3.45	-1.08	0.00	-0.01	0.00
138	19	12	66.97	9.23	4.50	4.73	0.00	1.00	0.46	4.92	-3.45	-1.07	0.00	-0.01	0.00
139	19	13	66.98	9.23	4.51	4.71	0.00	1.00	0.45	4.92	-3.44	-1.07	0.00	-0.01	0.00
140	20	1	67.38	9.19	4.54	4.65	0.00	1.00	0.00	4.88	-3.43	-1.08	0.00	-0.01	0.00
141	20	2	67.72	9.15	4.55	4.60	0.00	1.00	0.00	4.85	-3.41	-1.09	0.00	-0.01	0.00
142	20	3	68.00	9.12	4.56	4.56	0.00	1.00	0.00	4.83	-3.39	-1.10	0.00	-0.01	0.00
143	20	4	68.24	9.10	4.57	4.53	0.00	1.00	0.00	4.81	-3.37	-1.11	0.00	-0.01	0.00
144	20	5	68.44	9.08	4.58	4.50	0.00	1.00	0.00	4.79	-3.34	-1.12	0.00	-0.01	0.00
145	20	6	68.61	9.06	4.59	4.47	0.00	1.00	0.00	4.77	-3.30	-1.13	0.00	-0.01	0.00
146	20	7	68.75	9.05	4.60	4.45	0.00	1.00	0.00	4.75	-3.27	-1.13	0.00	-0.01	0.00
147	20	8	68.87	9.04	4.62	4.42	0.00	1.00	0.00	4.73	-3.23	-1.13	0.00	-0.01	0.00
148	20	9	68.98	9.03	4.63	4.39	0.00	1.00	0.00	4.71	-3.20	-1.14	0.00	-0.01	0.00

***** STEADY STATE SIMULATION *****

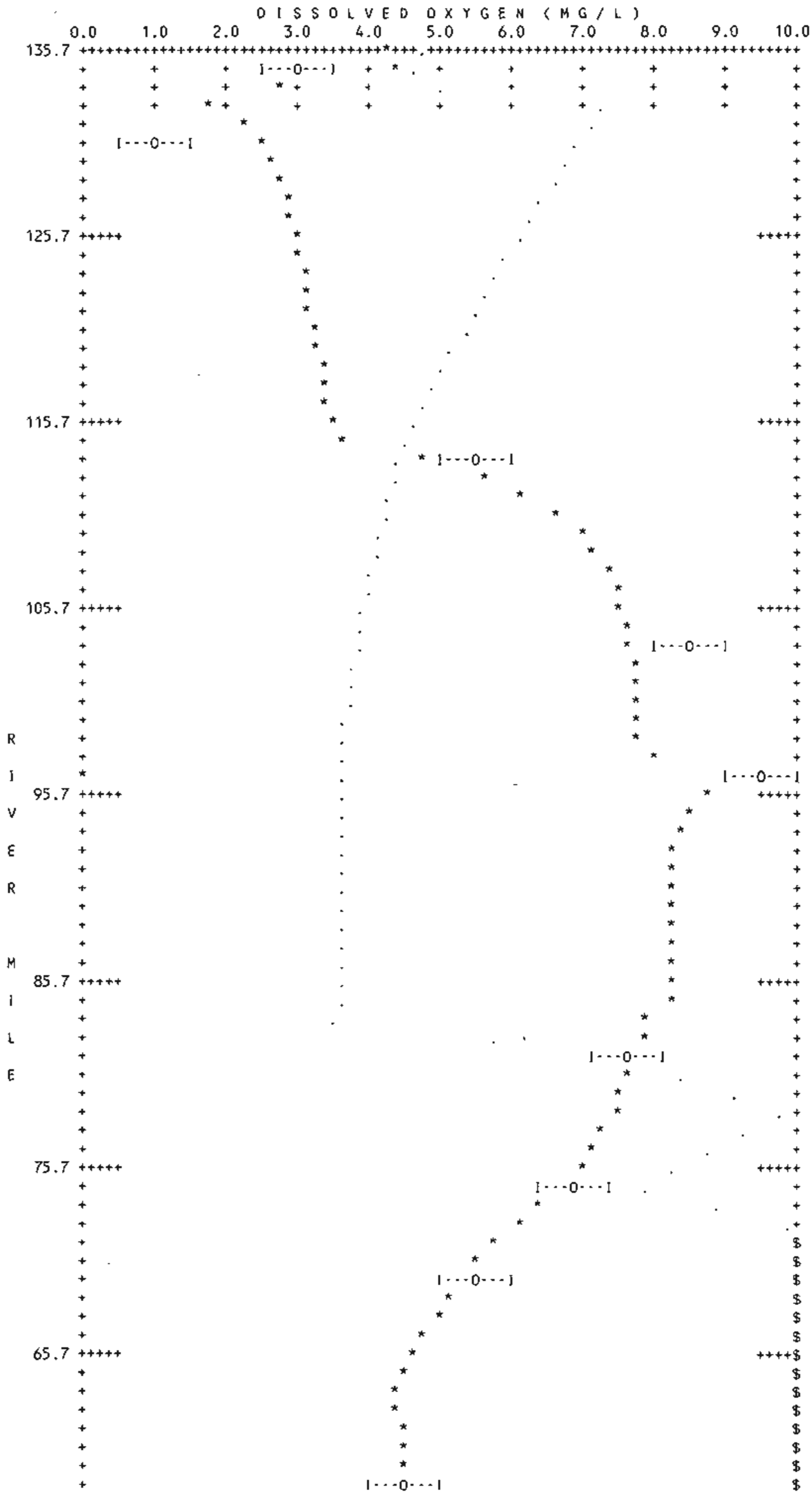
** DISSOLVED OXYGEN DATA **

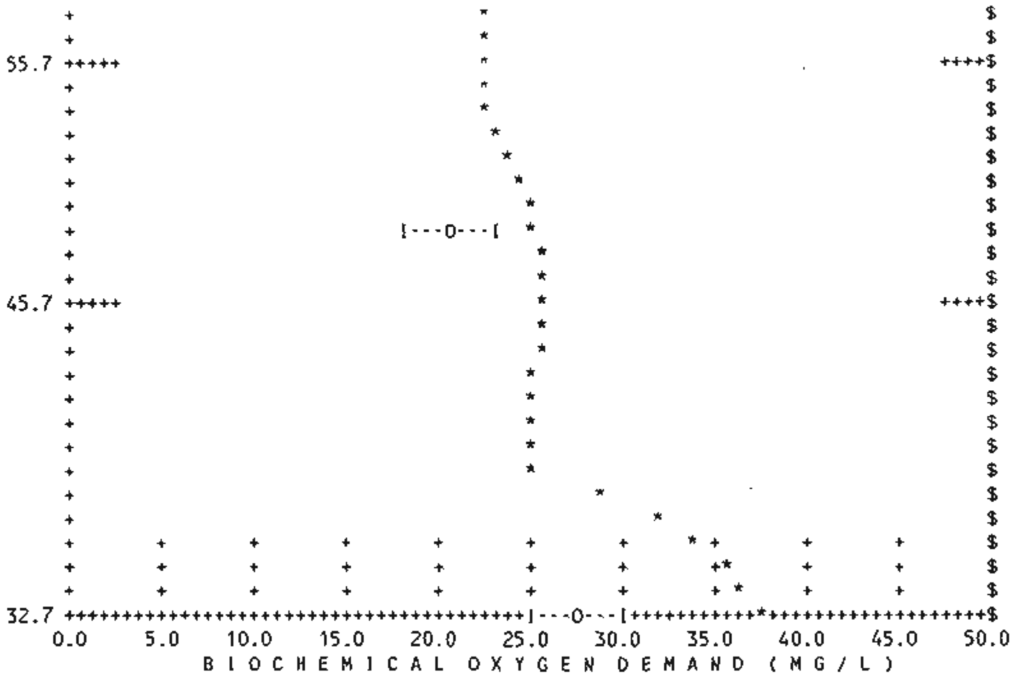
ELE ORD	RCH NUM	ELE NUM	TEMP DEG-F	DO SAT MG/L	DO MG/L	DO DEF MG/L	DAM INPUT MG/L	NIT INHIB FACT	COMPONENTS OF DISSOLVED OXYGEN MASS BALANCE (MG/L-DAY) F-FNCTN INPUT	OXYGN REAIR	C-BOD	SOD	NET P-R	NH3-N	NO2-N
149	20	10	69.06	9.02	4.66	4.36	0.00	1.00	0.00	4.68	-3.16	-1.14	0.00	-0.01	0.00
150	20	11	69.13	9.01	4.68	4.33	0.00	1.00	0.00	4.66	-3.12	-1.14	0.00	-0.01	0.00
151	20	12	69.20	9.00	4.70	4.30	0.00	1.00	0.00	4.63	-3.08	-1.15	0.00	-0.01	0.00
152	20	13	69.25	9.00	4.73	4.27	0.00	1.00	0.00	4.60	-3.04	-1.15	0.00	-0.01	0.00
153	20	14	69.29	9.00	4.76	4.24	0.00	1.00	0.00	4.56	-3.00	-1.15	0.00	-0.01	0.00
154	20	15	69.33	8.99	4.79	4.21	0.00	1.00	0.00	4.53	-2.96	-1.15	0.00	-0.01	0.00
155	20	16	69.36	8.99	4.82	4.17	0.00	1.00	0.00	4.50	-2.92	-1.15	0.00	-0.01	0.00
156	20	17	69.38	8.99	4.85	4.14	0.00	1.00	0.00	4.46	-2.88	-1.15	0.00	-0.01	0.00
157	20	18	69.41	8.98	4.88	4.10	0.00	1.00	0.00	4.43	-2.84	-1.15	0.00	-0.01	0.00
158	20	19	69.42	8.98	4.93	4.05	0.00	1.00	0.00	4.37	-2.80	-1.16	0.00	-0.01	0.00
159	21	1	66.25	9.30	7.95	1.35	0.00	1.00	16.26	14.71	-3.18	-12.54	0.00	0.00	0.00
160	21	2	68.50	9.07	7.57	1.50	0.00	1.00	0.00	16.85	-3.19	-13.49	0.00	0.00	0.00
161	21	3	69.21	9.00	7.45	1.55	0.00	1.00	0.00	17.57	-3.09	-13.81	0.00	0.00	0.00
162	22	1	69.44	8.98	5.93	3.05	0.00	1.00	0.00	23.07	-5.36	-9.15	0.00	-0.01	0.00
163	22	2	69.47	8.98	6.91	2.07	0.00	1.00	0.00	18.45	-5.23	-9.16	0.00	-0.01	0.00
164	23	1	66.46	9.28	7.05	2.23	0.00	1.00	3.21	14.89	-1.52	-4.75	0.00	-0.02	0.00
165	23	2	68.46	9.08	7.84	1.23	0.00	1.00	0.00	8.45	-1.58	-5.06	0.01	-0.03	0.00
166	23	3	69.15	9.01	7.93	1.08	0.00	1.00	0.00	7.45	-1.59	-5.18	0.01	-0.04	0.00
167	23	4	69.40	8.98	7.93	1.06	0.00	1.00	0.00	7.35	-1.58	-5.22	0.01	-0.05	0.00
168	23	5	69.48	8.98	7.92	1.06	0.00	1.00	0.00	7.35	-1.56	-5.23	0.02	-0.06	-0.01
169	23	6	69.51	8.97	7.92	1.06	0.00	1.00	0.00	7.35	-1.54	-5.24	0.02	-0.06	-0.01
	23	7	69.52	8.97	7.92	1.06	0.00	1.00	0.00	7.33	-1.52	-5.24	0.02	-0.07	-0.01
	23	8	69.52	8.97	7.92	1.05	0.00	1.00	0.00	7.32	-1.50	-5.24	0.03	-0.07	-0.01
172	24	1	69.52	8.97	7.92	1.05	0.00	1.00	0.00	7.30	-1.48	-5.24	0.03	-0.07	-0.01
173	24	2	69.52	8.97	7.93	1.05	0.00	1.00	0.00	7.28	-1.46	-5.24	0.04	-0.07	-0.01
174	24	3	69.52	8.97	7.93	1.04	0.00	1.00	0.00	7.25	-1.45	-5.24	0.04	-0.07	-0.02
175	24	4	69.52	8.97	7.93	1.04	0.00	1.00	0.00	7.23	-1.43	-5.24	0.05	-0.07	-0.02
176	24	5	69.52	8.97	7.94	1.04	0.00	1.00	0.00	7.20	-1.41	-5.24	0.06	-0.07	-0.02
177	24	6	69.52	8.97	7.94	1.03	0.00	1.00	0.00	7.18	-1.39	-5.24	0.06	-0.07	-0.02
178	24	7	69.52	8.97	7.94	1.03	0.00	1.00	0.00	7.15	-1.37	-5.24	0.07	-0.06	-0.02
179	24	8	69.52	8.97	7.95	1.02	0.00	1.00	0.00	7.12	-1.36	-5.24	0.08	-0.06	-0.02
180	24	9	69.52	8.97	7.95	1.02	0.00	1.00	0.00	7.09	-1.34	-5.24	0.09	-0.06	-0.02
181	24	10	69.52	8.97	7.96	1.02	0.00	1.00	0.00	7.06	-1.32	-5.24	0.11	-0.06	-0.02
182	25	1	69.52	8.97	7.96	1.01	0.00	1.00	0.00	7.02	-1.30	-5.24	0.12	-0.05	-0.02
183	25	2	69.52	8.97	7.97	1.01	0.00	1.00	0.00	6.98	-1.29	-5.24	0.14	-0.05	-0.02
184	25	3	69.52	8.97	7.97	1.00	0.00	1.00	0.00	6.95	-1.27	-5.24	0.16	-0.05	-0.02

***** STEADY STATE SIMULATION *****

** DISSOLVED OXYGEN DATA **

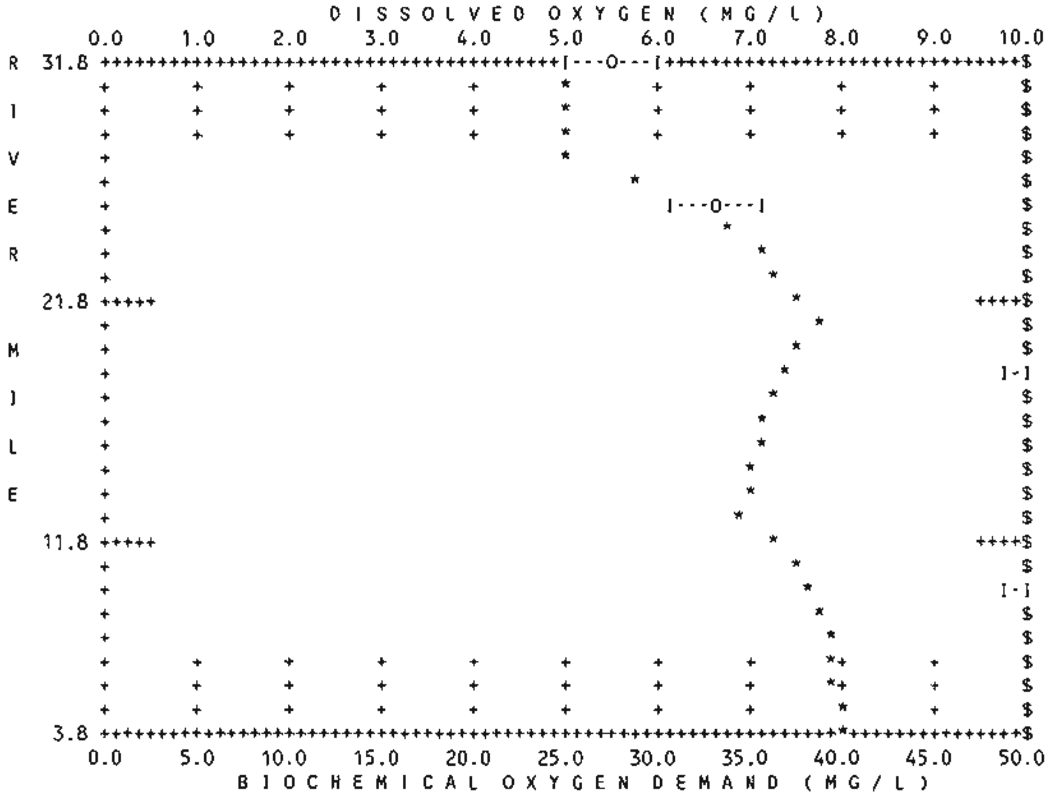
ELE ORD	RCH NUM	ELE NUM	TEMP DEG-F	DO SAT MG/L	DO MG/L	DO DEF MG/L	DAM INPUT MG/L	NIT INHIB FACT	F-FNCTN INPUT	OXYGN REAIR	C-BOD	SOD	NET P-R	NH3-N	NO2-N
									COMPONENTS OF DISSOLVED OXYGEN MASS BALANCE (MG/L-DAY)						
185	25	4	69.52	8.97	7.98	0.99	0.00	1.00	0.00	6.91	-1.25	-5.24	0.18	-0.04	-0.02
186	25	5	69.52	8.97	7.98	0.99	0.00	1.00	0.00	6.86	-1.24	-5.24	0.20	-0.04	-0.02
187	25	6	69.52	8.97	7.99	0.98	0.00	1.00	0.00	6.82	-1.22	-5.24	0.22	-0.03	-0.02
188	25	7	69.52	8.97	8.00	0.98	0.00	1.00	0.00	6.78	-1.21	-5.24	0.25	-0.03	-0.02
189	25	8	69.52	8.97	8.00	0.97	0.00	1.00	0.00	6.73	-1.19	-5.24	0.27	-0.03	-0.01
190	25	9	69.52	8.97	8.01	0.96	0.00	1.00	0.00	6.68	-1.18	-5.24	0.30	-0.02	-0.01
191	25	10	69.52	8.97	8.02	0.96	0.00	1.00	0.00	6.65	-1.16	-5.24	0.32	-0.02	-0.01
192	26	1	69.49	8.98	7.16	1.82	0.00	1.00	0.00	15.05	-1.05	-8.89	0.00	-0.01	0.00
193	26	2	69.50	8.97	7.60	1.38	0.00	1.00	0.00	11.89	-1.05	-8.89	0.00	-0.01	0.00
194	27	1	69.11	9.01	7.79	1.22	0.00	1.00	-0.65	5.77	-1.54	-2.81	0.01	-0.02	0.00
195	27	2	69.15	9.01	7.60	1.41	0.00	1.00	-0.64	3.00	-1.54	-2.81	0.01	-0.02	0.00
196	27	3	69.19	9.01	7.44	1.57	0.00	1.00	-0.63	3.32	-1.54	-2.82	0.01	-0.02	0.00
197	27	4	69.22	9.00	7.31	1.69	0.00	1.00	-0.62	3.57	-1.53	-2.83	0.01	-0.02	0.00
198	27	5	69.25	9.00	7.21	1.79	0.00	1.00	-0.61	3.76	-1.53	-2.83	0.01	-0.02	0.00
199	27	6	69.28	9.00	7.13	1.86	0.00	1.00	-0.60	3.92	-1.53	-2.84	0.01	-0.02	0.00
200	27	7	69.30	8.99	7.07	1.93	0.00	1.00	-0.60	4.04	-1.52	-2.84	0.01	-0.02	0.00
201	27	8	69.33	8.99	7.01	1.98	0.00	1.00	-0.60	4.14	-1.52	-2.85	0.01	-0.03	0.00
202	27	9	69.35	8.99	6.97	2.02	0.00	1.00	-0.59	4.20	-1.52	-2.86	0.01	-0.03	0.00
203	28	1	69.33	8.99	7.33	1.66	0.00	1.00	0.14	7.86	-1.51	-4.68	0.01	-0.03	0.00
204	28	2	69.32	8.99	7.54	1.45	0.00	1.00	0.14	10.74	-1.51	-4.68	0.01	-0.03	0.00
205	28	3	69.30	8.99	7.69	1.30	0.00	1.00	0.14	9.62	-1.51	-4.67	0.01	-0.03	0.00
	28	4	69.29	9.00	7.80	1.19	0.00	1.00	0.14	8.80	-1.51	-4.67	0.01	-0.03	0.00
	28	5	69.28	9.00	7.88	1.11	0.00	1.00	0.14	8.20	-1.51	-4.66	0.01	-0.03	0.00
208	28	6	69.26	9.00	7.94	1.05	0.00	1.00	0.14	7.76	-1.51	-4.66	0.01	-0.03	0.00
209	28	7	69.25	9.00	7.99	1.01	0.00	1.00	0.14	7.44	-1.50	-4.65	0.01	-0.03	0.00
210	28	8	69.24	9.00	8.02	0.98	0.00	1.00	0.14	7.20	-1.50	-4.65	0.01	-0.03	0.00
211	28	9	69.25	9.00	8.07	0.93	0.00	1.00	0.14	6.87	-1.50	-4.65	0.01	-0.03	0.00


DISSOLVED OXYGEN (MG/L)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
135.7
125.7
115.7
105.7
95.7
85.7
75.7
65.7
RIVER MILE



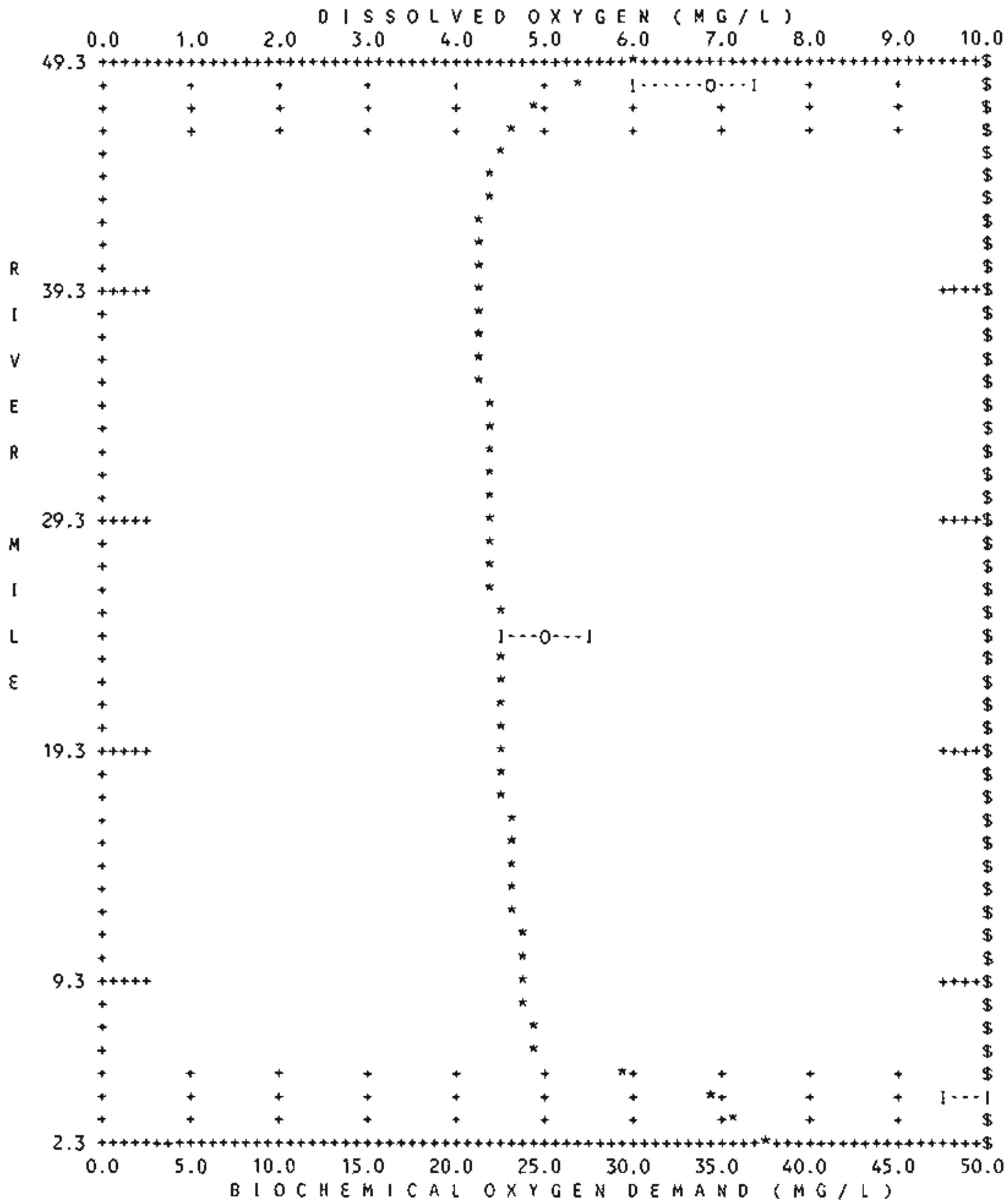
DISSOLVED OXYGEN = * * * *

BIOCHEMICAL OXYGEN DEMAND = ...



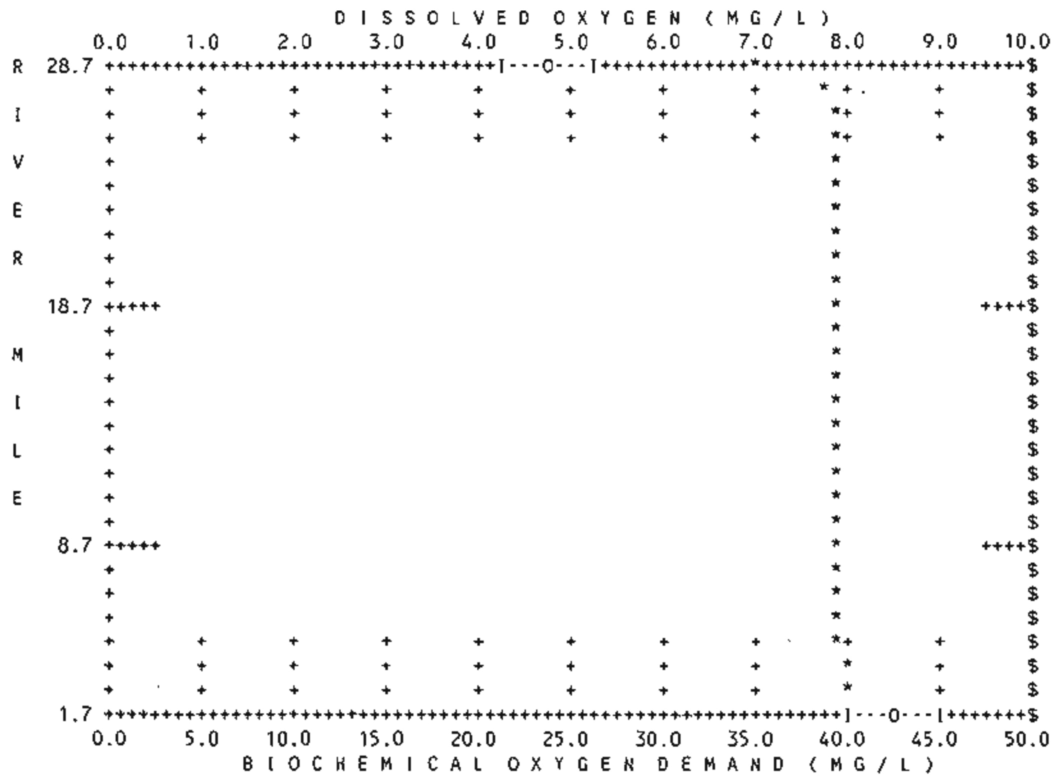
DISSOLVED OXYGEN = * * * *

BIOCHEMICAL OXYGEN DEMAND = ...



DISSOLVED OXYGEN = * * * *

BIOCHEMICAL OXYGEN DEMAND = ...



DISSOLVED OXYGEN = * * * *

BIOCHEMICAL OXYGEN DEMAND = ...

```
                          D I S S O L V E D   O X Y G E N   ( M G / L )
          0.0      1.0      2.0      3.0      4.0      5.0      6.0      7.0      8.0      9.0     10.0
R   3.5 +++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++.+++++++++++*+++++++++++++++++++++
        +         +         +         +         +         +         +   .     +     *   +         +         +
I   1.5 ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++.++++++++++++++*+++++++++++++++++++++++++
          0.0      5.0     10.0     15.0     20.0     25.0     30.0     35.0     40.0     45.0     50.0
                     B I O C H E M I C A L   O X Y G E N   D E M A N D   ( M G / L )
```

```
DISSOLVED OXYGEN          = * * * *

 BIOCHEMICAL OXYGEN DEMAND = . . . .
```

Clearwater Non-Point Polution Project
Hydraulics

SITE	POINT	Q	DEPTH	VELOCITY
Site #1 Clearwater R. SW of Bagley	8/6/92	4	1.85	0.1
	7/23/92	5	2.35	0.12
	7/9/92	21	3.25	0.325
	8/23/92	36	3.6	0.485
Site #2 Clearwater R. E of Bagley	5/1/92	11	3.1	0.1
	5/12/92	14	3.3	0.12
	10/14/92	21	4	0.15
	7/19/92	62	6.6	0.24
	3/31/93	108	5.3	0.58
Site #3 Clearwater R. Near Pinewood	8/6/92	11	0.85	0.625
	7/23/92	15	0.85	0.675
	8/13/92	17	0.8	0.95
	6/30/92	19	0.75	1.175
	7/1/92	39	0.9	1.525
	7/10/92	67	1.25	1.6
	8/31/92	105	1.9	1.95
Site #4 Clearwater R. Upstream of Clearwater Lake	6/30/92	30	1.7	0.425
	8/6/92	27	2.1	0.475
	8/13/92	30	2.1	0.575
	7/23/92	42	1.7	0.675
	7/1/92	70	1.9	0.925
	8/23/92	237	5.7	1.625
Site #6 Clearwater R. @Outlet of Clearwater Lake	8/30/82	22	0.95	0.525
	10/5/84	27	0.85	0.7
	6/23/82	63	1.4	0.925
	6/1/83	82	1.4	1.2
	6/21/83	125	1.7	1.4
	6/23/83	155	1.9	1.5
	6/17/83	170	1.8	1.8
Site #7 Clearwater R. @CR 11	6/17/91	30	1.4	0.55
	8/5/92	32	1.5	0.55
	8/18/92	37	1.4	0.575
	6/10/92	38	1.75	0.625
	6/25/92	47	1.75	0.625
	3/25/92	70	1.4	1.1
	3/3/92	67	1.6	1.05
	3/6/92	78	1.65	1.175
	3/19/92	132	1.8	1.675
	3/12/92	183	2.05	1.85

Clearwater Non-Point Polution Project
Hydraulics

SITE	POINT	Q	DEPTH	VELOCITY
Site #8 Ruffy Brook USGS Gage	8/13/92	1	0.35	0.175
	6/10/92	1	0.35	0.3
	5/11/83	7	0.6	0.8
	4/2/92	7	0.7	0.575
	7/1/92	13	0.8	0.775
	6/18/92	16	0.9	0.9
	7/10/92	17	0.95	1
	7/6/83	19	0.85	1.4
	4/24/92	18	1.05	0.875
	7/8/92	27	1.15	1.125
	8/28/92	52	1.55	1.625
Site #9 Clearwater R. C.R. 5	6/10/92	10	0.5	0.65
	5/7/92	100	1.7	1.75
	10/10/92	195	3	1.85
	9/1/92	300	3.8	2.1
	8/25/92	490	5	2.45
Site #10 Clearwater R. Trail Rd	10/16/90	10	0.7	0.35
	4/8/91	10	0.8	0.35
	4/8/92	30	1	* .875
	4/24/90	30	1.1	0.55
	4/17/87	50	0.9	1.1
	4/23/90	50	1.15	0.625
	6/13/91	30	1.5	0.45
	5/21/87	130	1.7	1.325
	6/26/90	220	3.6	0.875
	5/28/87	490	2.8	2.1
	7/24/87	1420	7.6	2.45
Site #11 Clearwater R. Linder Brg	5/27/92	72	1.3	1.125
	5/25/90	88	1.35	1.225
	6/25/92	95	1.7	1.025
	7/2/92	165	2.4	1.325
	7/27/92	215	2.6	1.6
	7/7/92	315	3.2	2.6
Site #12 Clearwater R. @ Plummer	4/8/91	25	1.3	0.4
	6/14/88	35	2.15	0.275
	5/11/83	77	1.35	0.9
	6/1/83	172	1.8	1.3
Site #14 Lost River @ Oklee	8/10/92	5	2.7	0.075
	4/27/92	45	3	0.4
	9/8/92	75	5	1.175
	8/23/92	395	6.7	1.875

Clearwater Non-Point Polution Project
Hydraulics

SITE	POINT	Q	DEPTH	VELOCITY
Site #15 Hill River	8/7/92	2	0.7	0.125
	7/2/92	12	1.2	0.625
	4/28/92	37	1.35	0.95
	9/3/92	55	1.75	1.025
	8/25/92	92	2.55	1.075
	4/4/80	112	2.35	1.4
	4/1/80	215	3.05	1.95
Site #16 Lost River	7/27/92	25	0.75	0.275
	7/2/92	25	1.25	0.275
	8/27/92	275	3.75	0.95
	7/3/79	925	8.75	1.3
	4/9/79	2825	13.75	2.725
Site #17 Poplar River @ Hwy 92	6/18/92	1	0.65	0.125
	7/2/92	3	1.15	0.125
	7/7/92	5	1.05	0.275
	8/26/92	135	2.85	1.9
Site #18 Clearwater R. @ Terrebarne	8/7/92	150	2.75	0.425
	7/1/81	810	2.65	2.3
	4/2/84	1080	3.15	2.475
	4/26/82	1210	3.35	2.525
	4/9/80	1420	3.8	2.6
Site #20 Clearwater R. @ Red Lake Falls	6/18/92	85	1.35	0.95
	7/8/92	385	2.4	2.3
	4/22/92	615	2.9	2.95
	9/8/92	775	3.2	3.4
	8/23/92	1560	4.35	4.6
Site #21 Walker Brook	8/31/92	5.5	4.4	0.08
	9/23/92	10	4.1	0.16
	7/9/92	19	4.7	0.27
	8/24/92	56	5	0.75
Site #23 C.D. #57	8/27/92	8	1.55	0.28
	9/9/92	12.75	1.55	0.41
	8/25/92	23.75	1.75	0.63
Site #24 Lost River @ Gonvick	7/8/92	1	2.1	0.02
	8/6/92	2.5	2.45	0.05
	6/18/92	19	2.95	0.29
	4/14/92	32	3.2	0.45
	4/27/92	37	3.3	0.5

Clearwater Non-Point Polution Project
Hydraulics

SITE	POINT	Q	DEPTH	VELOCITY
Site #25 Poplar R. N. of McIntosh	8/14/92	1	3	0.01
	5/28/92	8	4	0.07
	9/8/92	30	5	0.2
	8/25/92	119	5.2	0.745

Red Lake Watershed District

PRESIDENT
Richard Dougherty
VICE PRESIDENT
Leonard Moe
TREASURER
Gerhard Ross

102 North Main Avenue
P.O. Box 803
Thief River Falls, MN 56701
(218) 681-5800
(218) 681-5839 FAX

SECRETARY
Russell Sander
MANAGERS
Verner Arveson
Vernon Johnson
Arlan Fore

HDR Engineering, Inc.
DK MLW JWB CTC REE RJV TO PIM FJT
SEP 7 1993
RECEIVED
DEM HOM GLF WMM PEF EAW DRL RSM LML FILE

September 2, 1993

Mr. Mark Deutschmann, Proj. Mgr.
HDR Engineering, Inc.
300 Parkdale 1 Bldg., 5401 Gamble Dr.
Minneapolis, Minnesota 55416-1518

Dear Mark:

The following is the information you requested on Clearwater Lake and river miles points:

Clearwater Lake distance from upstream to downstream = 2.1 miles

Normal Elevation	Area	Storage	Av. Depth	Max. Depth
1274	1020 Acre	28800 AC/FT	28.2'	65

Ruffy Brook confluence with the Clearwater = mile point 78.1

County Ditch #57 confluence with the Clearwater = mile point 37.9

Sincerely,

Dave Fink

Dave Fink

DF:sr

Estimated Storage Volume and Discharge from Commercial Rice Production Along the Clearwater River.

River Mile	Crop Acres	Volume (acre-feet) Related to Depth in Paddy					Flow (cfs) Related to Depth in Paddy				
		6"	12"	18"	24"	30"	6"	12"	18"	24"	30"
58.4	228	114	228	342	456	570	1.9	3.8	5.7	7.7	9.6
59.1	333	166.5	333	499.5	666	832.5	2.8	5.6	8.4	11.2	14.0
59.1	397	198.5	397	595.5	794	992.5	3.3	6.7	10.0	13.3	16.7
59.2	924	462	924	1386	1848	2310	7.8	15.5	23.3	31.1	38.8
59.5	60	30	60	90	120	150	0.5	1.0	1.5	2.0	2.5
60.8	195	97.5	195	292.5	390	487.5	1.6	3.3	4.9	6.6	8.2
61	300	150	300	450	600	750	2.5	5.0	7.6	10.1	12.6
62.7	775	387.5	775	1162.5	1550	1937.5	6.5	13.0	19.5	26.0	32.6
62.7	1000	500	1000	1500	2000	2500	8.4	16.8	25.2	33.6	42.0
64.4	1328	664	1328	1992	2656	3320	11.2	22.3	33.5	44.6	55.8
67.3	1200	600	1200	1800	2400	3000	10.1	20.2	30.3	40.3	50.4
Subtotal	6740	3370	6740	10110	13480	16850	56.6	113.3	169.9	226.5	283.2
70.2	1260	630	1260	1890	2520	3150	10.6	21.2	31.8	42.4	52.9
71.7	1170	585	1170	1755	2340	2925	9.8	19.7	29.5	39.3	49.2
Subtotal	2430	1215	2430	3645	4860	6075	20.4	40.8	61.3	81.7	102.1
78.1	795	397.5	795	1192.5	1590	1987.5	6.7	13.4	20.0	26.7	33.4
78.4	1197	598.5	1197	1795.5	2394	2992.5	10.1	20.1	30.2	40.2	50.3
78.5	1284	642	1284	1926	2568	3210	10.8	21.6	32.4	43.2	53.9
Subtotal	3276	1638	3276	4914	6552	8190	27.5	55.1	82.6	110.1	137.6
Total	21616	6223.0	12446.0	18669.0	24892.0	31115.0	104.6	209.2	313.7	418.3	522.9

Note: Flow in cfs assumes steady discharge during a 30 day period.

Water Quality Characteristics of Water Within Commercial Rice Paddys for Samples Collected July 14, 1993.

Paddy Number	Water Temp (F)	pH	Chemical Oxygen Demand (mg/l)	Nitrate (as N) (mg/l)	Ammonia (as N) (mg/l)	Total Kjeldahl Nitrogen (as N) (mg/l)	Soluable Reactive Phosphorus (as P) (mg/l)	Organic Phosphorus (as P) (mg/l)	Total Phosphorus (as P) (mg/l)	Fecal Coliform Bacteria (No./100 ml)	Total Suspended Solids (mg/l)	Total Volatile Solids (mg/l)
2	64.9	8.0	97	0.004	bdl	1.24	0.034	0.042	0.076	6	18.8	10.0
3	66.4	8.2	89	0.019	bdl	1.18	0.031	0.065	0.096	TNC	22.3	11.5
7	64.6	8.3	62	0.007	bdl	1.22	0.003	0.043	0.046	2	3.8	2.8
9	64.4	7.9	69	0.003	bdl	0.42	0.01	0.035	0.045	336	2.3	2.0
13	64.0	7.8	64	0.024	bdl	1.02	0.007	0.082	0.089	182	3.0	2.3
15	65.3	7.6	89	0.003	bdl	1.96	0.03	0.046	0.076	4	3.8	2.5
24	65.3	7.7	76	0.13	bdl	1.69	0.004	0.027	0.031	2	1.5	1.3
26	66.7	7.8	115	0.004	bdl	1.64	0.212	0.261	0.473	8	15.5	10.3
27	67.1	8.9	83	0.006	bdl	1.52	0.014	0.029	0.043	0	4.0	2.5
30	66.4	7.6	63	0.002	bdl	1.03	0.011	0.054	0.065	300	3.5	2.5
31	66.7	8.3	95	0.003	bdl	1.19	0.018	0.101	0.119	2	12.3	6.5
34	67.1	7.9	91	0.021	bdl	0.96	0.132	0.009	0.141	272	25.3	18.5
36	67.3	7.9	86	0.069	bdl	0.45	0.028	0.061	0.089	20	1.0	1.0
Sample Size	13	13	13	13		13	13	13	13	12	13	13
Min	64.0	7.6	62	0.002		0.42	0.003	0.009	0.031	0	1.0	1.0
Max	67.3	8.9	115	0.130		1.96	0.212	0.261	0.473	336	25.3	18.5
Mean	65.9	8.0	83	0.023		1.19	0.041	0.066	0.107	95	9.0	5.7
Std. dev.	1.1	0.4	16	0.037		0.45	0.061	0.063	0.114	136	8.7	5.4

Notes: Data Source - Dr. Dan Svedarsky, University of Minnesota, Crookston, MN.
bdl means below detection limit.
TNC means too numerous to count. This value excluded from descriptive statistics.

Appendix C

CALCULATIONS AND ASSUMPTION USED TO MODEL BMPS

Estimates of Load Reductions for Total Suspended Solids and Solids Soil Loss.

	Load (kg) During Period Modeled			Estimated Annual Load (kg) (Based on Modeling)			Estimated Load Reduction (kg) (10% reduction)			Estimated Load Reduction (kg) (20% reduction)			Estimated Load Reduction (kg) (30% reduction)			Estimated Load Reduction (kg) (40% reduction)		
	CR-10	CR-11	CR-12	CR-10	CR-11	CR-12	CR-10	CR-11	CR-12	CR-10	CR-11	CR-12	CR-10	CR-11	CR-12	CR-10	CR-11	CR-12
Dissolved Oxygen	734	734	734	73405	73405	73405	7341	7341	7341	14681	14681	14681	22022	22022	22022	29362	28362	29362
Chemical Oxygen Demand	9787	612	40373	978739	61171	4037299	97874	6117	403730	195748	12234	807460	293622	18351	1211190	391496	24468	1614920
Total Suspended Solids	2447	2447	2447	244685	244685	244685	24468	24468	24468	48937	48937	48937	73405	73405	73405	97874	97874	97874
Total Solids (In Stream)	244685	244685	244685	24468480	24468480	24468480	2446848	2446848	2446848	4893696	4893696	4893696	7340544	7340544	7340544	9787392	9787392	9787392
Solids Soil Loss	32624640	2496784	2688844	326246400	249678367	268884396	32624640	24967837	26888440	65249280	49935673	53776879	97873920	74903510	80665319	130498560	99871347	107553758

	Load (ton) During Period Modeled			Estimated Annual Load (ton) (Based on Modeling)			Estimated Load Reduction (ton) (10% reduction)			Estimated Load Reduction (ton) (20% reduction)			Estimated Load Reduction (ton) (30% reduction)			Estimated Load Reduction (ton) (40% reduction)		
	CR-10	CR-11	CR-12	CR-10	CR-11	CR-12	CR-10	CR-11	CR-12	CR-10	CR-11	CR-12	CR-10	CR-11	CR-12	CR-10	CR-11	CR-12
Dissolved Oxygen	1	1	1	81	81	81	8	8	8	16	16	16	24	24	24	32	32	32
Chemical Oxygen Demand	11	1	44	1077	67	4441	108	7	444	216	13	888	323	20	1332	431	27	1776
Total Suspended Solids	3	3	3	269	269	269	27	27	27	54	54	54	81	81	81	108	108	108
Total Solids (In Stream)	269	269	269	26915	26915	26915	2692	2692	2692	5383	5383	5383	8075	8075	8075	10766	10766	10766
Solids Soil Loss	35887	2746	2958	358871	274646	295773	35887	27465	29577	71774	54929	59155	107661	82394	88732	143548	109858	118309
Approximate Area Requiring Treatment (acres) - 25 ton/acre erosion rate							2051	1569	1690	4101	3139	3380	6152	4708	5070	8203	6278	6761
Approximate Area Requiring Treatment (square miles) - 25 ton/acre erosion rate							3.2	2.5	2.6	6.4	4.9	5.3	9.6	7.4	7.9	12.8	9.8	10.6
Approximate Area Requiring Treatment (acres) - 15 ton/acre erosion rate							3418	2616	2817	6836	5231	5634	10253	7847	8451	13671	10463	11268
Approximate Area Requiring Treatment (square miles) - 15 ton/acre erosion rate							5.3	4.1	4.4	10.7	8.2	8.8	16.0	12.3	13.2	21.4	16.3	17.6
Additional Contributing Drainage Area From Upstream Monitoring Location (sq. mi.)							113.8	46.9	56.5	113.8	46.9	56.5	113.8	46.9	56.5	113.8	46.9	56.5
Percentage of Additional Contributing Drainage Area Requiring Treatment							4.7%	8.7%	7.5%	9.4%	17.4%	15.0%	14.1%	26.1%	22.6%	18.8%	34.9%	30.1%

Total suspended solids load for modeled period is 1% of total annual load (from monitoring data).
Total solids estimated assuming total suspended solids is 10% of total solids (approximate - from monitoring data)
Solids soil loss estimated using sediment delivery ratio = 0.31*(drainage area - sq. mi.)^-0.31 (Maidment 1992). Assumed approximate indicator of soil erosion rate.
Approximate area requiring treatment based on erosion of 25 and 15 tons/acre/year and 30% reduction with conservation practices.

HDR

Project: Clearwater BMP Modeling | Computed: MPO | Sheet 1 of 3

Subject: Assumptions Used | Date 5/11

Assumptions Used to Model Bagley Area Load

cfs = 27.0

Temp = 55.0 F

Dissolved O_2 = 1.0

COD = 40.0

Fecals = 275.

TSS = 3.0

NO_3 - N = 0.030

Org. - P = 0.03

Dissolved - P = 0.03

Assumptions Used for 50% Load Reduction

Flow remains @ 27 cfs

Temp " @ 55.0 F

COD decrease by 50% = 20 mg/l

TSS = 1.5

No Change in Nutrients OR FECALS

D.O Increases to 4.0 mg/l

Assumptions Used for 100% Load Reduction

Assume No Flow to River*

HDR

Project	Computed	Sheet 2	Of 3
Subject		Date	

Modeling of Priority Subwatersheds (CR-9, CR-10, CR-11, CR-12, CR-22)

Site 9 is @ downstream end of Rch 10
" 10 " " " " of Rch 12
" 11 " " " " " " 13
" 22 " " " " " Rch 11

<u>FOR REACHES 10, 11, 12</u>

Reach 10 50 cfs incremental inflow
" 11 25 " " "
" 12 39 cfs " "

Leave flows the same reduce Concentrations By 10% etc.

Reach No.

	10	11	12
Temp	65.9	65.9	65.9
D.O.	6	6	6
BOD	80	5	230
TSS	20	20	20
Fecals	150	190	800
Org-N	.005	.005	.005
NH_3	0	0	0
NO_2	0	0	0
NO_3	0	0	0
Org-P	0.	0	0
Dissolved-P	0.01	0.01	0.01

No Temp Change
No nutrient Control
% reduction in COD & TSS
No Fecal Control

Reach 13 has 44 cfs loss of water which is not explained; This will be ignored for purposes of evaluating relative improvement.

Percentage of Annual Load For Respective Months %

	COD	NO3-	NH3	TKN	OP	Org P	TP	TSS	TVS	TDS
CR-1										
JULY	0.92	0.82	0.91	0.89	0.96	0.95	0.95	0.96	0.96	0.88
AUGUST	0.88	0.72	0.84	0.99	0.92	0.93	0.93	0.93	0.93	0.82
CR-2										
JULY	1.25	1.19	0.41	2.20	1.51	2.09	1.77	1.34	1.45	1.02
AUGUST	1.19	1.17	0.60	1.58	1.30	1.64	1.41	1.23	1.27	1.10
CR-3										
JULY	0.40	0.68	0.51	0.26	0.47	0.42	0.45	0.37	0.31	0.54
AUGUST	0.87	0.82	0.91	1.06	0.93	0.96	0.95	0.99	1.03	0.89
CR-4										
JULY	1.35	0.82	1.11	0.85	1.21	1.14	1.17	1.53	1.40	1.03
AUGUST	1.31	0.84	1.10	0.87	1.18	1.13	1.16	1.48	1.36	1.03
CR-6										
JULY	1.22	1.09	1.15	1.62	0.93	1.43	1.30	1.22	1.24	1.13
AUGUST	0.84	0.80	0.81	0.96	0.75	0.90	0.86	0.84	0.84	0.81
CR-7										
JULY	0.82	0.73	0.80	0.77	0.79	0.90	0.86	0.91	0.86	0.80
AUGUST	1.02	0.74	0.96	0.86	0.84	1.27	1.16	1.29	1.16	0.95
RB-8										
JULY	1.02	1.03	0.99	1.14	0.89	1.13	0.99	1.13	1.11	0.93
AUGUST	1.84	1.88	1.76	2.24	1.40	2.19	1.76	2.21	2.14	1.55
CR-9										
JULY	1.68	1.59	1.36	1.66	1.68	1.76	1.72	1.98	1.96	1.35
AUGUST	1.36	1.34	1.28	1.33	1.36	1.38	1.37	1.43	1.43	1.28
CR-10										
JULY	2.36	2.42	2.03	2.66	2.14	2.47	2.24	2.24	2.19	1.98
AUGUST	1.86	1.87	1.75	1.94	1.79	1.89	1.82	1.82	1.80	1.74
CR-11										
JULY	2.40	2.83	1.97	2.41	2.60	2.84	2.61	2.91	2.94	1.97
AUGUST	1.64	1.62	1.47	1.65	1.66	1.62	1.68	1.63	1.64	1.47
CR-12										
JULY	2.22	2.79	1.94	2.42	2.16	2.77	2.39	2.99	2.94	1.89
AUGUST	1.52	1.61	1.47	1.56	1.60	1.61	1.54	1.65	1.64	1.48
CR-13										
JULY	2.27	2.73	1.94	2.27	2.37	2.60	2.41	2.95	2.92	1.90
AUGUST	1.63	1.60	1.47	1.52	1.64	1.56	1.55	1.64	1.63	1.46
LR-14										
JULY	0.68	0.30	0.64	0.29	0.33	0.51	0.42	0.36	0.44	0.56
AUGUST	1.17	1.27	1.19	1.27	1.26	1.20	1.23	1.25	1.22	1.18
HR-15										
JULY	0.16	0.14	0.22	0.07	0.14	0.48	0.21	0.08	0.13	0.24
AUGUST	1.39	1.49	1.10	1.89	1.54	-0.35	1.11	1.85	1.56	0.97
LR-16										
JULY	0.41	0.14	0.44	0.25	0.17	0.26	0.23	0.07	0.15	0.47
AUGUST	1.63	1.74	1.61	1.86	1.72	1.65	1.68	1.80	1.74	1.48
PR-17										
JULY	0.19	0.03	0.19	0.09	0.13	0.48	0.18	0.06	0.08	0.23
AUGUST	1.45	2.15	1.46	1.90	1.71	0.16	1.48	2.05	1.82	1.27
CR-18										
JULY	1.16	1.46	1.14	1.24	1.27	1.35	1.30	1.64	1.60	1.10
AUGUST	1.32	1.66	1.28	1.37	1.40	1.47	1.42	1.62	1.69	1.26
CR-19										
JULY	1.10	1.34	1.08	1.11	1.21	1.21	1.21	13.80	1.34	1.04
AUGUST	1.24	1.47	1.22	1.25	1.36	1.34	1.34	15.02	1.47	1.18
CR-20										
JULY	1.18	1.61	1.15	1.12	1.34	1.33	1.33	1.66	1.48	1.11
AUGUST	1.33	1.60	1.30	1.27	1.46	1.45	1.45	1.64	1.68	1.26
WB-21										
JULY	1.63	2.24	1.48	1.27	1.09	1.73	1.45	1.35	1.46	1.38
AUGUST	2.07	3.09	1.83	1.47	1.15	2.23	1.76	1.69	1.77	1.64
CR-22										
JULY	1.98	2.29	2.27	2.03	2.12	2.22	2.19	2.54	2.43	1.77
AUGUST	1.34	1.36	1.36	1.35	1.35	1.36	1.35	1.42	1.37	1.33
CD-23										
JULY	0.17	0.00	0.20	0.17	0.03	0.07	0.06	0.07	0.13	0.36
AUGUST	2.10	2.71	1.92	2.05	2.31	2.74	2.64	2.46	2.26	1.46
LR-24										
JULY	0.21	0.01	0.21	0.14	0.14	0.13	0.13	0.14	0.14	0.21
AUGUST	1.92	2.15	1.92	2.01	2.00	2.01	2.01	2.00	1.99	1.91
PR-25										
JULY	0.20	0.02	0.20	0.22	0.21	0.12	0.18	0.20	0.19	0.24
AUGUST	1.46	2.23	1.47	1.38	1.45	1.83	1.65	1.46	1.61	1.29

Appendix D

BAGLEY COMPLIANCE MONITORING SURVEY

Minnesota Pollution Control Agency

May 3, 1994

Mr. Mark Deutchman
HDR Engineering
300 Parkdale 1 Building
5401 Gamble Drive
Minneapolis, Minnesota 55416-1518

Mr. David Fink, Project Manager
Clearwater River Nonpoint Source Study
102 Main
Red Lake Watershed District
Thief River Falls, Minnesota 56701

Dear Mark and Dave:

Our discussions of water quality monitoring data generated during the Clearwater River Nonpoint Source Study have given us cause to investigate possible point source impacts on the river in the Bagley area. A routine Compliance Monitoring Survey of the Bagley Municipal Wastewater Treatment Facility was conducted by Jim Courneya, Regional Point Source Water Quality Specialist and myself on April 14, 1994. A copy of the Survey Report and transmittal letter is enclosed for your review and records.

You will note that the Bagley facility is hydraulically overloaded averaging 222,500 gallons per day(gpd) while designed and permitted for only 140,000 gpd. The overloading is primarily the result of excessive groundwater infiltration to the city's sewage collection system and discharges of residential sump pumps to the sanitary sewer. The city will begin a program to reduce infiltration by repairing and replacing sewer mains this year and will begin eliminating sump pump discharges next year. These programs are expected to reduce the hydraulic loading on the wastewater treatment facility but it will not solve the problem entirely.

Further reduction in inflow and infiltration along with consideration of expanded treatment plant capacity. Furthermore, our Water Quality Division staff have been requested to examine the monitoring data in the Clearwater River Nonpoint Study and other historical effluent and stream data to reevaluate the permit effluent limits for the city's discharge.

While at the Bagley plant we examined the cities Discharge Monitoring Reports for discharges, upsets, and bypasses. The following is a chronology of events which may have effected flow and water quality data at sampling location below the city:

Lake Avenue Plaza; Suite 220; 714 Lake Avenue; Detroit Lakes, Minnesota 56501; (218) 847-1519, FAX (281) 846-0719
Central Office: St. Paul Regional Offices: Duluth • Brainerd • Detroit Lakes • Marshall • Rochester

1992- No Bypasses

April - no date - Unauthorized overflow discharge began

April 8-May 24 - Authorized discharge - met effluent limits; Total discharge=32.76 million gallons.

May - City water main flushing - 100,00 gal/day for 1-2 days.
Sept 11 - Authorized discharge 6.7 million gal. Met effluent limits.

Sept. City water main flushing - 100,000 gal/day for 1-2 days.

Sept 30-Nov 15th - Authorized discharge 24.72 million gallons.

1993 -

April 5 - Unauthorized overflow discharge began

April 23-June 12 - Authorized discharge - met effluent limits.
May - (no dates available) Spring hydrant flushing (same rates and duration as above).

Aug 2 - Lift station failure - bypassed .075 million gallons untreated sewage to Clearwater River near treatment plant above U.S. Highway 2 bridge.

Aug 4 - Sewer main break - bypassed 2000 gallons untreated sewage to ditch to Clearwater River near Highway 92 bridge.

Aug 5 - Lift station prescribed bypass needed for repairs - 2 hrs. (no volume estimate).

Sept 1-Oct 20 - Authorized Discharge - Met effluent limits.

Sept (no dates available) Fall hydrant flushing

Other activities in the Bagley area which may have influenced flows and concentrations include the Clearwater County Highway Department destruction of several large beaver dams on the Clearwater River and Walker Brook above Bagley during the summer of 1993. If more specific dates for these activities or if any similar activity occurred in 1992 you could contact the County staff or MDNR staff in Bemidji.

That's the extent of additional information I have available. I hope this will be helpful in calibrating the computer model and understanding the Bagley area water and waste sources during the monitoring period for the Clearwater NPS study. Please feel free to contact me at this office if you have any questions.

Sincerely,

Willis Mattison
Regional Water Quality Specialist
Northwest Regional Office

WM:sb

cc: Jim Courneya, NW Regional Office
Roger Ramthun, Non-Point Section, Water Quality Division, MPCA, St. Paul

Willis

Minnesota Pollution Control Agency

April 18, 1994

The Honorable Steve Beltz
Mayor, City of Bagley
P.O. Box 178
City Hall
Bagley, Minnesota 56621

RE: Bagley Wastewater Treatment Facility
NPDES Permit No. MN0022691
Compliance Monitoring Survey

Dear Mayor Beltz:

Enclosed is a copy of the Compliance Monitoring Survey report which resulted from an inspection of the Bagley Wastewater Treatment Facility conducted on April 14, 1994, by Jim Courneya and Willis Mattison of the Minnesota Pollution Control Agency (MPCA) Detroit Lakes Regional Office in the presence of Mike Monsrud, the facility operator.

The Compliance Monitoring Survey consisted of a visual inspection of the facility and a review of the monthly Discharge Monitoring Reports. Based on the results of the Compliance Monitoring Survey, the facility was found to be in compliance with the terms and conditions set forth in the facility's NPDES permit. Please refer to the attached Inspection Summary.

The system continues to suffer the effects of hydraulic overloading due to excess Inflow and Infiltration (I&I). At the time of inspection, the ponds were full to the point of overflowing the lift gates at the outfall structure. The facility is being operated quite well despite the very challenging conditions present. Mr. Monsrud discussed the city's plans for renovation of parts of the collection system this summer. This should help alleviate some of the excess water problems.

In addition, the south bank of the gully below the outfall pipe requires some attention as soon as possible. This was discussed with Mr. Monsrud and is explained in greater detail in the attached report. Thank you for your efforts to help protect the water resources of northern Minnesota

No further response to this report is necessary.

Lake Avenue Plaza: Suite 220; 714 Lake Avenue; Detroit Lakes, Minnesota 56501; (218) 847-1519, FAX (281) 846-0719
Central Office: St. Paul Regional Offices: Duluth • Brainerd • Detroit Lakes • Marshall • Rochester

MINNESOTA POLLUTION CONTROL AGENCY
COMPLIANCE MONITORING SURVEY

Facility: *Bagley Wastewater Treatment Facility*	Permit Expiration: 06-30-93	Class: D
Address: *City Hall* *P.O. Box 178, Bagley, MN 56621*	Phone: *218-694-2300*	
Responsible Official: *Steve Beltz*	Title: *Mayor*	
Operator: *Mike Monsrud*	Certifications/Expiration: *D, 9-94*	

Transaction Code: *N*	NPDES/SDS #: *MN0022691*	Inspection Date: *04-14-94*
Inspection Type: *C*	Inspector Code: *S*	Facility Type: *1*

Facility Representatives *Mike Monsrud*	Titles *Superintendent of Utilities/Operator*
Inspectors: *Jim Courneya, Willis Mattison*	

AREAS EVALUATED DURING INSPECTION

Collection System	___	Process Control	___	Records	X
Lift Stations	X	Laboratory	___	Reporting	X
Flow Measurement/ Instrumentation	___	Maintenance Program	___	Discharge Monitoring Reports	X
Treatment System	X	Sampling	___	Effluent Data	X
Disinfection	___	Pretreatment	___	Compliance Sched.	___
Dechlorination	___	Solids Handling	___	Other: Disch. struct.	X

Compliance Status: *In compliance*

3. Inspection of the outfall pipe revealed substantial erosion of the steep gully walls leading from the outfall pipe to the Clearwater River. It appeared that during full discharge a cutbank is being formed along the south gully wall. This has the potential to allow washing of large amounts of sediments into the Clearwater river.

Corrective Action: It is recommended that the city repair the cutbank and protect the exposed soil with rock rip-rap to prevent further erosion problems. Recommended methods for completing this were discussed with the operator.

Signature of Inspector Jim Courneya	Date 4/18/94

Comments and questions should be addressed to: *Jim Courneya*

Regional Point Source Specialist
Minnesota Pollution Control Agency
714 Lake Avenue Suite 220.
Detroit Lakes, Minnesota 56501
218-847-0735

Appendix E

METHODS USED FOR STATISTICAL ANALYSIS

BOTTOM LINE

The evidence of effects of most of the predictors within 100 meters of the rivers is very strong – in some cases overwhelming. After adjusting for these effects, there is no evidence of effects of predictors beyond 100 meters.

However, there is much variability in the response variables that cannot be accounted for by the effects of the predictors. Therefore any predicted values of the response variables based on the predictors, including <u>time</u>, DRN, K, ORG, PHOS, SLP, a, HR, CSG, SGR, RCF, CRRE, WWR, Hay, UNPST, OH2O, VEGWE, POW, and UPWB, are not enormously more accurate than simply taking the average values of the response variables to be the predicted values, although they are somewhat more accurate. Specifically, the percentages of variability of each of the five response variables here considered are 48.7%, 54.9%, 33.7%, 44.3%, and 59.2%, for FLDDO, FECAL, TSS, TKN, and TP respectively, after doing the Box-Cox transformations of these response variables as described below.

WHAT WAS DONE

I did a sequential multivariate analysis of variance with five response variables: FLDDO, FECAL, TSS, TKN, and TP, and eighteen predictors: DRN, K, ORG, PHOS, SLP, a, and the twelve compositional predictors: HR, CSG, SGR, RCF, CRRE, WWR, Hay, UNPST, OH2O, VEGWE, POW, and UPWB. The five response variables were transformed by Box-Cox transformations (discussed below) before doing this analysis. Before looking at effects of the eighteen predictors named above, the Box-Cox transformed response variables were adjusted for seasonality.

The adjustment for seasonality was done as follows. "Time" was defined to be YR–92+(MO/12)+(DAY/366), thus it was the number of years since the starting point. Then cos1 was defined to be cos(2π(time)); sin1 was sin(2π(time)); cos2 was cos(4π(time)); sin2 was sin(4π(time)); and so on until cos8 was cos(16π(time)) and sin8 similarly. The Box-Cox transformed response variables were regressed on cos1, sin1, cos2, sin2, ... , cos8, sin8. The residuals from this regression were the seasonally adjusted response variables. All response variables referred to below were seasonally adjusted.

The seasonally adjusted response variables were regressed on the "100-meter" predictors: DRN100, K100, ORG100, PHOS100, SLP100, a100, HR100, CSG100, SGR100, RCF100, CRRE100,, WWR100, Hay100, UNPST100, OH2O100, VEGWE100, POW100, UPWB100. This was a "regression through the origin". This means that no constant term was estimated. This is important because some of the predictors are compoistional – they are nonnegative and their sum is 1. We cannot simultaneously increase or decrease all of them, yet the estimated constant term would purport to tell us what effect that kind of increase or decrease would have on the response variables, and that would be nonsense.

The fact that this was "sequential" means that the significance of each predictor was assessed only _after_ taking the previous predictors into account. A consequence of this is that (1) a predictor may appear significant if taken into account before the others, but not if taken into account after the others, or (2) vice-versa. For example, (1) if there were a substantial correlation between two predictors then it may be that either would be significant if taken into account before the other, but not significant if taken into account after the other, and (2) alternatively, a response variable may depend on the _difference_ between two predictors A and B, so that neither A nor B alone is worth anything by itself, but A and B together are useful. In that case A would not appear significant before B, but A would appear significant after B, and likewise B would not appear significant before A, but B would appear significant after A.

For each predictor there is a null hypothesis that states that that predictor is unrelated to the response variables and hence useless as a predictor of the response variables. A test statistic was computed for each of the predictors. The test statistic in each case was unlikely to have a large value if the null hypothesis was true. If the value of the test statistic in a particular case was 4.7, and if the probability that it would equal or exceed 4.7 was only 3% if the null hypothesis were true, then the "p-value" associated with that predictor was 3%. If the p-value is only 0.00001%, then we would have strong evidence against the null hypothesis, since the probability that the test statistic is so large would be very tiny if the null hypothesis were true. On the other hand, if the p-value is 40%, no one would call this significant – there would be no evidence compelling us to reject the null hypothesis.

So: small p-value <———> significant
large p-value <———> not significant

How small is small is a rather subjective matter. Often one draws the line at 5%. If one is more cautious about rejecting null hypotheses, one might draw the line at 1%.

Below we see p-values for the eighteen predictors, each measured within 100 meters of the rivers: (scientific notation is used for very small numbers: 5.1487e–07 is 5.1487 times ten to the minus seventh power, i.e. 0.00000051487.)

DRN100	0.0051032	
K100	5.1487e–07	
ORG100	0	
PHOS100	0.0043811	
SLP100	0.55952	<——NOT SIGNIFICANT
a100	0	
HR100	0.05955	<——marginally significant
CSG100	0.00013917	
SGR100	0.016672	
RCF100	2.3137e–07	
CRRE100	0.38916	<——NOT SIGNIFICANT
WWR100	1.9677e–10	
Hay100	3.5414e–09	
UNPST100	1.9257e–10	
OH2O100	1.8261e–12	<——overwhelmingly significant
VEGWE100	8.4563e–08	
POW100	1.7541e–09	
UPWB100	0.14978	<——NOT SIGNIFICANT

Now SLP100 is not significant if it appears _after_ the four predictors listed above it. Below we change the order in which the predictors appear. SLP100 now precedes the others, and now appears significant. This can happen because SLP100 is correlated with two of the other non-compositional predictors. (There is a 91% positive correlation between SLP100 and DRN100, and a 76% negative correlation between SLP100 and PHOS100.) We have also brought CRRE to the front of the list of compositional predictors and it still is not significant.

SLP100	0.0051096	<——significant now
DRN100	0.4297	<——NOT SIGNIFICANT
K100	7.3749e–07	
ORG100	0	
PHOS100	0.079232	<——no longer highly significant
a100	0	
CRRE100	0.21038	<——STILL NOT SIGNIFICANT
HR100	0.04785	<——lower p-value, so a bit more significant
CSG100	0.00024897	
SGR100	0.034705	
RCF100	1.6792e–07	
WWR100	1.9677e–10	
Hay100	3.5414e–09	
UNPST100	1.9257e–10	
OH2O100	1.8302e–12	
VEGWE100	8.4563e–08	
POW100	1.7541e–09	
UPWB100	0.14978	<——NOT SIGNIFICANT

UPWB becomes significant if it is taken into account _before_ the other compositional predictors:

SLP100	0.0051096	
DRN100	0.4297	<——NOT SIGNIFICANT
K100	7.3749e–07	
ORG100	0	
PHOS100	0.079232	
a100	0	
UPWB100	1.2797e–08	<——SIGNIFICANT NOW
CRRE100	0.012834	
HR100	0.020585	
CSG100	0.083585	<——much higher p-value than before – perhaps no longer significant
SGR100	0.035391	
RCF100	1.4049e–11	
WWR100	1.6111e–11	
Hay100	1.3686e–06	
UNPST100	1.341e–06	
OH2O100	1.4719e–12	
VEGWE100	0.0045627	
POW100	5.2847e–09	

Below we look a "coefficients". The number 3.2424 in under "FECAL" and to the right of SLP100 means that a one-unit increase in SLP100 corresponds to a 3.2424-unit increase in (transformed) FECAL. Likewise a one-unit increase in DRN100 corresponds to a 1.4933 _decrease_ in (transformed) FECAL, and so on. These quantities do not depend on the order in which the predictors appear. How to know the actual effect on the _untransformed_ value of FECAL is addressed later in this report.

(Box-Cox transformed)-->	FLDDO	FECAL	TSS	TKN	TP
SLP100	–0.9715	3.2424	–0.69731	0.0023789	–0.0015008
DRN100	1.0787	–1.4933	0.51581	0.004518	0.0045135
K100	0.059411	2.3984	–0.10933	–0.023433	–0.024113
ORG100	–0.27867	2.2102	0.061842	0.035838	0.015369
PHOS100	0.26796	–0.62236	–0.16219	–0.008042	–0.0014016
a100	0.83446	1.8051	–0.19514	–0.014756	–0.0046548
UPWB100	0.34592	–46.45	2.5115	–0.047459	0.050776
CRRE100	–1.8972	–35.551	5.2996	0.10547	0.09103
HR100	3.6794	9.7706	–0.26473	–0.11878	0.057239
CSG100	–14.045	124.04	5.846	0.25961	–0.06234
SGR100	4.4123	–70.615	–4.3331	0.034482	–0.056868
RCF100	46.825	412.68	–28.186	0.83046	0.58603
WWR100	8.3202	–138.24	3.387	–0.45349	–0.18188
Hay100	7.3909	–164.66	10.57	–1.2208	–0.37187
UNPST100	–11.743	–50.439	13.478	–0.41507	–0.1641
OH2O100	0.59671	–414.08	–14.171	–0.23142	–0.16785
VEGWE100	–6.3655	–6.2628	3.0701	–0.082204	0.060938
POW100	–25.555	104.71	–2.1491	0.067686	0.051271

If we want to decrease FECAL, should we do this by decreasing SLP, or by increasing DRN, or [. . . . etc. . . . .]? The answer to this may depend on what is practicable, and on whether causal connections exist (e.g. would decreasing SLP cause DRN to decrease too? They are positively correlated.). Suppose we note that a 1-unit increase in UNPST corresponds to a 11.743 unit decrease in transformed FLDDO. Is this because increasing some _other_ predictor makes FLDDO decrease _and_ makes UNPST increase? If so then changing UNPST might have no effect on FLDDO – we would only be altering the symptom and not the cause. These sorts of causal connections cannot be inferred from the numbers in this table alone. Such inferences of causality may depend on knowledge of chemistry or other things.

HOW TO GET PREDICTED VALUES OF THE _UN_TRANSFORMED RESPONSE VARIABLES is a question that is addressed below at the end of the section that deals with Box-Cox transformations.

EFFECTS OF CONDITIONS FARTHER FROM THE RIVERS

Next we consider whether the effects of predictors within 400 meters, 800 meters, etc. from the river are significant _after_ adjusting for predictors within 100 meters of the river. That was done by taking the _residuals_ from the multivariate regression above to be the _response_ variable in a multivariate regression in which the _predictors_ are DRN400, K400, ORG400, PHOS400, SLP400, a400, HR400, CSG400, SGR400, RCF400, CRRE400, WWR400, Hay400, UNPST400, OH2O400, VEGWE400, POW400, UPWB400, and likewise for 800, 1200, etc. Here are the p-values for 1200 meters:

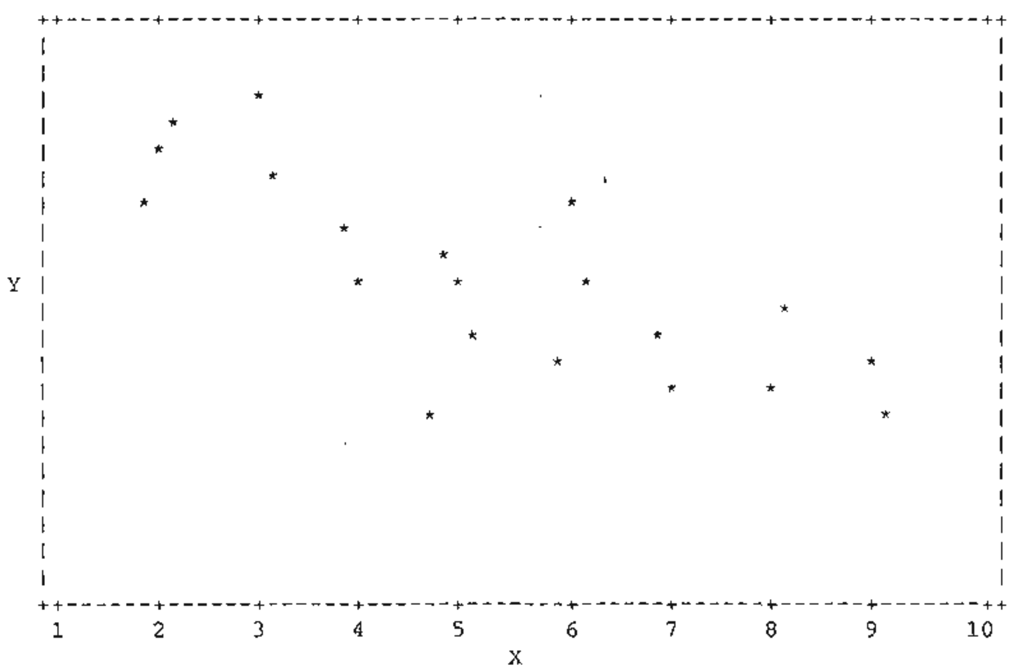
DRN1200	1	HR1200	0.99756
K1200	1	CSG1200	0.72131
ORG1200	0.99993	SGR1200	0.99491
PHOS1200	0.99999	RCF1200	0.99911
SLP1200	0.99947	CRRE1200	0.98753
a1200	0.95767	WWR1200	0.95488
		Hay1200	0.87205
		UNPST1200	0.52495
		OH2O1200	0.97849
		VEGWE1200	0.96621
		POW1200	0.41468
		UPWB1200	0.84266

None of these p-values comes anywhere nears being significant. Indeed what is striking about them is that they are so close to 1. One does not expect this if the predictors are wholly unrelated to the response variables – it is what might happen if someone were deliberately trying to make it look as if there were no correlation and overdid it. However in this case there is a simple explanation: DRN100 is highly correlated with DRN1200, and K100 with K1200, etc. (Three of these correlations exceed 98% and eight of them exceed 90%. All of them exceed 64%.) This is not surprising in view of the way these predictors are defined – rather it would be surprising if they were not highly correlated. For the record here are those correlations:

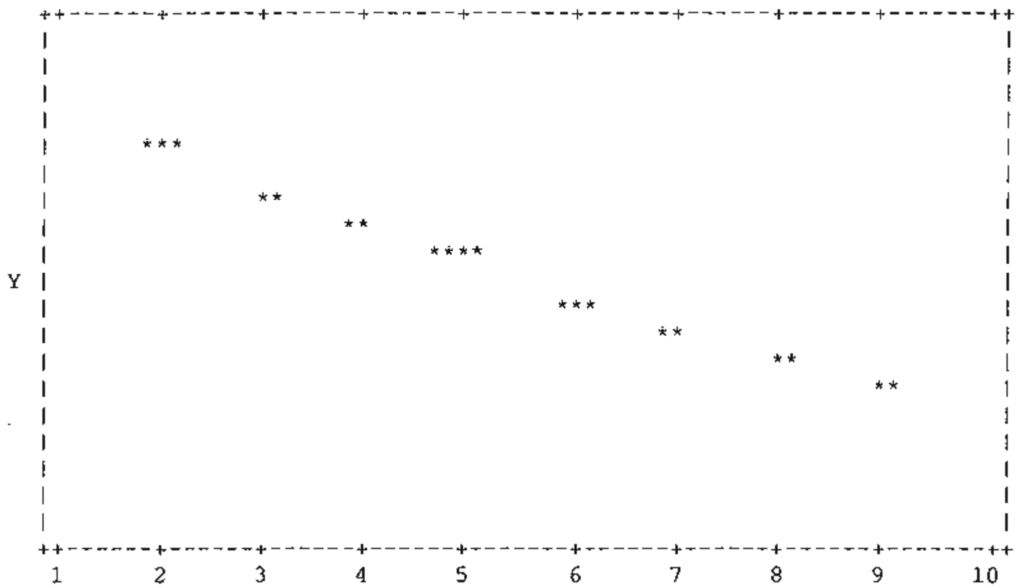
Between	SLP100	and	SLP1200	0.96303
Between	DRN100	and	DRN1200	0.99162
	K100		K1200	0.94852
	ORG100		ORG1200	0.97273
	PHOS100		PHOS1200	0.95787
	a100		a1200	0.85245
	UPWB100		UPWB1200	0.64733
	CRRE100		CRRE1200	0.8741
	HR100		HR1200	0.68297
	CSG100		CSG1200	0.89431
	SGR100		SGR1200	0.92561
	RCF100		RCF1200	0.9845
	WWR100		WWR1200	0.98635
	Hay100		Hay1200	0.70787
	UNPST100		UNPST1200	0.75158
	OH2O100		OH2O1200	0.75436
	VEGWE100		VEGWE1200	0.80132
	POW100		POW1200	0.80568

WHAT IS "MULTIVARIATE" ANOVA?

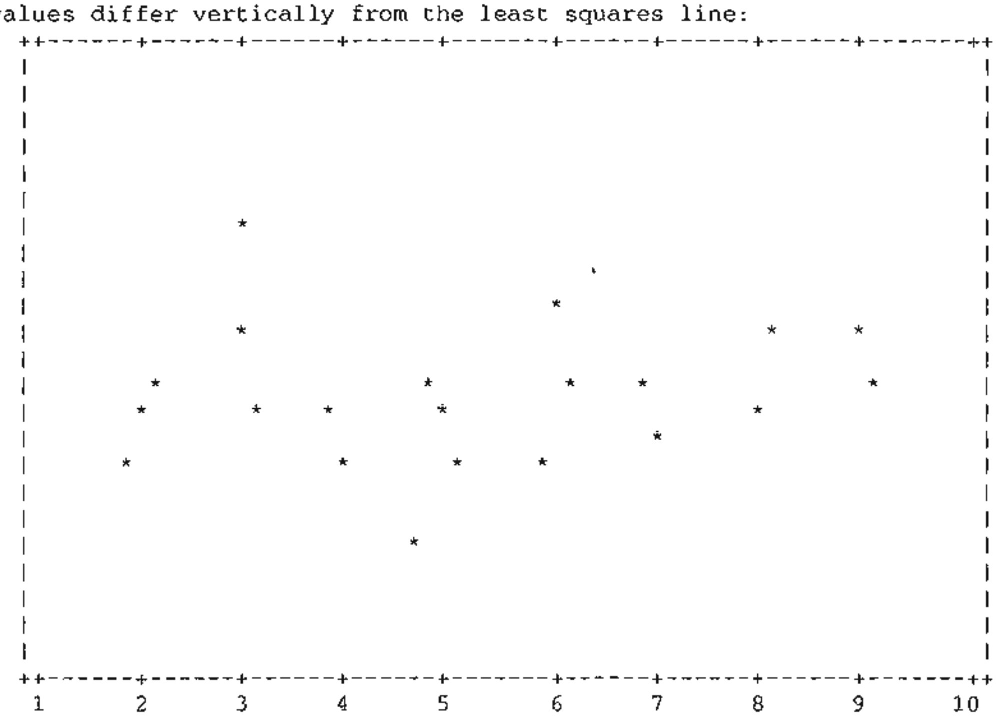
Consider an ordinary linear regression problem in which Y is the response variable and X is the predictor:



Let $\overline{Y}$ be the mean observed value of Y and look at the sum of $(Y - \overline{Y})^2$, where Y runs through all of the observed values of the response variable. This is the "total sum of squares" that measures how much variability there is in the response variable; it is a quantity to which we assign (n-1) degrees of freedom, where n is the number of cases (n=20 in the example depicted here). Now project each of the points in the scatterplot vertically onto the least squares line so that they fall on a perfectly straight line (pardon the imperfections of the graphical techniques used here):



With _this_ scatterplot compute the corresponding sum of squares - this is the "sum of squares due to regression". This measures how much of the variability in the response variable is "explained" by the predictor. To this we assign just one degree of freedom. Finally look at the residuals - the amounts by which the observed Y-values differ vertically from the least squares line:



With _this_ scatterplot compute the corresponding sum of squares - this is the "sum of squares due to error". This measures how much of the variability in the response variable is "not explained" by the predictor. To this we assign (n-2)=18 degrees of freedom. Now we can construct an ANOVA table:

	DF	SS	MS
REGRESSION	1	222.780	222.78
ERROR	18	40.702	2.261
TOTAL	19	261.482	

and based on this we can do a hypothesis test of the null hypothesis that the slope based on the whole population is zero, and we can construct a confidence interval for the slope based on the whole population.

This is a _univariate_ ANOVA table. Now imagine that we have _two_ response variables rather than just one. We can construct two separate univariate ANOVA tables, or we can construct one bivariate anova table. What is the difference? In fact we would use exactly the same least squares estimates of the two slopes and of the two intercepts, and we would get exactly the same residuals as if we had done the two separately. What is different is the confidence intervals and the hypothesis tests. In the first illustration above the slope of the least squares line, which we take to be an estimate of the slope of the line that would be based on the whole population, is negative. Suppose it is -0.2. We could construct a 90% confidence interval centered at -0.2 for the slope of the line that would be based on the whole population. Suppose this turns out to be the interval (-0.24, -0.16). Likewise we could have a 90% confidence interval for the slope of the other line. Suppose this turns out to be the interval (1.3, 1,8), centered halfway between 1.3 and 1.8 at 1.55. What would a confidence region for the pair of slopes look like? We could plausibly imagine it looking like this circular disk centered at the point (0.2,1.55), but that treats the two estimates of slope as uncorrelated. Information about correlation between the two cannot be obtained from doing the two anova problems _separately_. If we do a bivariate anova then we may find that the two are correlated, and then we may get a confidence region that looks like the graph below.

```
                |           ^
                |           |
                |           |
                |           |
                *           +1.8
          *     |     *     |
                |           |
 --------*------*------*-------+1.55------
                |           |
          *     |     *     |
                *           +1.3
                |           |
                |           |
                |           |
                |           |
    -0.24      0.2   -0.16  |
 -+------+------+------+------+-------+-+-----+------+------+-------+---->
                |           |
                |           |
                |           |
```

```
               |             ^
               |             |
               |             |
        * *    |             |
      *        *             +1.8
      *        |   *         |
               |             |
--------*------*------*------+1.55------
               |             |
           *   |        *    |
               *        *    +1.3
               |     **      |
               |             |
               |             |
               |             |
      -0.24   0.2   -0.16    |
-+------+------+------+------+------+------+------+------+-------+---->
               |             |
               |             |
```

If this confidence region were longer and thinner, i.e. if there were even more correlation between the two estimate of slope, it might actually include the origin. If a 90% confidence region for the pair of slopes includes the point (0,0) then we would not reject the null hypothesis that the two slopes are both 0 when testing at the 10% level. Thus we might not reject this null hypothesis when doing a bivariate anova even though we would reject it when doing two univariate anovas separately.

The opposite of this can also happen -- there are circumstances in which we would _not_ reject the two separate null hypotheses of zero slopes when doing two separate univariate anovas but we would reject the null hypothesis that the pair of slopes is (0,0) when doing bivariate anova. This can come about as follows:

```
                        ^
                        |
                 *      |
           *           *|
         *              |*
        *               | *
                        |
       *         *      |  *
                        |
        *               | *
---------*--------------+*------------->
           *           *|
                 *      |
                        |
```

Here we have a confidence region for the pair of slopes. The confidence region includes the origin (0,0), so we would not reject the null hypothesis that the two slopes are 0.

```
                        ^
                        |
                        |
                        * *
                    *   |    *
                 *      |     *
              *         |     *
                        |
          *             |    *
                        |
       *         *      |  *
                        |
     *                  *
------------------------+--------------->
    *               *   |
    *            *      |
     *        *         |
        * *             |
                        |
```

Here we have a different confidence region for the pair of slopes. This confidence region does not include the origin, even though it is still centered at the same point and the univariate confidence intervals that would have resulted from doing the two anovas separately would have been the same as in the case above. This time we do reject the null hypothesis. The information about correlation between the two slope estimates would not have been available if we had done the two anovas separately.

The observed correlations between the residuals from regressing the five seasonally adjusted response variables on the "100-meter" predictors are as follows:

	FLDDO	FECAL	TSS	TKN	TP
FLDDO	1	-0.11627	-0.086746	0.055626	-0.0088996
FECAL	-0.11627	1	0.061343	0.0091766	0.11064
TSS	-0.086746	0.061343	1	0.013105	0.28579
TKN	0.055626	0.0091766	0.013105	1	0.068336
TP	-0.0088996	0.11064	0.28579	0.068336	1

Among these the big one is about 29% between TSS and TP. There are 341 nonmissing cases. The probability of a correlation as large as 0.28579 or larger in a scatterplot that comes from a random sample for a population in which the two variables plotted are _independent_ (and hence uncorrelated) and normally distributed, with a sample size of 341, is only about 8/100,000,000 so we can safely reject the hypothesis that these populations are uncorrelated. The 11.6% correlation between FLDDO and FECAL is significant at the 3.2% level.

The computation of test statistics in multivariate anova, and their probability distributions (and hence p-values), are discussed in Christopher Chatfield's and A. J. Collins' "Introduction to Multivariate Analysis", chapter 8. Formula (8.19) on page 148 was used.

Here is a terse summary. In univariate anova one has a sum of square due to regression SSreg, which is defined as $\sum_i (\hat{y}_i - \bar{y})^2$ and a sum of squares due to error SSE, defined as $\sum_i (y_i - \hat{y})^2$. The test statistic for the null hypothesis of no effects of a predictor is F=(SSreg/d.f.)/(SSE/d.f.), where d.f. is the appropriate number of degrees of freedom and will in general be different in the numerator from what it is in the denominator. This test statistic will have an F distribution (see any book on regression and/or anova) if the null hypothesis is true. If we are doing sequential anova the each predictor will have an SSreg associated with it, which comes from regression on that predictor of the _residuals_ from fitting the data to the earlier predictors In multivariate anova, suppose we have two response variables y and w. Then for each predictor we get an SSreg: $\sum_i (\hat{y}_i - \bar{y})^2$ in one case and $\sum_i (\hat{w}_i - \bar{w})^2$ in the other. But in addition to sums of _squares_ due to regression, we get a sum of _products_ due to regression: $\sum_i (\hat{y}_i - \bar{y})(\hat{w}_i - \bar{w})$. If we have several response variables, we have an SSreg for each response variable and an "SPreg" – a sum of products due to regression, for each _pair_ of predictors. Thus a symmetric matrix H. In the present study H is a 5x5 matrix – a separate 5x5 matrix for each predictor. Likewise we have a 5x5 matrix R of sums of squares and sums of products due to _error_. Following the notation of Chatfield and Collins we let $\Lambda = \frac{|R|}{|H + R|}$ where the "absolute value sign" means "determinant".

Our test statistic for each predictor will be $F = \left(\frac{1-\Lambda}{\Lambda}\right)\left(\frac{323-5+1}{5}\right)$. The number "323" is the d.f. for error in this anova. The "5" in both the numerator and denominator is the number of response variables. NOTA BENE: This formula for the test statistic is valid only for predictors with 1 d.f. (and therefore valid for each of the predictors we are considering). If the null hypothesis is true then this test statistic has an F distribution with 5 numerator degrees of freedom and 323–5+1 denominator degrees of freedom. This tells us how to compute p-values: (1) compute the value of the test statistic, getting some number, (2) compute the probability that a random variable with an F-distribution with 5 and 323–5+1 d.f. exceeds that number. This probability is the p-value.

BOX-COX TRANSFORMATIONS and ADJUSTMENTS FOR CENSORING

Ordinary linear regression and analysis of variance presuppose that the "errors" -- the amounts by which observed values of the response variables differ from their conditional expected values given the values of the predictors, are independent and normally distributed with the same variance. That is not the case with the response variables in this problem. What is frequently done in this situation, (and what is appropriate in this case) is to use Box-Cox transformations.

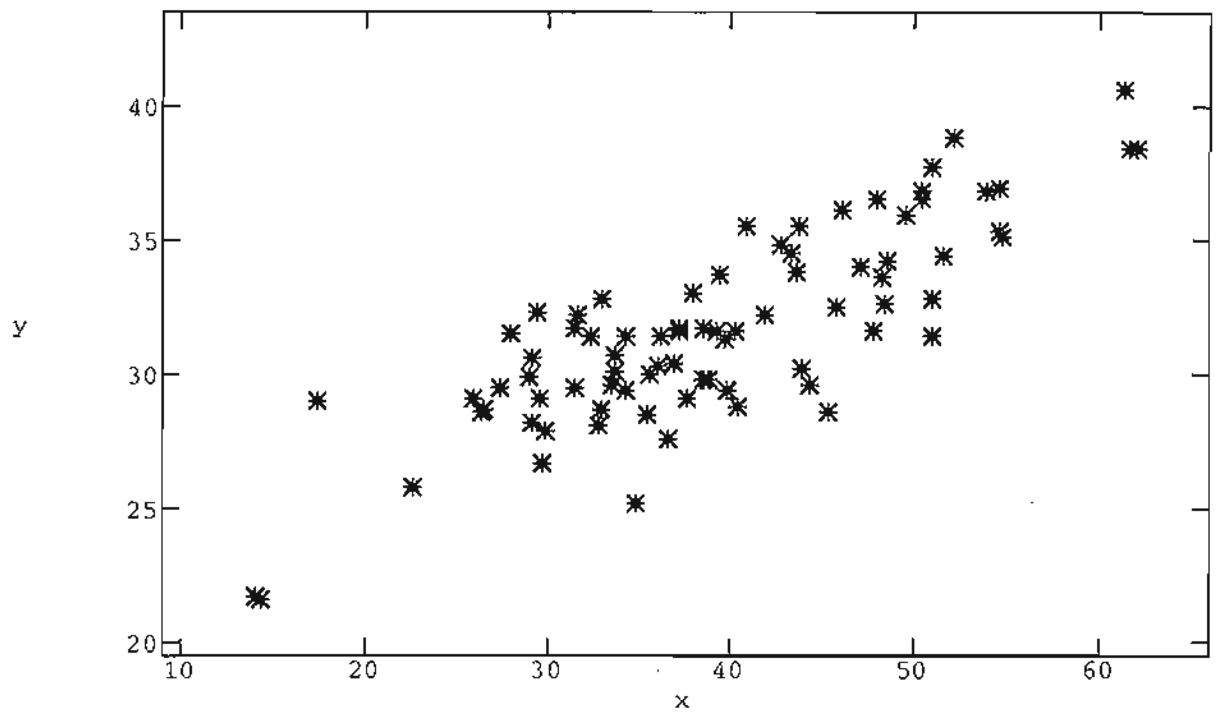
These are defined as follows: let $(y_1, y_2, y_3, \ldots, y_n)$ be the vector of values of one of the response variables. Let p be a real number – the Box-Cox parameter. This can be positive, negative, or 0. Then the Box-Cox transformation with parameter p of the vector $(y_1, y_2, y_3, \ldots, y_n)$ is a vector – let us call it $(w_1, w_2, w_3, \ldots, w_n)$ -- such that for i = 1, 2, 3, . . . , n, we have $w_i = \frac{(y_i^p - 1)}{pG^{p-1}}$ where G is the geometric mean of $(y_1, y_2, y_3, \ldots, y_n)$ i.e., G is the nth root of the product $y_1 y_2 y_3 \ldots\ldots y_n$. Once we have done this transformation, we use $(w_1, w_2, w_3, \ldots, w_n)$ as the response variable. The problem of assessing significance of predictors is then no different from what it would have been if we had simply raised each entry $y_1, y_2, y_3, \ldots$ to the power p (or in case p=0, if we had taken logarithms to get $w_1=\log(y_1)$, $w_2=\log(y_2)$, etc. The reason, then for subtracting 1 and dividing by pG^{p-1} is that when we do this, the residual sums of squares we get on regressing the response variable $(w_1, w_2, w_3, \ldots, w_n)$ on the predictors are measured in the same units regardless of the value of p. This makes it possible to judge what is the best value of p by choosing the value of p that gives the smallest residual sum of squares.

This is what would be done with these predictors if we were doing separate univariate anovas. In the multivariate setting, the sum of squares of residuals is replaced by the determinant of the matrix R defined above in the section on what multivariate anova is. Recall that R play a role analogous to that of the sum of squares due to error in univariate anova. R is the matrix of sums of squares and sums of products due to error. We have a separate "p" for each response variable, and we want to chose the "p's" so as to minimize the determinant of the matrix R.

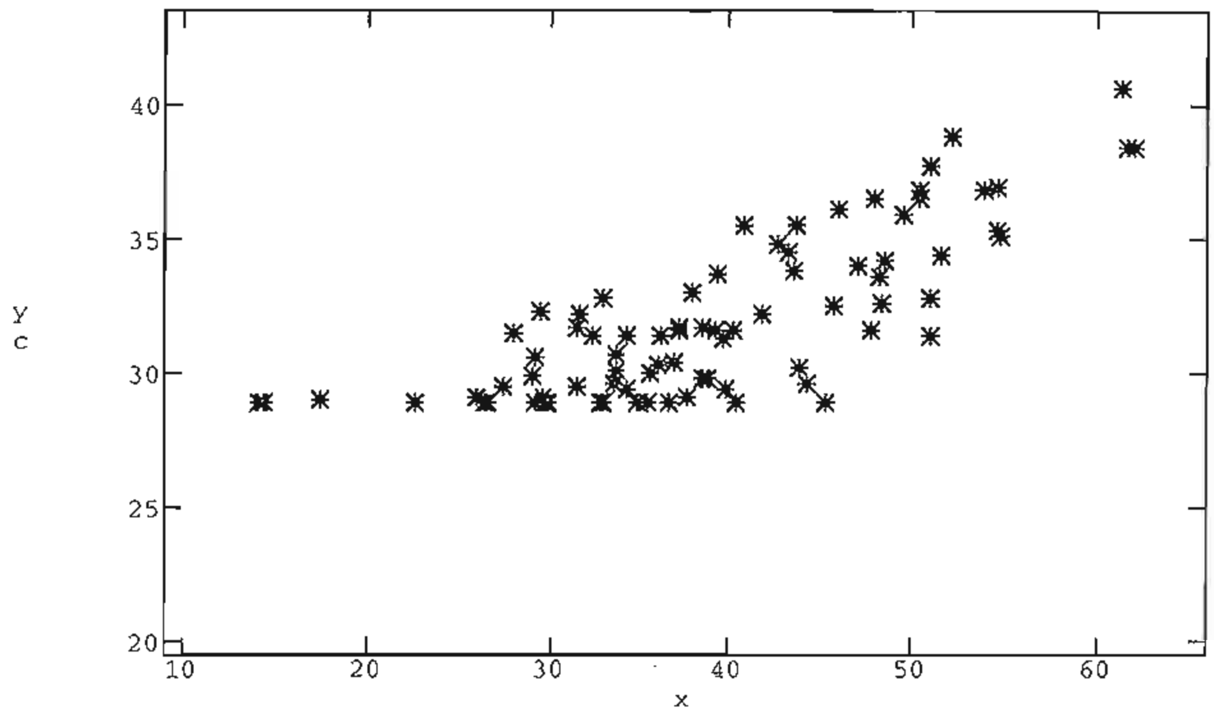
What was done about censoring had to be intertwined with what was done about Box-Cox parameter estimation, and this fact is one reason why I did not finish this report much earlier.

In thinking about censoring first consider the case where we have a univariate normally distributed response variable y and a single predictor x. Imagine that if y falls below a certain point it gets censored, so that what is reported is that y is below that point C, but not _how_far_ below. We can do something like this: as a first approximation take y to be equal to C when it gets censored. Then regress y on x. By the usual methods we get an estimated conditional variance of y given x – just an average of the squares of the residuals. We also get an estimated conditional expected value of y given x – just the height of the regression line above the x-axis at the particular value of x – the predicted y for a given value of x. Given the mean and the variance of y we can find the conditional expected value of y given that y is less than C. Specifically, if Y is normally distributed with mean μ and standard deviation σ, then $E(Y \mid Y < C)$ is $\mu - [\, \sigma\, \phi((C-\mu)/\sigma) \,/\, \Phi((C-\mu)/\sigma) \,]$, where ϕ and Φ are respectively the density and cumulative distribution functions of a standard normal random variable. Replace y by the appropriate conditional expected value (we get different values of μ in different cases because the x's are different!), and take this to be the second approximation. _Then_ regress y on x again, estimate the means and variances again, take conditional expected values again, to get a third approximation. This process converges after a few iterations.

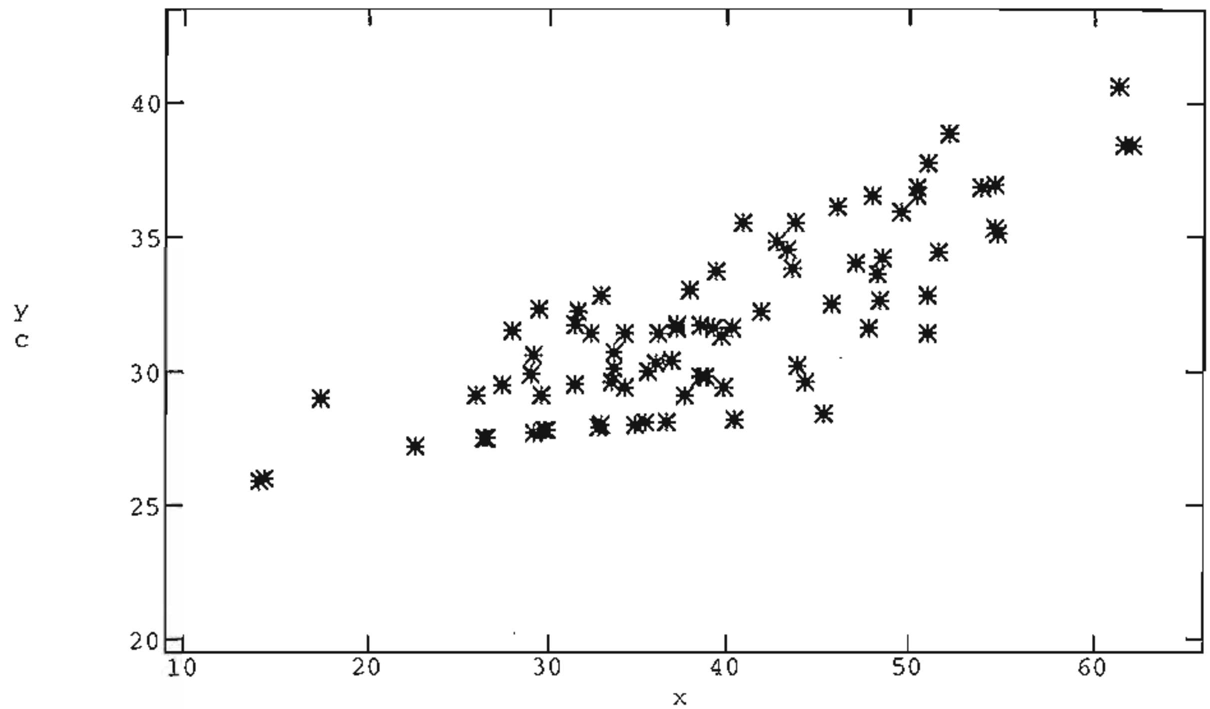
Here is an illustration of this idea with a concrete example consisting of a small (and fake) data set. We have 80 points in a scatterplot. Some of the y values are less than 29:



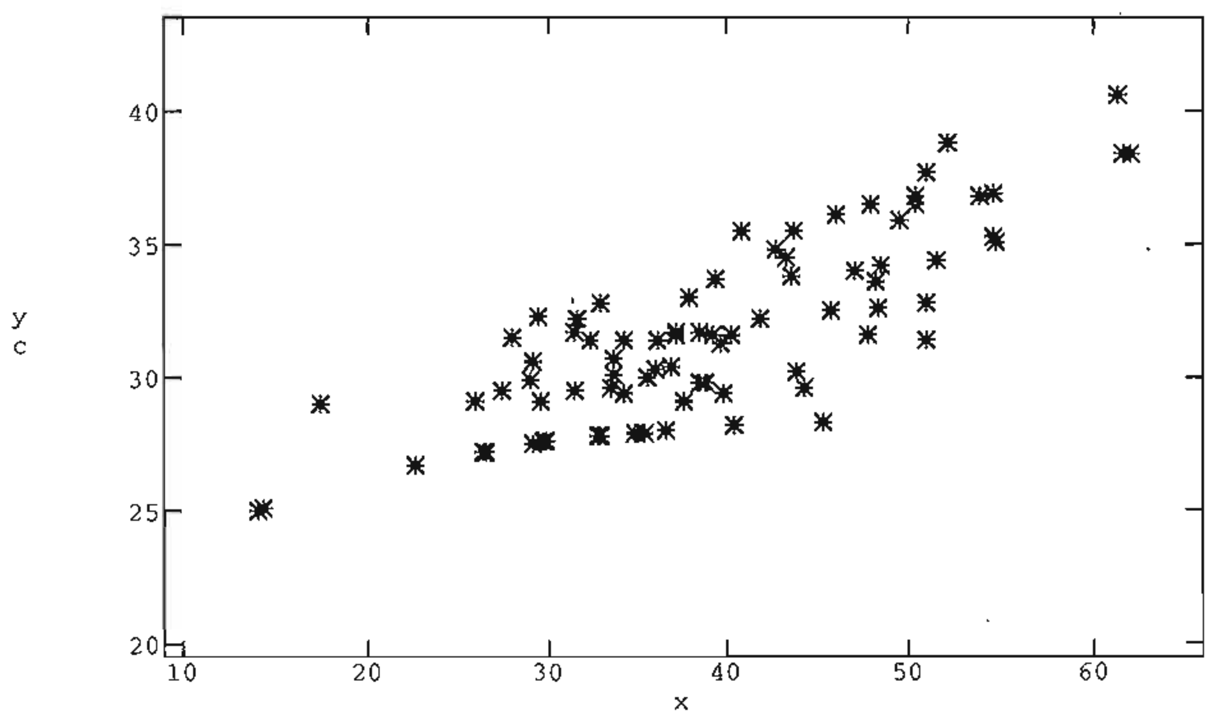
Suppose y values less than 29 get censored so they are reported as 28.9. When we see a y value of 28.9 we know that the actual y value was less than 29, but we don't know what it was. The graph of this censored data then looks like this:



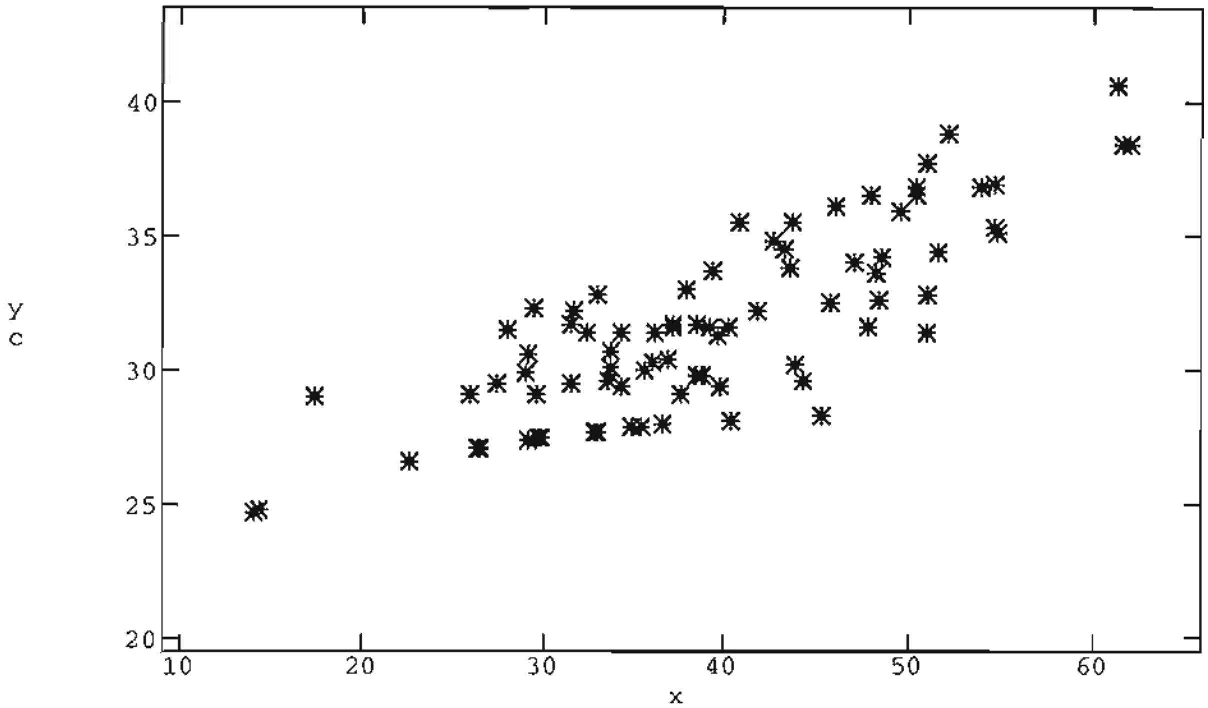
We now fit the least squares line, and in the usual way we come up with an estimate of the error variance and an estimated conditional expected value of y given x. We replace each censored point with a point whose y coordinate is the conditional expected value of y given (1) the value of x, and (2) the fact that the y-value is less than 29. This gives us a graph that looks like this:



We fit the least squares line again, then alter the censored points again in the same way, but with the new fitted line:



And we iterated the process several times. It converges fairly quickly to this:

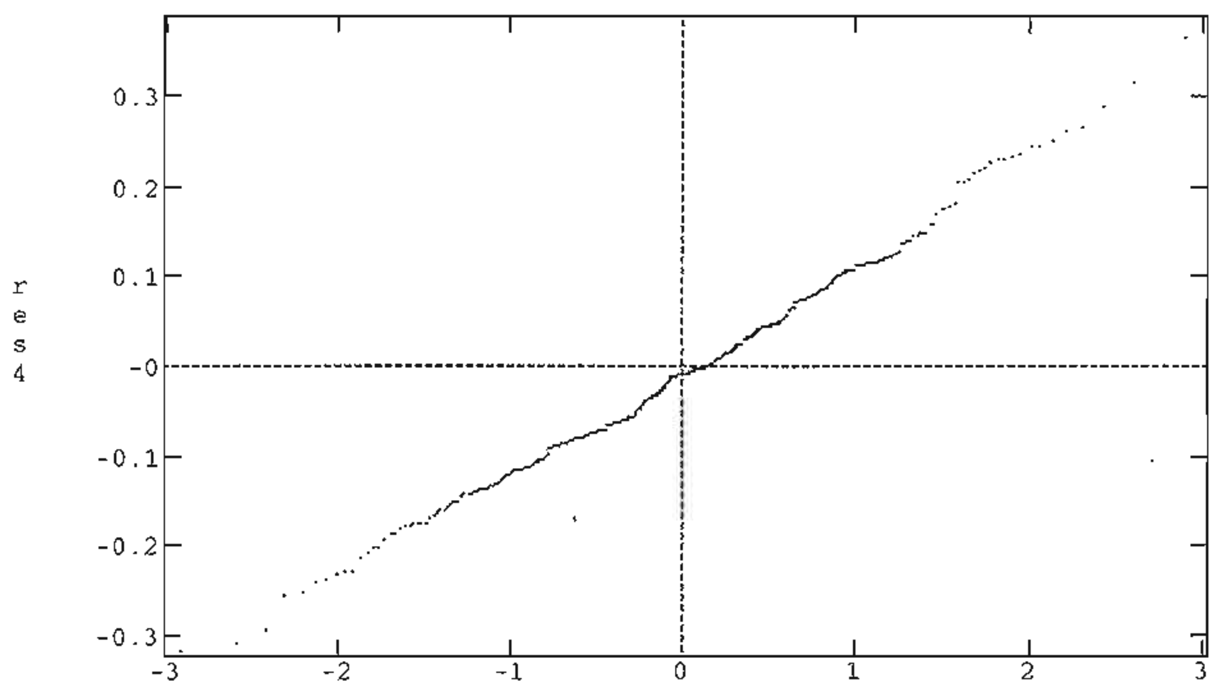


I did only univariate versions of this with different response variables separately. I regressed each response variable on the "100-meter" predictors after adjusting for seasonality. The highest correlation among response variables after adjusting for predictors was about 0.29, between TSS and TP, and the only one of the response variables in which this algorithm made drastic changes was TKN. I ended up doing this with only two of the response variables, TSS and TKN. In the others the changes would have been negligible (in particular there was no sign of censoring of FLDDO). I considered attempting a multivariate analog of this algorithm. It turns out that the multivariate analog of the formula $E(Y \mid Y < C) = \mu - [\sigma \phi((C-\mu)/\sigma) / \Phi((C-\mu)/\sigma)]$ is horrendously complicated and involves infinite series of Hermite functions, and I could not do it without spending enormously more time than that available, so I did the next best thing. The adjustment of TKN for censoring allowed a great reduction of the determinant of R, from about 5.1e+12 to about 1.23e+12, thus a much better fit.

This iterative process had to be done _separately_ for different proposed values of Box-Cox parameters in order to see which one gave the smallest value of the determinant of R.

The estimated Box-Cox parameters p ended up being (1.16, 0, −0.36, −1.4, 0.04) for FLDDO, FECAL, TSS, TKN, and TP, in that order.

After these adjustments for censoring and Box-Cox transforms the response variables did appear to be normally distributed. Normality was assessed by "rankit plots" (also called normal probability plots.) Rankits are expected values of "order statistics" of a random sample from a standard normal distribution. Suppose $X_1, \ldots, X_n$ are drawn independently from a standard normal population and _then_ sorted into increasing order. The expected value of the smallest one is –1.7394, and of the second smallest is –1.245, and of the third is –0.94578, ... we get a list of fifteen numbers: –1.7394, –1.245, –0.94578, –0.7137, –0.51499, –0.33489, –0.16512, 0, 0.16512, 0.33489, 0.51499, 0.7137, 0.94578, 1.245, 1.7394. In a rankit plot these "rankits" are plotted on the x-axis. The sorted observed values are plotted on the y-axis. For large samples, if the population is normally distributed the resulting rankit plot will almost certainly look approximately like a straight line; if the population is not normally distributed it will look like some other curve. The residuals from regression of the censoring-adjusted and Box-Cox transformed TKN on the "100-meter" predictors after adjusting for seasonality gave a rankit plot that looked like this:



This is very "normal-looking". So were the residuals from the other four response variables, and so were many linear combinations of residuals from the five predictors. (Normality of distributions of _linear_combinations_ of random variables is the essence of "multivariate normality", which is the assumption underlying the validity of the hypothesis testing methods of multivariate anova.) The only perceptible deviation from normality was in case number 311, where FECAL was censored because the value was below the detection limit.

The predictors predicted a much larger value of FECAL in that case. Consequently there was a large negative residual. This showed up in the rankit plot as a point at the extreme left edge of the graph that was well below the line formed by the other points.

HOW TO GET PREDICTED VALUES OF THE _UN_TRANSFORMED RESPONSE VARIABLES. If w is the transformed response variable and y is the untransformed response variable, then recall that $w = \frac{(y^p - 1)}{pG^{p-1}}$, and this is equivalent to $y = (1 + pG^{p-1}w)^{\frac{1}{p}}$. Consider the case where the transformed response variable is w=transformed FLDDO. In this case we have p=1.16. Above we give a set of coefficients. Now we need not only the coefficients given above but also the coefficients for cos1, sin1, cos2, sin2, . . . , cos8, sin8, and the constant coefficient. We get: w= –99.062–172.79*cos1+2.0617*sin1–105.58*cos2– . . . . –16.201*sin8–0.9715*SLP100 +1.0787*DRN100+ . . . . . . –25.555*POW100. The constant coefficient and the "time" coefficients used here are as follows:

CONSTANT	–99.062
cos1	–172.79
sin1	2.0617
cos2	–105.58
sin2	–43.232
cos3	–97.121
sin3	–127.06
cos4	–145.75
sin4	–200.77
cos5	–170.02
sin5	–211.53
cos6	–126.91
sin6	–153.16
cos7	–56.933
sin7	–71.075
cos8	–11.446
sin8	–16.201

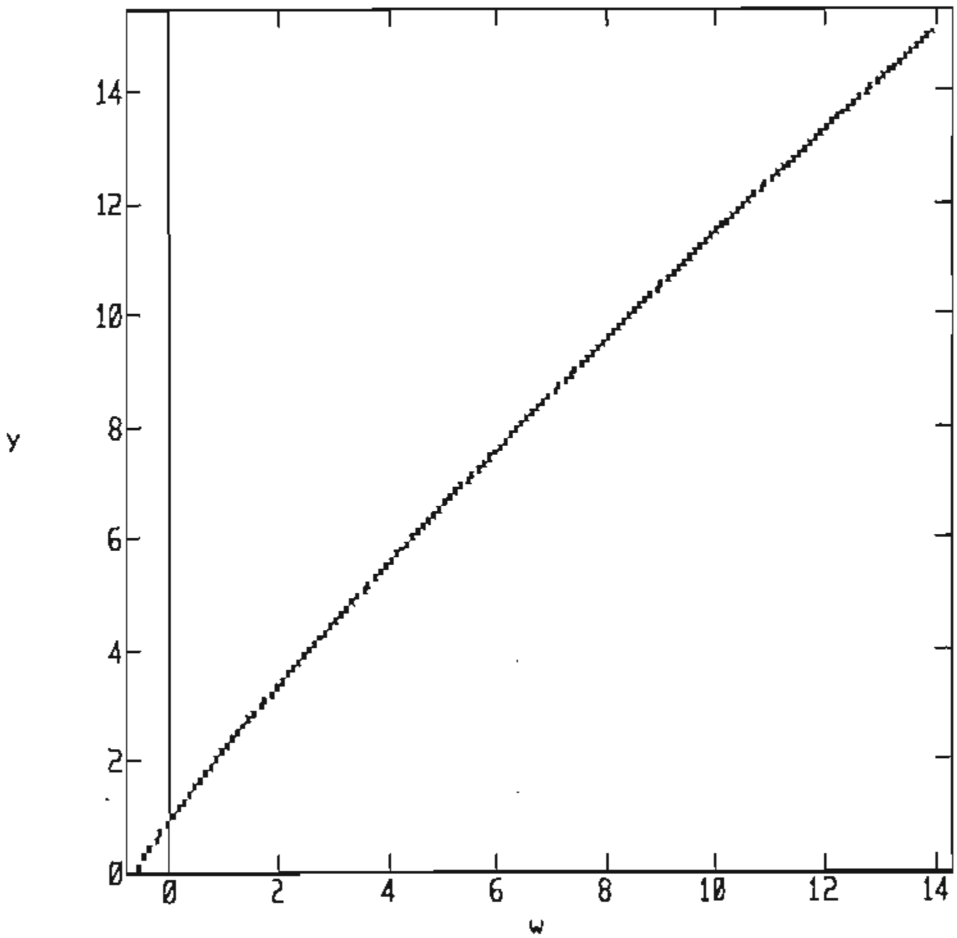
and the coefficients of SLP, DRN, ... , POW are as given in the earlier section where we deal with coefficients. Having ascertained the value of w for given values of the predictors we get y, which is the untransformed predicted value of FLDDO, by plugging our value of w into the formula $y = (1 + pG^{p-1}w)^{\frac{1}{p}}$. This of course requires us to know the values of p and G. For FLDDO p is just 1.16, the Box-Cox parameter given above. The value of G in this case is the geometric mean of the values of FLDDO that were used. It comes to G=7.5271. Here are the "time" coefficients and the values of G for the five response variables:

	FLDDO	FECAL	TSS	TKN	TP
CONSTANT	-99.062	-7711.5	-442.44	42.431	-1.2999
cos1	-172.79	-13399	-753.75	70.78	-1.8223
sin1	2.0617	-2075.2	-79.198	1.7514	0.050441
cos2	-105.58	-9810.4	-526.48	45.959	-1.0658
sin2	-43.232	-4462.9	-230.2	18.409	-0.37509
cos3	-97.121	-9758.1	-508.54	42.25	-0.89945
sin3	-127.06	-8457.8	-496.59	50.8	-1.344
cos4	-145.75	-12393	-677.22	60.022	-1.476
sin4	-200.77	-13434	-792.48	80.267	-2.1571
cos5	-170.02	-12270	-706.71	68.509	-1.8697
sin5	-211.53	-16397	-924.65	86.368	-2.2595
cos6	-126.91	-7265.8	-456.54	50.71	-1.4461
sin6	-153.16	-13816	-748	64.614	-1.602
cos7	-56.933	-1965	-157.15	22.777	-0.71286
sin7	-71.075	-6983.2	-365.48	30.453	-0.64228
cos8	-11.446	-64.549	-20.706	4.8979	-0.19672
sin8	-16.201	-1587.1	-79.468	6.7287	-0.089188
G	7.5271	37.263	3.3453	0.20475	0.057794
p	1.16	0	-0.36	-1.4	0.04

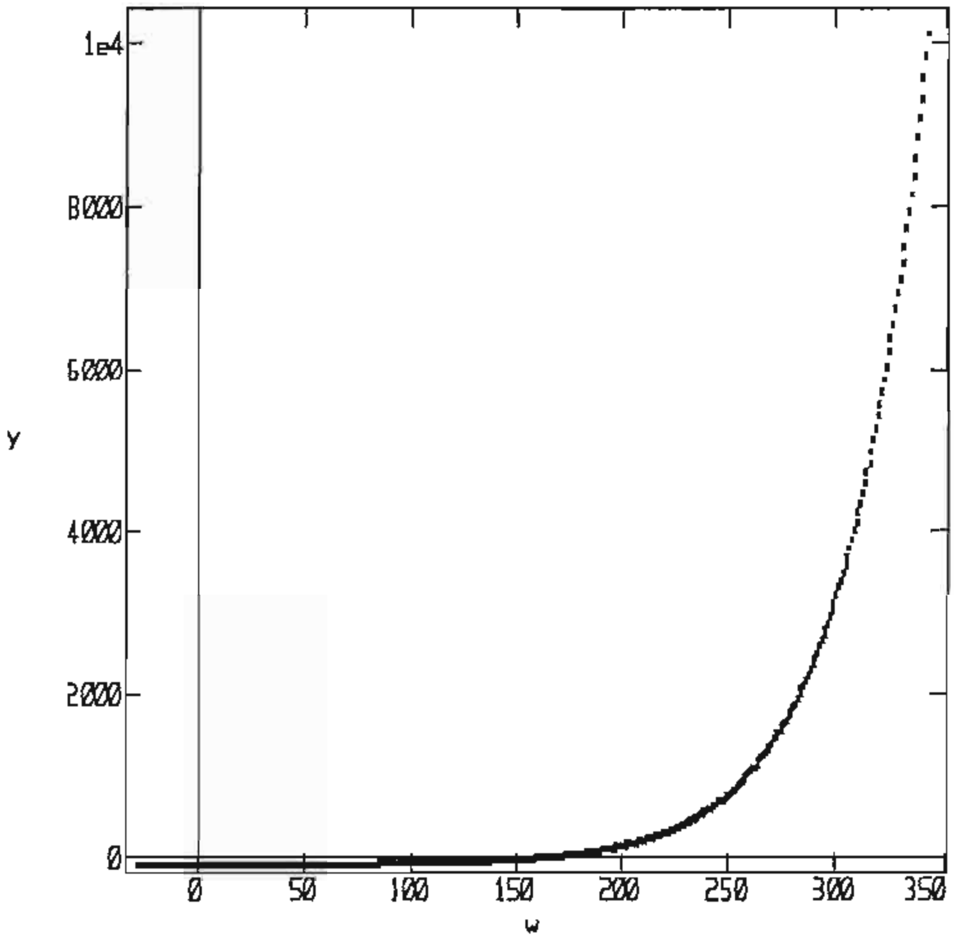
In one of these cases p is 0. When p=0, the two formulas given above for w as a function of y and y as a function of w are no longer valid. Instead we have: w=G log(y) (since $\frac{y^p - 1}{pG^{p-1}} \longrightarrow G \log(y)$ as $p \longrightarrow 0$), and $y = e^{\frac{w}{G}}$. (By "log" I mean of course _natural_ logarithm.)

It is also useful to know the derivative dy/dw. If we know that dy/dw=5 for a certain value of w, then that means that y is changing five times as fast as w at that point. From this we deduce that a small change in w results in a small change in y that is five times as big. However, if we make the "small" change in w very large, this doesn't work any more, since we may move w to a place in its range where, e.g., y is changing 22 times as fast as w. The derivative is $\frac{dy}{dw} = G^{p-1}(1 + pG^{p-1}w)^{\frac{1}{p}-1}$. In the case where p=0, we have $\frac{dy}{dw} = \frac{1}{G}e^{\frac{w}{G}}$. Below we see graphs of w=value of transformed response variable versus y=value of <u>un</u>transformed response variable for each of the five response variables.

For FLDDO, we have p=1.16 and G=7.5271:

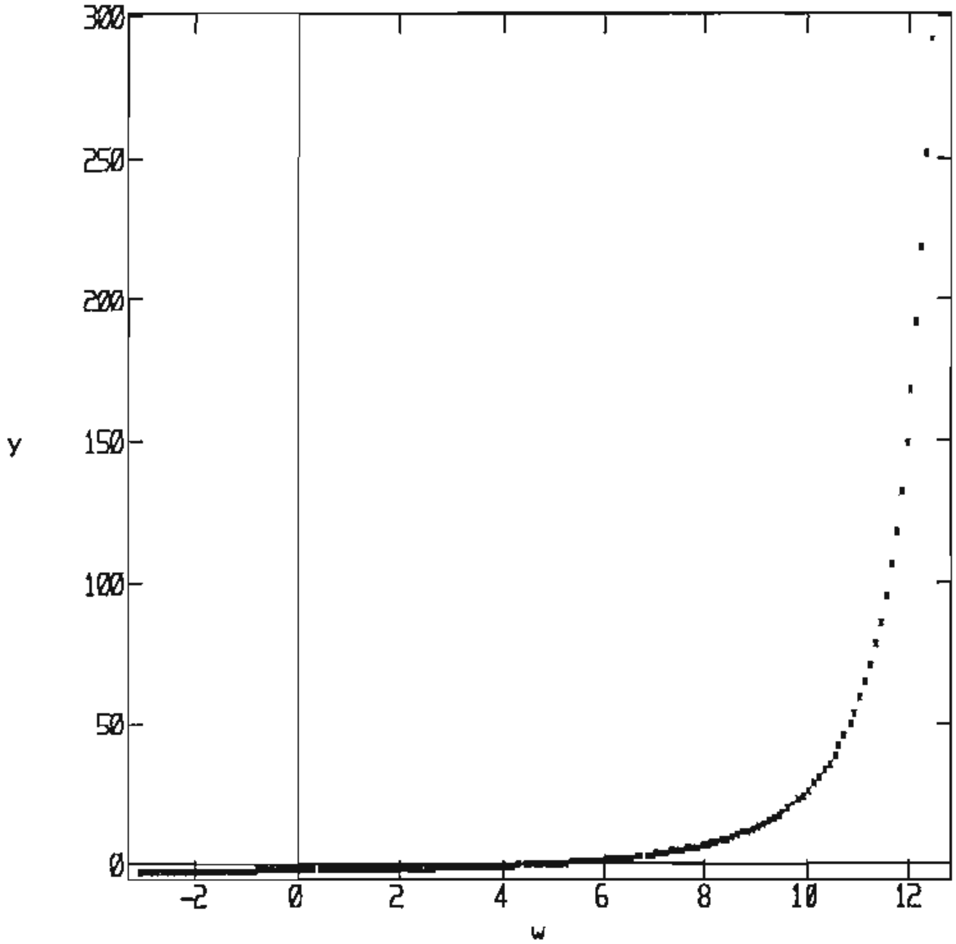


For FECAL we have p=0 and G=37.263:

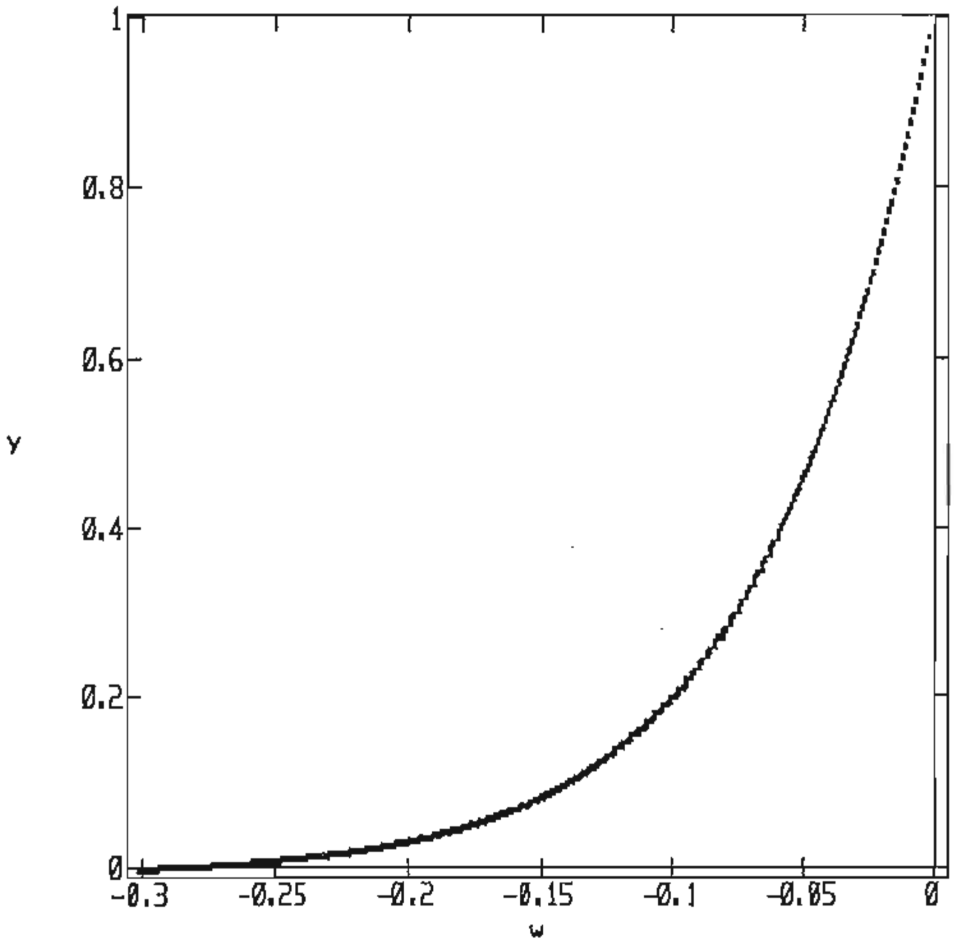


(There appears to be a flaw in the graphical technique – the y value does not actually go below 0, but approaches 0 as w approaches minus infinity.)

For TSS we have p=–0.36 and G=3.3453:



For TP we have p=0.04 and G=0.057794:



Appendix F

PUBLIC EDUCATION SURVEY RESULTS

____

(Name of Organization)

SURVEY

Desired Uses of the Clearwater River; Existing Problems, Issues

Please fill out the brief survey that is enclosed here. Your response will help us protect the water quality of the Clearwater River.

1. Desired Uses. For the purposes of this project, the Clearwater River has been divided into three segments: Reach #1 - from the confluence with the Red Lake River at Red Lake Falls upstream to the channelized section; Reach #2 - generally the channelized section of the river; and Reach #3 - that area from approximately Clearwater Lake to the beginning of the river upstream from Bagley.

It is proposed that all three sections of this river support a broad range of uses, and that all should be <u>fishable and swimmable</u>. To do this, the standards for dissolved oxygen, fecal coliform bacteria, and total suspended solids that are listed in the attached information sheets should be met. However, in Reach #2, the fishery would not be self-sustaining. According to DNR, a self-sustaining fishery would require that meanders would have to replace the channelized section of the river which would be very expensive. Rather, what is proposed for Reach #2 is that the fish habitat be improved, but not be self-sustaining, because of the cost.

In Reach #3, not only should the reach be fishable and swimmable, but the 11 mile designated stretch of trout stream within this area should also be self-sustaining. This will require some improvement in the fish habitat in this stretch, including the reduction of the loading of sediment on the stream bottom in this area.

1a. Generally, do the desired uses that are proposed make sense for each reach of the river?

_____ Yes _____ No

Comments: ____

____

1b. Do you agree that fish habitat should be improved in Reach #2, but that the fishery should not be self-sustaining because of the cost?

_____ Yes ______ No

Comments: ____

____

1c. Is it agreed that the fishery for trout should be self-sustaining on Reach #3?

_____ Yes ______ No

Comments: ____

____

2. **Problems Identified.** From the diagnostic work completed over the last two years, several problems have been identified on each part of the river. In Reach #1, several locations do not meet TSS and dissolved oxygen standards, and two stations occasionally do not meet fecal coliform standards. The likely cause of these problems are upstream water quality degradation, runoff from agricultural land, and feedlots.

2a. Do you agree with the problems and the likely causes as stated in the summary sheets that are attached.

_____ Yes ______ No

If not, please explain: ____

____

____

2b. Have we missed any problems?

_____ Yes ______ No

If yes, please explain: ____

____

____

In Reach #2, the identified problems were similar to those in Reach #1: TSS and DO levels exceeded standards on several occasions, and fecal coliforms levels exceeded standards in at least one instance. Causes include runoff from a variety of agricultural uses, including row crops, pasture land, wild rice, feedlot runoff, and a variety of erosion problems.

2c. Do you agree with the problems and the likely causes as stated in the summary sheets that are attached?

_____ Yes _____ No

If not, please explain: ____

____

____

2d. Have we missed any problems?

_____ Yes _____ No

If yes, please explain: ____

____

____

In Reach #3, problems included TSS and DO levels that exceeded standards. The TSS standards were exceeded largely as a result of natural conditions in the upstream portions of this river, as well as a few other erosionary sources. The DO levels were exceeded largely as a result of the loading of the Bagley sewage treatment facility. There was also evidence of some sandbed loading in the segment that is designated as a trout stream, and there appears to be excessive nutrient loading, and/or retention in the Clearwater Lake.

2e. Do you agree with the problems and the likely causes as stated in the summary sheets that are attached?

_____ Yes _____ No

If not, please explain: ____

____

____

2f. Have we missed any problems?

_____ Yes _____ No

If yes, please explain: ____

____

____

* * * * * *

Thank you very much for your help on this survey. Please return this in the self-addressed, stamped envelope that is provided for your use.

32 Surveys sent out
12 received

1. DESIRED USES

1a. Generally, do the desired uses that are proposed make sense for each reach of the river?

Yes 12

No

Of course in the future you can explore options for Reach #2 and you may decide to do some things with that reach.

How much money does a 200 - 300 acre waterway warrant spending on questionable improvements?

The exception maybe the self-sustaining aspect of trout stream designation.

1b. Do you agree that fish habitat should be improved in Reach #2, but that the fishery should not be self-sustaining because of the cost?

Yes 11

No 1

As long as it can maintain adequate quality without making it self-sustaining.

Could be more self-sustaining just by digging dip holes periodically.

At this point yes. Always try to leave future doors/options open for consideration.

But only if it can be done at a reasonable cost. Reasonable to me would be less than $10,000.

No. Perhaps there are things which rice growers could try which could improve the fishing.

1c. Is it agreed that the fishery for trout should be self-sustaining on Reach #3.

Yes 10

No 1

No. Improvement for now because of the cost.

But is should be explained why the trout area is worth making it self-sustaining and not Reach #2. Is just the cost? or is a trout area of more value? Some people may wonder.

Does the word on mean all of reach 3? I think it is only in part of reach 3 now.

If the cost is reasonable.

Possibly. Didn't know this was a trout stream. Are the costs manageable.

It is partially self-sustaining now, but needs stocking.

Makes sense!

Only if it can be done cheap. How many trout fisherman use this river? We've got to be realistic. If the people wanting these improved conditions had to pay for some of this I don't think much money would be spent.

Only a portion of reach #3.

2. PROBLEMS IDENTIFIED.

2a. Do you agree with the problems and the likely causes as stated in the summary sheets that are attached.

Yes 10

No 1

Has the discharge from the Plummer Sewage lagoon been checked?

No. I don't feel we can say that agriculture is the problem at this point.

They are reasonable. It seems to me that a public facility such as Bagley Sewage treatment facilities should be a priority to correct, especially since it is upstream of other sites.

Needs to be fixed if economically feasible.

Maybe not entirely upstream. Seems to me I recall reading in the final report that some problem areas along reach 1 existed along reach 1.

The year the testing was done was unusual that a drought was followed by excessive rain giving the impression that the river is in worse shape than it really is.

2b. Have you missed any problems?

Yes 1

No 5

Unknown 5

Unknown - keep looking.

Yes. Individual sewage systems from adjacent homes on the river.

But can we ever find all the problems?

Not sure.

Difficult to know for sure.

Possibly. What about any manufacturing somewhere close. How about city/municipal sewer drainage, or new garbage regulations that promote illegal dumping.

I do not know. Don't know area. I do not know. But, as I stated above in 2a I recall some reference to some problem areas along reach 1.

2c. Do you agree with the problems and the likely causes as stated in the summary sheets that are attached?

Yes 10

No 1

Unknown 1

I am unfamiliar with this area.

No. I don't feel we can say that agriculture is the problem at this point.

But as stated before there may be others.

It is difficult to isolate which "sources" the problems are coming from. It would be nice if we had a simple percent from this, and a percent from that. It would make these decisions simple, monitoring can tell all.

The data is only applicable for the time sampled. If sampling had been done for 10 years previous 1992 was likely worse than any of the other nine.

2d. Have we missed any problems?

Yes 4

No 3

Unknown 5

Yes. Individual sewage systems from adjacent homes along the river.

But can we ever find all the problems?

Not sure.

Possibly. What about any manufacturing somewhere close. How about city/municipal sewer drainage, or new garbage regulations that promote illegal dumping.

Yes. Farmers shouldn't be farming the bottom of road ditches, need to address uncontrolled drainage.

Now I wish direct ricing discharge monitoring had been performed. Though we had stations above and below to capture that influence.

Yes. I don't know. They physical characteristics of the landscape in this area and highly organic soil may be big factors.

Yes. Consideration should be given to keeping livestock away from the river by fencing.

2e. Do you agree with the problems and the likely causes as stated in the summary sheets that are attached?

Yes 9

No 2

Unknown 1

No. The sewage plant may be one of the problems - not the only one.

But what do we do about them, are there any suggested solutions to remedy identified problems.

I agree with problems but I am not sure we can say that the only cause is Bagley but that we should correct problems and continue testing.

Based on my review of the final report you have submitted.

No. I don't see lakeside nutrient loading as a big problem here and that is not documented.

2f. Have we missed any problems?

Yes 3

No 6

Unknown 3

Not sure.

Maybe. When these problems are corrected, there may or may not be a need to look at other things.

Yes. Clear cutting of timber, no buffer strips.

Nothing that is apparent to me at this time.

Yes. Paying for everything at a time when taxes are already too high.

Yes. Don't know specifically but organic soils, beaver, etc. could be factors.

POSSIBLE IMPLEMENTATION STRATEGIES TO MITIGATE PROBLEMS FOUND IN THE CLEARWATER RIVER

Reach #3
Headwaters of Clearwater River (milepoint #145) to Downstream (CR7 - milepoint #79.2)

Summary of Problems

- Low levels of dissolved oxygen were detected after storm events and during ice-over periods at Station CR-1. Problems likely caused by bottom scour moving more oxygen-demanding materials downstream.
- Dissolved oxygen readings approaching zero were detected at CR-2. Major cause of problem is likely the discharge from Bagley's sewage treatment lagoons (lagoons exceed capacity on a regular basis).
- Elevated levels of TSS at CR-4. Likely due to streambank erosion within this stream segment.
- Clearwater Lake experiences substantial loading of nutrients and/or substantial retention of nutrients. More work needs to be done to identify cause and to structure mitigative measures.
- Some sandbed loading on the stretch of the river that is designated as a trout stream by DNR. The sandbed loading affects trout habitat.

Possible Implementation Strategies

Strategy 3.1: Reduce nutrient loading by the Bagley sewage treatment facility into the Clearwater River through a combination of measures that could include a phosphorus removal system, or alternative tertiary treatment of effluent.

Participating Organizations: City of Bagley, Minnesota PCA, Clearwater SWCD

Comments: The first steps would include the more precise problem identification and the development of potential alternatives. These alternatives may include some sort of a tertiary wetland treatment, or possibly some sort of phosphorus removal system.

Strategy 3.2: Design and implement traditional streambank erosion control projects to address all areas subject to erosion within this segment.

Participating Organizations: Clearwater SWCD. Red Lake Watershed District

Comments: These implementation measures could include installation of ripwrap, vegetative mats, etc. The RLWD in conjunction with the SWCD would be responsible for the initial reconnaissance and subsequent implementation. The RLWD would also be responsible for the engineering of the structure. Cost share money may be available through a variety of sources.

Strategy 3.3: Institute the Lake Assessment Program (LAP) for Clearwater Lake, and design and implement mitigative measures for problems that are identified in that project.

Participating Organizations: Minnesota PCA, Clearwater SWCD, Red Lake Watershed District

Comments: PCA's LAP program is designed to provide, through technical analysis, some answers to questions regarding nutrient loading on lakes. This program could be used to identify problems, if they exist, and other resources could be used in concert with PCA to identify mitigative strategies.

Strategy 3.4: Implement sandbed load tests on the stretch of the Clearwater River that is designated as a trout stream, and design erosion control measures (see 3.2) to reduce, to some specified level, the sediment loading on this stretch.

Participating Organizations: Minnesota DNR, Clearwater SWCD, Red Lake Watershed District

Comments: It might be possible to have the DNR conduct the test, and to have implementation of specific upstream erosion control projects undertaken by Clearwater SWCD and the Red Lake Watershed District as identified in strategy 3.2.

Strategy 3.5: Reduce pollution from urban runoff from the City of Bagley into the Clearwater River through the implementation of stormwater catch basins, retention ponds, wetland treatment ponds, etc.

Participating Organizations: HRDC, Clearwater SWCD

Comments: Clearwater SWCD, along with the HRDC and two other SWCDs have an application in to the Board of Water and Soil Resources to fund a project that would result in strategies identified and implemented to mitigate urban runoff in three communities in northern Minnesota, including the City of Bagley.

Reach #2

Beginning approximately 1 mile upstream of the Clearwater River confluence with Ruffy Brook (RB-8, milepoint #79.2) and ends approximately 2 miles downstream of CR11 (milepoint #46.2)

Summary of Problems

- Several areas in this segment exhibited elevated fecal coliform levels, which are most likely due to runoff from feedlots.
- A number of areas showed high suspended solid levels, which are a result of both runoff from agricultural land as well as some streambank erosion.
- A couple of sites exhibited significantly reduced dissolved oxygen levels, which were the result of some of the above problems as well as a result of the discharge of wild rice paddies.

Possible Implementation Strategies

Strategy 2.1: Set priorities for the 27 feedlots within 100 meters of the Clearwater River and its tributaries in terms of pollution sources, and implement strategies to mitigate that pollution.

Participating Organizations: Minnesota PCA (enforcement), Red Lake Watershed District and SWCD's (implementation)

Comments: There are approximately 27 feedlots within 100 meters of the Clearwater River and its tributaries. SWCDs and the Red Lake Watershed District could set priorities through field work for most important sites to address. PCA could use its permitting authority to act as a catalyst for improvements, and SWCDs and the Red Lake Watershed District could use cost share programs to assist farmers in improving their feedlot management.

Strategy 2.2: Identify and set priorities for streambank erosion sites, and implement streambank erosion mitigative measures as identified in strategy 3.2.

Strategy 2.3: Identify top priority agricultural areas contributing to sedimentation. and identify specific mitigative measures for those areas to be implemented.

Participating Organizations: SWCDs. Red Lake Watershed District

Comments: After reviewing the magnitude of the problem. specific goals can be set for a number of acres to be dealt with each year.

Strategy 2.4: Implement 2-3 demonstration projects to reduce nutrient loading by wild rice paddies into the Clearwater River.

Participating Organizations: Red Lake Watershed District. SWCDs

Comments: Although precise figures are not known, data suggests that wild rice paddies are contributors to some of the problems identified in the Clearwater River. The most appropriate approach would be to work with a handful of willing wild rice operators to try two or three different mitigative measures that may include sediment traps. wetland restoration. etc.. in order to reduce nutrient loading into the Clearwater River

Reach #1

Clearwater River from milepoint #46.2 to the Clearwater River's confluence with the Red Lake River at Red Lake Falls

Summary of Problems

- Elevated fecal coliform counts were likely the result of runoff from feedlots from upstream as well as in this segment of the river.
- Runoff from agricultural practices contributed to levels of TSS above standards set as well as reduced levels of dissolved oxygen
- Streambank erosion, both in reaches 1 and 2, contributed to sedimentation in this segment.

Possible Implementation Strategies

Implementation strategies would be similar to those identified for Reach #2.

Survey of Possible Implementation Strategies to Mitigate Problems on the Clearwater River

1. Do you think the following strategies are appropriate, given the problems that have been identified?

Strategy #3.1	_____ Yes	_____ No
Strategy #3.2	_____ Yes	_____ No
Strategy #3.3	_____ Yes	_____ No
Strategy #3.4	_____ Yes	_____ No
Strategy #3.5	_____ Yes	_____ No
Strategy #2.1	_____ Yes	_____ No
Strategy #2.2	_____ Yes	_____ No
Strategy #2.3	_____ Yes	_____ No
Strategy #2.4	_____ Yes	_____ No

Please comment on any of those strategies that you checked that you deemed inappropriate.

____

____

____

____

____

____

2. If there are problems that you feel are not being addressed on the Clearwater River with these strategies, please describe to us the problem that you see, and suggest what you think should be done about it.

____

____

____

3. Please identify the strategies that you feel your organization would like to become involved in in the implementation phase. Also, please identify your organization.

____

____

____

____

____

____

4. Are there any other comments that you would like to make on how the Red Lake Watershed District can improve its management plan for the Clearwater River.

____

____

____

____

____

____

32 surveys sent out
8 received

1. Do you think the following strategies are appropriate, given the problems that have been identified?

Strategy #3.1	8 yes	no
Strategy #3.2	8 yes	no
Strategy #3.3	8 yes	no
Strategy #3.4	8 yes	no
Strategy #3.5	8 yes	no
Strategy #2.1	8 yes	no
Strategy #2.2	8 yes	no
Strategy #2.3	8 yes	no
Strategy #2.4	8 yes	no

2.4 Sediment traps and a viable option that wouldn't be overly costly. Wetland restoration I don't believe would work. The Clearwater is dredged so deep that any widening of the channel to create a riparian wetland would be working with unstable unproductive subsoil that would likely be a poor quality wetland and may add to erosion problems. It would be extremely costly for little benefit. Any natural ground elevation wetland would do little because drainage requires low elevation of water in ditches or it won't drain in order for paddy to flow.

3.1 Tertiary wetland treatments should be avoided.

3.5 Avoid wetland treatment ponds.

All are reasonable provided adequate time is given to implement change in operations.

2.1 Feedlots the East Polk SWCD has plan's for feedlots in the county.

2. If there are problems that you feel are not being addressed on the Clearwater River with these strategies, please describe to us the problem that you see, and suggest what you think should be done about it.

The details and site specific information required for several of the strategies are lacking and need better definition.

Livestock in the river, details of the wastewater problem from towns including Bagley.

Through a wetland the wetland would need to be at least 6 to 8 feet below paddy soil elevation which leaves sediment traps as the viable option. We have already implemented these on some of our paddies and believe most of our discharge water is quite clean and once it tumbles through our discharge gate oxygen levels are ok.

The golf course at Red Lake Falls and storm sewers at Red Lake Falls need to be addressed. Nutrient loading and pesticide application rates are traditionally higher on urban lawns and golf courses than on agricultural lands.

Has any time or effort been made to determine the potential benefits to making these improvements - i.e. increased fish population or reduction in weeds in Clearwater Lake etc.

There should be some landowner responsibility to control erosion, reduce pollution etc.

3. Please identify the strategies that you feel your organization would like to become involved in the implementation phase. Also, please identify your organization.

Clearwater SWCD - All strategies.

Development of constructed wetlands.

Gunvalson and Imle Wild Rice. We can work on sediment traps together with tile drainage to keep the soil on the farm where we all want it to stay.

DNR Fisheries - Strategy 3.4.

SWCD - all of them.

MN Extension Service - We would be interested in helping with all aspects of the implementation phase, however I think we would be most helpful in the feedlot issues.

East Polk SWCD - any project located in E. Polk County, the District would consider becoming involved and participating if time, staff and $ is available.

The MN Extension Service is an educational organization. Any information found during the Clearwater River Project will be valuable in educating the entire public. #3.2 on erosion control, #3.5 is a program already in MES making public aware of the hazards of dumping into sewers, #2.1 feedlots, #2.3.52

4. Are there any other comments that you would like to make on how the Red Lake Watershed District can improve its management plan for the Clearwater River.

The Red Lake Watershed District and the Clearwater SWCD need to strengthen their ties and develop some specific erosion control and water quality projects through some means of job/responsibility sharing.

Don't try any far fetched expensive programs that have questionable benefit. Instead do simple things that can be implemented for either costs. Be realistic. If you pooled all the water from the Clearwater River and make a lake it would only be 2-3 feet deep and cover 200 - 300 acres under normal conditions. Is it worth spending six figure sums of money to make questionable gains in water quality. If its fish we want we can grow fish in our paddies where they will be protected for three months from the major predator (larger fish) we can grow them. When we release our water in July they'll go into the river in such numbers that they should re-stock the river very well each year, at almost no cost.

The utilization of conservation easements for buffer zones or wetland restorations in areas of special concerns.

This is a great project! It reminds me of what's now being proposed on the Minnesota River! But we did it first!

Appendix G

Qual 2E Model Results

Summary of Qual-2e Model Results

Purposes of Model Application

The purpose of applying the Qual-2e model to the Clearwater River is to establish a method for evaluating water quality improvements from the implementation measures. Load reductions can be estimated for each of the implementation measures, by subwatershed, and tracked using a spreadsheet (see attached format). The new estimated loads following the implementation of various measures can be evaluated within the Qual-2e model.

The model was also used to set target load reductions from within the Bagley area and the 5 priority subwatersheds and evaluate the effects of various load reduction scenarios (see *Section 6.0, Management Plan for Improving Water Quality,* of the report and Appendix C). The Qual-2e model formed the basis for setting target loads needed to achieve water quality goals within the Clearwater River.

Once ancillary benefit associated with applying the Qual-2e model is a greater understanding of water quality within the Clearwater River. For example, model application during the low flow period of July 27 - August 10, 1992, showed lower surface water temperature within the channelized stream reach than upstream or downstream, suggesting the influence of ground water.

Reasons for Selection of Qual-2e

The Technical Steering Committee selected Qual-2e as the preferred model after an evaluation of existing models. An evaluation of the existing models and selection criteria are summarized in, *Evaluation of Qual-2e Technical Memorandum, Water Quality Models - Clearwater Nonpoint Source Project* (HDR Engineering, Inc. 1993).

Area of Coverage

The Qual-2e model has been developed for the Clearwater River and its tributaries. Specifically, the model has been developed for the Clearwater River from river mile 135.7 upstream of Bagley, Minnesota to the mouth, for the tributaries Walker Brook and Ruffy Brook, for the Poplar River from river mile 28.7 to the mouth, for the Lost River from river mile 49.3 to the mouth, and for the Hill River (see Figure 3-1 within the report). The area covered by the model can be expanded in the future simply by adding new point and nonpoint sources.

Period of Coverage

The Qual-2e model was developed for the period of time with poorest observed water quality, based on the monitoring data. The monitoring data showed water quality to be poorest during the late summer low flow period. One requirement of the Qual-2e model is steady flows during the period of model application. The period meeting the low flow and steady flow requirements was the period from July 27 - August 10, 1992. The model was developed using measured flow and water quality during the time period. The model may be applied to other time periods in the future by altering the model flow and chemistry data.

Sources Modeled

The model included nonpoint and know point source discharges. Nonpoint sources were included by using the incremental inflow feature of the model. This means water and the mass of the modeled parameters (e.g., total phosphorus) was added to the river incrementally along the stream reach. Rice paddy discharges were treated in this manner.

Substances Modeled

The substances modeled were temperature, biochemical oxygen demand, algae, organic phosphorus, dissolved phosphorus, organic nitrogen, ammonia nitrogen, nitrite nitrogen, nitrate nitrogen, dissolved oxygen, fecal coliform bacteria, and total solids.

Summary of Results

Items learned during model application were numerous and are summarized here. Although the items are presented in numerical order, the ordering has no meaning relative to importance.

1. Bagley Area as a Source of Pollutants - Table 3-4 within the report shows the flows used to develop the model. The table shows a large increase in unexplained flow (≈30 cfs) from upstream to downstream of Bagley (sites CR-1, WB-21 and CR-2). This may be error in estimating flows or an unexplained source of water may have been present. Or, the discharge may be from point sources within Bagley, whose present wastewater stabilization lagoons are hydraulically overloaded. By using the amount of unexplained flow and water quality typical of secondary waste, the model better reproduced the dissolved oxygen sag downstream from Bagley.

2. A second unexplained increase in flow (≈ 80 cfs) occurred within the channelized reach of the Clearwater River (sites CR-9 to CR-10). Rice paddy discharge was initially suspected for this increase. An attempt was made to recreate the flows, the observed sag in dissolved oxygen and the increase in total solids within this reach using operational data gathered for typical rice operation and chemistry data (see tables at the end of Appendix B). The data suggest the discharge of 18" of water from all rice paddies along the Clearwater River during a 30 day period typical of rice paddy operation (beginning in early July and ending by late July) is approximately 80 cfs. This assumes all paddies operate identically. Normally, the period of discharge from the paddy varies from operator to operator.

   By combining the limited water quality data available from within the rice paddy (see table at the end of Appendix B) and the estimated flow data, the modeled concentrations should mimic the observed concentrations. Using these data the model in fact predicted greater dissolved oxygen and lower total solids concentrations than observed (based on monitoring data collected within this reach). Therefore, the sediment oxygen demand and sediment fall velocity within the channelized reach were adjusted to reproduce the observed water quality. This suggests that sediment may play a greater role in determining oxygen demand within the channelized reach and that channelization may result in greater resuspension of solids.

3. One other interesting observation resulting from model application is the surface water temperature of the Clearwater River. Surface water temperature decreased within the channelized reach (see Table 3-9 for sites CR-10, CR-11, and CR-12). This may be the result of difference in the time of temperature measurement or the influence of groundwater within this reach. The time of measurement differed by 2 hours between the upstream and downstream sites (see Table 3-1), suggesting the importance of groundwater. Some rice paddy have subsurface tiling for dewatering of

the peat soils prior to harvest. However, most of the water is surface discharges. The model results suggest the temperature of the entire 80 cfs would need to be approximately 65 degrees F to reproduce the observed temperature of the Clearwater River. This is in fact the approximate temperature of paddy water.

4. The model results provide new information about the Clearwater River. However, the results provide insight and are not definitive. ***The results are inferential, and do not demonstrate cause and affect.*** Low flow sampling from each of the rice paddy discharges and upstream sources is needed to assess the magnitude of loads from each of the specific sources.

Pollutant: Chemical Oxygen Demand

Subwatershed	Present Load	Estimated Load Reduction by Implementation Measure				Future Load
		Cons. Tillage	Feedlot Prog.	Riparian Buffer Strips	Others	
1						
2						
3						
4						
5						
6						

Appendix H

Wildrice Operational Data Summarization

Wildrice Operational Data Summarization
for the 1992 Growing Season

- Water began being released at a limited rate during the first week in July.

- Drawdown was accelerated towards the end of July.

- Paddies were generally drawndown below field level by the first week in August.

- Combining commenced on the second or third week of August. The harvest was somewhat delayed by the large storm event that took place in late August. Harvesting was generally complete by the first week in September.

- Water was impounded in the paddies after the completion of all field work. In 1992 this was approximately by the end of September.

- Some growers work fertilizer into the soil (anhydrous ammonia) after harvest late in the fall. As a general rule most growers use an aerial application (usually urea) as the plant needs it during the growing season. Some growers have been using a chlorophyll meter to judge when the paddies need fertilization.