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Report on Assessment of Minnesota Pollution Control Agency's Ambient Water Quality Monitoring Network

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by

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I. Executive Summary

This report presents an assessment of water quality trends in Minnesota as represented by fixed station ambient water monitoring data stored in USEPA's STORET data bases. The period of study is from January 1978 to December 1985 and covers 75 fixed ambient monitoring stations. Approximately 70,000 observations were analized to get the statistical trends for this study. The overall objective of this is report to assess fixed ambient monitoring network station, parametric coverage and to determine current water quality trends of streams in Minnesota and types of pollution sources impacting the surface waters.

Water quality, as determined by the trend analyses for the past eight year period, has shown some change in Minnesota. In fact, the following types of pollution showed increasing trends as indicated by the analysis of monitoring data:

- ° Point source pollution increased at 8% and decreased at 7% of the stations.
- ° Non-point source pollution trends increased at 12% of the stations.

As a result of this study, the following changes to Minnesota's ambient monitoring network are recommended:

- ° Conduct biomonitoring and bioassays at monitoring stations where increased pollution trends were observed.
- ° Expand monitoring of sediments and water column for toxic variables at the existing stations or establish new ones to detect toxicants.
- ° Eliminate or relocate those stations based on trend indications and professional judgement.
- ° Avoid duplication by sharing monitoring information with the neighboring states that have common waterbodies with Mi nesota.

II. Introduction

The 1972 Water Pollution Control Act Ammendments (PL-92-500) require the states to monitor water quality and report their findings to Congress bi-annually via 305(b) reports. In partial fullfillment of the requirements of this Act, states and EPA operate and maintain fixed monitoring stations as a part of their ambient monitoring efforts.

The Minnesota Pollution Control Agency (MPCA) operates and maintains 75 fixed ambient monitoring stations on a rotating basis to monitor the states' water quality. The objectives of these ambient water quality monitoring network of stations are to:

° Assess long term trends in water qualilty;

° Assess the effectiveness of pollution control efforts;

° Determine effects of Point and Non-point sources on stream quality;

° Determine the overall water quality at specific locations.

Thus, the overall objective of this report is to assesses Minnesota's fixed ambient monitoring network stations locations, parametric coverage, to determine water quality trends of surface waters and pollution impacts. To achieve this objective, the following aspects of ambient monitoring stations were evaluated, analyzed and summarized:

1. Station location, type and objective;

2. Classification of the monitoring area;

3. Classifation of station siting purpose;

4. Parameter coverage and sampling frequency;

5. Uses of data collected;

6. Pollution trends.

This study analyzed fixed station monitoring data stored in STORET for the period beginning in January 1978 and ending on December 1986.

In Table 1, the list of Minnesota's monitoring stations is given with their respective map locations are shown on Figure 1.

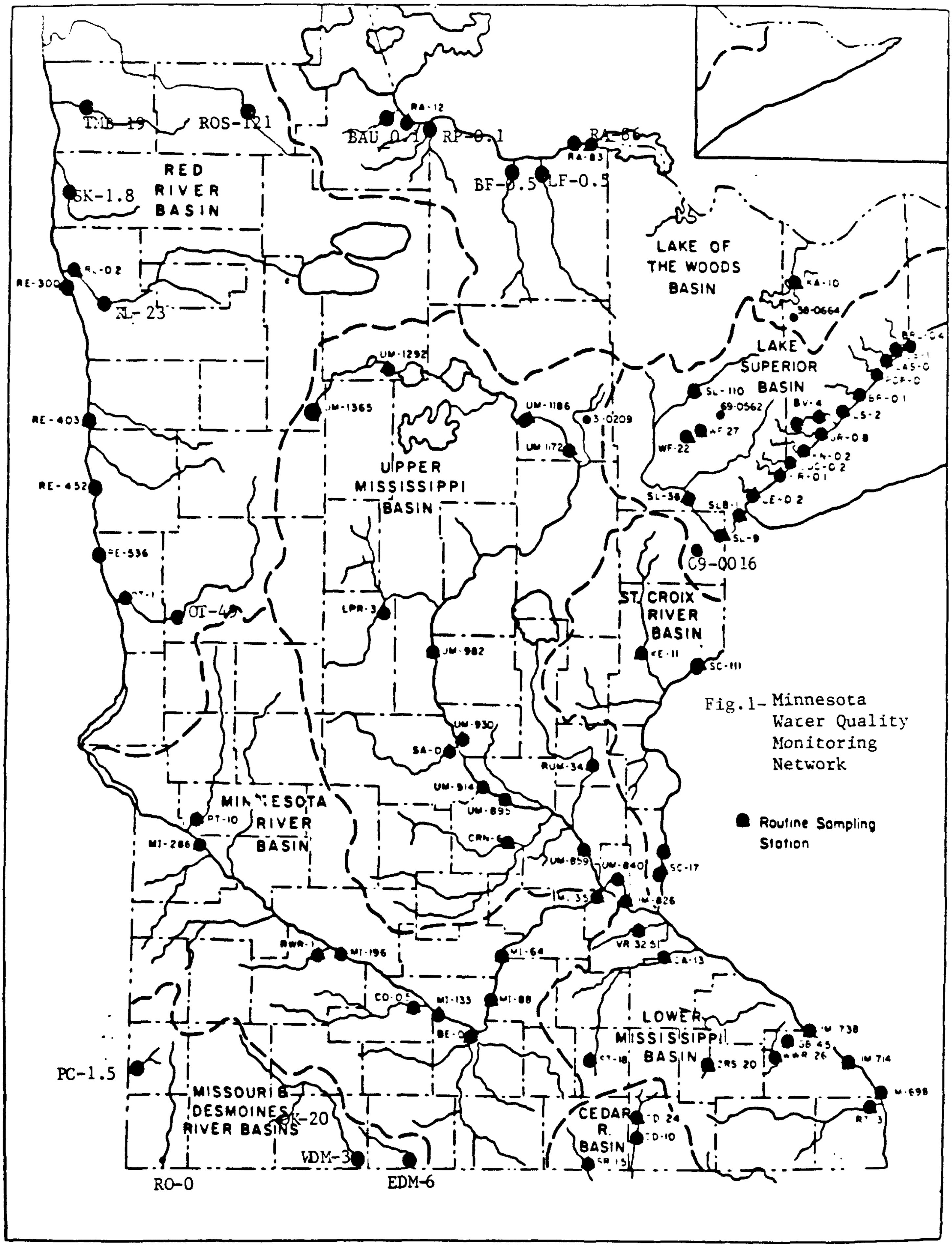


Fig.1- Minnesota Water Quality Monitoring Network

Table 1. Minnesota Routine Monitoring Network stations

LAKE SUPERIOR BASIN

	River	Station	Location
1.	Beaver River*	BV-4	1½ miles SW on CSAH-3 from junction of CSAH-4, 1½ miles north of Beaver Bay
2.	St. Louis Bay*	SLB-1	Below interstate 535 bridge, Duluth
3.	St. Louis Bay	SL-9	Bridge on SH-23 at Fond du Lac
4.	St. Louis River*	SL-38	Bridge on USH-2 near Brookstone
5.	St. Louis River	SL-110	Bridge on CSAH-7 near Forbes
6.	Whiteface River***	WF-22	Bridge on CR-29, 1 mile south and 2 miles west of Kelsey
7.	Whiteface River***	WF-27	Bridge on CSAH-7, ½ mile south of Kelsey

MINNESOTA RIVER BASIN

8.	Minnesota River	MI-3.5	Fort Snelling State Park-below airport landing lights
9.	Minnesota River*	MI-64	Bridge on SH-19 at Henderson
10.	Minnesota River	MI-88	Bridge on SH-22 at St. Peter
11.	Minnesota River	MI-133	Bridge on CSAH-24 at Courtland
12.	Minnesota River*	MI-196	Bridge on SH-19 and USH-71 at Mortan
13.	Minnesota River	MI-288	Bridge on SH-40, 3 miles W of Milan
14.	Blue Earth River*	BE-0	At confluence with Minnesota River in Sibley Park above dam, Mankato
15.	Elm Creek	EMC-18	Bridge on CSAH-149, 5 miles SE of Truman
16.	Cedar Run Creek	CDR-12.8	Bridge on CSAH-9, 4 miles NW of Trimont
17.	Pomme de Terre R.	PT-10	Bridge on SH-7 at Appleton
18.	Redwood River	RWR-1	Bridge on CSAH-101 at North Redwood
19.	Cottonwood River	CO-0.5	Bridge E of SH-15 bridge at New Ulm

Table 1. (cont'd)

MISSISSIPPI RIVER BASIN

	River	Station	Location
20.	Mississippi River*	UM-698	Bridge on USH-14 at LaCrosse, Wisconsin
21.	Mississippi River	UM-714	Lock and Dam #6, near LaMoille, across via WI
22.	Mississippi River	UM-738	Lock and Dam #5, SE of Minneiska
23.	Mississippi River	UM-815	Lock and Dam #2 at Hastings
24.	Mississippi River*	UM-826	J.L.Shiely Company Larson Plant Dock at Grey Cloud Island, Cottage Grove
25.	Mississippi River	UM-840	St. Paul Rowing Club dock below Wabasha Street bridge, St. Paul
26.	Mississippi River	UM-859	Minneapolis waterworks intake, Fridley
27.	Mississippi River	UM-895	Bridge on SH-25 at Monticello
28.	Mississippi River	UM-914	Bridge on SH-24 at Clearwater
29.	Mississippi River	UM-930	Bridge on SH-152 at Sauk Rapids
30.	Mississippi River	UM-982	Bridge on SH-115 at Camp Ripley
31.	Mississippi River*	UM-1172	Bridge on CR-441, 5 miles SE of Grand Rapids near Blackberry
32.	Mississippi River*	UM-1186	Bridge on SH-6, 6 miles SW of Cohasset
33.	Mississippi River	UM-1292	Bridge on CSAH-8, E of Bemidji
34.	Mississippi River*	UM-1365	Bridge on USH-200, ½ mile W of Lake Itasca (town)
35.	Sauk River*	SA-0	Bridge on CSAH-1, N of St. Cloud
36.	Crow River, N Fork	CRN-6	Bridge on CSAH-14, 4 miles W of Rockford
37.	Rum River	RUM-34	Bridge on CSAH-5 at Isanti
38.	Cannon River	CA-13	Bridge on CR-1, 1 mile SE of Clinton Falls

Table 1. (cont'd)

	River	Station	Location
39.	Straight River	ST-18	Bridge on CR-1, 1 mile SE of Clinton Falls
40.	Long Prairie River	LPR-3	Bridge on USH-10, S of Motley
41.	Zumbro River, S.Fork	ZRS-20	Bridge on CSAH-14, 3 miles N of Rochester
42.	Whitewater River	WWR-26	Bridge on county road E ½ of Section 2, T106, R10, NW of Utica
43.	Root River	RT-3	Bridge on SH-26, 3 miles E of Hokah
44.	Vermillion River	VR-32.5	Bridge on Blain Avenue, Farmington
45.	Garvin Brook	GB-4.5	Bridge on CSAH-23, 1.5 miles SW of Minnesota River
46.	Swan River	SW-8.6	Bridge on CSAH-14, 3 miles W. of Sobieski
47.	Swan River	SW-4.1	Bridge on SH-238, 3 miles E. of Sobieski
		ST. CROIX RIVER BASIN	
48.	St. Croix River*	SC-17	C & NW Railway bridge at Hudson, Wisconsin
49.	St. Croix River	SC-111	Bridge on SH-48, 2 miles W of Danbury, Wisconsin
50.	Kettle River	KE-11	Bridge on SH-48, 4½ miles E of Hinckley
		CEDAR RIVER BASIN	
51.	Cedar River*	CD-10	Bridge on CSAH-14, 3 miles S of Austin
52.	Cedar River	CD-24	Bridge on CSAH-2, 0.5 miles E of Lansing
53.	Shell Rock River	SR-1.5	Bridge on CSAH-1 near Gordonsville
		RED RIVER BASIN	
54.	Red River*	RE-300	At Grand Forks waterworks intake, Alemont Ave. S., Grand Forks, N.D.
55.	Red River	RE-403	Bridge on CSAH-39, W of Perley

Table 1. (cont'd)

	River	Station	Location
56.	Red River*	RE-452	First Street Bridge, Moorhead
57.	Red River	RE-536	Bridge on CSAH-18 at Brushvale
58.	Rabbit River	RBT-6	Bridge on US-75, 4 miles W. of Campbell
59.	Whiskey Creek	WSK-4.4	Bridge on US-75 at Kent
60.	Otter Tail River	OT-1	Bridge on 4th Street N in Breckenridge
61.	Otter Tail River	OT-49	Bridge on CSAH-15, 2½ miles W. of Fergus Falls
62.	Red Lake River*	RL-0.2	Bridge on SH-220 at East Grand Forks
63.	Red Lake River	RL-23	Bridge on CSAH-15 at Fisher
64.	Snake River	SK-1.8	Bridge on SH-220, N of Big Woods
65.	Two Rivers (Middle Branch)	TMB-19	Bridge on USH-75, N of Hallock
66.	Roseau River	RCS-121	Bridge on CSAH-2 at Malung
		RAINY RIVER BASIN	
67.	Rainy River*	RA-12	International bridge at Baudette
68.	Rainy River*	RA-83	International toll bridge at International Falls
69.	Rainy River	RA-86	Railroad Bridge at Rainer
70.	Kawishiwi River	KA-10	Bridge on SH-1 at Birch Lake
71.	Baudette River	BAU-0.1	Bridge on SH-11 at Baudette
72.	Winter Road River	WR-1	Bridge on SH-11, W of Baudette
73.	Rapid River	RP-0.1	Bridge on SH-11 at Clemenson
74.	Big Fork River	BF-0.5	Bridge on SH-11, 4 miles E of Loman
75.	Little Fork River	LF-0.5	Bridge on SH-11, W. of Pelland

* national fixed station network
** acid rain streams
*** peat monitoring stations

III. Description of Monitoring Stations

1. Station Locations, Types and Objectives

STORET contains comprehensive information for each station in Minnesota's fixed ambient monitoring network. Specifically, for each station the following characteristics are included: waterbody, reach #, purpose, waterbody type, parametric coverage,sampling frequency, data entry into STORET, siting type, location and site description, and siting purpose. Minnesota's network includes the following categories of stations:

- upstream and downstream of major metropolitan areas
- large and small streams
- streams influenced by Point and Non-Point sources
- near the mouth of major tributaries to the Mississippi and Minnesota rivers
- on pollution free streams for background reference

Also in Table 2, each station's specific characteristics, location, parameters, basins, and other pertinent information are shown. Fifty-eight stations are located in rural areas, nine are in urban areas and eight stations are in non-classifiable locations. Twenty stations are National Network and fifty five are state network stations. There are a total of 75 stations located in Minnesota as shown in Figure 1. Eight are paired as upstream and downstream of municipalities, major dischargers or other non-point source impact sources. The remaining 67 stations are on: large and small streams, point and non-point source impact free streams for background reference purposes.

2. Classification of Monitoring Areas

In classifying stations by basins, 27 stations are in the Mississippi River basin, seven are in the Lake Superior basin, 12 are in the Minnesota River basin, 3 are in the Cedar River basin, 12 are in the Red River basin, and 9 are in the Rainy River basin. Furthermore, stations are classified into four categories based on the types of pollution categories, such as urban, industrial, municipal and non-point as well as areas which are relatively free from pollution so as to qualify as pristine streams. These general groupings are given in Table 4.

3. Station Siting Purpose(s)

All of the 75 stations are placed to measure basin status, water quality standards attainment/maintenance and water quality conditions for trends assessment purposes. Fifty-nine stations detect non-point source impacts and twelve stations detect point source problems due to municipal and industrial dischargers. Four stations detect basin level water quality. However non of the ambient stations are located on streams near major waste disposal or Superfund sites where water quality maybe impaired by toxics form these locations.

4. Analysis of Parametric Coverage and Sampling Frequency

The MPCA generally follows the recommendations of the Water Monitoring Program Guidance in selecting parameters and sampling frequency for fixed station monitoring. However, sampling frequency has been reduced to nine months per year due to budgetary constraints. The chemical measurements as shown in Table 2 consist of dissolved oxygen, oxygen demanding substances, nutrients, solids and metals at all stations. The biological measurements are limited to fish tissue which has been sporodically conducted at the fixed stations during the past eight years.However, the MPCA conducts an extensive annual fish tissue monitoring program which covers a very limited number of organic compounds and metals. The state's fish tissue residue monitoring program is not conducted at fixed network stations on a routine basis. A list of all the parameters for biological and chemical analyses are given in Table 3.

5. Monitoring Stations Network Deficiencies

The following deficiencies were observed in monitoring capabilities of the stations reviewed:

- Lack of monitoring on streams near major hazardous and non-hazardous waste disposal facilities and Superfund sites.
- Biomonitoring for macro or micro invertebrates is not done.
- Routine monitoring for fish tissue residue is too sporadic at fixed monitoring stations.
- Toxics monitoring is not conducted at ambient monitoring sites.
- Bioassays are not conducted at any of the monitoring stations.

Table 2- MINNESOTA FIXED STATION MONITORING ANALYSIS MATRIX *

Station Number	Basin	Location Purpose	Location Type	Biological Type	Biological Freq.	Chemical Type	Chemical Freq.	Configutation Single/Paired	Flow Meas.
UM-698	Miss.R.	C,W,B,NP,	*,U,BG,I,M	FT	P	D,O,N,S,M	Mo	Si	
UM-714	" "	C,W,B,NP	S,BG			D,O,N,S,M	Mo	Si	
UM-738	" "	C,W,B,NP	S,BG			D,O,N,S,M	Mo	Si	
UM-815	" "	C,W,B,PS	M,I	FT	P	D,O,N,S,M	Mo	Si	
UM-826	" "	C,W,B,PS	*,U,M,S,I	FT	P	D,O,N,S,M	Mo	Si	Yes
UM-840	" "	C,W,B	*,U,I,M,S	FT	P	D,O,N,S,M	Mo	Si	Yes
UM-859	" "	C,W,B	*,U,I,M,S	FT	P	D,O,N,S,M	Mo	Si	
UM-895	" "	C,W,B,NP	R,S,BG	FT	P	D,O,N,S,M	Mo	Si	
UM-914	" "	C,W,B,NP	S,R,BG			D,O,N,S,M	Mo	Si	
UM-930	" "	C,W,B,NP	S,R,BG	FT	P	D,O,N,S,M	Mo	Si	
UM-982	" "	C,W,B,NP	S,R,BG			D,O,N,S,M	Mo	Si	
UM-1172	" "	C,W,B,NP	S,R,BG			D,O,N,S,M	Mo	Si	
UM-1186	" "	C,B,NP	*,R,BG,S	FT	P	D,O,N,S,M	Mo	Si	
UM-1292	" "	C,W,B,NP	S,R,BG			D,O,N,S,M	Mo	Si	
UM-1365	" "	C,W,B,NP	*,R,BG,S	FT	P	D,O,N,S,M	Mo	Si	
SA-0	" "	C,W,B,NP	*,R,BG,S	FT	P	D,O,N,S,M	Mo	Si	
CRN-6	" "	C,W,B,NP	S,R,BG			D,O,N,S,M	Mo	Si	
RUM-34	" "	C,W,B,NP	S,R,BG			D,O,N,S,M	Mo	Si	
CA-13	" "	C,W,B,NP	S,R,BG			D,O,N,S,M	Mo	Si	
BV-4	Lk.SUP.	C,W,B,NP	*,BG,R	FT	P	D,O,N,S,M	Mo	Si	No
SLB-1	" "	C,W,PS,B	*,M,S,U	FT	P	D,O,N,S,M	Mo	Si	No
SL-9	" "	C,W,B,PS	BG,S			D,O,N,S,M	Mo	Si	

* See page 14 for Legend for Table 2

Table 2(cont'd) MINNESOTA FIXED STATION MONITORING ANALYSIS MATRIX

ion er	Basin	Location Purpose	Location Type	Biological Type	Biological Freq.	Chemical Type	Chemical Freq.	Configutation Single/Paired	Flow Meas.	Stream Lake
8	Lk.SUP.	C,NP,W,B	*,R,BG,S	FT	P	D,O,N,S,M	Mo	Si		S
10	" "	C,W,B,NP	S,R,BG			D,O,N,S,M	Mo	Si		S
2	" "	C,W,B,NP	S,R,BG			D,O,N,S,M	Mo	Pa		S
7	" "	C,W,B,NP	S,R,BG			D,O,N,S,M	Mo	Pa		S
.5	MINN Rv	C,W,B,PS	S,U,I,BG	FT	P	D,O,N,S,M	Mo	Si		S
4	" "	C,W,NP	*,M,R,BS	FT	P	D,O,N,S,M	Mo	Si		S
8	" "	C,W,B,NP	S,R,BG	FT	P	D,O,N,S,M	Mo	Si		S
33	" "	C,W,B,NP	S,R,BG			D,O,N,S,M	Mo	Si		S
96	" "	C,NP,W	*,R,BG	FT	P	D,O,N,S,M	Mo	Si		S
88	" "	C,B,W,NP	S,R,BG			D,O,N,S,M	Mo	Si		S
	" "	C,NP,W,B	*,R,BG	FT	P	D,O,N,S,M	Mo	Si	Yes	S
18	" "	C,W,NP	S,R,BG			D,O,N,S,M	Mo	Pa		S
12.8	" "	C,W,NP	S,R,BG			D,O,N,S,M	Mo	Pa		S
0	" "	C,W,B,PS	S,R,M			D,O,N,S,M	Mo	Si		S
1	" "	C,W,B,PS	S,R,M			D,O,N,S,M	Mo	Si		S
.5	" "	C,W,B,NP	S,R,BG			D,O,N,S,M	Mo	Si		S
8	MISS Rv	C,W,B,PS	S,R,M			D,O,N,S,M	Mo	Si		S
3	" "	C,W,B,NP	S,R,BG			D,O,N,S,M	Mo	Si		S
5.7	" "	C,W,B,PS	S,U,M,I			D,O,N,S,M	Mo	Si		S
26	" "	C,W,B,NP	S,R,BG	FT	P	D,O,N,S,M	Mo	Si		S
	" "	C,W,B,NP	S,R,BG			D,O,N,S,M	Mo	Si		S
2.5	" "	C,W,B,NP	S,R,BG			D,O,N,S,M	Mo	Si		S

Table 2(cont'd) MINNESOTA FIXED STATION MONITORING ANALYSIS MATRIX

tation umber	Basin	Location Purpose	Location Type	Biological Type	Biological Freq.	Chemical Type	Chemical Freq.	Configutation Single/Paired	Flow Meas.	Str Lak
B-4.5	MISS.Rv	C,W,B,NP	S,R,BG			D,O,N,S,M,P&H	Mo	Si	Yes	S
WAN-8.6	" "	C,W,NP	S,R,BG			D,O,N,S,M	Mo	Pa		S
WAN-4.1	" "	C,W,NP	S,R,BG			D,O,N,S,M	Mo	Pa		S
C-17	SAINT CROIX R	C,NP,W	*,R,BG	FT	P	D,O,N,S,M	Mo	Si		S
C-111	"	C,B,W,NP	S,R,BG			D,O,N,S,M	Mo	Si		S
E-11	"	C,W,B,NP	S,R,BG			D,O,N,S,M	Mo	Si		S
D-10	CEDAR R	C,W,B,PS	*,R,M	FT	P	D,O,N,S,M	Mo	Si		S
D-24	"	C,W,B,NP	S,R,BG			D,O,N,S,M	Mo	Si		S
R-1.2	"	C,W,B,PS	S,M,R			D,O,N,S,M	Mo	Si		S
E-300	RED Rv	C,W,B,NP	*,U,M,I	FT	P	D,O,N,S,M	Mo	Si		s
E-403	"	C,W,B,NP	S,BG	FT	P	D,O,N,S,M	Mo	Si		S
E-452	"	C,W,NP,B	S,R,BG	FT	P	D,O,N,S,M	Mo	Si		S
BT-6	"	C,W,NP,B	S,R,BG			D,O,N,S,M	Mo	Si		S
SK-4.4	"	C,W,B,NP	S,R,BG			D,O,N,S,M	Mo	Pa		S
T-1	"	C,B,W,NP	S,R,BG			D,O,N,S,M	Mo	Si		S
)T-49	"	C,B,W,NP	S,R,BG	FT	P	D,O,N,S,M	Mo	Si		S
RL-0.2	"	C,B,W,NP	*,M,I,U	FT	P	D,O,N,S,M	Mo	Si		S
RL-23	"	C,B,W,NP	S,R,BG			D,O,N,S,M	Mo	Si		S
SK-1.8	"	C,W,B,NP	S,R,BG			D,O,N,S,M	Mo	Si		S
TMB-19	"	C,W,B,NP	S,R,BG			D,O,N,S,M	Mo	Si		S
RCS-121	"	C,W,B,NP	S,R,BG			D,O,N,S,M	Mo	Si		S
RA-12	RAINY R	C,W,B,NP	M,I,R	FT	P	D,O,N,S,M	Mo	Si		S

Table 2 (cont'd) MINNESOTA FIXED STATION MONITORING ANALYSIS MATRIX

tation umber	Basin	Location Purpose	Type	Biological Type	Freq.	Chemical Type	Freq.	Configutation Single/Paired	Flow Meas.	Stream Lake
A-83	RAINY R	C,W,B,NP	*,U,BG	FT	P	D,O,N,S,M	Mo	Si		S
A-86	"	C,W,B,NP	S,R,BG			D,O,N,S,M	Mo	Si		S
\-10	"	C,W,B,NP	S,R,BG			D,O,N,S,M	Mo	Si		S
\U-0.1	"	C,B	S,BG			D,O,N,S,M	Mo	Si		S
ʔ-1	"	C,B	S,BG			D,O,N,S,M	Mo	Si		S
›-0.1	"	C,B	S,BG			D,O,N,S,M	Mo	Si		S
ˉ-0.5	"	C,B	S,BG			D,O,N,S,M	Mo	Si		S
ˉ-0.5	"	C,B	S,BG			D,O,N,M,S	Mo	Si		S

* Metals are not used as an indicator of long term water quality trends.

Legend for Table 2 - Minnesota Fixed Station Monitoring Analysis Matrix

Location

Purpose

C - Conditions and Trend Assessment
W - Water Quality Standards Attainment/Maintenance
B - Basin Status
PS - Point Source
NP - Non-point Source

Type

* - National Core Network Station
S - State Network Station
R - Rural
U - Urban
I - Industrial Dischargers
M - Municipal Dischargers
BG - Background

Variables

Biological

FT - Fish Tissue

Chemical

D - Dissolved Oxygen
O - Oxygen Demanding
N - Nutrients
S - Solids
M - Metals
R - Radiochemical

Frequency

Mo - Monthly
Y - Yearly
P - Periodically

Configuration

Si - Single
Pa - Paired

Table 3. Routine Water Quality Monitoring Parameters

A. Monthly Analysis at all Stations

	STORET Codes	Description
1.	00010	Temperature-C°-field
2.	00300	Dissolved Oxygen-field
3.	00310	BOD_5
4.	31613	Fecal Coliform
5.	31633	E. Coli
6.	31639	Enterococci
7.	00530	Suspended Solids
8.	00400	pH
9.	00095	Conductivity
10.	00630	Nitrite + Nitrate (NO_2+NO_3)
11.	00665	Total Phosphorus
12.	00625	Total Kjeldahl Nitrogen
13.	00610	Ammonia Nitrogen (NH_3)
14.	00605	Organic Nitrogen

B. Additional Monthly Analyses at Selected Stations

1.	00940	Chloride at RE-300, RE-403, RE-452, RE-536, OT-1, OT-49, RL-0.2, RL-23, SK-1.8, TMB-19, WF-22, WF-27, BV-4, SLB-b-1, GB-4.5, SW-8.6, SW-4.1, RBT-6, WSK-4.4, EMC-18, CDR-12.8
2.	32730	Phenols at RA-12, RA-83, RA-86, ROS-121, WR-1, RP-0.1, BF-0.5, LF-0.5, BAU-0.1, WF-22, WF-27
3.	01051	Total Lead at BV-4, SLB-1
4.	00910	Calcium (as CACO3) at BV-4, SLB-1
5.	00929	Total Sodium at BV-4, SLB-1
6.	00945	Total Sulfate at BV-4, SLB-1, GB-4.5
7.	00958	Reactive Silicate at BV-4, SLB-1
8.	00076	Tubidity at GB-4.5, SW-8.6, SW-4.1, RBT-6, WSK-4.4, EMC-18, CDR-12.8
9.	80082	BOD5-Carbonaceous at GB-4.5
10.	00335	COD at GB-4.5
11.	00680	TOC at GB-4.5
12.	70507	Ortho Phosphorus at GB-4.5
13.	00615	Nitrite at GB-4.5
14.	00500	Total Solids at GB-4.5
15.	00505	Total Vol. Solids at GB-4.5
16.	00535	Dissolved Vol. Solids at GB-4.5

Table 3 (cont'd)

C. <u>Quarterly (January, April, July and October) Analyses at Peat Stations (WF-22, WF-27)</u>

1.	00410	Total Alkalinity
2.	00076	Turbidity
3.	00080	Color
4.	00945	Total Sulfate
5.	01002	Total Arsenic
6.	01027	Total Cadmium
7.	01034	Total Chromium
8.	01042	Total Copper
9.	01900	Total Mercury
10.	01051	Total Lead
11.	01067	Total Nickel
12.	01092	Total Zinc
13.	00910	Total Calcium
14.	00920	Total Magnesium
15.	01105	Total Aluminum
16.	01037	Total Cobalt
17.	01045	Total Iron
18.	01055	Total Mangenese

Table 4 Minnesota Network Stations Groupings Based on Pollution Sources

Group I - Non-Point Sources/Rural

UM-698	UM-1292	WF-27	CO-0.5
UM-714	UM-1365	MI-64	LPR-3
UM-738	SA-0	MI-88	WWR-2.6
UM-895	CRN-6	MI-133	RT-3
UM-914	RUM-34	MI-196	VR-32.5
UM-930	CA-13	MI-288	GR-4.5
UM-982	BV-4	BE-0	SWAN-8.6
UM-1172	SL-110	EMC-18	SWAN-4.1
UM-1186	WF-22	PT-10	SC-17
OT-49	KA-10	SC-111	RL-0.2
BAU-0.1	KE-11	RL-23	WR-1
CD-24	SK-1.8	RP-0.1	RE-300
ME-403	RCS-121	LF-0.5	RBT-6
RA-12	WSK-4.4	RA-83	OT-1
RA-86			

Group II - Homogenous - Background, Recreation, Fishing and General Water Quality Conditions

UM-714	CA-13	MI-133	RT-3
UM-738	BV-4	MI-196	VR-32.5
UM-895	SL-9	MI-288	GR-4.5
UM-914	SL-38	BE-0	SWAN-8.6
UM-930	SL-110	EMC-18	SWAN-4.1
UM-982	WF-22	CDR-12.8	SC-17
UM-1172	WF-27	PT-10	SC-111
UM-1292	MI-3.5	CO-0.5	KE-11
CRN-6	MI-64	LPR-3	CD-24
RUM-34	MI-88	WWR-26	RE-403
RCS-121	RBT-6	RA-83	WSK-4.4
RA-86	OT-1	BAU-0.1	OT-49
WR-1	RL-23	RP-0.1	SK-1.8
BF-0.5	TMB-19	LF-0.5	

Group III - Point-Source, Urban, Municipal and Industrial

UM-815	UM-826	SL-9	MI-3.5
RWR-1	ST-18	ZSF-5.7	CD-10
SR-1.2	RE-300	RL-0.2	RA-12

Group IV - Paired Stations, Upstream and Downstream

WF-2.7	WF-22
SWAN-8.6	SWAN-4.1
EMC-18	CDR-12.8
RBT-6	WSK-4.4

IV. Statistical Analysis

The purpose of the statistical analysis is to determine if trends in the selected water quality indicators have occurred from 1977 through 1986. A trend is defined as a series of observations which exhibit a steady increase or decrease over time. Thus, the selected procedures are used to differentiate random fluctuations from those change patterns which have sufficient directional consistency to be trends. This section describes the data and the statistical procedures used for the trend analyses. An exemplary case is provided in the appendices.

The information employed are from the STORET data base. STORET, a information management system of the U.S.E.P.A., contains water quality data from more than 200,000 water quality sampling stations in river basins. The data are from January 1977 through December 1986. There were 75 stations eligible for the analysis. Several stations could not be used due to missing information. A potential trend was only assessed if for the water quality indicator there was at least 75 per cent data completeness. Because the data sufficiency criteria was applied separately per variable, stations often have trends measured for fewer than all the indicators. The indicators were chosen due to relatively complete information for the period as well as being representative of water quality. The water quality indicators were:

STORET CODE	Water Quality Indicator
00095	Conductivity at 25^{o} Centigrade
00300	Dissolved Oxygen
00530	Total Suspended Solids
00625	Total Kjeldahl Nitrogen
00630	Total NO2 & NO3 (Nitrate and Nitrite)
00671 and 00665	Total Dissolved Phosphorous
00940	Total Chloride
31613	Fecal Coliform
00610	Ammonia

There were several statistical procedures used to measure environmental trends. The initial consideration was whether the stations' data distributions reasonably approximated the normal distribution. The skewness and kurtosis coefficients indicated that the stations' data distributions were not normal. Non-parametric rank order statistical procedures were used to demonstrate trends because the kurtosis coefficients were not within +/- .25 and the skewness coefficients were not within +/- .50. The two ranges are the generally accepted values within which the coefficients must be within to consider a distribution to be normal. Both Spearman's rho and Kendall's tau were used to support conclusions. A trend is said to exist if both statistics have statistically significant results at the 90 per cent level. Both statistics have approximately 91 per cent power efficiency. The two approaches are briefly discussed below:

Spearman's rho - Spearman's rho is one of the most widely used measures of association for rank ordered data. The initial step is to rank the values of the selected water quality indicator (from lowest to highest) and the time variable (year). The computational formula is:

$$r_s = 1 - \frac{6 \sum_{i=1}^{i=n} di^2}{3}$$

where: n = number of measurements in the sample and d_i = an individual difference between ranks.

Kendall's tau - Kendall's tau, like Spearman's rho, requires ranked data for at least two variables and measures the level of association between sets of rankings. The range of possible values is plus or minus one. The computational formula is:

$$\text{tau} = \frac{\sum_{i=1}^{i=n} (K_i+) - \sum_{i=1}^{i=n} (K_i-)}{n\,(n+1)/2}$$

where: $\sum_{i=1}^{i=n} (K_i+)$ = number of pairs ordered in the same way as the years; and

$\sum_{i=1}^{i=n} (K_i-)$ = number of pairs not ordered in the same way as the years.

The next step in the analytical process is to use ordinary least squares regression to demonstrate trend strength for those trends suggested by the nonparametric correlations. Trend strength for this discussion is the average level of change among years. Admittedly, the data are not amenable to ordinary least squares linear regression analysis according to statistical theory. However, for the mere purpose of line fitting to determine average annual change the procedure is sufficient. The computational formula is:

$$r = \frac{SS_{xy}}{\sqrt{SS_{yy}SS_{xx}}}$$

where: SS = sum of squares.

The results of the linear regression procedure are shown on the trend graphs in the appendix. The availability of the graphics permitted a final trend verification procedure. The graphs were individually examined and a trend was retained only if the following somewhat subjectively applied criteria were satisfied:

1. The statistically significant annual trends did not visually appear to be minimal within years; and 2. The trends were not mainly due to abrupt but discontinued change rather than a persistent pattern. Several statistically significant trends were deleted due to the visual examination.

V. Results

1. Seven Year Trend Analyses Summaries

The following parameters and corresponding stations which have shown trends as indicated by the statistical analysis of the data in STORET are listed in Table 5.

All of the stations monitor basically the same parameters listed below. The following is a brief summary of these parameters and associated trends.

Conductivity (umhos/cm) @ 25°C #00095

Conductivity is a measurement of the resistance of a solution to electrical flow which is related to the content of ionized salts in water. This parameter also indicates the degree to which dissolved solids contribute to the overall water quality. An increasing trend for this parameter may be due to potential problems associated with solids loading and non-point source problems. Only two (2) stations exhibited conductivity trends. Two stations showed decreasing trends.

Dissolve Oxygen (mg/l) #00300

Dissolved oxygen concentration is an important indicator of existing water quality and the ability of a waterbody to support a well-balanced aqquatic fauna. Water should contain sufficient dissolved oxygen to maintain aerobic conditions in the water column to maintain a good fish population. Due to seasonal and diurnal fluctuations, dissolved oxygen values measured at monitoring stations provide at best an aproximate value of actual dissolved oxygen concentration in existence. Three (3) showed positive dissolved oxygen level trends. Only two stations exhibited decreasing trends. The remaining stations did not indicate any statistical trends.

Total Suspended Solids (mg/l) #00530

Total suspended solids (TSS) is the amount of organic and inorganic particulate matter in the water. An increase in TSS has been found to adversely affect fish population, growth rate, fish food source, development of fish eggs and larvae as well as the esthetics of the waterbody for swimming. Seven stations showed an increase and none showed decreasing trends for this parameter.

Total Kjeldahl Nitrogen (mg/l) #00625

Total Kjeldahl Nitrogen which measures organic nitrogen and ammonia concentrations is indicative of increased loadings from municipal and industrial facilities. The trend for these parameters were positive for two stations (increasing). Eight stations showed decreasing trends which indicated an improvement of water quality at at those sites.

Nitrates and Nitrite (mg/l) #00631

The Nitrate and Nitrite ions are formed from the breakdown of ammonia which may enter the waterbodies via municipal and industrial discharges, septic tanks and feedlot discharges. These ions are also indicative of the stage and degree of nitrification. There were increasing trends at two stations.

Phosphorus-Dissolved Ortho #00671 & Total Phosphorus #00665 in (mg/l)

The total dissolved phosphorus concentrtions are indicative of the nutrient loadings received by the stream. It has been determined that high phosphorus concentrations are associated with accelerated eutrophication of waters, especially in lakes and reservoirs. Most of the Minnesota network stations did not show substantial trends for this parameter. One station showed an increasing trend.

Total Chloride (mg/l) #00940

Chloride in the form of chlorine ions is present in lakes and rivers. The chloride concentrations in streams may show an increase due to increased industrial and sewage treatment plant effluents and septic tanks and other non-point source discharges, such as road salting and natural occurrences. This parameter showed an increasing trend in one station and a decreasing trend in one.

Fecal Coliform Bacteria (m-cagar/100 ml) #31613

Microbiological indicators are used to determine the safety of water for drinking, swimming and shellfish population growth. The fecal coliform is the primary indicator of fecal contamination in a waterbody. An increasing trend for this parameter is a result of poor chlorination of municipal treatment plant discharges, feedlot effluents and leakages from septic tank fields. For the period of this study only one station indicated an increasing trend.

Ammonia (mg/l) #00610

Un-ionized ammonia (NH_3) which has been shown to a toxic form of ammonia for aquatic life. Ammonia was reported to be acutely toxic to freshwater organisms at concentrations ranging from 0.083 to 4.60 mg/l NH_3 for many fish species. This form of ammonia pollution is usually due to municipal waste water treatment plant discharges and other point sources of pollution. Six stations showed decreasing ammonia levels.

Table 5. Parameters Showing Increasing and Decreasing Trends with corresponding Station Numbers

1. Conductivity #00095

Increasing Trend Statons:

None

Decreasing Trend Stations:

SLB-1, SL-9

2. Dissolved Oxygen #00300

Increasing Trend Stations:

PT-10, SR-1.2, ZSF-5.7 (ZRS-20)

Decreasing Trend Stations:

UM-1292, UM-982

3. Total Suspended Solids #00530

Increasing Trend Stations:

UM-859, MI-133, RL-0.2, RE-403, RE-452, SL-9, RE-300

Decreasing Trend Stations:

None

4. Total Kjeldahl Nitrogen #00625

Increasing Trend Stations:

KA-10, UM-895

Decreasing Trend Station:

ZSF-5.7, UM-1172

Table 5 (Continued)

5. Nitrate and Nitrite #00630

   Increasing Trend Stations:

   SR-1.2, ZSF-5.7

   Decreasing Trend Stations:

   None

6. Total and Dissolved Phosphorus #00671 & 00665

   Increasing Trend Stations:

   None

   Decreasing Trend Stations:

   ZSF-5.7

7. Total Chloride #00940

   Increasing Trend Stations:

   OT-1

   Decreasing Trend Stations:

   RE-300

8. Fecal Coliform Bacteria #31613

   Increasing Trend Stations:

   MI-64

   Decreasing Trend Stations:

   None

Table 5 (Cont'd)

9. Ammonia #00610

Increasing Trend Stations:

None

Decreasing Trend Stations:

RE-452, UM-738, UM-1292, SL-9, ZSF-5.7, UM-1186

In general, the potential pollution sources generally impact environmental parameters and cause these parameters to exhibit increasing or decreasing trends over a given time period. Furthermore, there is a correlation between environmental parameter levels and point and non-point sources of pollutants. For the purpose of this study, point sources of pollution are considered to originate from identifiable or known sources, such as industrial or municipal treatment plant discharges. Unlike point sources of pollution, non-point sources are more diffuse ,difficult to identify and cover large areas of origin. Non-point sources of pollution are generally recognized to be due to: agriculture, mining, urban runoff, silviculture and construction. Non-point source pollution will exhibit itself in waterbodies when the rate at which matter/pollutants entering a waterbody exceeds natural levels. As shown in Table 6, the point and non-point sources of pollution are generally associated with respective environmental parameters and affect the trend as indicated in the table.

Table 6 - Environmental Parameter & Associated Pollution Sources

Environmental Parameter	Trend Change	Pollution Source
Dissolved Oxygen	Decrease	Point
Ammonia	Increase	Point
Fecal Coliform	Increase	Point
Kjeldahl Nitrogen	Increase	Point
Nitrate-Nitrite	Increase	Non-point
Total Suspended Solids	Increase	Non-point
Phosphorus	Increase	Non-point

As shown in the above Table, if the trend over a given period of time for suspended solids showed an increase at a given station, then the station and the county where the station is located were considered to be an increasing non-point source pollution area. Likewise, an increasing trend for ammonia was regarded as associated with increase in point Source pollution for that station and surrounding county where the station is located. For example, point source pollution was associated with a decreasing trend in dissolved oxygen or an increasing trend in any one of the following parameters: Ammonia, Fecal Coliform, Kjeldahl Nitrogen . Also, non-point source pollution was associated with an increase in any one of the following parameters: Nitrate-Nitrite, Total Suspended Solids and Phosphorus. In summary, any increase or decrease in a trend for a given parameter is related to either point or non-point sources of pollution.

Thus, based on the relationships among variables in Table 6,trends and corresponding pollution sources maps were plotted as shown on Figures 3 through 7. The maps were plotted in terms of two broad pollution sources which are:

- ° Non-Point Sources
- ° Point Sources

For each pollution source two types of trend maps were plotted. The first trend map shows the counties where the monitoring stations are located. The county map shows the pollution trend in a county as determined from the statistical analysis of STORET data. A county's trend status is shown as decreasing or increasing. As previously specified, a positive or negative trend is said to exist if the correlation coefficients are statistically significant with 90 % significance level. Trend directions (positive,negative,neutral) corresponds to the signs of the coefficients. A neutral condition is present if either of the coefficients are not statistically significant. Data are considered insufficient if 75% completeness criteria is not met. The second trend map shows the locations of monitoring stations on streams as well as the specific pollution trend; e.g. non-point. The stream trend maps show arrows next to the stations with an upward pointing arrow indicating an increasing pollution trend and a downward pointing arrow a decreasing trend. If an arrow is not shown adjacent to a station, then trend was not observed at that station. The observed trends for point and non-point sources are given on Figures 3 through 6 and in Tables 6 and 7 respectively.

1. <u>Non-Point Source Pollution Trends</u>

As shown on Figures 3 and 5 , nine stations exhibited increasing trends and the rest of the stations did not show any trends. In general, non-point source pollution showed an increase of 12 percent for the period of this study. The stations which showed trends and locations are given in Table 6.

2. <u>Point Source Pollution Trends</u>

As shown on Figure 4 and 6, five stations showed an increasing trends, six stations showed decreasing pollution trends and the rest were unchanged. Based on the long term trends for the fixed network stations, the point source pollution remained relatively unchanged. The stations which exhibited trends are given in Table 7.

In summary, water quality conditions as determined by the trend analyses for the eight year period (1978-1985) were as follows: of the 75 stations analyzed 15 percent had point source pollution trends and 12 per cent showed non-point source trends respectively. Thus,only 27 percent of all the stations exhibited trends.

° Non-Point Source Pollution trend increased 12% of the stations.

° Point Source Pollution trend increased at 8% and decreased at 7% of the stations.

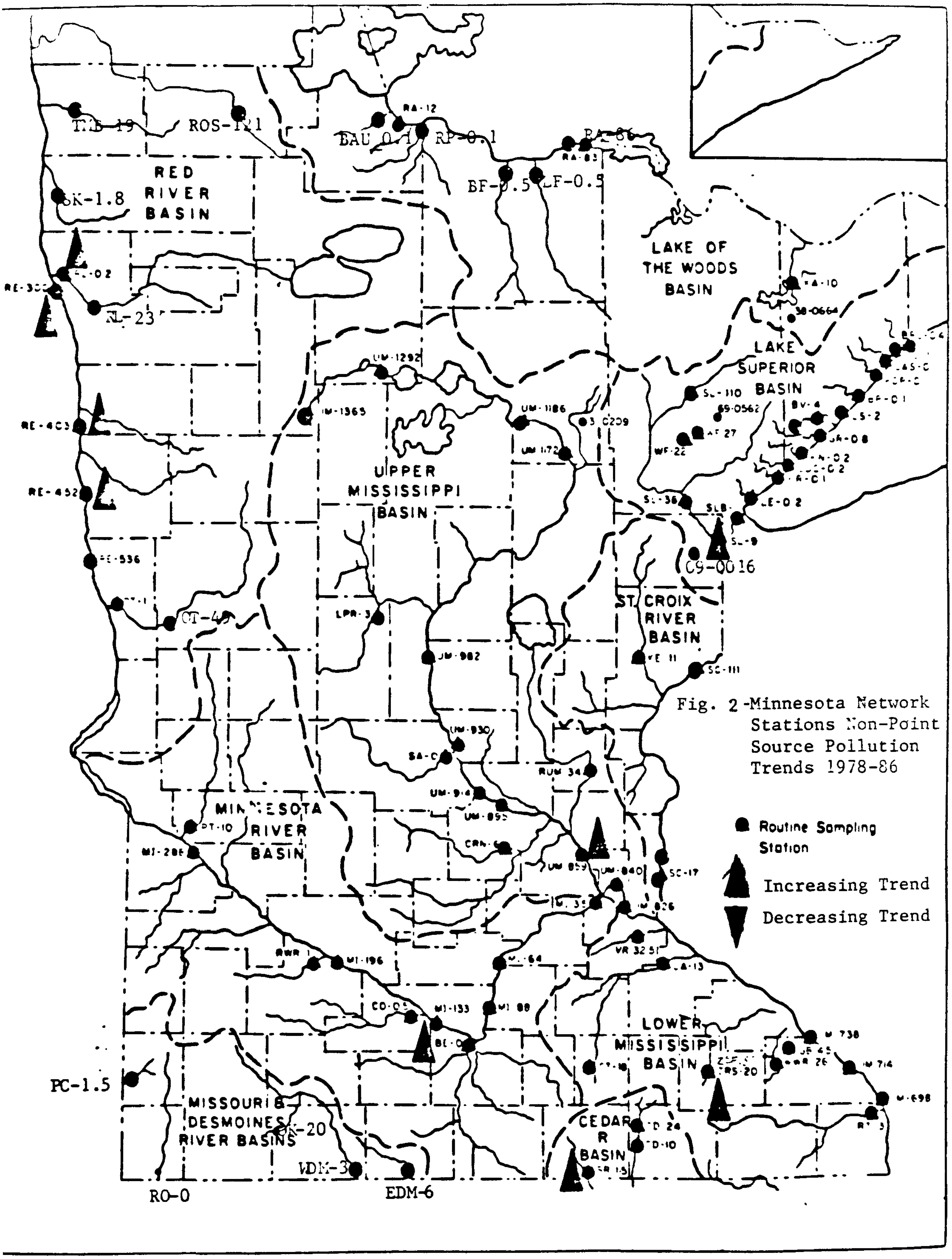


Fig. 2 -Minnesota Network Stations Non-Point Source Pollution Trends 1978-86

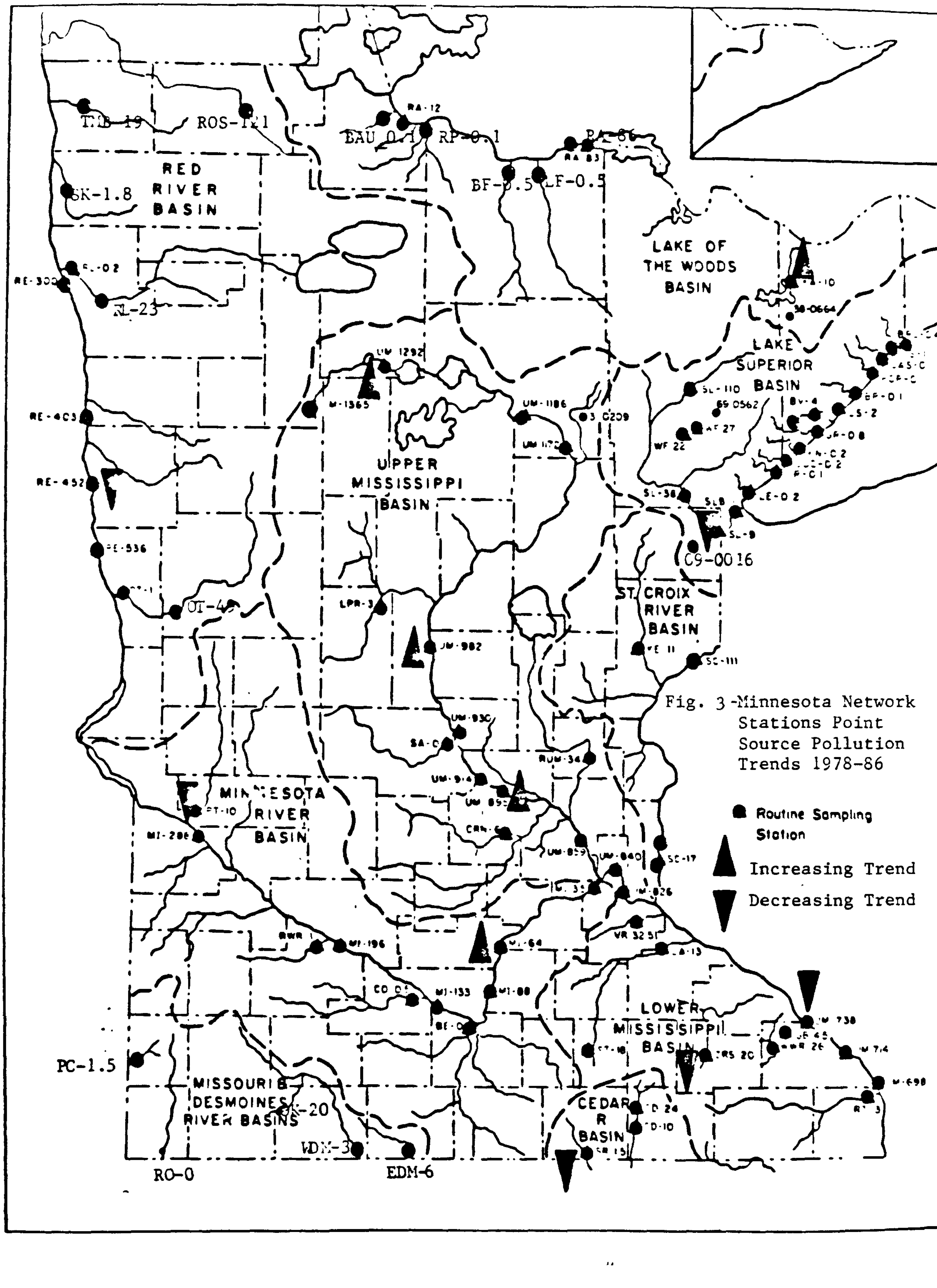


Fig. 3 -Minnesota Network Stations Point Source Pollution Trends 1978-86

MINNESOTA

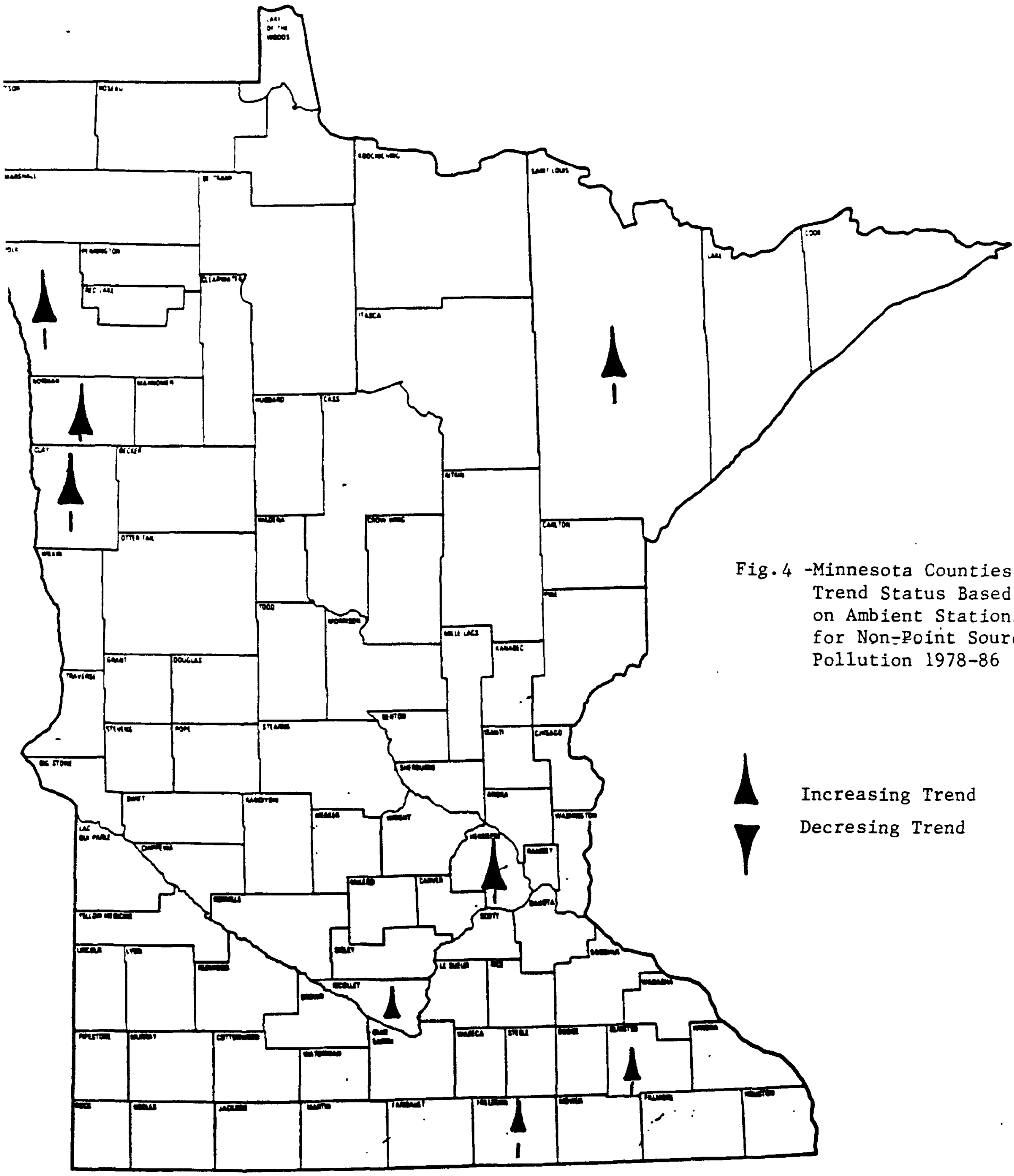


Fig.4 -Minnesota Counties Trend Status Based on Ambient Stations for Non-Point Source Pollution 1978-86

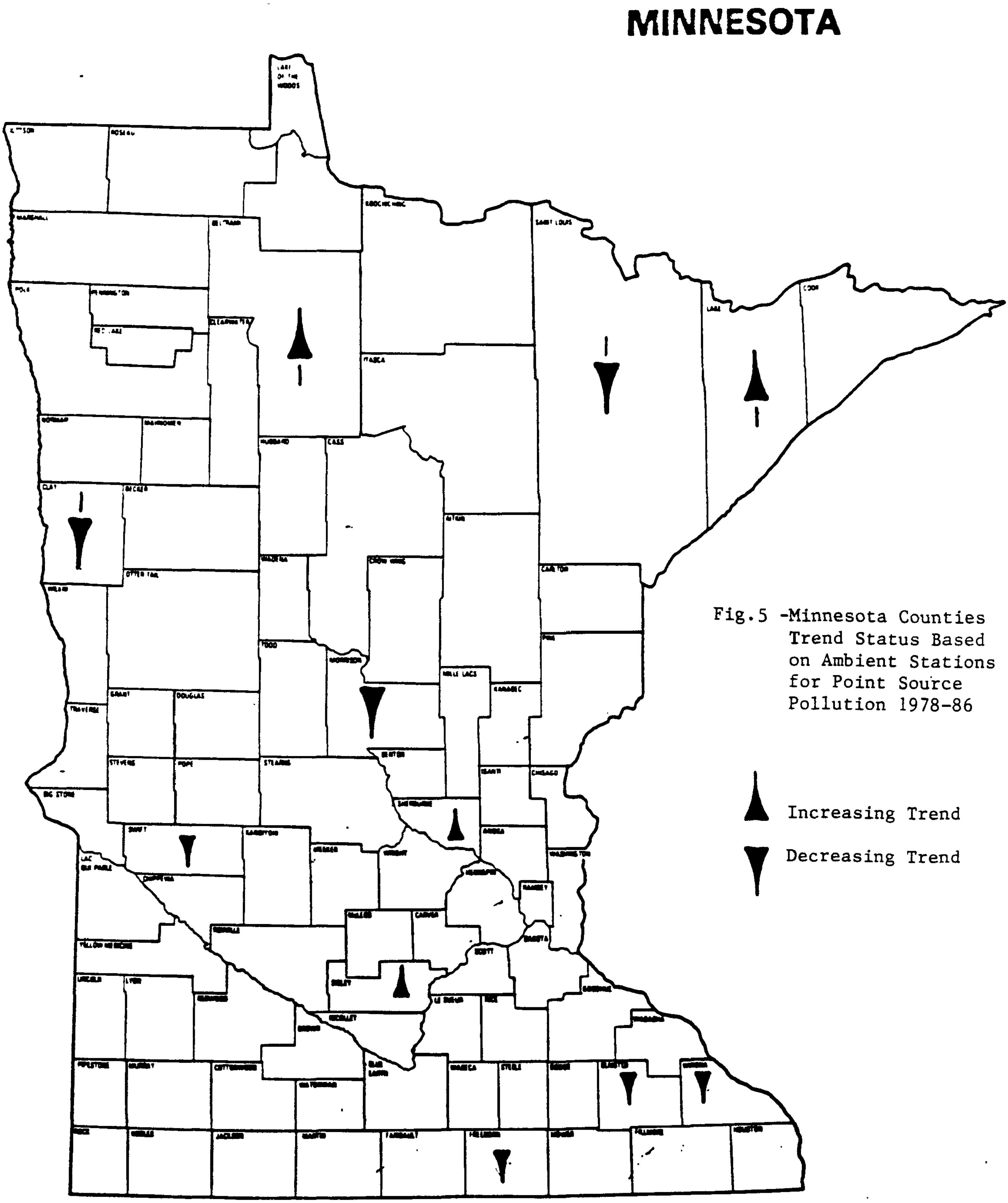


Fig.5 -Minnesota Counties Trend Status Based on Ambient Stations for Point Source Pollution 1978-86

Table 6- Non-Point Source Pollution Trends at Stations by County and Stream Locations

River and Location	STORET #	Trend	County
Shell Rock Rv. near Gordonsville	SR-1.5	UP	Freeborn
Minnesota Rv. @ Courtland	MI-133	UP	Nicolet
Zumbro Rv. S.Fork @ Rochester	ZRS-20	UP	Olmsted
Mississippi Rv. @ Minneapolis	UM-859	UP	Hennepin
Red Lake Rv. @ E.Grand Forks	RL-0.2	UP	Polk
Red Rv. @ Moorhead	RE-452	UP	Clay
Red Rv. West of Perley	RE-403	UP	Norman
St. Louis Bay, Fondu-Lac	SL-9	UP	St. Louis
Red River @ Grand Forks	RE-300	UP	Polk

Table 7- Point Source Pollution Trends at Stations by County and Stream Locations

River and Location	STORET #	Trend	County
Mississippi River, E. of Bemidji	UM-1292	UP	Beltrami
" " @ Camp Riley	UM-982	UP	Morrison
" " @ Monticello	UM-895	UP	Sherburne
Minnesota " @ Courtland	MI-64	UP	Sibley
Kawishiwi " @ Birch Lake	KA-10	UP	Lake
Zumbro Rv. S.Fork @ Rochester	ZRS-20	DOWN	Olmsted
Pomme de Terre Rv. @ Appleton	PT-10	DOWN	Swift
Mississippi Rv. SE of Minneiska	UM-738	DOWN	Winona
St. Louis Bay @ Fond du Lac	SL-9	DOWN	St. Louis
Red River @ Moorhead	RE-452	DOWN	Clay
Shell Rock Rv. @ Grand Forks	SR-1.5	DOWN	Freeborn

VI. Conclusions and Recommendations

- Because non-point source pollution has shown an increase at 12% of the stations expanded programs for non-point source monitoring and pollution controls are recommended.

- Establish stations at locations on the same stream where water quality is high and low to conduct bioassays to be used for reference purposes.

- Biological monitoring on a routine basis is non-existent. It would be highly desirable to conduct biomonitoring on impacted areas at least on an annual basis.

- If a station appears not to be representative of water quality, then investigate the possibilty of eliminating it or moving it to a more representative location.

- Establish stations or add variables to existing stations to measure toxics' impact at such locations.

- Chemical variable coverage is rather limited, expanded monitoring for other suspected toxic metals and organics would be helpful.

- The stations which did not exhibit trends and did not have high pollution levels may be worth investigating for relocation or elimination.

- MPCA would benefit from shared monitoring of waterways with neighboring states to reduce duplication of monitoring efforts with the help of USEPA.

Appendices

Appendix A

Statistical Analysis - Exemplary Case

The appendix contains an illustration of the manner in which the statistical procedures in the statistical analysis section were performed. The calculations are done with the SAS (Statistical Analysis System) STORET programs. The example shows the results for station RL-0.2.

The first program and its accompanying output is designed to integrate SAS with STORET. Line 20 allows the use of SAS. Lines 30 through 90 identify the STORET stations, water qaulity variables, and the time frame. The variable Y, defined on line 190, is the trend (time) variable.

The STORET output provides stream quality measurement information as well as station number and location. The numbers of measurements per variable per year also are shown. The most important SAS output for this report are the Spearman and Kendall correlation matrices. In this case trends were found for ph (P3), organic nitrogen (P7), total kjeldahl nitrogen (P9) and fecal coliform (P12). Only the variables P9 and P12 were used as water quality indicators in the report. The above listed variables were viewed as having definitive trends because the probabilities were .100 or lower for each of the variables correlation coefficients with the variable Y (the probabilities are shown by the numbers immediately below the coefficients). As previously indicated, because a station may not have a sufficient number of measurements for every water quality variable, it often was not possible to derive conclusions from the statistical analyses for certain water quality characteristics used as indicators. (See Program 1 and Output 1).

Program 1

```
STORET RETRIEVAL DATE  86/12/08        ECHO OF ORIGINAL REQUEST
PGM=INVENT,PURP=106/EPA,PRT=NO,
MORE=SAS,
HEAD=STATE.AMBIENT.NETWORK.MINN,
HEAD=MINN FISCAL YEAR 1986,
A=21MINN,
S=RL-0.2,
P=95,P=300,P=530,P=60,P=940,P=310,P=605,P=610,P=625,
P=630,P=665,P=31615,
BD=780101,ED=851231,
NOECHO,
SASPARMS=BEGIN,
*;
OPTIONS S=72 LS=131;
DATA LUBIN;
*
INCLUDE=(FCFREAD)
 PREVIOUS KEYWORD REPLACED BY -
* MACRO (FCFREAD)  - SAS -  READS STORET MORE=3,4 & SAS FCF FORMATS
 *
  * WRITTEN BY LEE MANNING    LAST MODIFIED BY LEE MANNING 4/25/84
   *
    * FUNCTION -
        BREAKDOWN A STORET MORE=4 (MORE=3 OR MORE=SAS) FCF FILE
        INTO ITS ELEMENTS FOR SUBSEQUENT PROCESSING BY ANY SAS
        PROCEDURES ;
OPTIONS NOSOURCE;
*   REF  -  THE STORET ADVANCED RETRIEVAL MANUAL UNDER PROGRAM
         'RET' FOR A DETAILED DESCRIPTION OF THE MORE=3,4 & SAS
         RECORD FORMATS.
    NOTE -  THIS ROUTINE DECODES DOUBLE-CHARACTER REMARK CODES
         STORED WITH USGS DATA, AS DESCRIBED WITHIN THE DATASET
         'STORET.HELP.USGS.REMARKS'
  *;
FORMAT DATE YYMMDD8.;
FORMAT TIME HHMM5.;
FORMAT DEPTH $6.;
FORMAT MEDIA $3.;
FORMAT SMK   $8.;
FORMAT UMK   $8.;
FORMAT USGSRMK $1.;
FORMAT BEGDATE YYMMDD8.;
FORMAT BEGTIME HHMM5.;
FORMAT REMDATE YYMMDD8.;
FORMAT REMTIME HHMM5.;
FORMAT ENDDATE YYMMDD8.;
FORMAT ENDTIME HHMM5.;
LENGTH AGENCY $ 8;
LENGTH STATION $ 24;
ARRAY P(I) P1-P50;
ARRAY R(I) $1 R1-R50;
INFILE FCF LENGTH=L;
FORMAT MORE $3.;
RETAIN MORE '3';
IF _N_=1 THEN DO; INPUT @24 MORE $1. @;
IF MORE='9' THEN MORE='SAS';
PUT ' ';
PUT 'NOTE: FCF FORMAT IS MORE=' MORE;
IF MORE='3' THEN DO;
PUT '      REMARK CODES, DEPTH INFORMATION, AND COMPOSITE';
PUT '      SAMPLE DESCRIPTORS WILL BE MISSING.';
```

```
PUT ' ';
END;  END;
INPUT @26 YYDLIM $2. @ ;
IF L=305 ! L=350 ! L=75 ! L=120;
                    * OMITS PARAMETER HEADERS AND STATION HEADERS ;
IF YYDLIM^='99'; * OMITS DELIMITER RECORDS ;
INPUT @1 AGENCY $8. @9 STATION $15. @26 DATE YYMMDD6.
@32 KHR $2. KMN $2.
@36 (P1-P10)(RB4.) @;
IF L=120 THEN INPUT @76 MEDIA $8.
                    @84 SMK   $8.
                    @93 UMK   $8.
                    @     ;
IF MORE='3' THEN DO; INPUT; GO TO SKIP; END;
INPUT
@76 (P11-P50)(RB4.) @236 (R1-R50)($1.) @296 TYPE $1. @287 CALC $1.
@288 RYY 2. RMM 2. RDD 2. @294 RHR $2. RMN $2. @298 NUMBER $2.
@300 DEPTH $6. @;
IF L=350 THEN INPUT @306 MEDIA $8.
                    @314 SMK   $8.
                    @323 UMK   $8.
                    @     ;
INPUT;
IF RHR<'25' THEN REMTIME=HMS(INPUT(RHR,2.),INPUT(RMN,2.),0);
IF RYY>0 THEN REMDATE=MDY(RMM,RDD,RYY);
SKIP: IF KHR<'25' THEN TIME=HMS(INPUT(KHR,2.),INPUT(KMN,2.),0);
STATION=AGENCY!!' '!!STATION;
DO OVER P;  IF P > 0. & P < 1.E-15 THEN P=. ;  END;
IF AGENCY='112WRD' THEN DO;
  USGSRMK=NUMBER;                    * USGS 'SAMPLE' RMK CODE ;
  NUMBER='  ';
  END;
IF REMDATE ^= . &
    PUT(DATE,YYMMDD6.)!!KHR!!KMN <= PUT(REMDATE,YYMMDD6.)!!RHR!!RMN
     THEN DO;
       BEGDATE=DATE;BEGTIME=TIME;ENDDATE=REMDATE;ENDTIME=REMTIME;
     END;
IF REMDATE ^= . &
    PUT(DATE,YYMMDD6.)!!KHR!!KMN > PUT(REMDATE,YYMMDD6.)!!RHR!!RMN
     THEN DO;
       BEGDATE=REMDATE;BEGTIME=REMTIME;ENDDATE=DATE;ENDTIME=TIME;
     END;
DROP KHR KMN RYY RMM RDD RHR RMN REMDATE REMTIME YYDLIM I ;
OPTIONS SOURCE;
       *
       *
    SOURCE LISTING SUPPRESSED
 (FULL SOURCE - 'STORET.HELP.FCFREAD')
       *
       *
    DEFINITION OF VARIABLES CREATED BY MACRO (FCFREAD)

 MORE    - 3 CHAR CODE ('3','4', OR 'SAS')
 AGENCY  - 8 CHAR STORET AGENCY CODE
 STATION - 24 CHARACTERS
              8 - STORET AGENCY CODE
              1 - BLANK
             15 - STORET PRIMARY STATION IDENTIFIER
 DATE    - SAMPLE DATE (SAS DATE FORM)
 TIME    - SAMPLE TIME (SAS TIME FORM)
 DEPTH   - 6 CHAR SAMPLE DEPTH + REMARK
```

```
          MEDIA   - 8 CHAR SAMPLE MEDIA CODE.
          SMK     - 8 CHAR SAMPLE SMK CODE.
          UMK     - 8 CHAR SAMPLE UMK CODE.
          P1-P50  - 50 FLOATING POINT NUMBERS.
                    VALUES OF 50 PARAMETERS.
          R1-R50  - 50 1 CHAR STORET RMK CODES
          USGSRMK - 1 CHAR USGS 'SAMPLE' RMK CODE
          BEGDATE - COMPOSITE SAMPLE BEGINNING DATE
          BEGTIME - COMPOSITE SAMPLE BEGINNING TIME
          ENDDATE - COMPOSITE SAMPLE ENDING DATE
          ENDTIME - COMPOSITE SAMPLE ENDING TIME
          TYPE    - COMPOSITE SAMPLE TYPE (STB)
          CALC    - COMPOSITE SAMPLE CALC CODE (AMLN)
          NUMBER  - COMPOSITE SAMPLE NO. OF GRABS (OR 'C') ;
         *        ;
         * - - - - - - - - - - - - - - - - - - - - - - - - - ;
         *                  WARNING                           ;
         * MACRO (FCFREAD) CONTAINS A "DROP" STATEMENT.       ;
         * USERS MAY -NOT- USE THE "KEEP" STATEMENT.          ;
         *                                                    ;
         * - - - - - - - - - - - - - - - - - - - - - - - - - ;
         * MACRO (FCFREAD)  - END-OF-MACRO ;
         * - - - - - - - - - - - - - - - - ;
          END OF REPLACE

*;
X =QTR(DATE);
Y=YEAR(DATE);
PROC SORT; BY AGENCY STATION;
PROC CORR SPEARMAN KENDALL DATA=LUBIN;
VAR P1 P2 P3 P4 P5 P6 P7 P8 P9 P10 P11 P12 Y;
*;
STOPSAS,
./LML       JOB (A500STORPLML,MLML),'ARTHUR LUBIN',NOTIFY=LML,
./                 TIME=(,30),MSGLEVEL=(0,0),PRTY=3
**ROUTE  PRINT HOLD
**JCBPARM LINES=30

# SAS DIAGNOSTICS (IF ANY) WILL BE PRINTED BELOW #
```

Output 1

```
STORET RETRIEVAL DATE 86/12/08                    PGM=INVENT                                                       PAGE:     1
STATE.AMBIENT.NETWORK.MINN                                           RRRL-.2---10A53               RL-0.2
MINN FISCAL YEAR 1986                                                47 55 24.0 097 01 00.0 2
                                                                     RED LAKE RIVER-EAST GRAND FORKS
                                                                     27119   MINNESOTA        POLK
                                                                     MAJ BASIN:  HUDSON BAY   230104
/TYPA/AMBNT/STREAM/SOLIDS/TISSUE/NET                                 MIN BASIN:  RED RIVER OF THE NORTH
                                                                     21MINN                   09020303001         ON
INDEX                                                                             0000 FEET  DEPTH
MILES
```

PARAMETER				MEDIUM	RMK	NUMBER	MEAN	VARIANCE	STAN DEV	MAXIMUM	MINIMUM	BEG DATE	END DATE
00010	WATER	TEMP	CENT	WATER		78	11.27600	80.19300	8.955000	27.0	.0	78/01/17	85/10/22
00060	STREAM	FLOW	CFS	WATER		41	1228.000	2376500	1541.600	9235	130	78/01/17	81/09/22
00095	CNDUCTVY	AT 25C	MICROMHO	WATER		77	406.4200	4686.400	68.45700	600	220	78/01/17	85/10/22
00300	DO		MG/L	WATER		77	9.136300	4.239500	2.059000	13.7	5.3	78/01/17	85/10/22
00400	PH		SU	WATER		77	8.084400	.0352080	.1876400	8.50	7.70	78/01/17	85/10/22
00530	RESIDUE	TOT NFLT	MG/L	WATER		77	57.20400	5538.000	74.41800	470	3	78/01/17	85/10/22
00605	ORG N	N	MG/L	WATER		78	1.019900	.0797190	.2823500	1.850	.540	78/01/17	85/10/22
00625	TOT KJEL	N	MG/L	WATER		65	1.182300	.0849680	.2914900	1.970	.700	79/02/13	85/10/22
00665	PHOS-TOT		MG/L P	WATER		78	.1487200	.0097376	.0986790	.502	.038	78/01/17	85/10/22
00940	CHLORIDE	TOTAL	MG/L	WATER		75	6.551200	21.34700	4.620200	30	3	78/01/17	85/10/22
31613	FEC COLI	M-FCAGAR	/100ML	WATER		6	117.5000	11575.00	107.5900	280	5	85/04/23	85/10/22

Output 1 (continued)

STORET RETRIEVAL DATE 86/12/08 PGM=INVENT
GROSS

1 TOTAL STATIONS PROCESSED
STATE.AMBIENT.NETWORK.MINN
MINN FISCAL YEAR 1986

	STA BEG	STA END	# OF OBS	# OF SAMPLE	STA END-PERIOD OF RECD IN YRS =0	<.5	<3	>=3
<1967	0	0	0	0	0	0	0	0
1967	0	0	0	0	0	0	0	0
1968	0	0	0	0	0	0	0	0
1969	0	0	0	0	0	0	0	0
1970	0	0	0	0	0	0	0	0
1971	0	0	0	0	0	0	0	0
1972	0	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0
1974	0	0	0	0	0	0	0	0
1975	0	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0
1978	1	0	108	12	0	0	0	0
1979	0	0	109	11	0	0	0	0
1980	0	0	99	10	0	0	0	0
1981	0	0	89	9	0	0	0	0
1982	0	0	80	9	0	0	0	0
1983	0	0	81	9	0	0	0	0
1984	0	0	77	9	0	0	0	0
1985	0	1	86	9	0	0	0	1
1986	0	0	0	0	0	0	0	0
TOTAL	1	1	729	78	0	0	0	1

SAS 13:51 TUESDAY, DECEMBER 9, 19

SPEARMAN CORRELATION COEFFICIENTS / PROB > |R| UNDER H0:RHO=0 / NUMBER OF OBSERVATIONS

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	
P1	1.00000	-0.09472	-0.10182	-0.51129	0.52614	-0.18636	0.23831	0.01253	0.23172	0.09790	-0.10533	0.14375	0.1263
	0.0000	0.4157	0.3782	0.0006	0.0001	0.1070	0.0369	0.9139	0.0654	0.3969	0.3619	0.2422	0.273
	77	76	77	41	75	76	77	77	64	77	77	68	7
P2	-0.09472	1.00000	-0.54325	0.07703	-0.14191	-0.00492	-0.26697	0.21863	-0.17172	0.20795	-0.49210	-0.10703	-0.0701
	0.4157	0.0000	0.0001	0.6322	0.2278	0.9666	0.0189	0.0561	0.1749	0.0696	0.0001	0.3850	0.544
	76	77	76	41	74	75	77	77	64	77	77	68	7
P3	-0.10182	-0.54325	1.00000	0.57998	0.06922	0.41137	0.57416	-0.21143	0.48274	0.05829	0.71451	-0.06771	0.2364
	0.3782	0.0001	0.0000	0.0001	0.5551	0.0002	0.0001	0.0649	0.0001	0.6145	0.0001	0.5833	0.038
	77	76	77	41	75	76	77	77	64	77	77	68	7
P4	-0.51129	0.07703	0.57998	1.00000	-0.55130	0.16681	-0.03352	0.12851	-0.10978	0.11814	0.28369	-0.01879	-0.3928
	0.0006	0.6322	0.0001	0.0000	0.0002	0.2972	0.8352	0.4233	0.5781	0.4619	0.0723	0.9072	0.011
	41	41	41	41	40	41	41	41	28	41	41	41	4
P5	0.52614	-0.14191	0.06922	-0.55130	1.00000	0.09236	0.27931	-0.07228	0.33617	0.22147	0.20223	-0.06098	0.0109
	0.0001	0.2278	0.5551	0.0002	0.0000	0.4338	0.0152	0.5377	0.0076	0.0562	0.0819	0.6267	0.925
	75	74	75	40	75	74	75	75	62	75	75	66	7
P6	-0.18636	-0.00492	0.41137	0.16681	0.09236	1.00000	0.37936	0.01921	0.37638	0.11715	0.45497	-0.32346	0.1258
	0.1070	0.9666	0.0002	0.2972	0.4338	0.0000	0.0007	0.8692	0.0024	0.3135	0.0001	0.0071	0.278
	76	75	76	41	74	76	76	76	63	76	76	68	7
P7	0.23831	-0.26697	0.57416	-0.03352	0.27931	0.37936	1.00000	0.02424	0.91527	0.25913	0.49049	-0.17203	0.3408
	0.0369	0.0189	0.0001	0.8352	0.0152	0.0007	0.0000	0.8332	0.0001	0.0220	0.0001	0.1607	0.002
	77	77	77	41	75	76	78	78	65	78	78	68	7
P8	0.01253	0.21863	-0.21143	0.12851	-0.07228	0.01921	0.02424	1.00000	0.39782	0.64417	0.03343	0.12487	-0.1857
	0.9139	0.0561	0.0649	0.4233	0.5377	0.8692	0.8332	0.0000	0.0010	0.0001	0.7714	0.3103	0.103
	77	77	77	41	75	76	78	78	65	78	78	68	7
P9	0.23172	-0.17172	-0.48274	-0.10978	0.33617	0.37638	0.91527	0.39782	1.00000	0.54086	0.53765	-0.19371	0.334
	0.0654	0.1749	0.0001	0.5781	0.0076	0.0024	0.0001	0.0010	0.0000	0.0001	0.0001	0.1565	0.00
	64	64	64	28	62	63	65	65	65	65	65	55	
P10	0.09790	0.20795	0.05829	0.11814	0.22147	0.11715	0.25913	0.64417	0.54086	1.00000	0.29197	0.14428	0.064
	0.3969	0.0696	0.6145	0.4619	0.0562	0.3135	0.0220	0.0001	0.0001	0.0000	0.0095	0.2405	0.57
	77	77	77	41	75	76	78	78	65	78	78	68	
P11	-0.10533	-0.49210	0.71451	0.28369	0.20223	0.45497	0.49049	0.03343	0.53765	0.29197	1.00000	-0.11123	0.138
	0.3619	0.0001	0.0001	0.0723	0.0819	0.0001	0.0001	0.7714	0.0001	0.0095	0.0000	0.3665	0.22
	77	77	77	41	75	76	78	78	65	78	78	68	
P12	0.14375	-0.10703	-0.06771	-0.01879	-0.06098	-0.32346	-0.17203	0.12487	-0.19371	0.14428	-0.11123	1.00000	-0.347
	0.2422	0.3850	0.5833	0.9072	0.6267	0.0071	0.1607	0.3103	0.1565	0.2405	0.3665	0.0000	0.00
	68	68	68	41	66	68	68	68	55	68	68	68	
Y	0.12635	-0.07011	0.23647	-0.39292	0.01095	0.12585	0.34082	-0.18575	0.33418	0.06418	0.13812	-0.34748	1.000
	0.2735	0.5446	0.0384	0.0111	0.9257	0.2787	0.0023	0.1035	0.0065	0.5767	0.2278	0.0037	0.00
	77	77	77	41	75	76	78	78	65	78	78	68	

KENDALL TAU B CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / NUMBER OF OBSERVATIONS

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	Y
P1	1.00000 0.0000 77	-0.07308 0.3247 76	-0.07966 0.3167 77	-0.34213 0.0020 41	0.36915 0.0000 75	-0.12550 0.1233 76	0.17562 0.0274 77	0.01532 0.8494 77	0.16280 0.0644 64	0.07248 0.3777 77	-0.07997 0.3146 77	0.10049 0.2504 68	0.09257 0.2679 77
P2	-0.07908 0.3247 76	1.00000 0.0000 77	-0.38411 0.0000 76	0.05299 0.6287 41	-0.10070 0.2105 74	-0.00668 0.9342 75	-0.19578 0.0127 77	0.13748 0.0840 77	-0.12141 0.1620 64	0.14371 0.0761 77	-0.35595 0.0000 77	-0.08251 0.3394 68	-0.05086 0.5371 77
P3	-0.07966 0.3167 77	-0.38411 0.0000 76	1.00000 0.0000 77	0.39902 0.0003 41	0.04227 0.5954 75	0.28726 0.0003 76	0.39393 0.0000 77	-0.12379 0.1187 77	0.34857 0.0001 64	0.02335 0.7726 77	0.55860 0.0001 77	-0.02294 0.7897 68	0.17509 0.0331 77
P4	-0.34213 0.0020 41	0.05299 0.6287 41	0.39902 0.0003 41	1.00000 0.0000 41	-0.38756 0.0005 40	0.11488 0.3000 41	-0.04674 0.6692 41	0.09877 0.3732 41	-0.08415 0.5377 28	0.08129 0.4724 41	0.16554 0.1292 41	-0.03512 0.7521 41	-0.31061 0.0096 41
P5	0.36915 0.0000 75	-0.10070 0.2105 74	0.04227 0.5954 75	-0.38756 0.0005 40	1.00000 0.0000 75	0.06336 0.4372 74	0.18964 0.0173 75	-0.04548 0.5728 75	0.22992 0.0092 62	0.16428 0.0454 75	0.12787 0.1081 75	-0.03427 0.6959 66	-0.01274 0.8788 75
P6	-0.12550 0.1233 76	-0.00668 0.9342 75	0.28726 0.0003 76	0.11488 0.3000 41	0.06336 0.4372 74	1.00000 0.0000 76	0.26073 0.0011 76	0.01611 0.8429 76	0.28386 0.0014 63	0.08539 0.3023 76	0.33316 0.0000 76	-0.23073 0.0084 68	0.09280 0.2703 76
P7	0.17562 0.0274 77	-0.19578 0.0127 77	0.39393 0.0000 77	-0.04674 0.6692 41	0.18964 0.0173 75	0.26073 0.0011 76	1.00000 0.0000 78	0.01228 0.8763 78	0.79221 0.0001 65	0.18696 0.0199 78	0.36025 0.0000 78	-0.12043 0.1621 68	0.24799 0.0024 78
P8	0.01532 0.8494 77	0.13748 0.0840 77	-0.12379 0.1187 77	0.09877 0.3732 41	-0.04548 0.5728 75	0.01611 0.8429 76	0.01228 0.8763 78	1.00000 0.0000 78	0.26851 0.0021 65	0.49013 0.0001 78	0.03133 0.6908 78	0.08576 0.3255 68	-0.12633 0.1269 78
P9	0.16280 0.0644 64	-0.12141 0.1620 64	0.34857 0.0001 64	-0.08415 0.5377 28	0.22992 0.0092 62	0.28386 0.0014 63	0.79221 0.0001 65	0.26851 0.0021 65	1.00000 0.0000 65	0.39711 0.0000 65	0.39923 0.0000 65	-0.14978 0.1232 55	0.24545 0.0068 65
P10	0.07248 0.3777 77	0.14371 0.0761 77	0.02335 0.7726 77	0.08129 0.4724 41	0.16428 0.0454 75	0.08539 0.3023 76	0.18696 0.0199 78	0.49013 0.0001 78	0.39711 0.0000 65	1.00000 0.0000 78	0.19570 0.0146 78	0.09423 0.2898 68	0.05000 0.5528 78
P11	-0.07997 0.3146 77	-0.35595 0.0000 77	0.55860 0.0001 77	0.16554 0.1292 41	0.12787 0.1081 75	0.33316 0.0000 76	0.36025 0.0000 78	0.03133 0.6908 78	0.39923 0.0000 65	0.19570 0.0146 78	1.00000 0.0000 78	-0.07200 0.4022 68	0.10122 0.2146 78
P12	0.10049 0.2504 68	-0.08251 0.3394 68	-0.02294 0.7897 68	-0.03512 0.7521 41	-0.03427 0.6959 66	-0.23073 0.0084 68	-0.12043 0.1621 68	0.08576 0.3255 68	-0.14978 0.1232 55	0.09423 0.2898 68	-0.07200 0.4022 68	1.00000 0.0000 68	-0.26515 0.0036 68
Y	0.09257 0.2679 77	-0.05086 0.5371 77	0.17509 0.0331 77	-0.31061 0.0096 41	-0.01274 0.8788 75	0.09280 0.2703 76	0.24799 0.0024 78	-0.12633 0.1269 78	0.24545 0.0068 65	0.05000 0.5528 78	0.10122 0.2146 78	-0.26515 0.0036 68	1.00000 0.0000 78

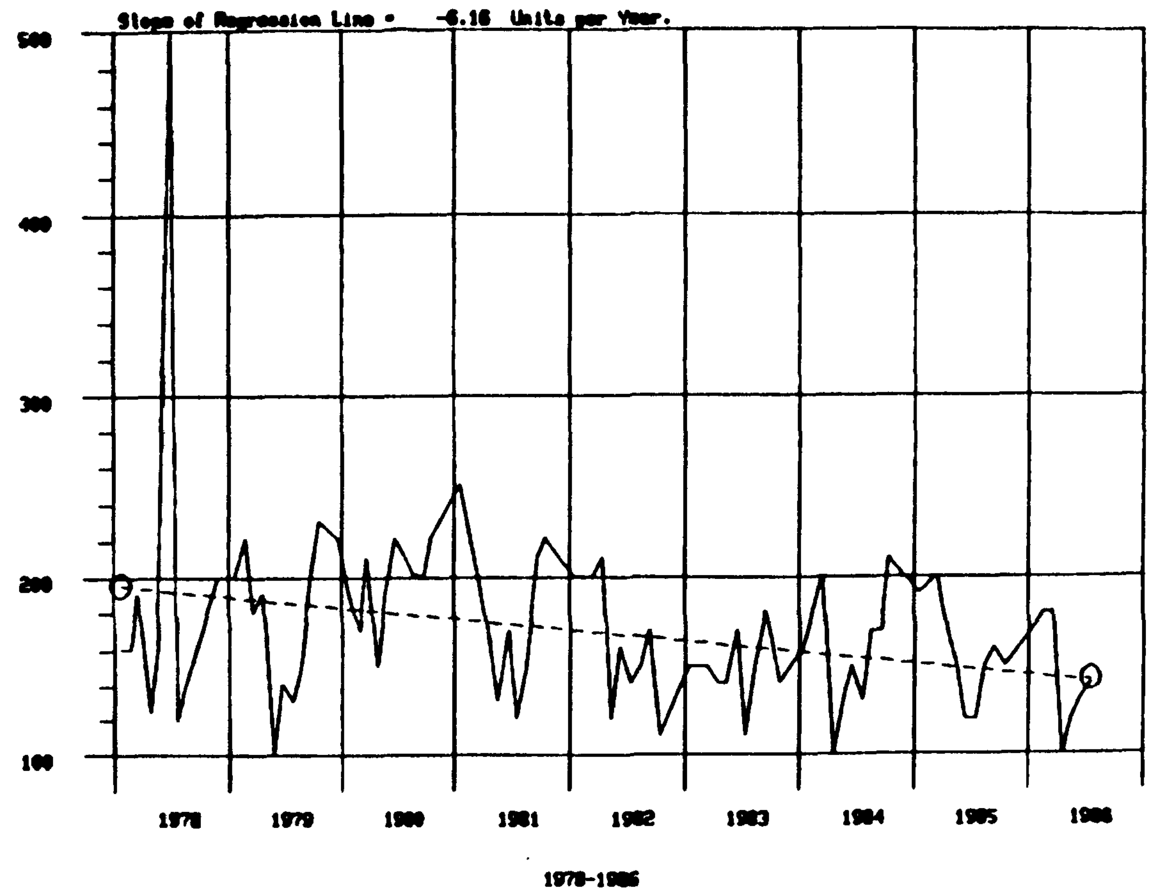
Appendix B

Regression Analysis Graphs of Parameters at Stations Showing Significant Trends

Appendix B contains linear regression plots of water quality variables at the monitoring stations which showed statistically as well as substantively significant water quality trends. The plots were obtained by using the Water Quality Analysis Branch's Browse interactive program. On each figure the data are plotted in terms of the measured variable's value verse time. The dotted line on graphs indicates the predicted bivariate linear regression line for the period of measurement.

030 SLD-1 STORET System
46 45 05.0 092 06 00.0 2
ST LOUIS BAY AT DULUTH-SUPERIOR
27137 MINNESOTA ST LOUIS
MAJ BASIN: GREAT LAKES 222306
MIN BASIN: LAKE SUPERIOR
21MINN 04010201003 ON /TYPA/AMBNT/STREAM/SOLIDS/TISSUE/WET/BOWN
DEPTH 0
INDEX
MILES

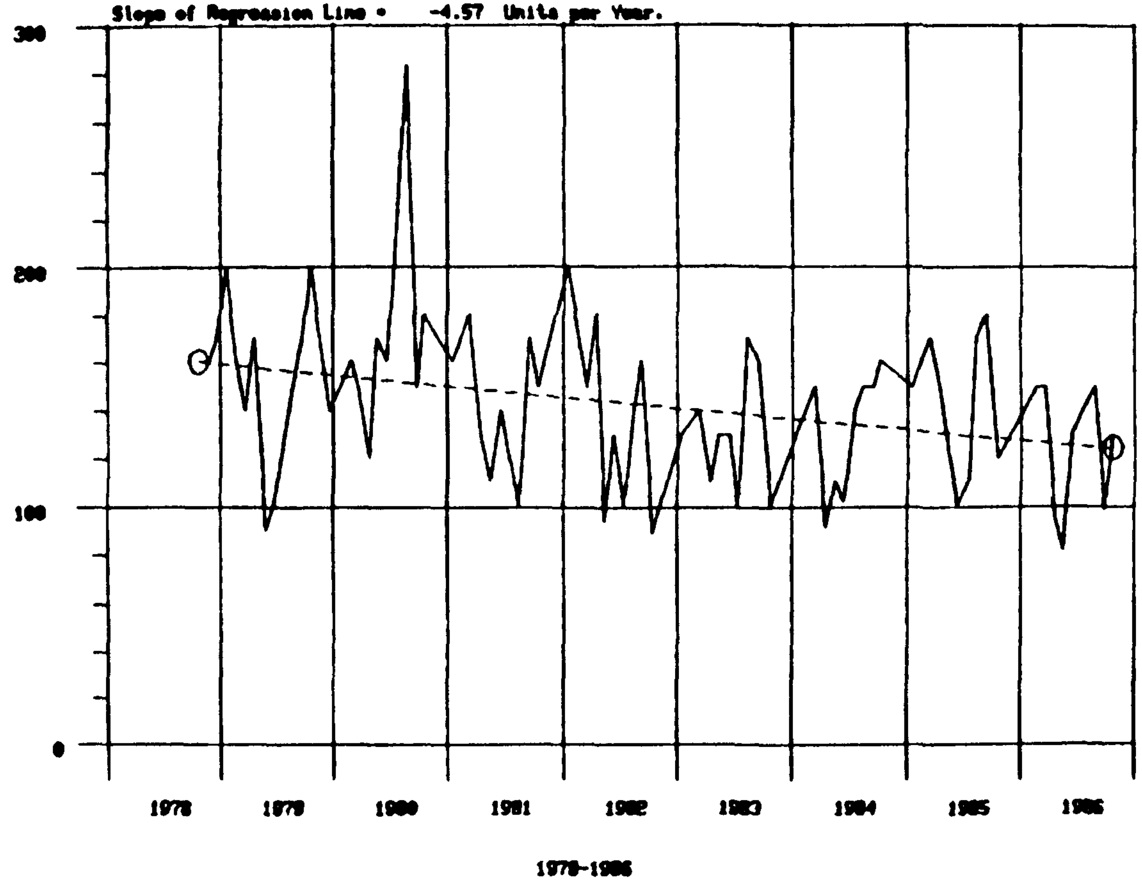
PARAMETER			NOBS	AVE	MAX	MIN	BEG-DATE	END-DATE
95 CNDUCTVY	AT 25C	MICROMHO	84	170	500	100	78/01/24	86/07/14



LSSL-19-CB15E53 SL-9 STORET System
46 39 31.0 092 17 04.0 3
ST LOUIS R. SH-23 AT FOND DU LAC
27137 MINNESOTA ST LOUIS
MAJ BASIN: GREAT LAKES 222306
MIN BASIN: LAKE SUPERIOR
21MINN 04010201009 ON /TYPA/AMBNT/STREAM/NET/DOWN
DEPTH 0
INDEX
MILES

PARAMETER	NOBS	AVE	MAX	MIN	BEG-DATE	END-DATE
95 CNDUCTVY AT 25C MICROMHO	78	143	283	82	78/10/23	86/10/20

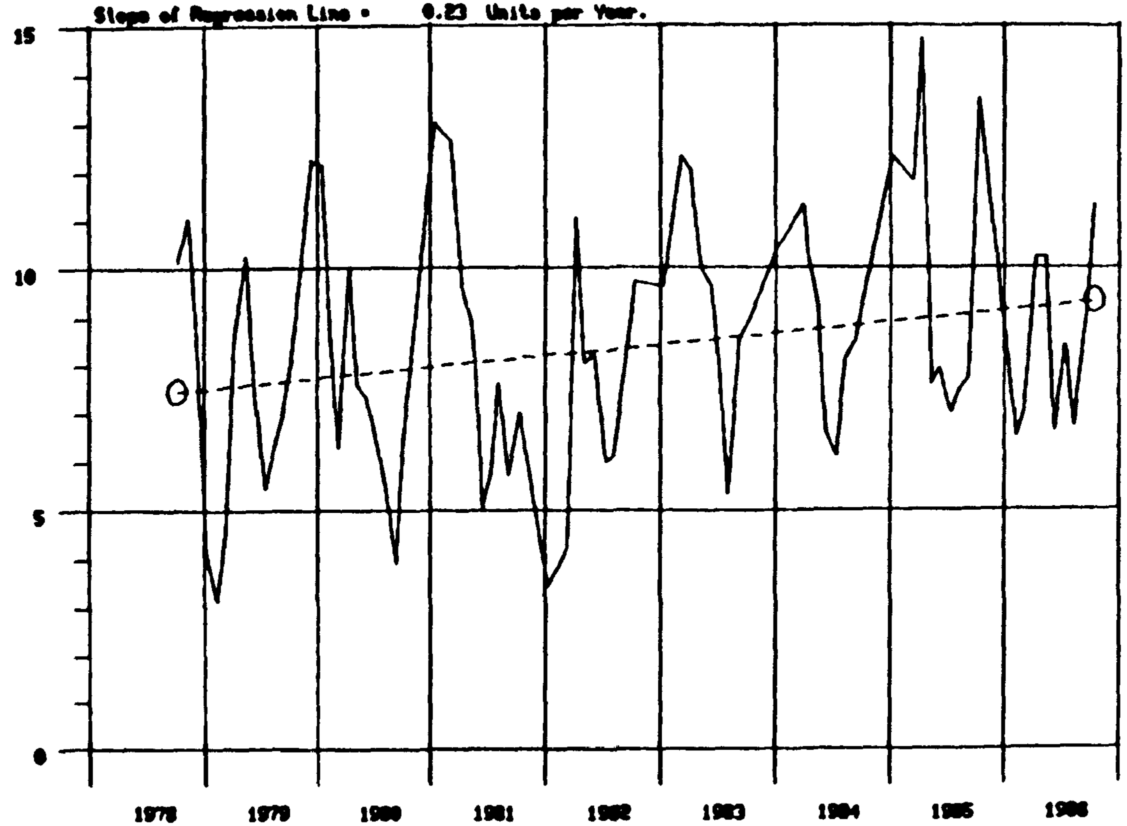
Slope of Regression Line = -4.57 Units per Year.



MNPT-10-0014A71   PT-10   STORET System
45 12 31.0 096 01 85.0 3
POMME DE TERRE R. AT APPLETON
27151 MINNESOTA   SWIFT
MAJ BASIN: UPPER MISS   070406
MIN BASIN: MINNESOTA RIVER
21MINN   07020002001   ON /TYPA/AMBNT/STREAM/NET
                    DEPTH   0
INDEX
MILES

	PARAMETER		NOBS	AVE	MAX	MIN	BEG-DATE	END-DATE
300	DO	MG/L	79	8.3	14.7	3.1	78/10/02	86/10/08

Slope of Regression Line = 0.23 Units per Year.

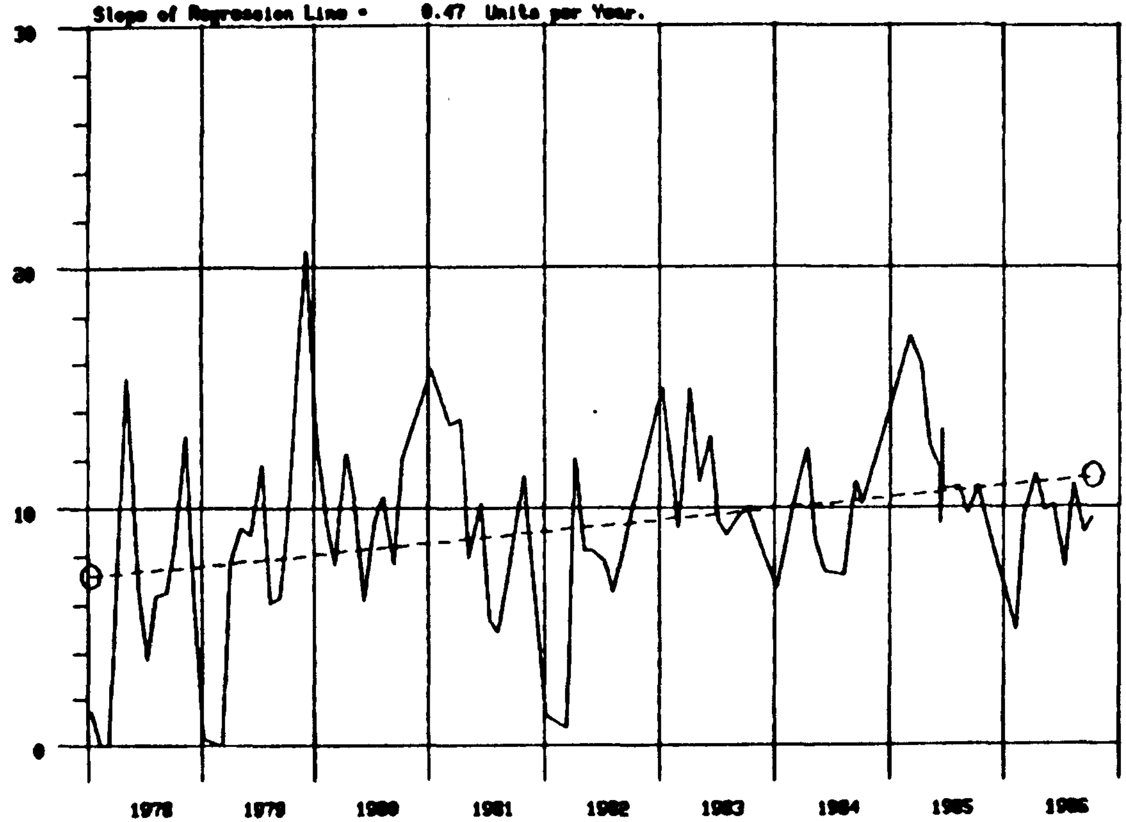


1978-1986

CRSR1.5-0015EG0 SR-1.2 [SR-1.5] STORET System
43 30 42.0 093 16 21.0 2
SHELL ROCK R. W OF GORDONSVILLE
27047 MINNESOTA FREEBORN
MAJ BASIN: UPPER MISS 071006
MIN BASIN: CEDAR RIVER
21MINN 07080202009 ON /TYPA/AMBNT/STREAM/NET/DOWN
DEPTH 0
INDEX
MILES

	PARAMETER		NOBS	AVE	MAX	MIN	BEG-DATE	END-DATE
300	DO	MG/L	89	9.1	20.6	0.0	78/01/10	86/10/07

Slope of Regression Line = 0.47 Units per Year.

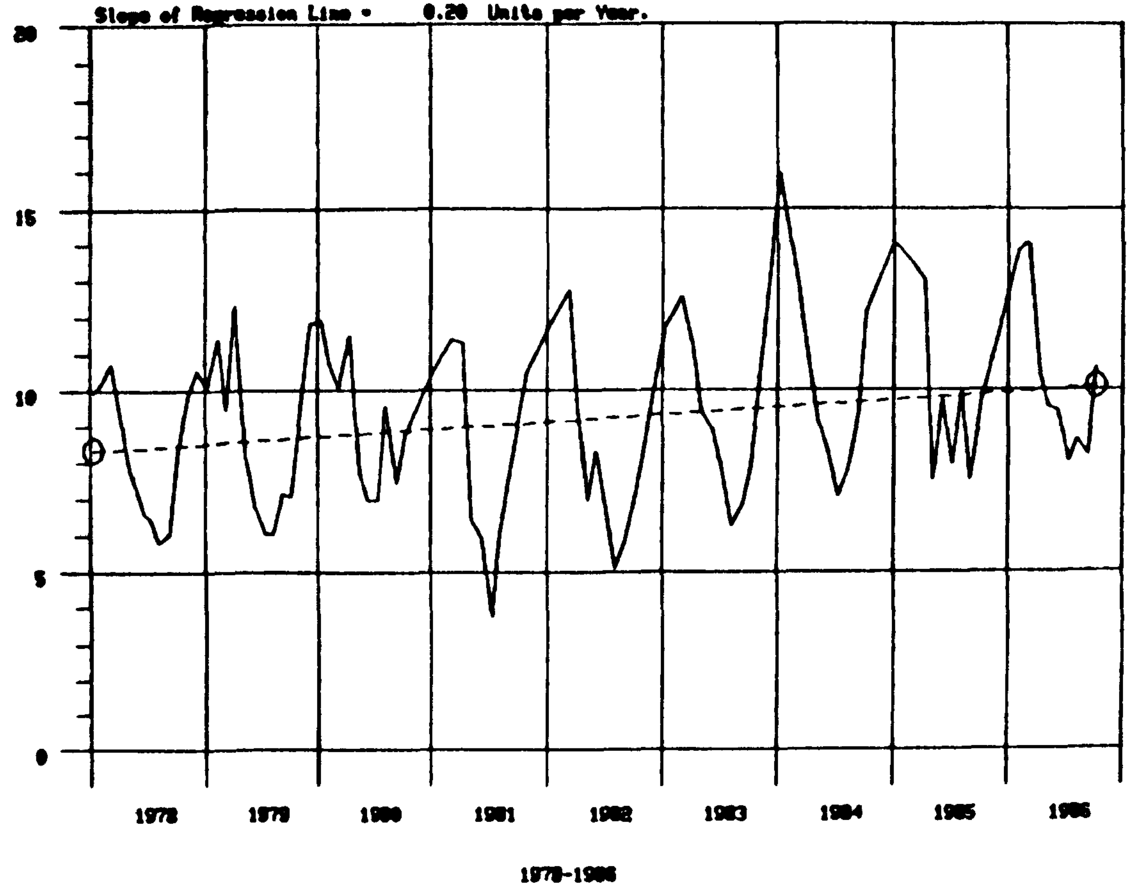


1978-1986

GRR 2SF-5.7 EZRS-803 STORET System
44 06 30.0 092 28 54.0 2
ZUMBRO R.-SOUTH FORK BY ROCHESTER
27109 MINNESOTA OLMSTED
MAJ BASIN: UPPER MISS. 070606
MIN BASIN: LOWER PORTION UPPER MISS
21MINM 07040004016 ON /TYPA/AMBNT/STREAM/NET/DOWN
DEPTH 990
INDEX
MILES

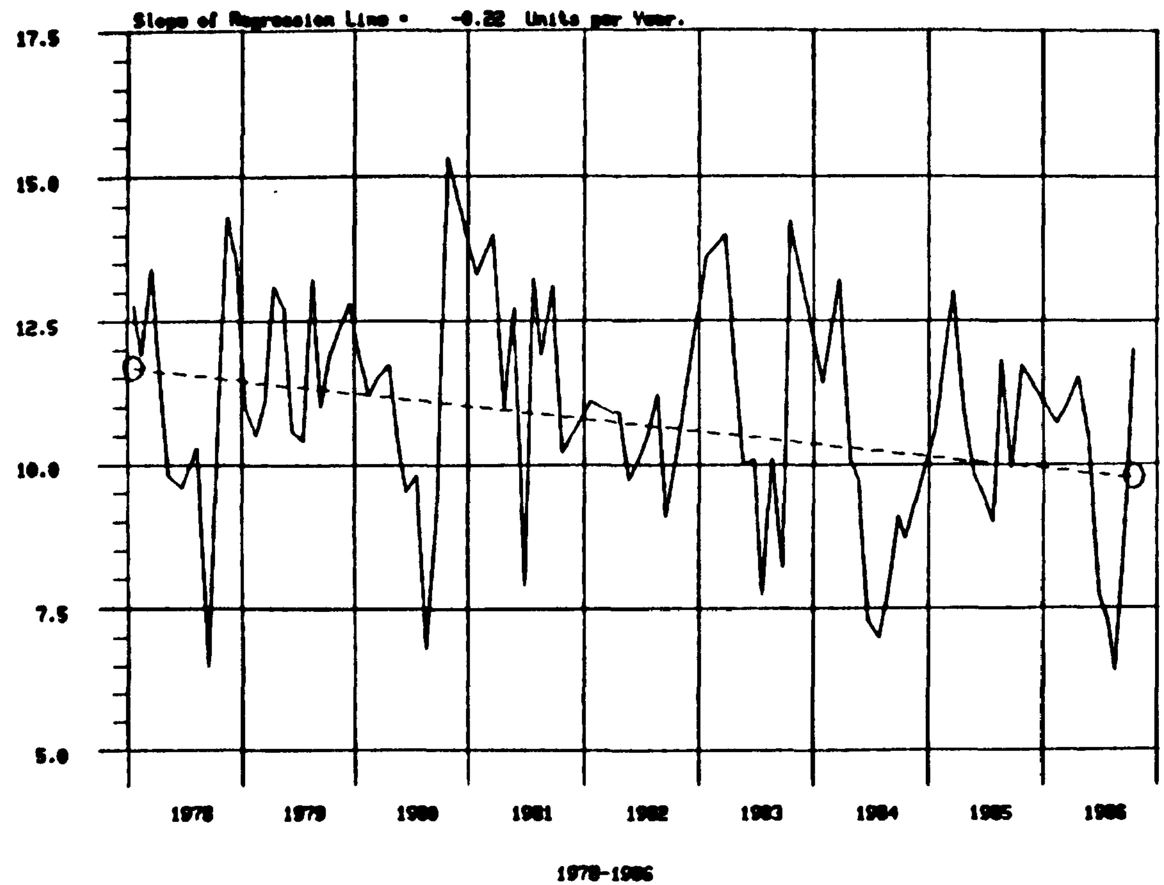
	PARAMETER		NOBS	AVE	MAX	MIN	BEG-DATE	END-DATE
300	DO	MG/L	86	9.2	15.9	3.7	78/01/10	86/10/06

Slope of Regression Line = 0.20 Units per Year.



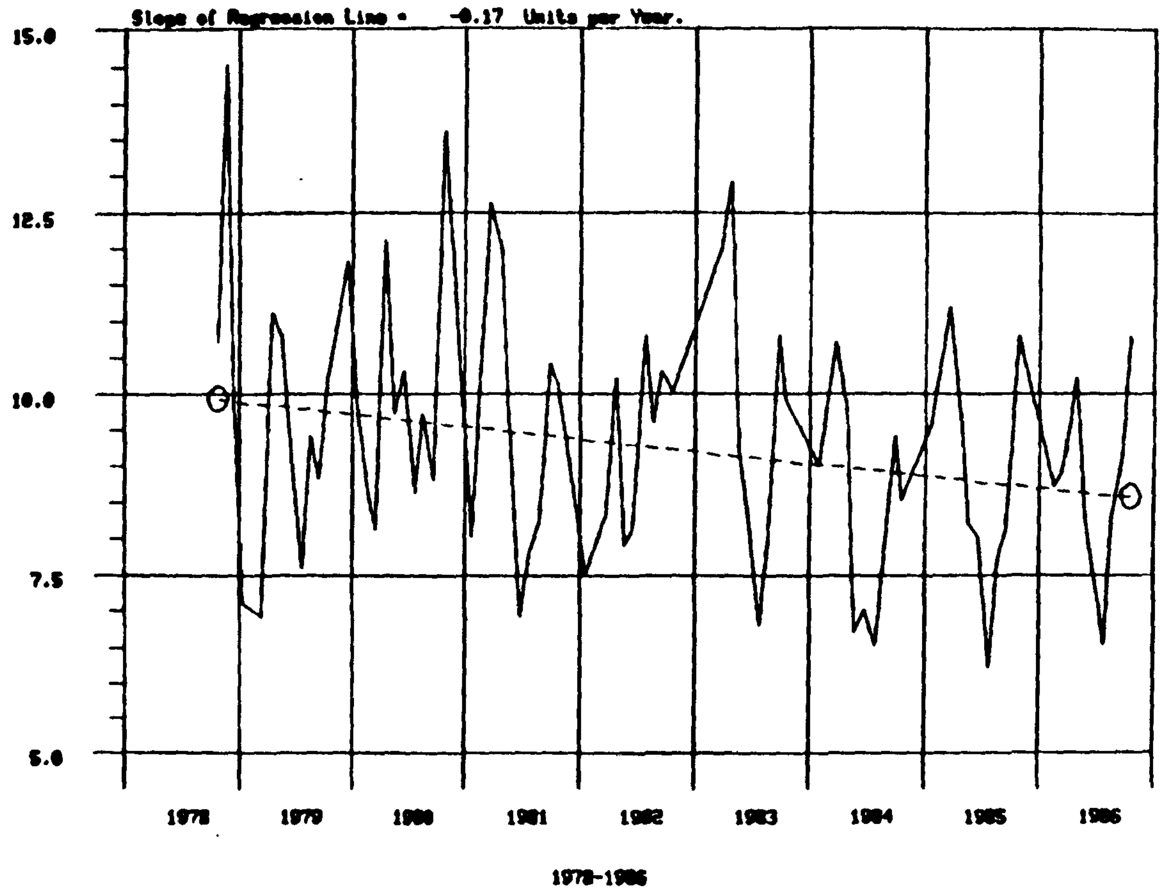
MGU1292-0015E67 UA-1292 STORET System
47 27 12.0 094 42 44.0 2
MISSISSIPPI R. EAST OF BEMIDJI
27007 MINNESOTA BELTRAMI
MAJ BASIN: UPPER MISS 070306
MIN BASIN: UPPER PORTION UPPER MISS
21MINN 07010101027 0005.230 ON /TYPA/AMBNT/STREAM/NET
DEPTH 0
INDEX
MILES

	PARAMETER		NOBS	AVE	MAX	MIN	BEG-DATE	END-DATE
300	DO	MG/L	87	10.8	15.3	6.4	78/01/17	86/10/14



MSU-000C0015E67 UM-902 STORET System
46 04 29.0 094 20 04.0 2
MISSISSIPPI R. AT CAMP RIPLEY
27097 MINNESOTA MORRISON
MAJ BASIN: UPPER MISS 070304
MIN BASIN: UPPER PORTION UPPER MISS
21MINN 07010104005 0001.200 ON /TYPA/AMBNT/STREAM/NET
DEPTH 0
INDEX
MILES

	PARAMETER		NOBS	AVE	MAX	MIN	BEG-DATE	END-DATE
300	DO	MG/L	77	9.3	14.5	6.2	78/10/19	86/10/15

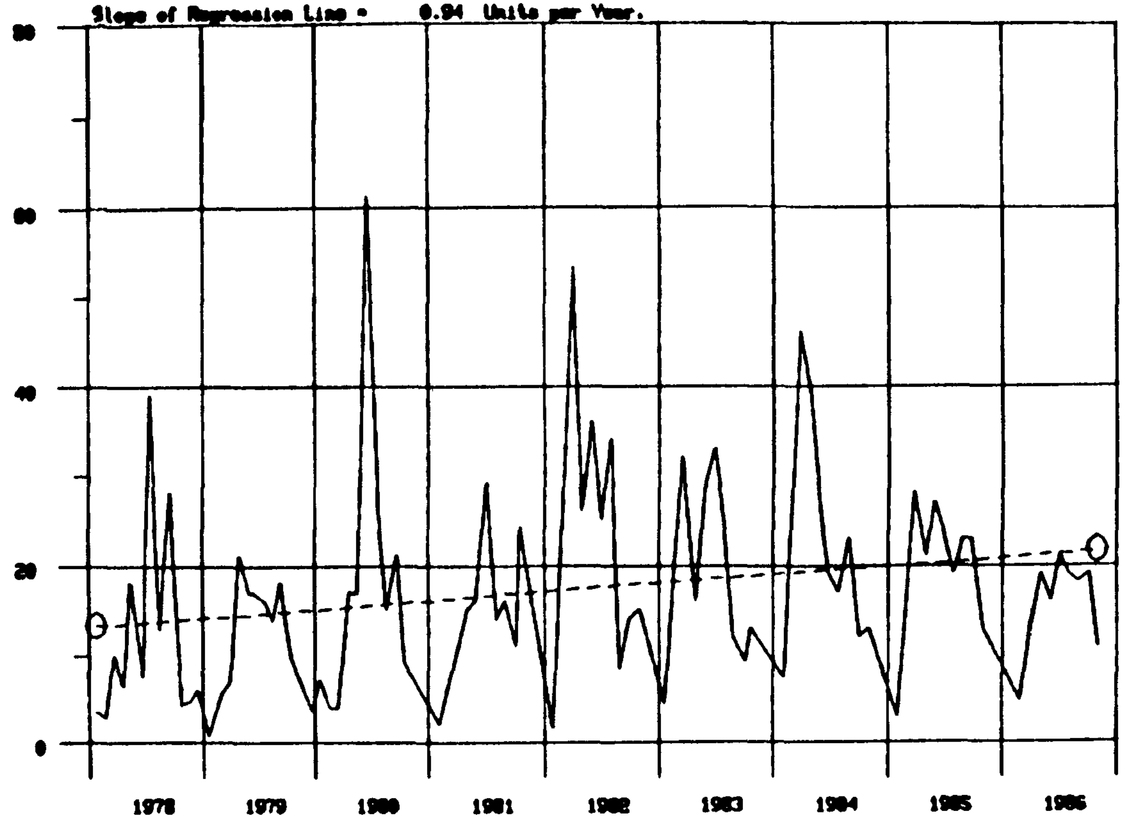


MSU-050---01E53 UM-050 STORET System
45 02 57.0 093 16 45.0 2
MISSISSIPPI R. AT FRIDLEY
27053 MINNESOTA HENNEPIN
MAJ BASIN: UPPER MISS 070304
MIN BASIN: UPPER PORTION UPPER MISS
21MINN 07010206002 0013.640 ON /TYPA/AMBNT/STREAM/SOLIDS/TISSUE/NET
DEPTH 0

INDEX
MILES

PARAMETER		NOBS	AVE	MAX	MIN	BEG-DATE	END-DATE
530 RESIDUE TOT NFLT	MG/L	87	17	61	1	78/01/24	86/10/27

Slope of Regression Line = 0.94 Units per Year.

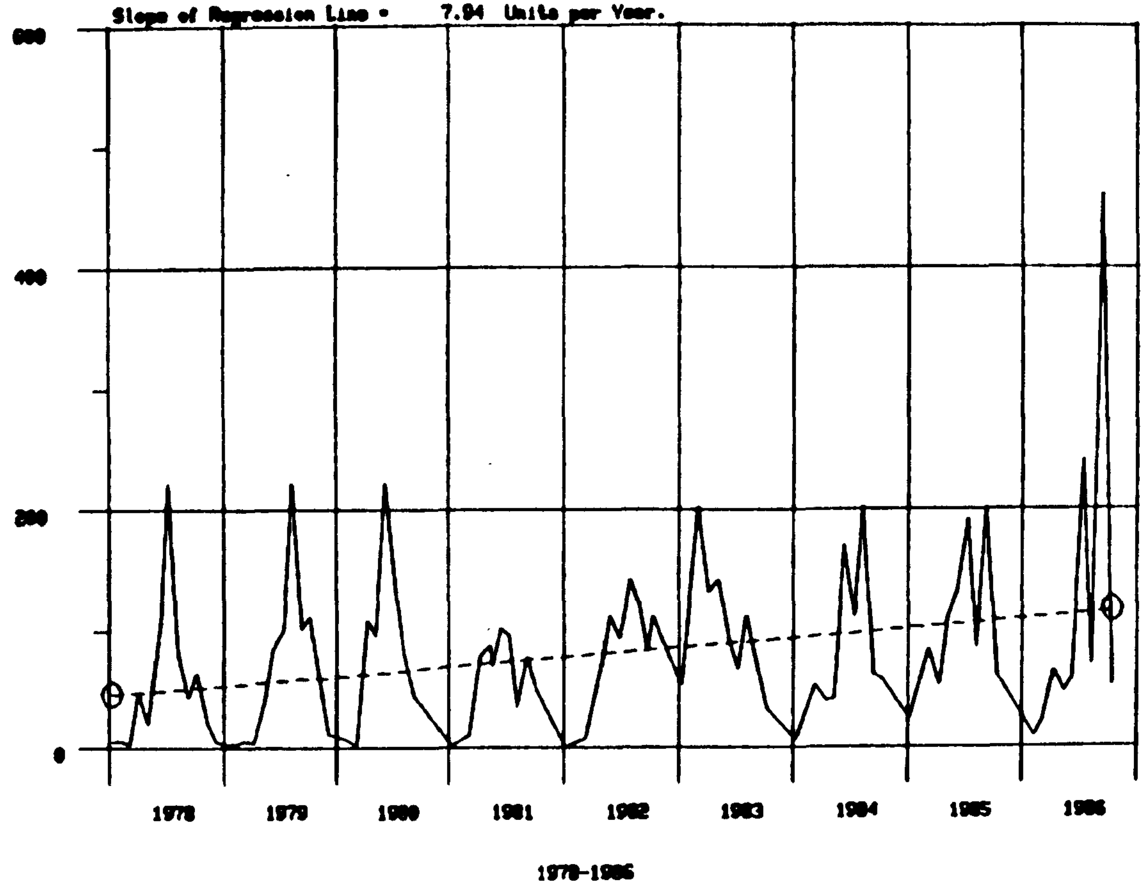


1978-1986

MN00129-B015E55 MI-133 STORET System
44 15 16.0 094 20 28.0 2
MINNESOTA R.CSAH-24 AT COURTLAND
27103 MINNESOTA NICOLLET
MAJ BASIN: UPPER MISS 070406
MIN BASIN: MINNESOTA RIVER
21MINN 07020007010 ON /TYPA/AMBNT/STREAM/SOLIDS/NET
DEPTH 0
INDEX
MILES

PARAMETER	NOBS	AVE	MAX	MIN	BEG-DATE	END-DATE
530 RESIDUE TOT NFLT MG/L	88	79	460	1	78/01/00	86/10/07

Slope of Regression Line = 7.94 Units per Year.



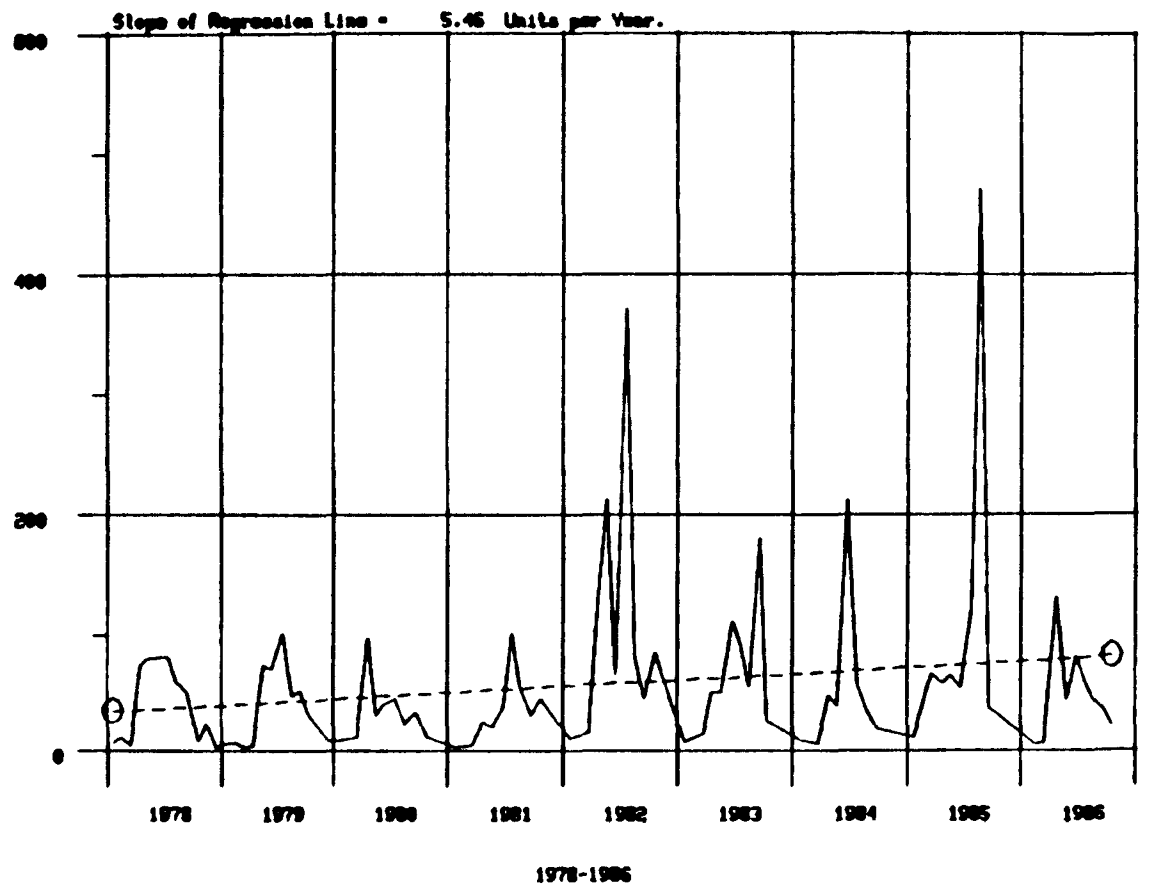
WRRL-.2---10A53 RL-0.2 STORET System

47 55 24.0 097 01 00.0 2
RED LAKE RIVER-EAST GRAND FORKS
27119 MINNESOTA POLK
MAJ BASIN: HUDSON BAY 230104
MIN BASIN: RED RIVER OF THE NORTH
21MINN 00020303001 ON /TYPA/AMBNT/STREAM/SOLIDS/TISSUE/NET
DEPTH 0

INDEX
MILES

PARAMETER			NOBS	AVE	MAX	MIN	BEG-DATE	END-DATE
530 RESIDUE	TOT NFLT	MG/L	86	56	470	3	78/01/17	86/10/13

Slope of Regression Line = 5.46 Units per Year.



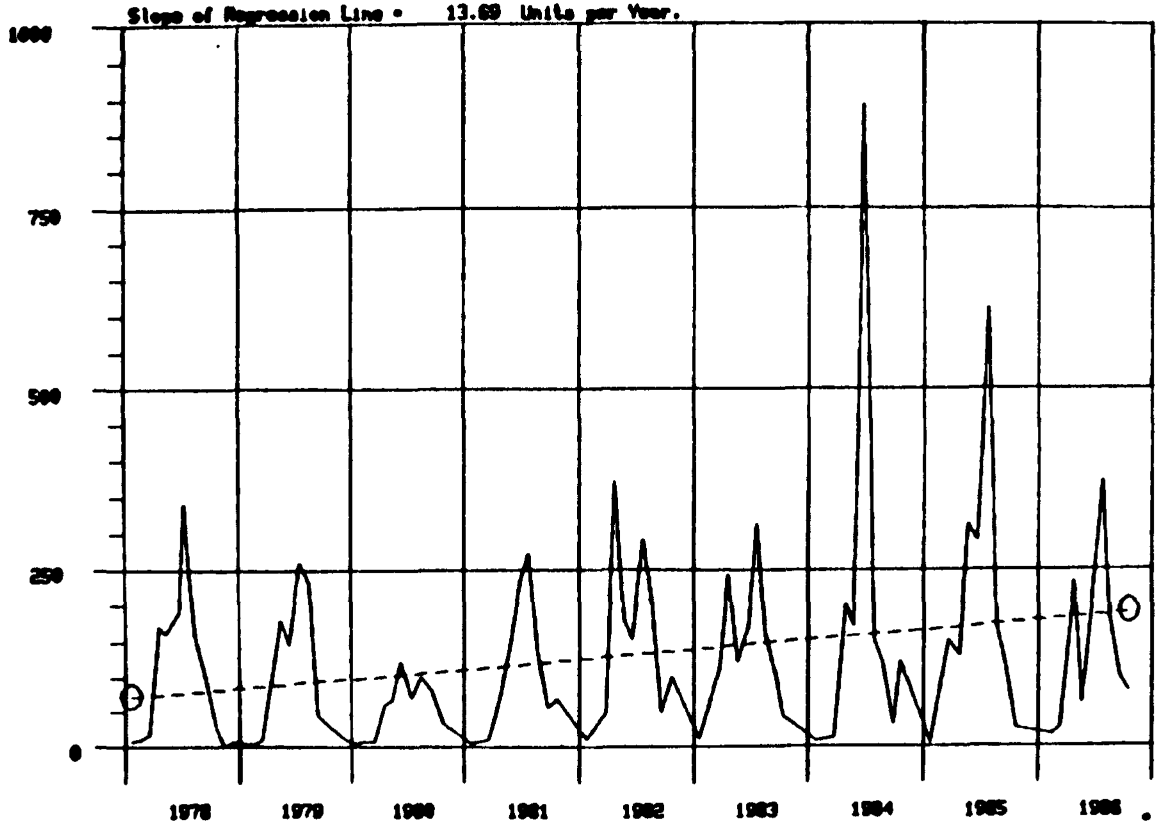
MMMR403---10E67 RE-403 STORET System

47 10 47.0 096 40 27.0 2
RED RIVER CSAH-39 W. OF PERLEY
27107 MINNESOTA NORMAN
MAJ BASIN: HUDSON BAY 230104
MIN BASIN: RED RIVER OF THE NORTH
21MINN 00020107009 ON /TYPA/AMBNT/STREAM/NET
DEPTH 0

INDEX
MILES

PARAMETER		NOBS	AVE	MAX	MIN	BEG-DATE	END-DATE
530 RESIDUE TOT NFLT	MG/L	87	128	890	1	78/01/17	86/10/13

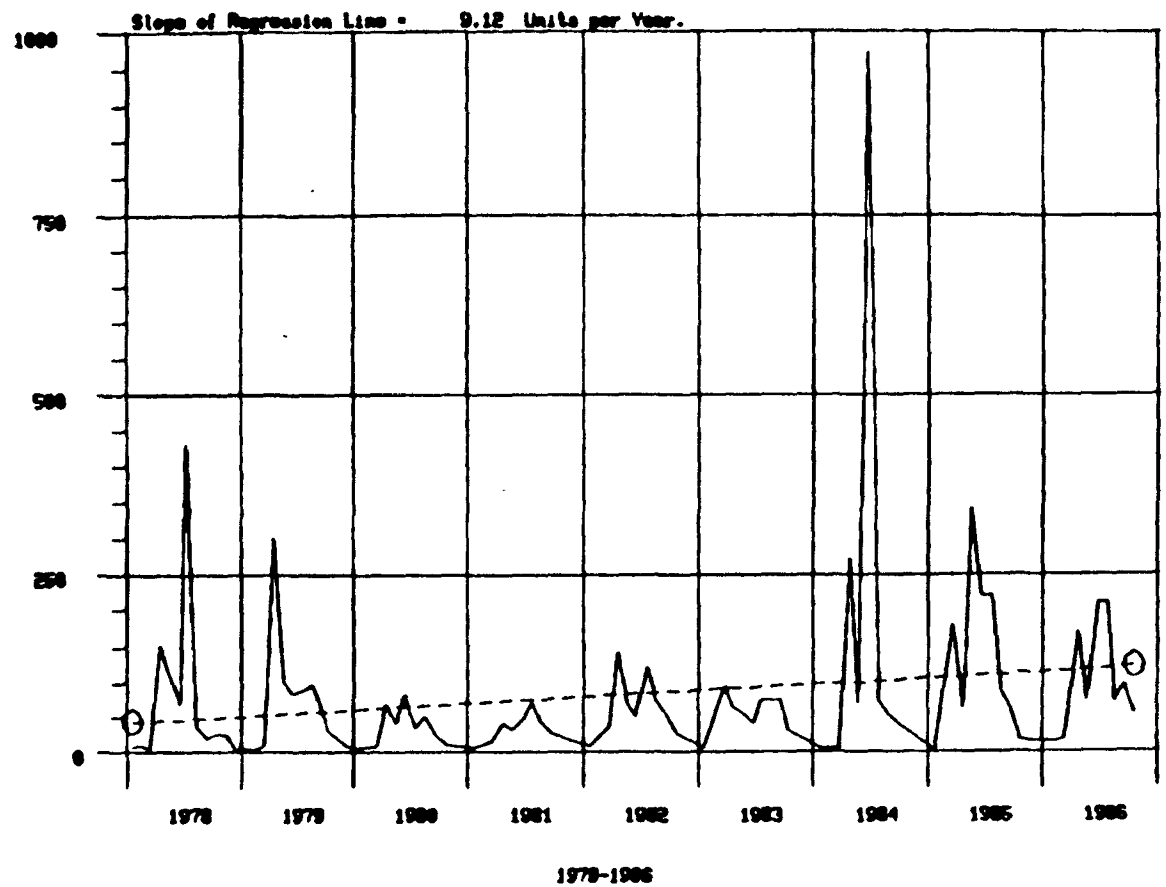
Slope of Regression Line = 13.69 Units per Year.



1978-1986

```
[illegible]452---10E71          RE-452                                    STORET System
46 52 26.3 096 46 34.5  2
RED RIVER MAIN & FIRST AT FARGO
27027 MINNESOTA          CLAY
MAJ BASIN: HUDSON BAY   230104
MIN BASIN: RED RIVER OF THE NORTH
21MINN   0000010400Z          ON  /TYPA/AMBNT/STREAM/SOLIDS/TISSUE/MET
                    DEPTH    0
INDEX
MILES
```

PARAMETER			NOBS	AVE	MAX	MIN	BEG-DATE	END-DATE
530 RESIDUE	TOT NFLT	MG/L	87	80	970	3	78/01/17	86/10/13



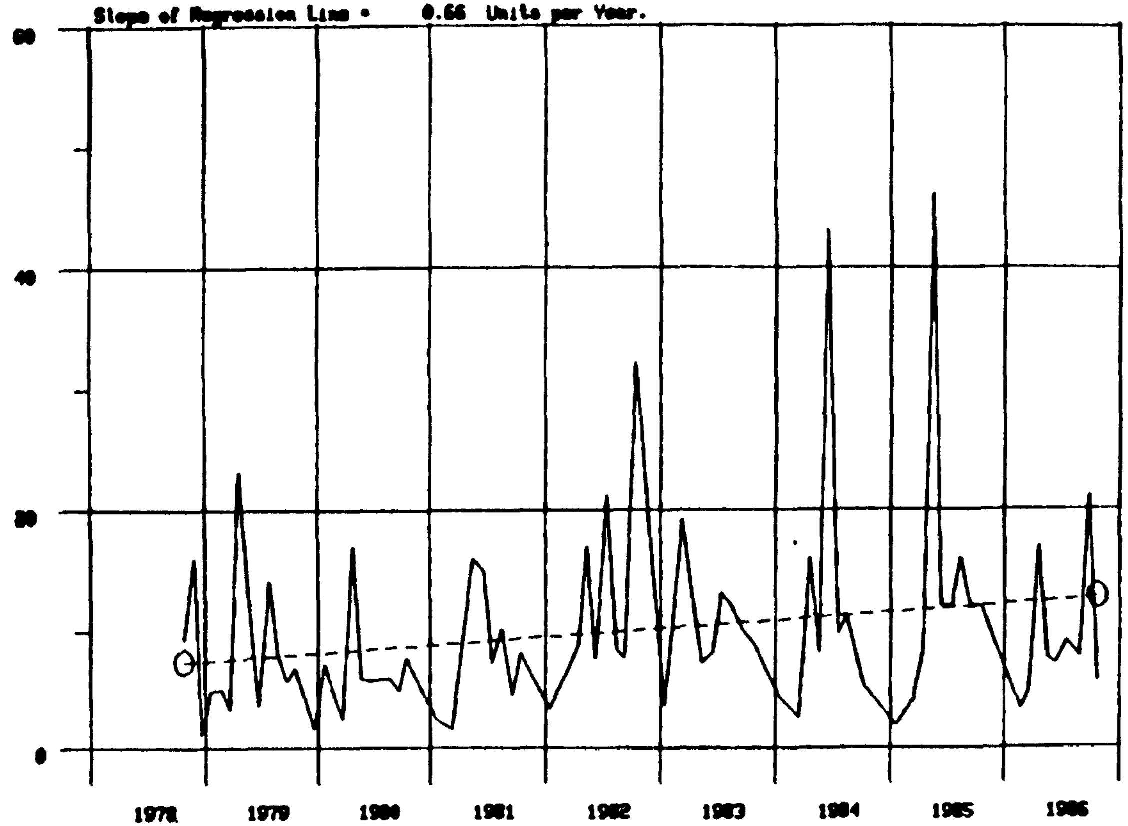
LSSL-19-C015E53 SL-9

STORET System

46 39 31.0 092 17 04.0 3
ST LOUIS R. SH-23 AT FOND DU LAC
27137 MINNESOTA ST LOUIS
MAJ BASIN: GREAT LAKES 222306
MIN BASIN: LAKE SUPERIOR
21MINN 04010201009 ON /TVPA/AMBNT/STREAM/NET/DOWN
DEPTH 0
INDEX
MILES

PARAMETER			NOBS	AVE	MAX	MIN	BEG-DATE	END-DATE
530 RESIDUE	TOT NFLT	MG/L	78	10	46	1	78/10/23	86/10/20

Slope of Regression Line = 0.66 Units per Year.



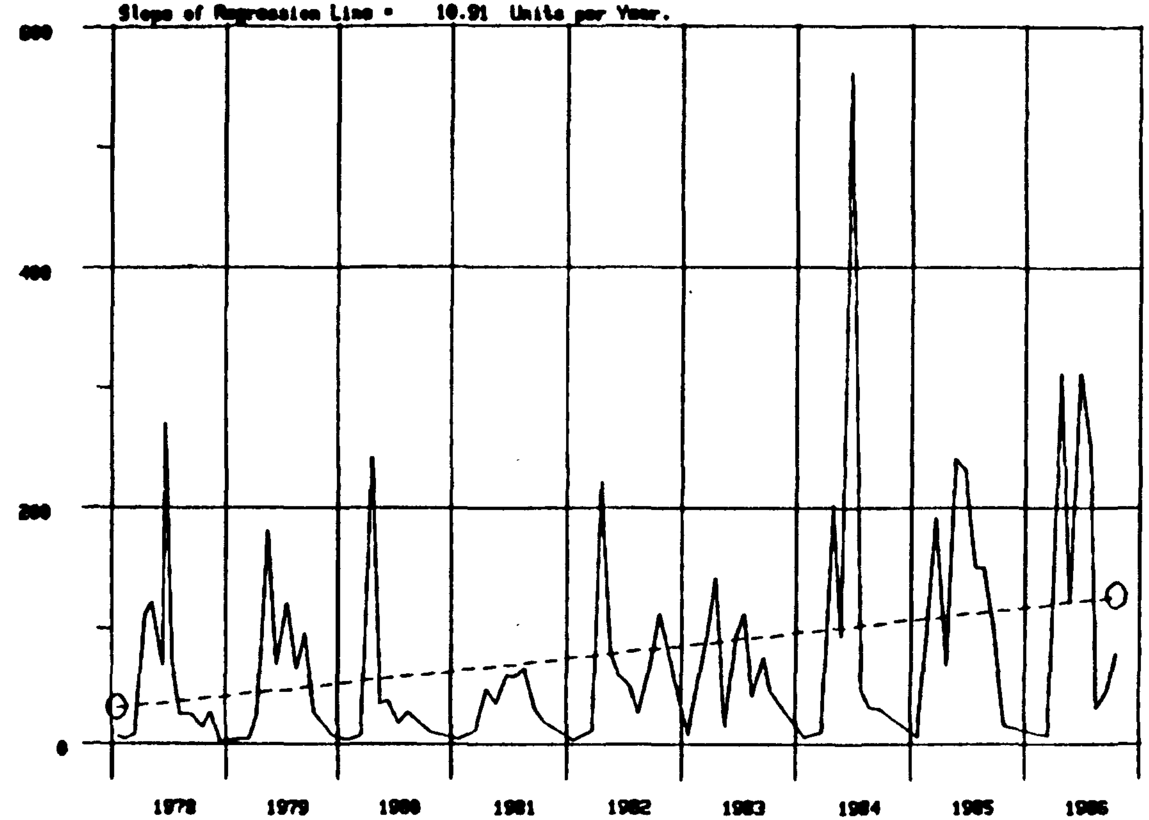
1978-1986

NNNN2098---10E53 RE-300 STORET System
47 54 28.0 097 01 30.0 2
RED RIVER AT GRAND FORKS
27119 MINNESOTA POLK
MAJ BASIN: HUDSON BAY 230104
MIN BASIN: RED RIVER OF THE NORTH
21MINN 00020301004 ON /TYPA/AMBNT/STREAM/INTAKE/PIPE/SOLIDS/TISSUE/NET
DEPTH 0

INDEX
MILES

PARAMETER		NOBS	AVE	MAX	MIN	BEG-DATE	END-DATE
530 RESIDUE TOT NFLT	MG/L	87	76	560	1	78/01/17	86/10/13

Slope of Regression Line = 10.91 Units per Year.



1978-1986

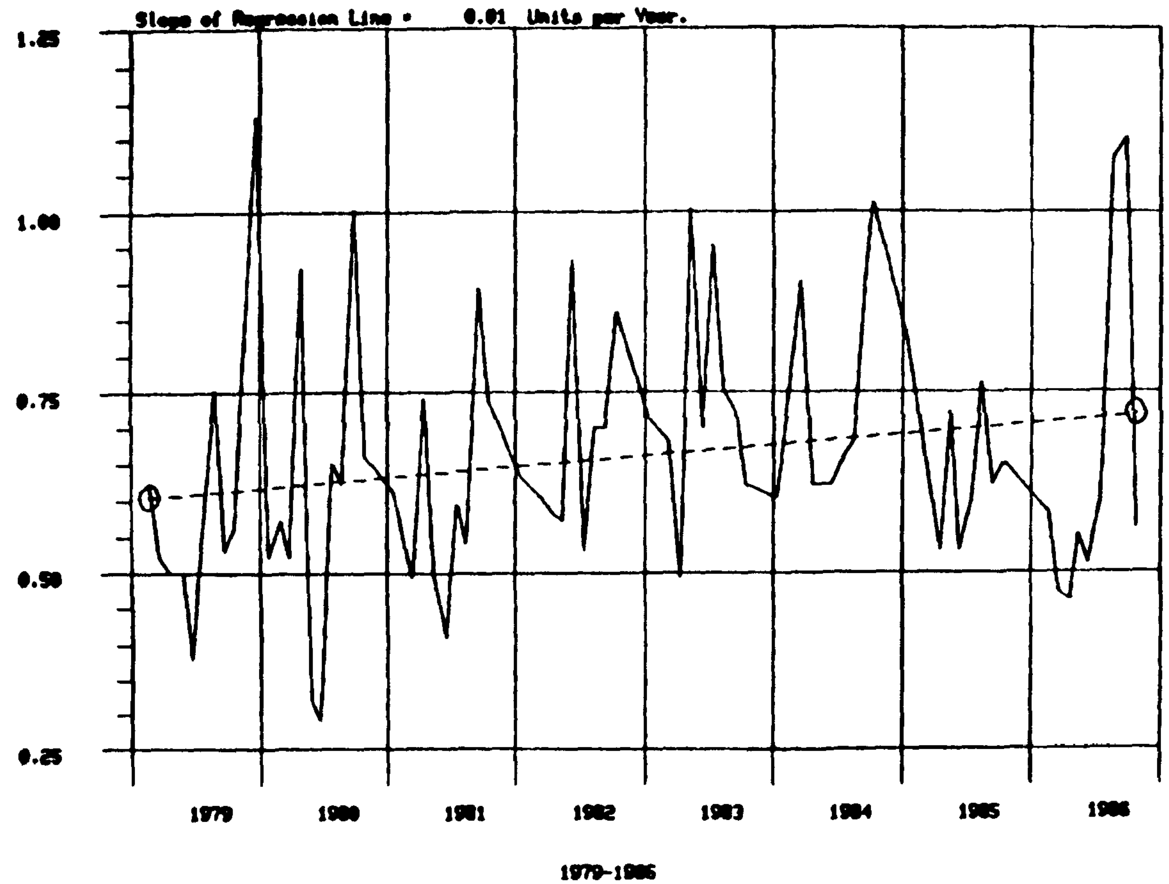
LRKA-100001SE57 KA-10

47 48 57.0 091 47 02.0 3
KAWISHIWI R. BIRCH LAKE OUTLET
27075 MINNESOTA LAKE
MAJ BASIN: HUDSON BAY 230004
MIN BASIN: RAINY RIVER
21MINN 09030001006 ON /TYPA/AMBNT/STREAM/NET
DEPTH 0

INDEX
MILES

STORET System

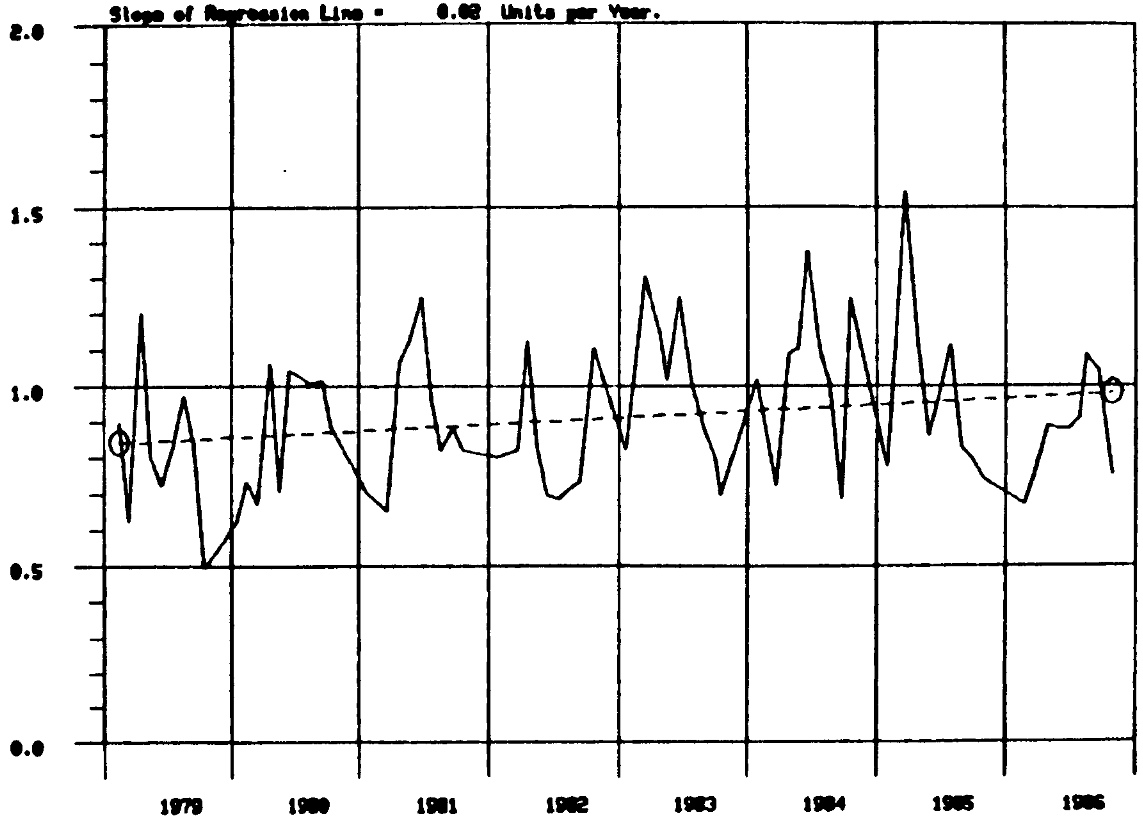
PARAMETER			NOBS	AVE	MAX	MIN	BEG-DATE	END-DATE
625 TOT KJEL	N	MG/L	74	0.650	1.130	0.290	79/02/21	86/10/22



054 UM-896 STORET System
45 18 23.0 093 47 30.4 4
MISSISSIPPI RIVER AT MONTICELLO
27141 MINNESOTA SHERBURNE
MAJ BASIN: UPPER MISS. 070304
MIN BASIN: UPPER PORTION UPPER MISS
21MINN 07010203000 0011.290 ON /TYPA/AMBNT/STREAM/TISSUE/NET
760917 DEPTH 0
INDEX
MILES

PARAMETER			NOBS	AVE	MAX	MIN	BEG-DATE	END-DATE
625 TOT KJEL	N	MG/L	74	0.908	1.540	0.490	79/02/12	86/10/27

Slope of Regression Line = 0.02 Units per Year.

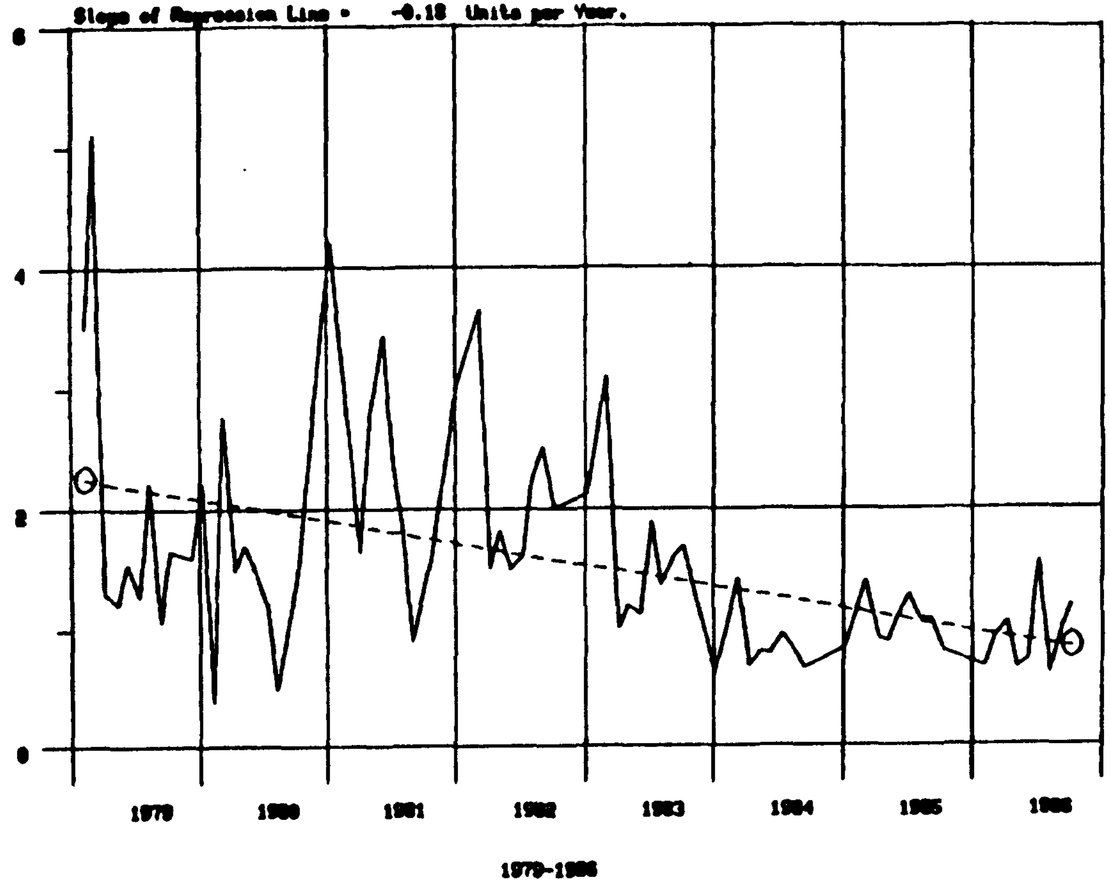


ZSF-5.7 [ZRS-28] STORET System

```
08R
44 06 30.0 092 26 54.0  2
ZUMBRO R.-SOUTH FORK BY ROCHESTER
27109 MINNESOTA        OLMSTED
MAJ BASIN:  UPPER MISS.  070000
MIN BASIN:  LOWER PORTION UPPER MISS
21MINN   07040004016         ON  /TYPA/AMBNT/STREAM/NET/DOWN
                   DEPTH  900
INDEX
MILES
```

PARAMETER			NOBS	AVE	MAX	MIN	BEG-DATE	END-DATE
00625 TOT KJEL	N	MG/L	74	1.586	5.100	0.300	79/02/08	86/10/06

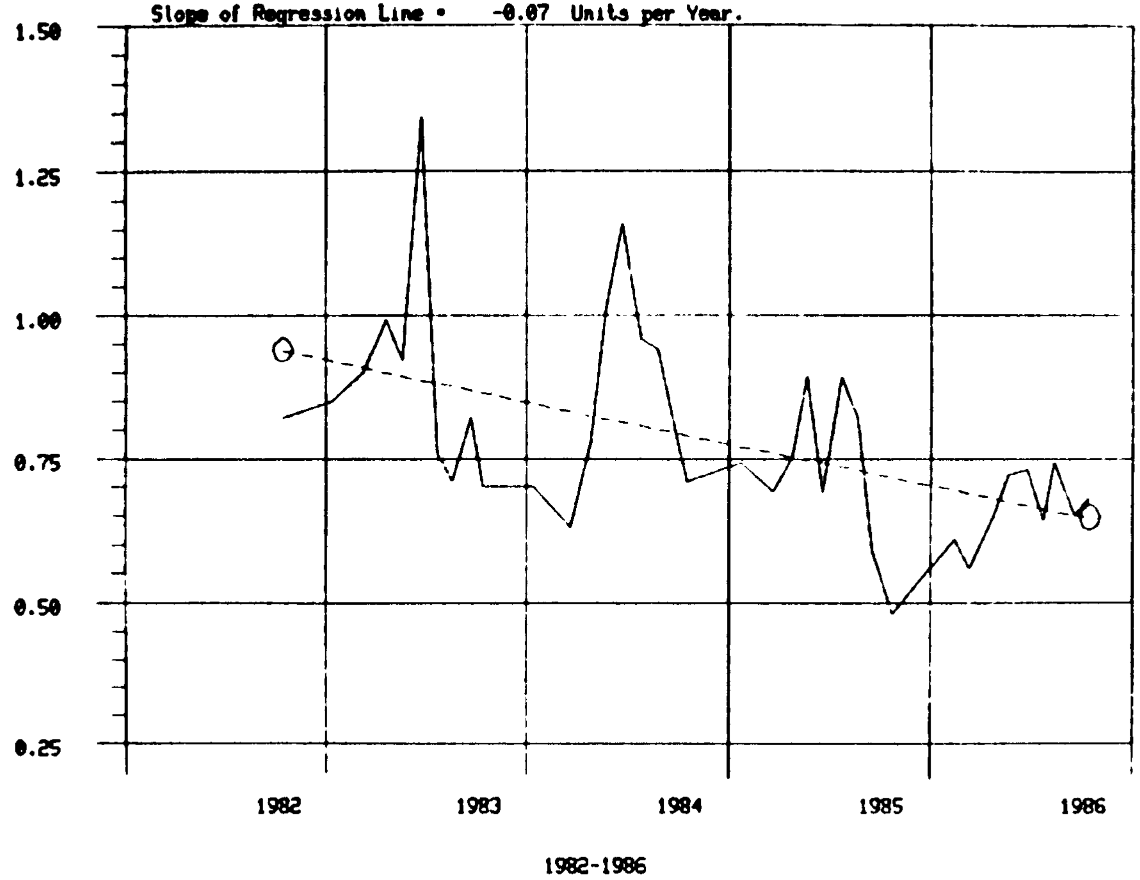
Slope of Regression Line = -0.18 Units per Year.



010 UM-1172 STORET System
47 10 33.0 093 24 42.0 2
MISSISSIPPI R. BY GRAND RAPIDS
27061 MINNESOTA ITASCA
MAJ BASIN: UPPER MISS 070306
MIN BASIN: UPPER PORTION UPPER MISS
21MINN 07010103023 0009.920 ON /TYPA/AMBNT/STREAM/NET
DEPTH 0
INDEX
MILES

PARAMETER			NOBS	AVE	MAX	MIN	BEG-DATE	END-DATE
625 TOT KJEL	N	MG/L	37	0.784	1.340	0.480	82/10/13	86/10/15

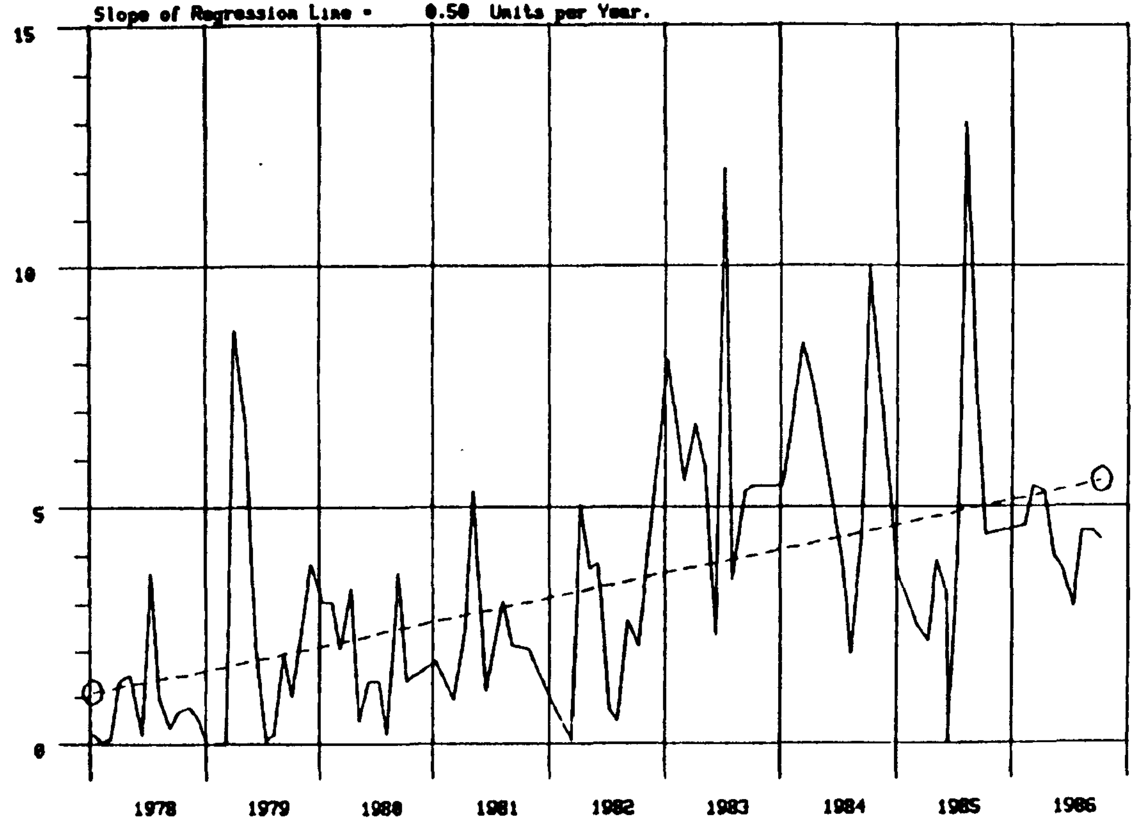
Slope of Regression Line = -0.07 Units per Year.



CRSR1.5-BB15E60 SR-1.2 [SR-1.5] STORET System
43 30 42.0 093 16 21.0 2
SHELL ROCK R. W OF GORDONSVILLE
27047 MINNESOTA FREEBORN
MAJ BASIN: UPPER MISS 071006
MIN BASIN: CEDAR RIVER
21MINN 07080202009 ON /TYPA/AMBNT/STREAM/NET/DOWN
DEPTH 0
INDEX
MILES

PARAMETER			NOBS	AVE	MAX	MIN	BEG-DATE	END-DATE
630 NO2&NO3	N-TOTAL	MG/L	88	3.24	13.00	0.01	78/01/10	86/10/07

Slope of Regression Line = 0.50 Units per Year.



1978-1986

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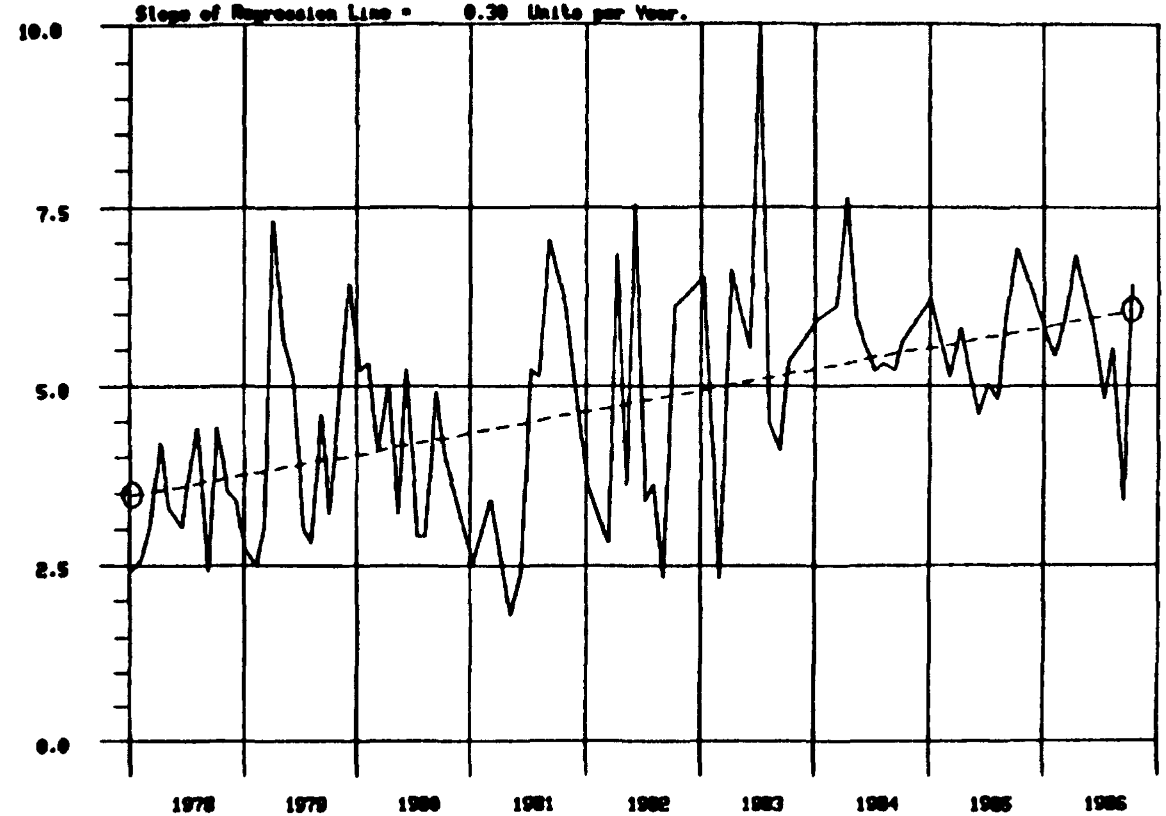
680                                    29F-5.7      [ZRS-80]                                   STORET System
44 06 30.0 092 26 54.0  2
ZUMBRO R.-SOUTH FORK BY ROCHESTER
27109 MINNESOTA         OLMSTED
MAJ BASIN:  UPPER MISS.  070606
MIN BASIN:  LOWER PORTION UPPER MISS
21MINN    07040004016          ON  /TYPA/AMBNT/STREAM/NET/DOWN
                          DEPTH  900
 INDEX
 MILES
```

PARAMETER			NOBS	AVE	MAX	MIN	BEG-DATE	END-DATE
630 NO2&NO3	N-TOTAL	MG/L	87	4.69	10.00	1.80	78/01/10	86/10/06

Slope of Regression Line = 0.30 Units per Year.



1978-1986

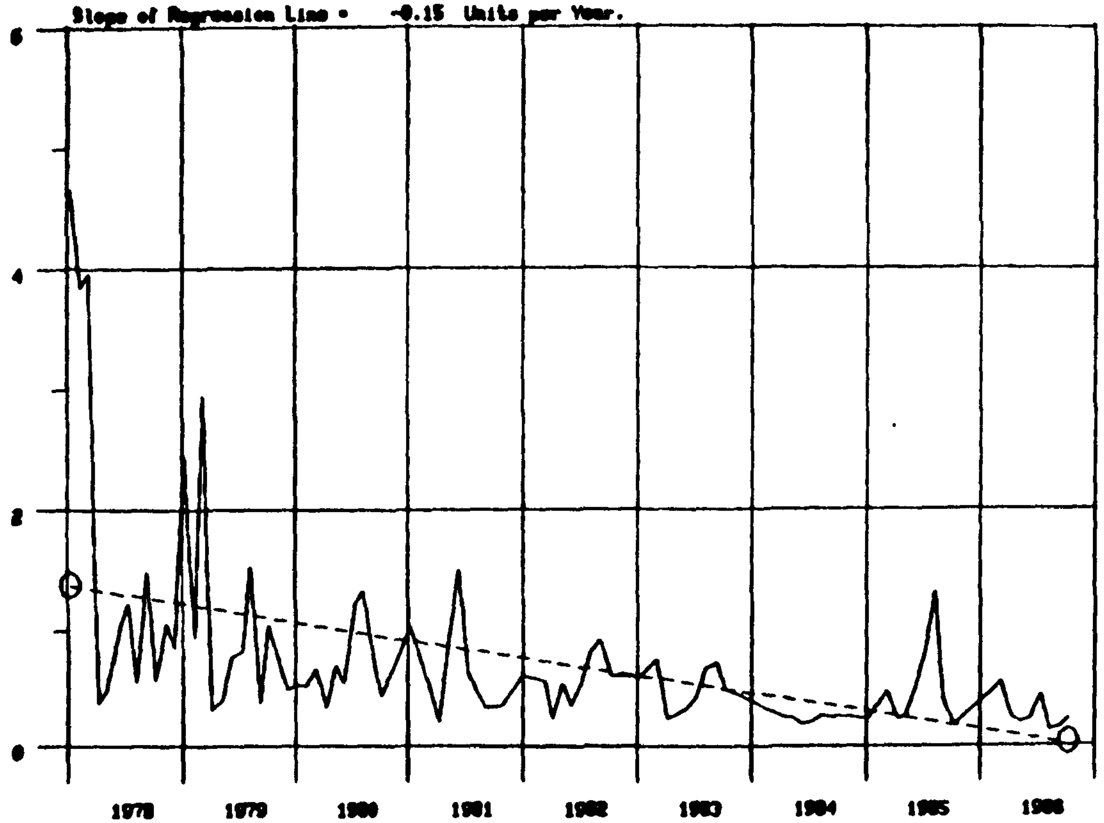
ZSF-5.7 CZRS-203 STORET System

002
44 06 30.0 092 26 54.0 2
ZUMBRO R.-SOUTH FORK BY ROCHESTER
27109 MINNESOTA OLMSTED
MAJ BASIN: UPPER MISS. 070606
MIN BASIN: LOWER PORTION UPPER MISS
21MINN 07040004016 ON /TYPA/AMBNT/STREAM/NET/DOWN
DEPTH 999

INDEX
MILES

PARAMETER		NOBS	AVE	MAX	MIN	BEG-DATE	END-DATE
665 PHOS-TOT	MG/L P.	87	0.730	4.660	0.128	78/01/10	86/10/06

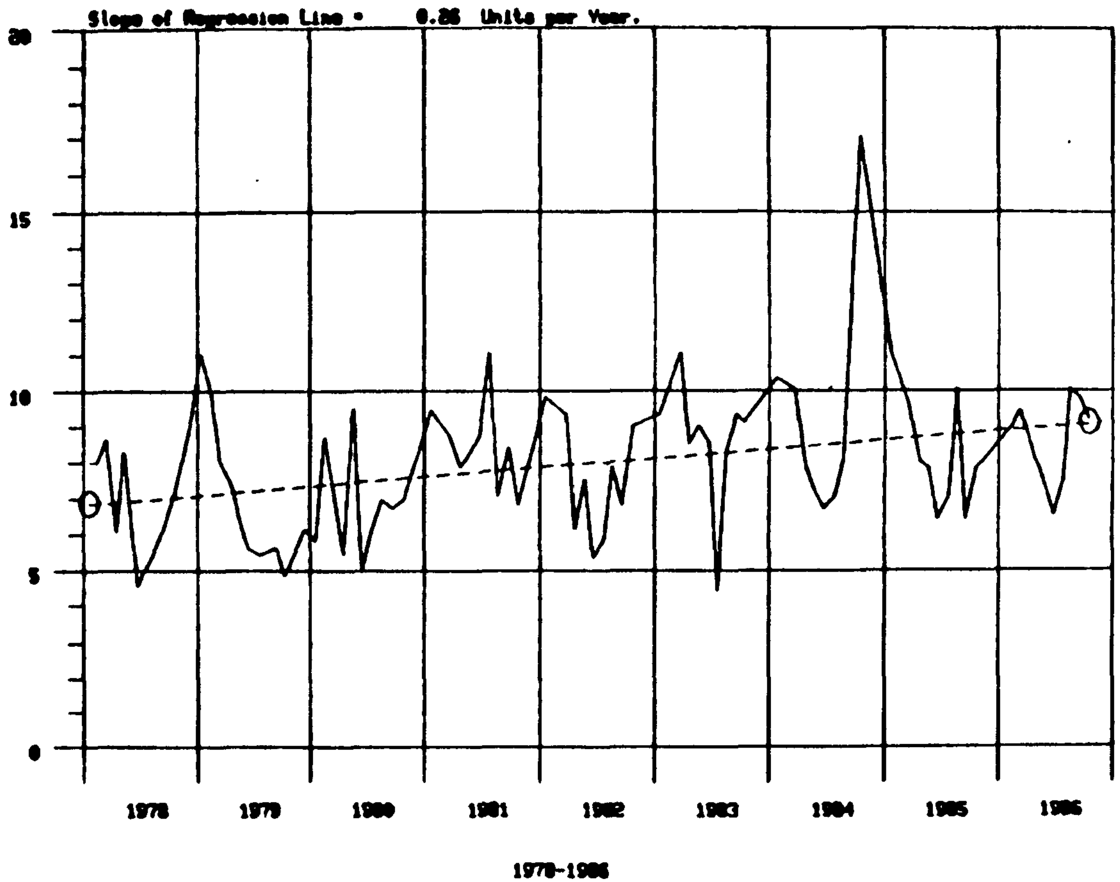
Slope of Regression Line = -0.15 Units per Year.



1978-1986

MROT--1---10A53 OT-1 STORET System
46 16 02.0 096 35 23.0 2
OTTER TAIL RIVER AT BRECKENRIDGE
27167 MINNESOTA WILKIN
MAJ BASIN: HUDSON BAY 230104
MIN BASIN: RED RIVER OF THE NORTH
21MINN 00020103001 ON /TYPA/AMBNT/STREAM/NET
DEPTH 0
INDEX
MILES

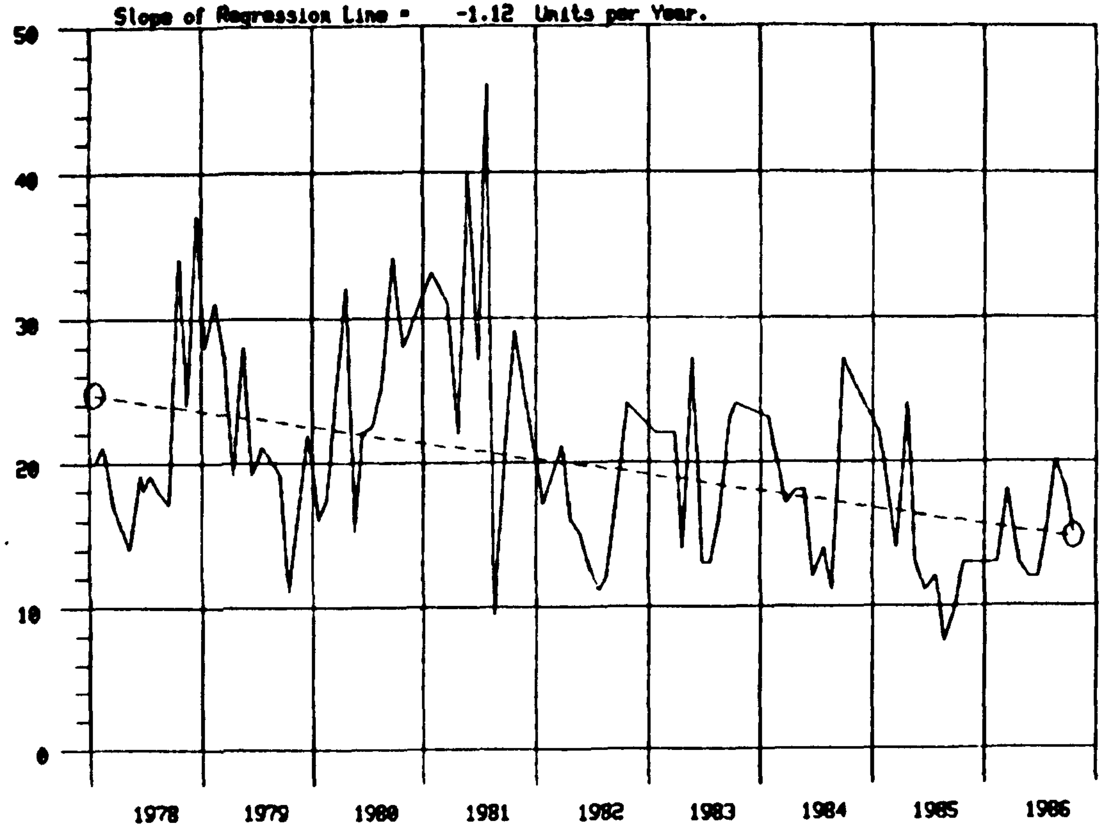
PARAMETER			NOBS	AVE	MAX	MIN	BEG-DATE	END-DATE
940 CHLORIDE	TOTAL	MG/L	85	8	17	4	78/01/16	86/10/13



RRRP296---10E53 RE-300 STORET System
47 54 28.0 097 01 32.0 2
RED RIVER AT GRAND FORKS
27119 MINNESOTA POLK
MAJ BASIN: HUDSON BAY 230104
MIN BASIN: RED RIVER OF THE NORTH
21MINN 09020301004 ON /TYPA/AMB/NTRTMT/INTAKE/NONAMB/PIPE/SOLIDS/TISSUE/NET
DEPTH 0
INDEX
MILES

PARAMETER			NOBS	AVE	MAX	MIN	BEG-DATE	END-DATE
940 CHLORIDE	TOTAL	MG/L	84	20	46	8	78/01/17	86/10/13

Slope of Regression Line = -1.12 Units per Year.



1978-1986

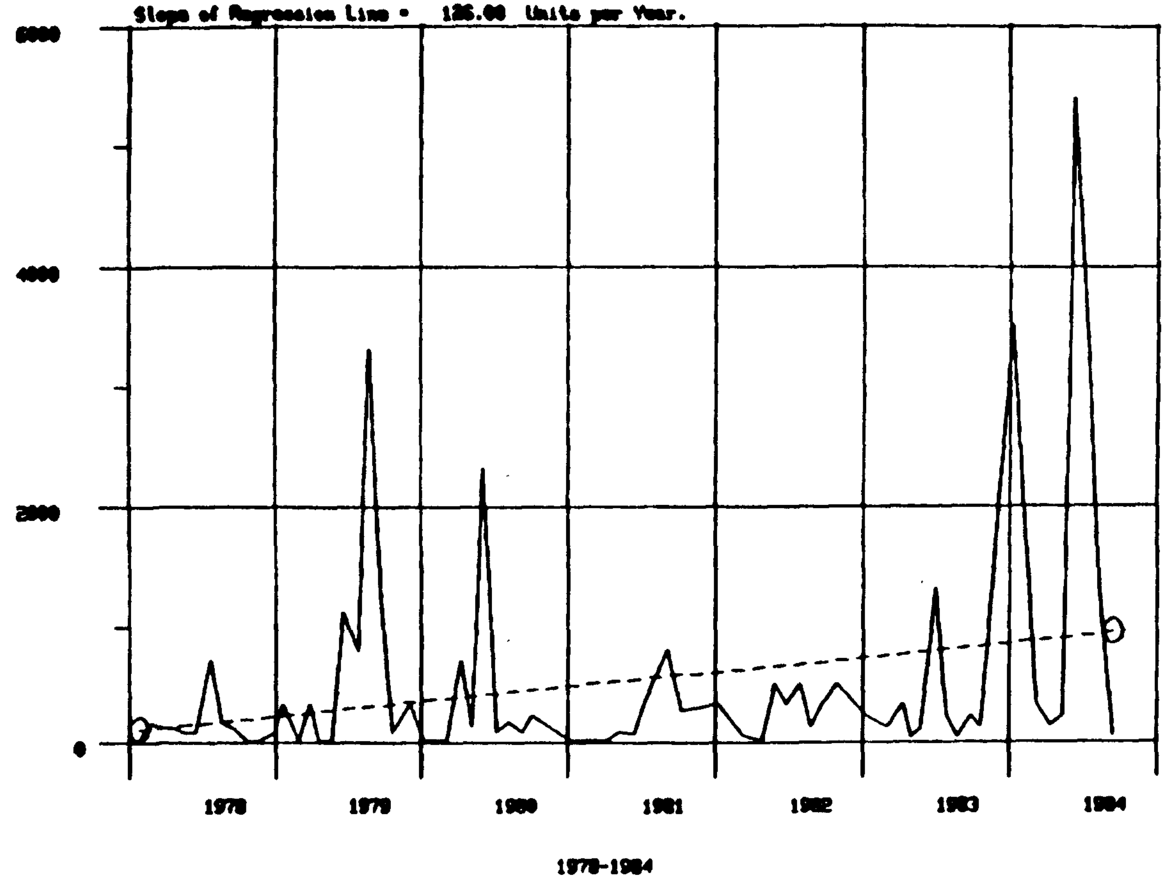
MNMN-70-001SE55 MI-64 STORET System

44 31 44.0 093 53 56.0 2
MINNESOTA R. SH-19 AT HENDERSON
27143 MINNESOTA SIBLEY
MAJ BASIN: UPPER MISS 070406
MIN BASIN: MINNESOTA RIVER
21MINN 07020012013 ON /TYPA/AMBNT/STREAM/SOLIDS/TISSUE/NET
DEPTH 0

INDEX
MILES

PARAMETER	NOBS	AVE	MAX	MIN	BEG-DATE	END-DATE
31615 FEC COLI MPNECMED /100ML	68	505	5400	20	78/01/25	84/09/11

Slope of Regression Line = 126.00 Units per Year.



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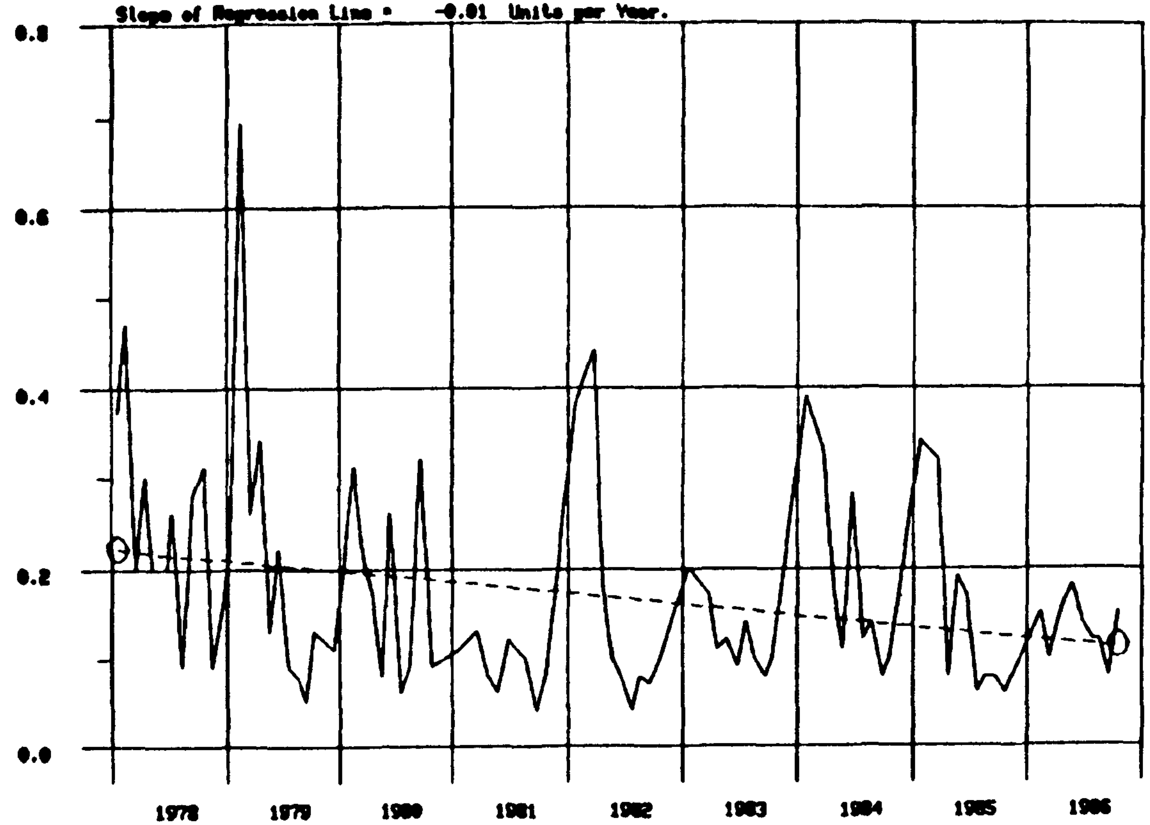
0000452---10E71            RE-452                                              STORET System
46 52 26.3 096 46 34.5  2
RED RIVER MAIN & FIRST AT FARGO
27027 MINNESOTA         CLAY
MAJ BASIN:  HUDSON BAY   230104
MIN BASIN:  RED RIVER OF THE NORTH
21MINN   00020104002        ON  /TYPA/AMBNT/STREAM/SOLIDS/TISSUE/NET
                  DEPTH    0
 INDEX
 MILES

          PARAMETER                             NOBS      AVE       MAX       MIN    BEG-DATE   END-DATE
    610 NH3+NH4-  N TOTAL      MG/L              87     0.170     0.690     0.040   78/01/17   86/10/13
```

Slope of Regression Line =   -0.01 Units per Year.

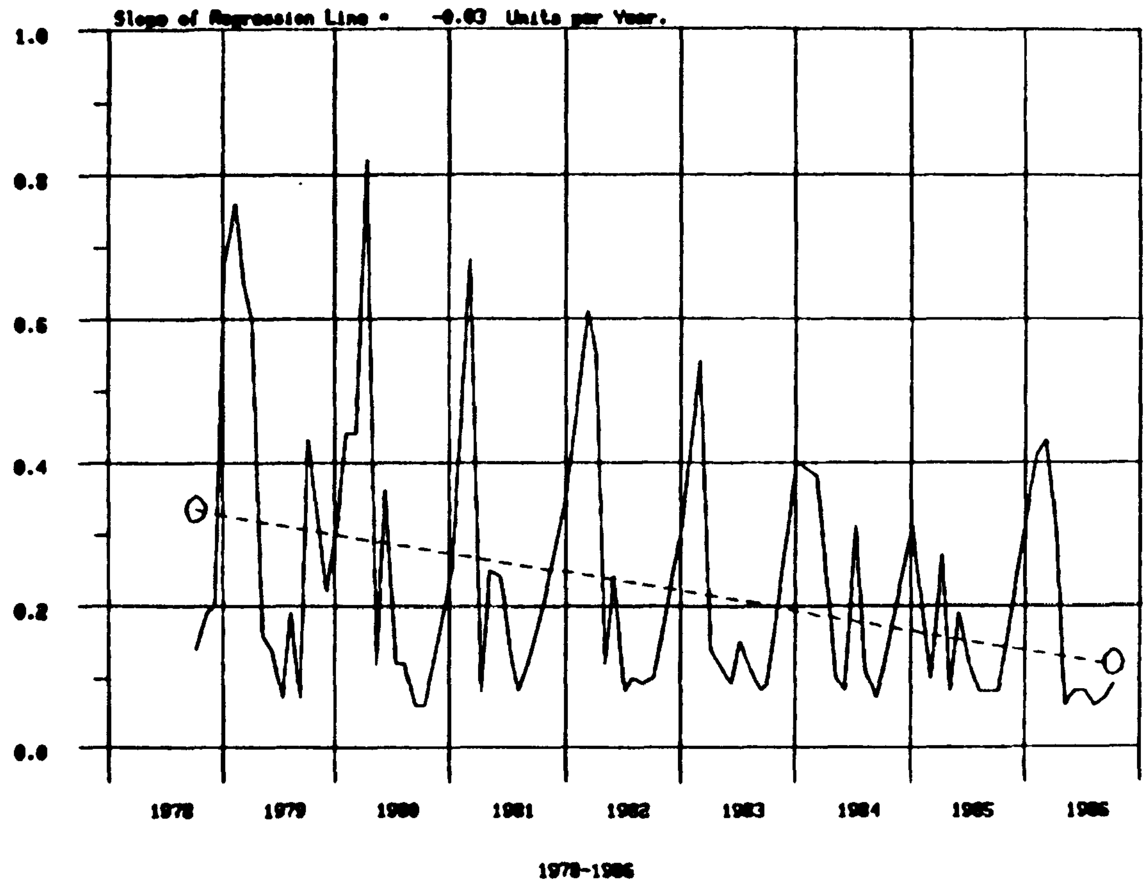


1978-1986

047 UM-738 STORET System
44 00 46.0 091 48 44.0 2
MISSISSIPPI R. AT LOCK&DAM 5
27169 MINNESOTA WINONA
MAJ BASIN: UPPER MISS. 070606
MIN BASIN: LOWER PORTION UPPER MISS
21MINN 07040003007 0004.050 ON /TYPA/AMBNT/STREAM/NET
DEPTH 999

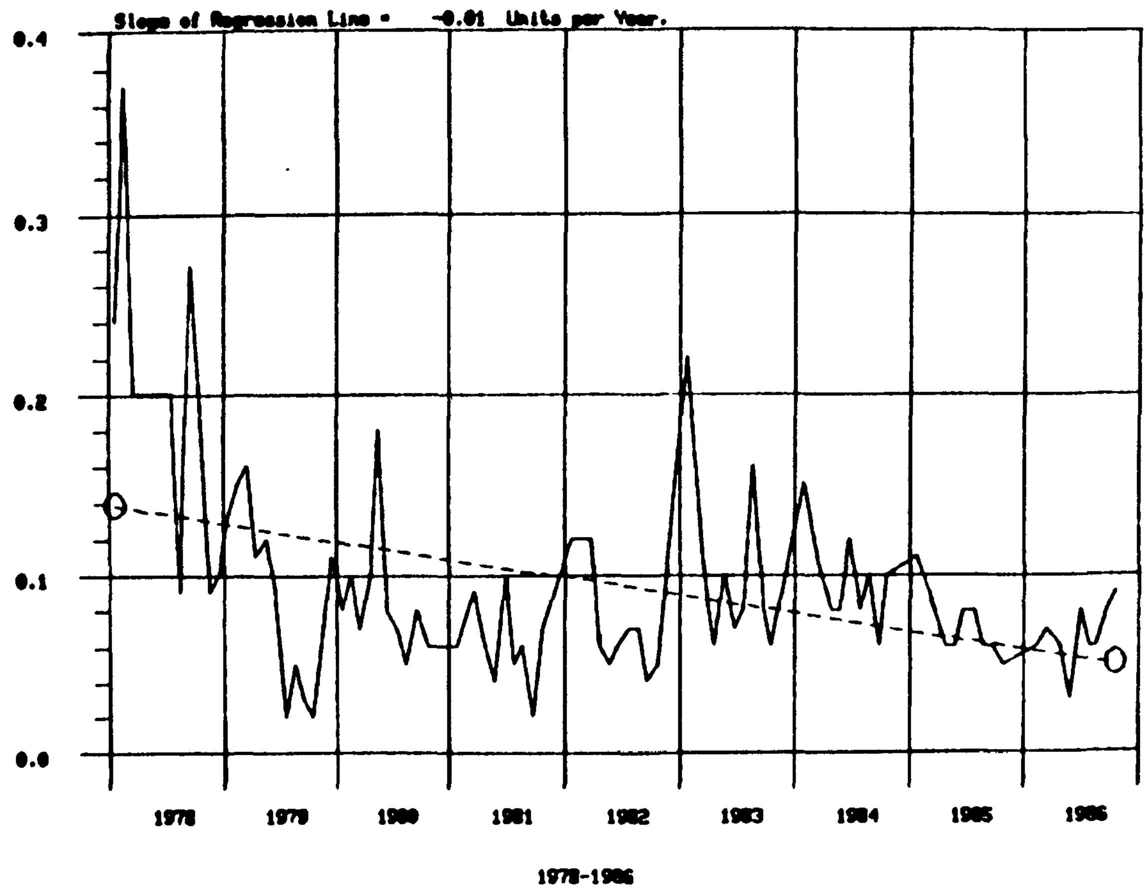
INDEX
MILES

PARAMETER		NOBS	AVE	MAX	MIN	BEG-DATE	END-DATE
610 NH3+NH4- N TOTAL	MG/L	78	0.230	0.820	0.060	78/10/04	86/10/06



MBU1280-B015E67 UM-1282 STORET System
47 27 12.0 094 42 44.0 2
MISSISSIPPI R. EAST OF BEMIDJI
27007 MINNESOTA BELTRAMI
MAJ BASIN: UPPER MISS 070306
MIN BASIN: UPPER PORTION UPPER MISS
21MINN 07010101027 0005.230 ON /TYPA/AMBNT/STREAM/NET
DEPTH 0
INDEX
MILES

PARAMETER		NOBS	AVE	MAX	MIN	BEG-DATE	END-DATE
610 NH3+NH4- N TOTAL	MG/L	87	0.097	0.370	0.020	78/01/17	86/10/14



L98L-10-C015ES3 SL-8

46 39 31.0 092 17 04.0 3

ST LOUIS R. SH-23 AT FOND DU LAC

27137 MINNESOTA ST LOUIS

MAJ BASIN: GREAT LAKES 222306

MIN BASIN: LAKE SUPERIOR

21MINN 04010201000 ON /TYPA/AMBNT/STREAM/NET/DOWN

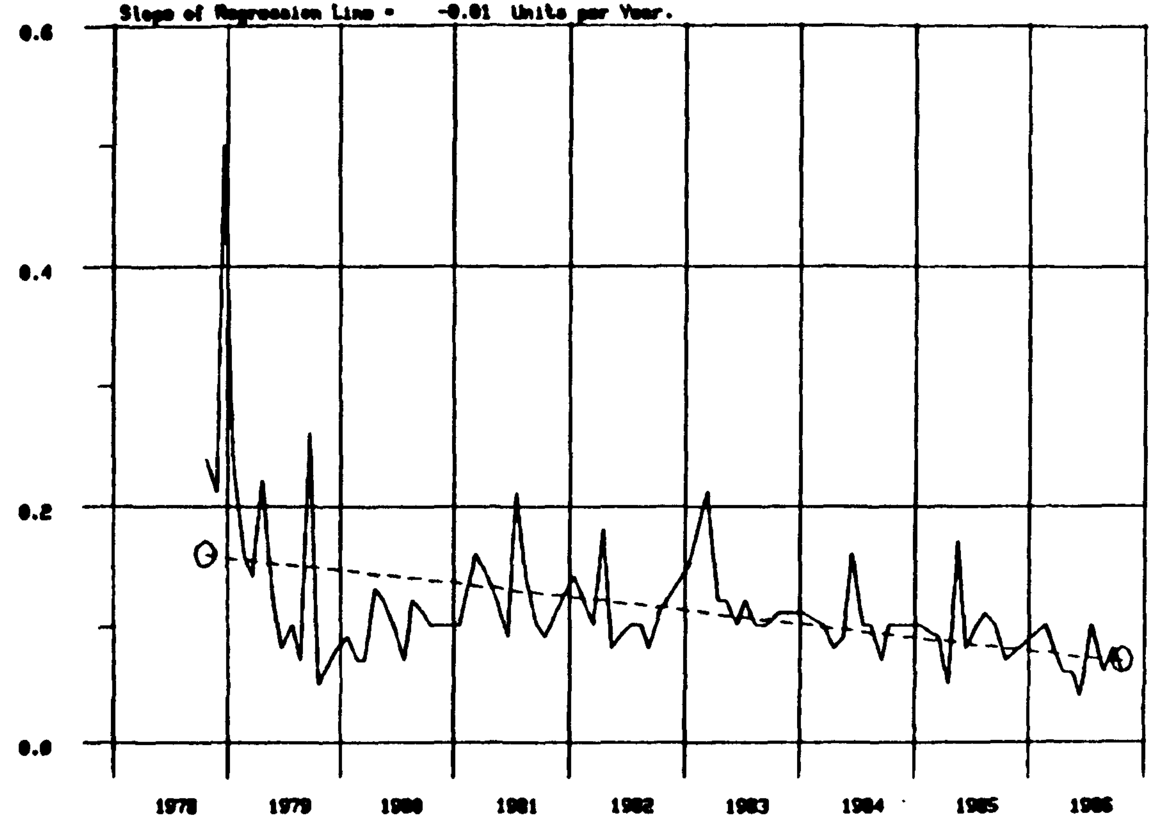
DEPTH 0

INDEX

MILES

PARAMETER		NOBS	AVE	MAX	MIN	BEG-DATE	END-DATE
610 NH3+NH4- N TOTAL	MG/L	78	0.117	0.500	0.040	78/10/23	86/10/20

Slope of Regression Line = -0.01 Units per Year.



1978-1986

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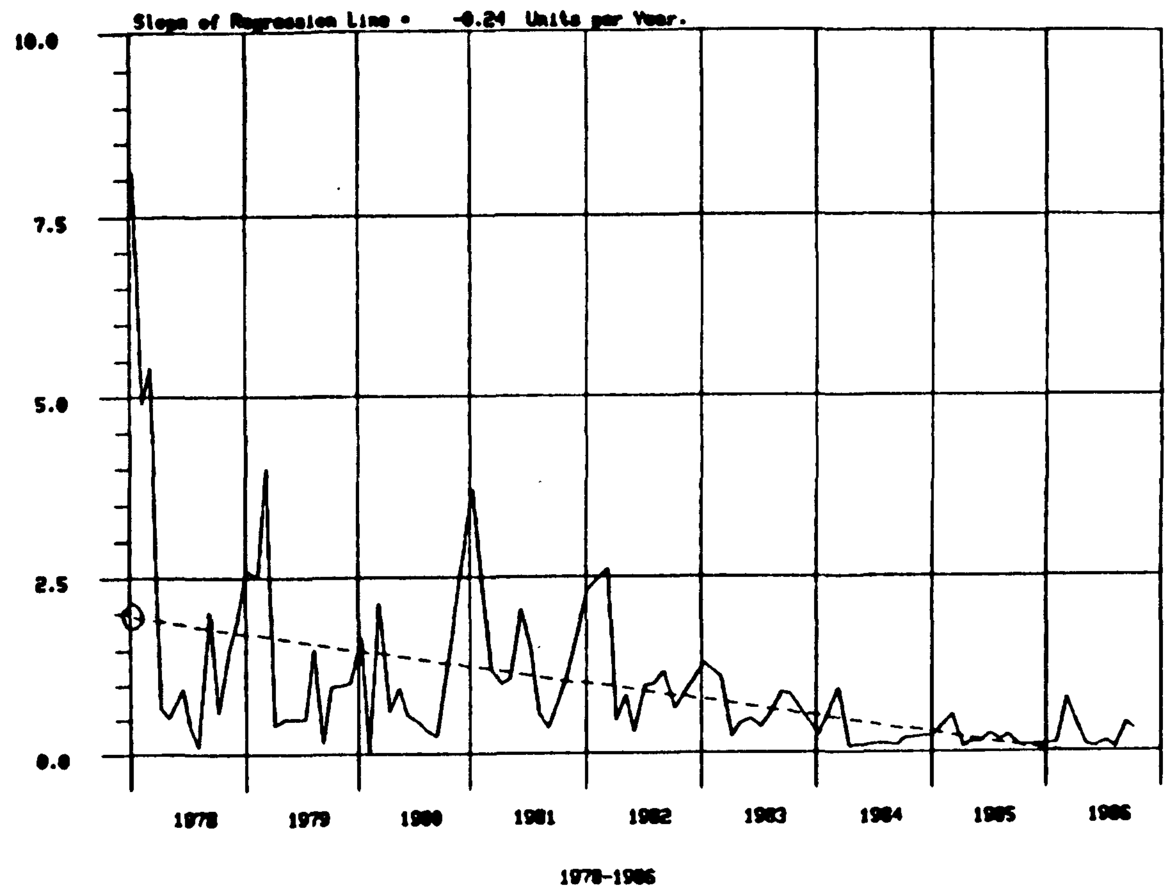
G2R                                    Z9F-5.7     [Z9S-283]                     STORET System
44 06 30.0 092 26 54.0  2
ZUMBRO R.-SOUTH FORK BY ROCHESTER
27109 MINNESOTA          OLMSTED
MAJ BASIN:  UPPER MISS.  070606
MIN BASIN:  LOWER PORTION UPPER MISS
21MINN   07040004016          ON  /TYPA/AMBNT/STREAM/NET/DOWN
                         DEPTH  999
INDEX
MILES
```

PARAMETER		NOBS	AVE	MAX	MIN	BEG-DATE	END-DATE
610 NH3+NH4- N TOTAL	MG/L	87	0.964	8.100	0.020	78/01/10	86/10/06

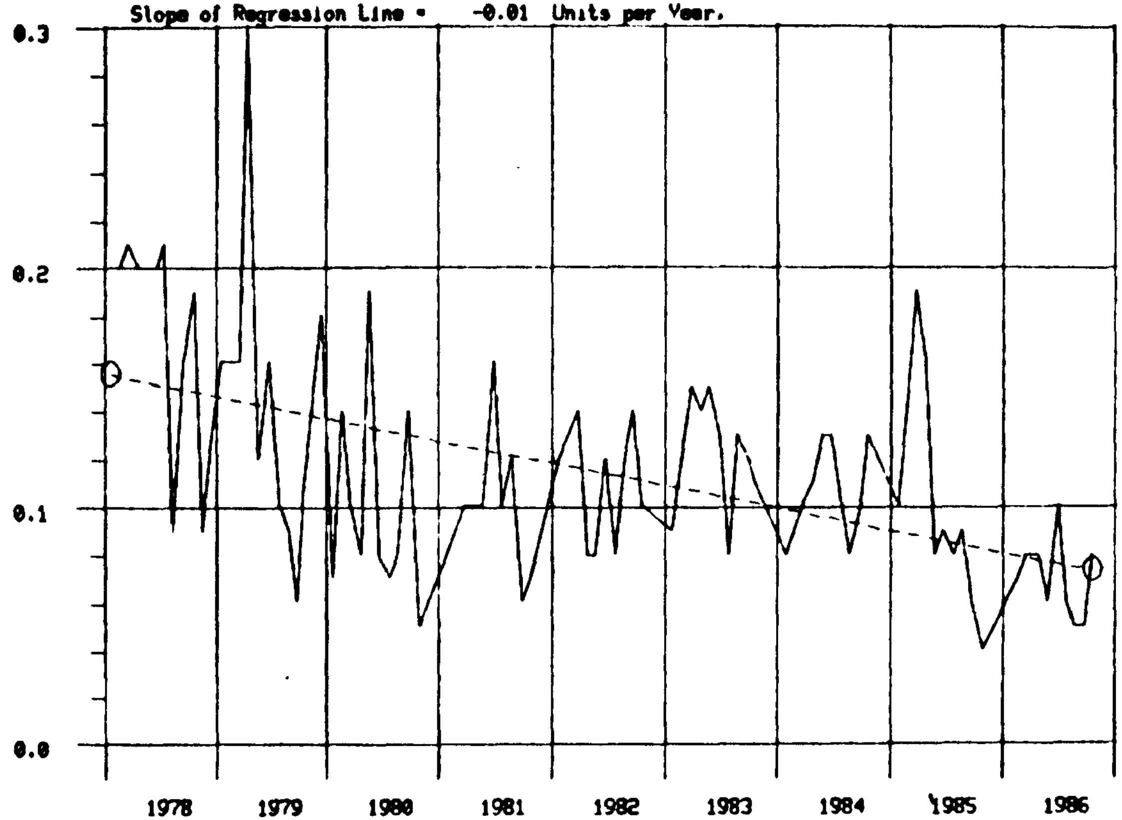


MSU1186-BB15E67 UM-1186 STORET System

47 13 48.0 093 45 20.0 3
MISSISSIPPI R. S.W. OF COHASSET
27061 MINNESOTA ITASCA
MAJ BASIN: UPPER MISS 070306
MIN BASIN: UPPER PORTION UPPER MISS
21MINN 07010101004 0003.820 ON /TYPA/AMBNT/STREAM/SOLIDS/NET
DEPTH 0
INDEX
MILES

PARAMETER		NOBS	AVE	MAX	MIN	BEG-DATE	END-DATE
610 NH3+NH4- N TOTAL	MG/L	87	0.116	0.300	0.040	78/01/19	86/10/15

Slope of Regression Line = -0.01 Units per Year.



1978-1986