

**U.S. ENVIRONMENTAL PROTECTION AGENCY
NATIONAL EUTROPHICATION SURVEY
WORKING PAPER SERIES**



REPORT
ON
TORONTO RESERVOIR
GREENWOOD AND WOODSON COUNTIES
KANSAS
EPA REGION VII
WORKING PAPER No. 523

**CORVALLIS ENVIRONMENTAL RESEARCH LABORATORY - CORVALLIS, OREGON
and
ENVIRONMENTAL MONITORING & SUPPORT LABORATORY - LAS VEGAS, NEVADA**

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ON
TORONTO RESERVOIR
GREENWOOD AND WOODSON COUNTIES
KANSAS
EPA REGION VII
WORKING PAPER No. 523

WITH THE COOPERATION OF THE
KANSAS DEPARTMENT OF HEALTH AND ENVIRONMENT
AND THE
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APRIL, 1977

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FOR E W O R D

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

- a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.
- b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.
- c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's freshwater lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Kansas State Department of Health and Environment for professional involvement, to the Kansas National Guard for conducting the tributary sampling phase of the Survey, and to those Kansas wastewater treatment plant operators who voluntarily provided effluent samples and flow data.

The staff of the Kansas Division of Environmental Health provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

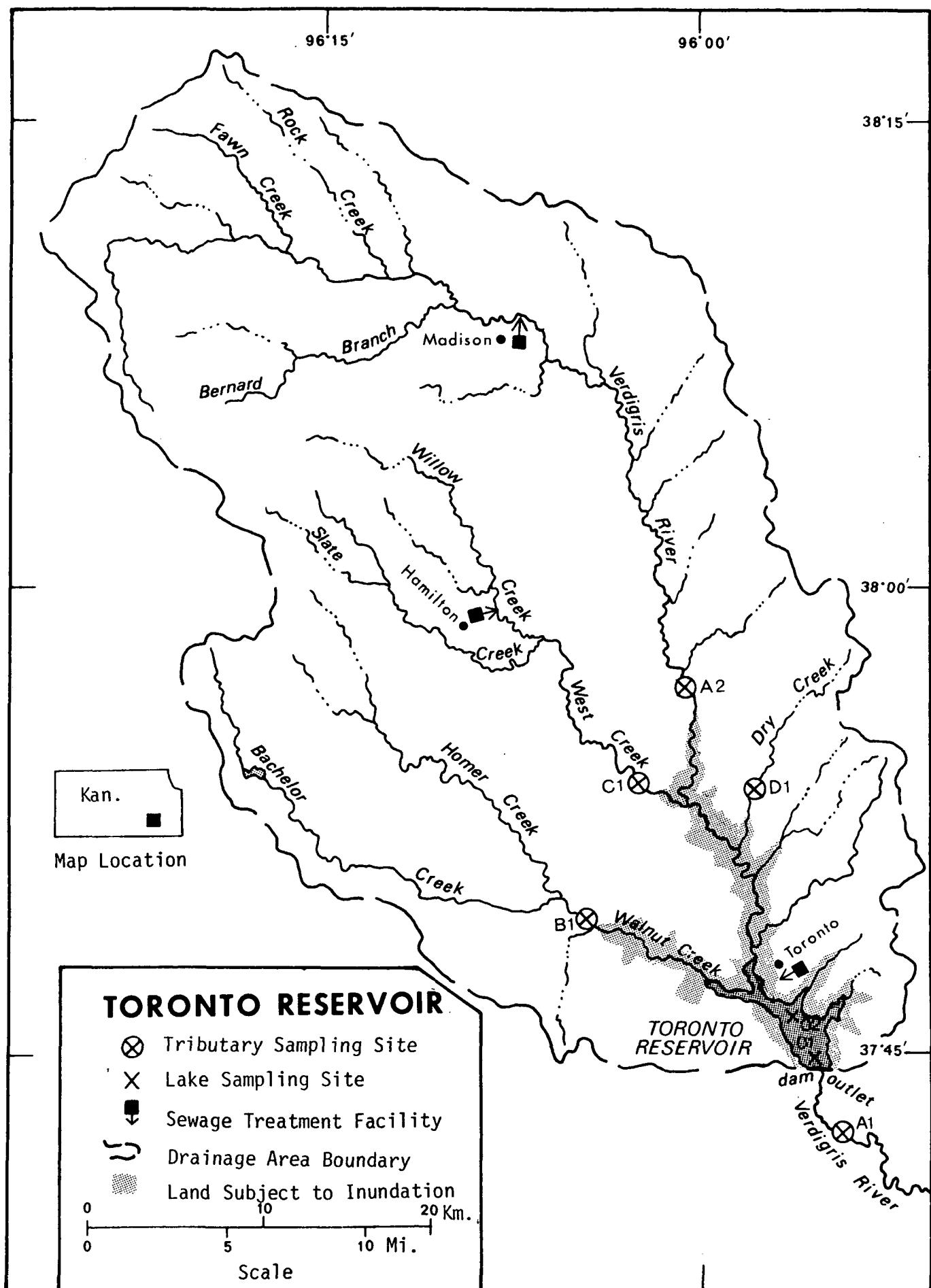
Major General Edward R. Fry, the Adjutant General of Kansas, and Project Officer Colonel Albin L. Lundquist, who directed the volunteer efforts of the Kansas National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY RESERVOIRS

STATE OF KANSAS

<u>NAME</u>	<u>COUNTY</u>
Cedar Bluff	Trego
Council Grove	Morris
Elk City	Montgomery
Fall River	Greenwood
John Redmond	Coffey, Lyon
Kanopolis	Ellsworth
Marion	Marion
Melvern	Osage
Milford	Clay, Geary
Norton	Norton
Perry	Jefferson
Pomona	Osage
Toronto	Greenwood, Woodson
Tuttle Creek	Marshall, Pottawatomie, Riley
Wilson	Russell



TORONTO RESERVOIR

STORET NO. 2013

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate Toronto Reservoir is potentially eutrophic. However, the reservoir becomes quite turbid during periods of runoff, and primary productivity is intermittently light-limited (Kring, 1977).

This water body ranked seventh in overall trophic quality when the 15 Kansas reservoirs sampled in 1974 were compared using a combination of six parameters*. Nine of the reservoirs had less median total phosphorus, five had less and one had the same median orthophosphorus, four had less median inorganic nitrogen, three had less mean chlorophyll a, and eleven had greater mean Secchi disc transparency.

B. Rate-Limiting Nutrient:

The algal assay results indicate the reservoir was phosphorus limited at the times the assay samples were taken (04/10/74 and 10/02/74).

The reservoir data also indicate phosphorus limitation at those times. However, the low Secchi disc transparencies and numbers of phytoplankton (page 7) indicate primary productivity is light-limited at times rather than nutrient-limited as noted above.

* See Appendix A.

C. Nutrient Controllability:

1. Point sources--Point sources contributed 9.0% of the total phosphorus load to Toronto Reservoir during the sampling year. The Hamilton, Madison, and Toronto wastewater treatment plants added 1.6%, 5.3%, and 2.0%, respectively. Septic tanks serving shoreline dwellings and recreational areas contributed an estimated 0.1% of the phosphorus load.

The present phosphorus loading of $2.26 \text{ g/m}^2/\text{yr}$ is nearly twice that proposed by Vollenweider (Vollenweider and Dillon, 1974) as a eutrophic loading (see page 14). However, the median hydraulic retention time of the reservoir is a short 22 days, and Vollenweider's model probably is not applicable.

Even complete removal of phosphorus at the point sources noted above would still leave a loading of $2.06 \text{ g/m}^2/\text{yr}$; and because primary productivity is light-limited part of the time, point-source phosphorus control would not be expected to result in a significant improvement in the trophic condition of Toronto Reservoir.

2. Non-point sources--The phosphorus contributions of non-point sources accounted for 91.0% of the total input to the reservoir during the sampling year. The Verdigris River contributed 31.1% of the total load; Walnut Creek, 17.5%; West Creek, 14.7%; and the ungauged minor tributaries and immediate drainage added an

estimated 26.9% of the total load.

The phosphorus export rates of the gaged tributaries were quite low (page 13) and are comparable to the rates of the two gaged tributaries of nearby Fall River Reservoir* (9 and 11 kg/km²/yr).

* Working Paper No. 514.

II. RESERVOIR AND DRAINAGE BASIN CHARACTERISTICS[†]

A. Morphometry^{††}:

1. Surface area: 11.33 kilometers².
2. Mean depth: 2.5 meters.
3. Maximum depth: 10.0 meters.
4. Volume: 28.73×10^6 m³.
5. Fourteen-year median hydraulic retention time: 22 days.

B. Tributary and Outlet: (See Appendix C for flow data)

1. Tributaries -

<u>Name</u>	<u>Drainage area (km²)*</u>	<u>Mean flow (m³/sec)*</u>
Verdigris River	795.1	5.79
Walnut Creek	331.5	2.63
West Creek	305.6	2.42
Minor tributaries & immediate drainage -	<u>491.2</u>	<u>3.88</u>
Totals	1,923.4	14.72

2. Outlet -

Verdigris River	1,934.7**	14.42
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C. Precipitation***:

1. Year of sampling: 114.5 centimeters.
2. Mean annual: 93.5 centimeters.

[†] Table of metric conversions--Appendix B.

^{††} Kring, 1977.

^{*} For limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".

^{**} Includes area of reservoir.

^{***} See Working Paper No. 175.

III. WATER QUALITY SUMMARY

Toronto Reservoir was sampled three times during the open-water season of 1974 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from two or more depths at two stations on the reservoir (see map, page v). During each visit, a single depth-integrated (4.6 m or near bottom to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the first and last visits, a single 18.9-liter depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depths sampled were 6.1 meters at station 1 and 4.6 meters at station 2.

The sampling results are presented in full in Appendix D and are summarized in the following table (the June nutrient samples were not properly preserved and were not analyzed).

A. SUMMARY OF PHYSICAL AND CHEMICAL CHARACTERISTICS FOR TORONTO RESERVOIR
STORET CODE 2013

PARAMETER	1ST SAMPLING (4/10/74)				2ND SAMPLING (6/24/74)				3RD SAMPLING (10/ 2/74)			
	> SITES				2 SITES				2 SITES			
	RANGE	MEAN	MEDIAN		RANGE	MEAN	MEDIAN		RANGE	MEAN	MEDIAN	
TEMP (C)	11.1 - 11.9	11.4	11.1		24.1 - 26.2	25.0	24.9		16.5 - 16.7	16.6	16.5	
DISS OXY (MG/L)	9.4 - 9.8	9.6	9.6		2.0 - 9.6	6.3	6.4		7.8 - 8.2	8.0	8.0	
CNDCTVY (MCROMO)	170. - 365.	302.	365.		327. - 340.	335.	335.		257. - 272.	265.	270.	
PH (STAND UNITS)	8.2 - 8.2	8.2	8.2		7.9 - 8.0	7.9	7.9		7.8 - 7.9	7.9	7.9	
TOT ALK (MG/L)	166. - 186.	174.	168.	*****	*****	*****	*****		112. - 122.	117.	118.	
TOT P (MG/L)	0.060 - 0.087	0.074	0.068	*****	*****	*****	*****		0.050 - 0.086	0.066	0.066	
ORTHO P (MG/L)	0.011 - 0.014	0.013	0.013	*****	*****	*****	*****		0.003 - 0.015	0.008	0.007	
NO2+NO3 (MG/L)	0.420 - 0.520	0.466	0.470	*****	*****	*****	*****		0.250 - 0.380	0.359	0.380	⑤
AMMONIA (MG/L)	0.050 - 0.100	0.072	0.060	*****	*****	*****	*****		0.020 - 0.050	0.027	0.020	
KJEL N (MG/L)	0.200 - 0.600	0.380	0.400	*****	*****	*****	*****		0.200 - 0.600	0.271	0.200	
INORG N (MG/L)	0.470 - 0.610	0.538	0.530	*****	*****	*****	*****		0.270 - 0.430	0.386	0.400	
TOTAL N (MG/L)	0.670 - 1.020	0.846	0.890	*****	*****	*****	*****		0.450 - 0.980	0.630	0.580	
CHLRPYL A (UG/L)	12.0 - 13.5	12.8	12.8	2.3 - 2.3	2.3	2.3	2.3		3.5 - 5.9	4.7	4.7	
SECCHI (METERS)	0.3 - 0.3	0.3	0.3	0.3 - 0.3	0.3	0.3	0.3		0.3 - 0.3	0.3	0.3	

B. Biological characteristics:

1. Phytoplankton -

<u>Sampling Date</u>	<u>Dominant Genera</u>	<u>Algal Units per ml</u>
04/10/74	1. <u>Stephanodiscus</u> sp. 2. <u>Cryptomonas</u> sp. 3. <u>Chroomonas</u> sp. 4. <u>Melosira</u> sp. 5. <u>Ankistrodesmus</u> sp.	2,355 449 393 336 168
	Total	3,701
06/24/74	1. <u>Cryptomonas</u> sp. 2. <u>Chroomonas</u> sp. 3. <u>Melosira</u> sp. 4. <u>Stephanodiscus</u> sp.	255 255 127 42
	Total	679
10/02/74	1. <u>Anabaena</u> sp. 2. <u>Cryptomonas</u> sp. 3. <u>Chroomonas</u> sp. 4. <u>Melosira</u> sp. 5. <u>Chlamydomonas</u> sp. Other genera	103 103 69 69 34 139
	Total	517

2. Chlorophyll a -

<u>Sampling Date</u>	<u>Station Number</u>	<u>Chlorophyll a ($\mu\text{g/l}$)</u>
04/10/74	1	12.0
	2	13.5
06/24/74	1	2.3
	2	2.3
10/02/74	1	3.5
	2	5.9

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

a. April sample -

<u>Spike (mg/l)</u>	<u>Ortho P Conc. (mg/l)</u>	<u>Inorganic N Conc. (mg/l)</u>	<u>Maximum yield (mg/l-dry wt.)</u>
Control	0.010	0.465	5.1
0.050 P	0.060	0.465	12.3
0.050 P + 1.0 N	0.060	1.465	26.3
1.0 N	0.010	1.465	3.6

b. October sample -

<u>Spike (mg/l)</u>	<u>Ortho P Conc. (mg/l)</u>	<u>Inorganic N Conc. (mg/l)</u>	<u>Maximum yield (mg/l-dry wt.)</u>
Control	0.025	0.415	3.6
0.050 P	0.075	0.415	8.5
0.050 P + 1.0 N	0.075	1.415	18.3
1.0 N	0.025	1.415	3.7

2. Discussion -

The control yields of the assay alga, Selenastrum capricornutum, indicate that the potential primary productivity of Toronto Reservoir was high at the times the samples were taken (04/10/74 and 10/02/74). The lack of growth response to the addition of only nitrogen and the significant increase in yield when phosphorus alone was added, indicate that phosphorus was limiting at those times.

The reservoir data also indicate phosphorus limitation. The mean inorganic nitrogen to orthophosphorus ratios were 41 to 1 in April and 48 to 1 in October and phosphorus limitation would be expected. However, primary productivity is light-limited rather than nutrient-limited part of the time (Kring, 1977).

IV. NUTRIENT LOADINGS
(See Appendix E for data)

For the determination of nutrient loadings, the Kansas National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), except for the high runoff months of May, June, and July when two samples were collected. Sampling was begun in October, 1974, and was completed in September, 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Kansas District Office of the U.S. Geological Survey for the tributary sites nearest the reservoir.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. Nutrient loads shown are those measured minus point-source loads, if any.

Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the means of the nutrient loads, in kg/km²/year, at station B-1 and multiplying the means by the ZZ area in km².

The operators of the Hamilton, Madison, and Toronto wastewater treatment plants provided monthly effluent samples but could not provide corresponding flow data. Therefore, nutrient loads were

* See Working Paper No. 175.

estimated at 1.134 kg P and 3.401 kg N/capita/year, and flows were estimated at 0.3785 m³/capita/day.

A. Waste Sources:

1. Known municipal* -

<u>Name</u>	<u>Pop. Served</u>	<u>Treatment</u>	<u>Mean Flow (m³/d)</u>	<u>Receiving Water</u>
Hamilton	363	stab. pond	137.4	Willow Creek
Madison	1,200	tr. filter	454.2	Verdigris River
Toronto	458	tr. filter	173.4	Verdigris River arm of Reservoir

2. Known industrial - None

* Treatment plant questionnaires.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

<u>Source</u>	<u>kg P/ yr</u>	<u>% of total</u>
a. Tributaries (non-point load) -		
Verdigris River	7,975	31.1
Walnut Creek	4,490	17.5
West Creek	3,760	14.7
b. Minor tributaries & immediate drainage (non-point load) -	6,875	26.9
c. Known municipal STP's -		
Hamilton	410	1.6
Madison	1,360	5.3
Toronto	520	2.0
d. Septic tanks* -	15	0.1
e. Known industrial - None	-	-
f. Direct precipitation** -	200	0.8
Total	25,605	100.0

2. Outputs -

Reservoir outlet - Verdigris River 35,940

3. Net annual P loss - 10,335 kg.

* Estimate based on 40 shoreline dwellings and two campgrounds; see Working Paper No. 175.

** See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

<u>Source</u>	<u>kg N/ yr</u>	<u>% of total</u>
a. Tributaries (non-point load) -		
Verdigris River	222,380	34.9
Walnut Creek	114,615	18.0
West Creek	110,145	17.3
b. Minor tributaries & immediate drainage (non-point load) -	169,955	26.7
c. Known municipal STP's -		
Hamilton	1,235	0.2
Madison	4,080	0.6
Toronto	1,560	0.3
d. Septic tanks* -	565	0.1
e. Known industrial - None	-	-
f. Direct precipitation** -	<u>12,230</u>	<u>1.9</u>
Total	636,765	100.0

2. Outputs -

Reservoir outlet - Verdigris River 661,285

3. Net annual N loss - 24,520 kg.

D. Non-point Nutrient Export by Subdrainage Area:

<u>Tributary</u>	<u>kg P/km²/yr</u>	<u>kg N/km²/yr</u>
Verdigris River	10	280
Walnut Creek	14	346
West Creek	12	360

* Estimate based on 40 shoreline dwellings and two campgrounds; see Working Paper No. 175.

** See Working Paper No. 175.

E. Mean Nutrient Concentrations in Ungaged Stream:

<u>Tributary</u>	Mean Total P Conc. (mg/l)	Mean Total N Conc. (mg/l)
Dry Creek	0.053	1.092

F. Yearly Loads:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

	Total Phosphorus Total Accumulated	Total Nitrogen Total Accumulated
grams/m ² /yr	2.26	loss*

Vollenweider phosphorus loadings
(g/m²/yr) based on mean depth and 14-year median
hydraulic retention time of Toronto Reservoir:

"Dangerous" (eutrophic loading)	1.22
"Permissible" (oligotrophic loading)	0.61

* There was an apparent loss of nutrients during the sampling year. This may have been due to unknown and unsampled point sources discharging directly to the reservoir but more likely was due to insufficient outlet sampling in relation to the short hydraulic retention time of the reservoir.

V. LITERATURE REVIEWED

Kring, R. Lynn, 1977. Personal communication (revised reservoir morphometry; primary productivity). KS Dept. of Health & Environment, Topeka.

Vollenweider, R. A., and P. J. Dillon, 1974. The application of the phosphorus loading concept to eutrophication research. Natl. Res. Council of Canada Publ. No. 13690, Canada Centre for Inland Waters, Burlington, Ontario.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500- MEAN SEC	MEAN CHLORA	15- MIN DO	MEDIAN DISS ORTHO P
2001	CEDAR BLUFF RESERVOIR	0.017	0.055	431.667	4.217	10.800	0.004
2002	COUNCIL GROVE	0.069	0.830	485.889	9.789	10.400	0.028
2003	ELK CITY	0.030	0.590	490.400	3.212	14.000	0.003
2004	FALL RIVER RESERVOIR	0.053	0.470	488.667	7.683	9.200	0.016
2005	JOHN REDMOND RESERVOIR	0.118	1.250	492.667	9.467	8.200	0.066
2006	KANOPOLIS RESERVOIR	0.056	0.640	487.000	16.033	10.200	0.011
2007	MARION RESERVOIR	0.052	0.430	483.667	12.400	9.000	0.010
2008	MELVERN RESERVOIR	0.034	0.265	459.111	30.400	14.400	0.007
2009	MILFORD RESERVOIR	0.079	0.710	466.333	18.883	12.800	0.036
2010	NORTON RESERVOIR	0.122	0.110	476.750	21.360	8.000	0.036
2011	PERRY RESERVOIR	0.055	0.970	478.571	5.614	13.400	0.017
2012	POMONA RESERVOIR	0.040	1.240	481.333	8.312	13.000	0.021
2013	TORONTO RESERVOIR	0.067	0.425	488.500	6.583	13.000	0.011
2014	TUTTLE CREEK RESERVOIR	0.162	0.970	470.667	11.278	13.600	0.067
2015	WILSON RESERVOIR	0.023	0.265	445.222	8.867	13.400	0.004

LAKES RANKED BY INDEX NOS

RANK	LAKE CODE	LAKE NAME	INDEX NO
1	2001	CEDAR BLUFF RESERVOIR	539
2	2015	WILSON RESERVOIR	439
3	2007	MARION RESERVOIR	357
4	2003	ELK CITY	350
5	2004	FALL RIVER RESERVOIR	328
6	2008	MELVERN RESERVOIR	326
7	2013	TORONTO RESERVOIR	303
8	2010	NORTON RESERVOIR	292
9	2011	PERRY RESERVOIR	279
10	2006	KANOPOLIS RESERVOIR	271
11	2012	POMONA RESERVOIR	267
12	2002	COUNCIL GROVE	230
13	2009	MILFORD RESERVOIR	214
14	2005	JOHN REDMOND RESERVOIR	164
15	2014	TUTTLE CREEK RESERVOIR	139

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500- MEAN SEC	MEAN CHLORA	15- MIN DO	MEDIAN DISS ORTHO P	INDEX NO
2001	CEDAR BLUFF RESERVOIR	100 (14)	100 (14)	100 (14)	93 (13)	57 (8)	89 (12)	539
2002	COUNCIL GROVE	29 (4)	29 (4)	36 (5)	43 (6)	64 (9)	29 (4)	230
2003	ELK CITY	86 (12)	50 (7)	7 (1)	100 (14)	7 (1)	100 (14)	350
2004	FALL RIVER RESERVOIR	57 (8)	57 (8)	14 (2)	71 (10)	79 (11)	50 (7)	328
2005	JOHN REDMOND RESERVOIR	14 (2)	0 (0)	0 (0)	50 (7)	93 (13)	7 (1)	164
2006	KANOPOLIS RESERVOIR	43 (6)	43 (6)	29 (4)	21 (3)	71 (10)	64 (9)	271
2007	MARION RESERVOIR	64 (9)	64 (9)	43 (6)	29 (4)	86 (12)	71 (10)	357
2008	MELVERN RESERVOIR	79 (11)	82 (11)	86 (12)	0 (0)	0 (0)	79 (11)	326
2009	MILFORD RESERVOIR	21 (3)	36 (5)	79 (11)	14 (2)	50 (7)	14 (2)	214
2010	NORTON RESERVOIR	7 (1)	93 (13)	64 (9)	7 (1)	100 (14)	21 (3)	292
2011	PERRY RESERVOIR	50 (7)	18 (2)	57 (8)	86 (12)	25 (3)	43 (6)	279
2012	POMONA RESERVOIR	71 (10)	7 (1)	50 (7)	64 (9)	39 (5)	36 (5)	267
2013	TORONTO RESERVOIR	36 (5)	71 (10)	21 (3)	79 (11)	39 (5)	57 (8)	303
2014	TUTTLE CREEK RESERVOIR	0 (0)	18 (2)	71 (10)	36 (5)	14 (2)	0 (0)	139
2015	WILSON RESERVOIR	93 (13)	82 (11)	93 (13)	57 (8)	25 (3)	89 (12)	439

APPENDIX B

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR KANSAS

05/03/76

LAKE CODE 2013 TORONTO

TOTAL DRAINAGE AREA OF LAKE(SQ KM) 1890.7

TRIBUTARY	SUB-DRAINAGE AREA(SQ KM)	NORMALIZED FLOWS(CMS)												MEAN
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
2013A1	1934.7	9.06	8.50	17.84	16.71	18.41	27.47	13.31	4.81	17.56	15.57	14.72	9.06	14.42
2013A2	795.1	2.66	3.40	6.80	9.06	9.63	10.76	8.50	3.40	4.81	4.81	3.11	2.41	5.79
2013B1	331.5	1.25	1.59	3.40	4.25	4.81	4.25	3.96	1.42	1.98	2.12	1.30	1.19	2.63
2013C1	305.6	1.19	1.47	3.11	3.96	4.25	3.96	3.68	1.25	1.81	1.98	1.19	1.08	2.42
2013Z2	458.4	1.84	2.35	4.81	6.23	6.51	6.80	5.66	2.35	3.11	3.11	2.01	1.70	3.88

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 1890.7 TOTAL FLOW IN = 176.30
 SUM OF SUB-DRAINAGE AREAS = 1890.7 TOTAL FLOW OUT = 173.02

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
2013A1	10	74	6.116	24	0.510				
	11	74	63.996	9	30.299				
	12	74	22.965	14	28.600				
	1	75	13.309	9	28.034				
	2	75	39.644	11	58.899				
	3	75	29.733	12	19.765				
	4	75	25.060	16	18.123				
	5	75	12.431	3	6.711	18	18.066		
	6	75	56.351	16	59.749	29	58.899		
	7	75	2.662	12	0.850	30	0.269		
2013A2	8	75	0.396	28	0.368				
	9	75	0.269	20	0.269				
	10	74	2.010	24	11.327				
	11	74	8.778	9	13.989				
	12	74	3.398	14	11.723				
	1	75	4.248	9	9.911				
	2	75	7.929	11	8.495				
	3	75	6.513	12	11.610				
	4	75	7.079	16	9.345				
	5	75	5.663	3	3.681	18	1.699		
	6	75	24.636	15	5.380	29	4.248		
	7	75	0.963	12	0.991	30	0.311		
	8	75	0.088	28	0.028				
	9	75	0.125	20	0.127				

TRIBUTARY FLOW INFORMATION FOR KANSAS

05/03/76

LAKE CODE 2013 TORONTO

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
2013B1	10	74	0.904	24	2.039				
	11	74	3.681	9	2.265				
	12	74	1.699	14	2.832				
	1	75	1.982	9	2.690				
	2	75	3.681	11	2.549				
	3	75	3.398	12	7.532				
	4	75	3.398	16	1.841				
	5	75	2.747	3	0.425	18	0.425		
	6	75	9.911	16	0.481	29	0.085		
	7	75	0.453	12	0.170	30	0.006		
	8	75	0.037	28	0.003				
	9	75	0.054	20	0.0				
2013C1	10	74	0.850	24	2.520				
	11	74	3.398	9	2.520				
	12	74	1.557	14	2.549				
	1	75	1.869	9	2.209				
	2	75	3.398	11	2.124				
	3	75	3.115	12	10.194				
	4	75	3.115	16	1.642				
	5	75	2.549	3	1.019	18	9.061		
	6	75	9.061	16	1.218	29	0.878		
	7	75	0.396	12	0.218	30	0.116		
	8	75	0.034	28	0.011				
	9	75	0.048	20	0.011				
2013ZZ	10	74	1.331						
	11	74	5.947						
	12	74	2.435						
	1	75	2.832						
	2	75	5.380						
	3	75	4.531						
	4	75	4.814						
	5	75	3.681						
	6	75	15.574						
	7	75	0.651						
	8	75	0.062						
	9	75	0.088						

APPENDIX D
PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 76/05/03

201301
 37 44 50.0 095 55 29.0 3
 TORONTO RESERVOIR
 20207 KANSAS

100491

11EPALES 2111202
 0027 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 TALK CACO ₃ MG/L	00610 NH ₃ -N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO ₂ &NO ₃ N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
74/04/10	15 30	0000	11.1		12	365	8.20	167	0.060	0.400	0.490	0.013
	15 30	0005	11.1	9.6		365	8.20	166	0.090	0.200	0.520	0.012
	15 30	0015	11.1	9.8		365	8.20	168	0.060	0.200	0.470	0.014
74/06/24	13 55	0000	26.2	6.8	10	338	8.00					
	13 55	0005	25.7	6.8		335	7.90					
	13 55	0010	25.0	6.4		334	7.90					
	13 55	0015	24.3	6.4		332	7.90					
	13 55	0020	24.1	9.6		327	7.90					
	15 20	0000	16.7	8.0		12	257	7.80	114	0.040	0.300	0.380
74/10/02	15 20	0005	16.7	8.2		258	7.90	113	0.050	0.200K	0.380	0.009
	15 20	0010	16.7	8.0		258	7.90	112	0.020K	0.200K	0.250	0.003

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL UG/L	00031 INCDLT A REMNING PERCENT
74/04/10	15 30	0000	0.068	12.0	
	15 30	0005	0.067		
	15 30	0015	0.060		
74/06/24	13 55	0000		2.3	
	15 20	0000	0.069	3.5	
74/10/02	15 20	0005	0.050		
	15 20	0010	0.069		

K VALUE KNOWN TO BE
 LESS THAN INDICATED

STORET RETRIEVAL DATE 76/05/03

201302
 37 46 03.0 095 56 03.0 3
 TORONTO RESERVOIR
 20207 KANSAS

100391

11EPALES 2111202
 0008 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	WATER TEMP CENT	00010 DO MG/L	00300 TRANSP INCHES	00077 SECCHI FIELD	00094 CNDUCTVY MICROMHO	00400 PH SU	00410 TALK CACO ₃ MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
74/04/11	10 15	0000	11.9		12	170	8.20	183	0.050	0.600	0.420	0.011	
	10 15	0005	11.9	9.4		245	8.20	186	0.100	0.500	0.430	0.013	
74/06/24	14 20	0000	24.9	2.0	11	340	8.00						
	14 20	0005	24.8	6.0		336	7.90						
74/10/02	15 45	0000	16.5	7.8	12	271	7.90	121	0.020K	0.200	0.370	0.005	
	15 45	0005	16.5	8.2		270	7.90	121	0.020	0.200K	0.380	0.007	
	15 45	0010	16.5	8.0		272	7.89	122	0.020K	0.200K	0.370	0.013	
	15 45	0015	16.5	8.0		271	7.85	118	0.020	0.600	0.380	0.015	

DATE FROM TO	TIME OF DAY	DEPTH FEET	PHOS-TOT MG/L P	00665 CHLRPHYL UG/L	32217 INCOT LT A REMNING PERCENT	00031
74/04/11	10 15	0000	0.086	13.5		
	10 15	0005	0.087			
74/06/24	14 20	0000		2.3		
74/10/02	15 45	0000	0.066	5.9		
	15 45	0005	0.060			
	15 45	0010	0.061			
	15 45	0015	0.086			

K VALUE KNOWN TO BE
 LESS THAN INDICATED

APPENDIX E

**TRIBUTARY AND WASTEWATER
TREATMENT PLANT DATA**

STORET RETRIEVAL DATE 76/05/04

2013A1
 37 42 20.0 095 54 20.0 4
 VERDIGRIS RIVER
 20 15 FREEDOMIA
 O/TORONTO RESERVOIR 100491
 BRDG ON SEC RD 1828 1.5 M NW OF COYVILLE
 11EPALES 2111204
 0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 N02&N03 N-TOTAL	00625 TOT KJEL MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
			00630 N02&N03 N-TOTAL	00625 TOT KJEL MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
74/10/24	09 12		0.312	0.600	0.015	0.015	0.060
74/11/09	09 00		0.184	2.300	0.440	0.045	0.100
74/12/14	08 45		0.296	1.000	0.030	0.020	0.060
75/01/09	13 30		0.368	1.700	0.024	0.005	0.030
75/02/11	09 30		0.375	1.100	0.048	0.008	0.090
75/03/12	10 45		0.376	0.500	0.032	0.008	0.050
75/04/16	09 15		0.315	2.100	0.035	0.010	0.050
75/05/03	14 00		0.130	1.200	0.080	0.010	0.080
75/05/18	10 50		0.107	1.300	0.075	0.010	0.070
75/06/16	13 30		0.400	0.650	0.015	0.020	0.100
75/06/29	17 20		0.375	0.850	0.045	0.025	0.140
75/07/12	10 30		0.330	0.650	0.055	0.025	0.090
75/07/30	09 45		0.315	0.550	0.025	0.020	0.090
75/08/28	13 15		0.230	0.675		0.025	0.110
75/09/20	10 05		0.310	1.000	0.015	0.025	0.105

STORET RETRIEVAL DATE 76/05/04

2013A2
 37 53 30.0 096 00 43.0 4
 VERDIGRIS RIVER
 20 7.5 VIRGIL
 T/TORONTO RESERVOIR 100391
 BROG ON LGHT DTY RD 2.8 MI S OF VIRGIL
 11EPALES 2111204
 0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 N02&N03	00625 TOT KJEL	00610 NH3-N N	00671 PHOS-DIS ORTHO	00665 PHOS-TOT MG/L P
			MG/L	MG/L	MG/L	MG/L P	MG/L P
74/10/24	10 20		0.112	0.500	0.020	0.005	0.040
74/11/09	10 30		0.352	0.800	0.025	0.025	0.060
74/12/14	10 05		0.336	1.000	0.020	0.010	0.060
75/01/09	14 55		0.288	1.100	0.096	0.010	0.050
75/02/11	10 50		0.464	0.700	0.032	0.008K	0.050
75/03/12	12 05		0.400	0.800	0.024	0.008K	0.030
75/04/16	10 45		0.270	0.650	0.030	0.005	0.050
75/05/03	16 00		0.345	1.200	0.055	0.010	0.060
75/05/18	13 10		0.650	1.750	0.040	0.010	0.060
75/06/16	15 00		0.560	0.700	0.020	0.030	0.100
75/06/29	18 35		0.740	0.700	0.025	0.020	0.070
75/07/12	12 15		0.840	0.550	0.025	0.015	0.050
75/07/30	11 45		0.315	0.900	0.035	0.010	0.050
75/08/28	14 50		0.105	0.550	0.012	0.005	0.030
75/09/20	12 10		0.250	0.700	0.030	0.015	0.040

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORED RETRIEVAL DATE 76/05/04

201381
 37 49 20.0 096 05 20.0 4
 WALNUT CREEK
 20 7.5 NEAL
 T/TORONTO RESERVOIR 100391
 COUNTY RD BRDG 1 MI S OF NEAL
 11EPALES 2111204
 0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3	00625 TOT KJEL	00610 NH3-N N	00671 PHOS-DIS TOTAL ORTHO	00665 PHOS-TOT MG/L P
			MG/L	MG/L	MG/L	MG/L P	
74/10/24	09 45		0.064	1.303	0.030	0.025	0.052
74/11/09	09 35		0.320	1.200	0.345	0.025	0.040
74/12/14	09 25		0.192	1.000	0.015	0.020	0.080
75/01/09	14 00		0.192	1.300	0.072	0.020	0.070
75/02/11	10 05		0.320	1.000	0.024	0.008K	0.060
75/03/12	11 20		0.168	0.500	0.012	0.008K	0.030
75/04/16	10 00		0.090	1.750	0.025	0.005	0.050
75/05/03	15 20		0.070	0.350	0.030	0.010	0.050
75/05/18	11 25		0.240	1.450	0.025	0.015	0.070
75/06/16	14 15		0.230	1.150	0.085	0.020	0.090
75/06/29	18 00		0.030	2.000	0.080	0.010	0.060
75/07/12	11 00		0.025	0.850	0.020	0.010	0.070
75/07/30	10 45		0.010	0.600	0.020	0.010	0.070
75/08/28	13 50		0.010	1.000	0.015	0.030	0.120
75/09/20	11 20		0.095	1.000	0.095	0.025	0.110

K VALUE KNOWN TO BE
 LESS THAN INDICATED

STORET RETRIEVAL DATE 76/05/04

2013C1
37 53 45.0 096 02 45.0 4
WEST CREEK
20 7.5 VIRGIL
T/TORUNTO RESERVOIR 100391
BRDG ON LIGHT DTY RD 4 MI NW OF QUINCY
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE	TIME	DEPTH	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
FRUM TO	OF DAY	FEET					
74/10/24	10 05		0.024	1.700	0.030	0.010	0.055
74/11/09	10 25		0.540	0.900	0.375	0.020	0.030
74/12/14	09 50		0.336	1.400	0.260	0.020	0.120
75/01/09	14 25		0.320	1.900	0.040	0.025	0.105
75/02/11	10 30		0.448	0.900	0.024	0.008K	0.050
75/03/12	11 50		0.268	0.500	0.012	0.008K	0.020
75/04/16	10 30		0.190	0.600	0.005	0.005K	0.040
75/05/03	15 45		0.290	1.400	0.035	0.005	0.070
75/05/18	12 55		0.140	1.900	0.025	0.005	0.060
75/06/16	14 40		0.450	1.050	0.080	0.010	0.070
75/06/29	18 20		0.175	0.662	0.025	0.010	0.055
75/07/12	12 00		0.095	1.000	0.020	0.010	0.040
75/07/30	11 30		0.125	0.775	0.055	0.005	0.055
75/08/28	14 28		0.100	0.550	0.005K	0.005	0.050
75/09/20	11 50		0.340	0.500	0.045	0.010	0.050

K VALUE KNOWN TO BE
LESS THAN INDICATED

201301
 37 52 50.0 096 57 55.0 4
 DRY CREEK
 20 7.5 QUINCY
 T/TORONTO RESERVOIR 100291
 BRDG ON LGHT DTY RD 1.1 MI E OF QUINCY
 11EPALES 2111204
 0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 N02&N03 MG/L	00625 TOT KJEL MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
74/10/24	10 40	0.008	1.200	0.025	0.035	0.100	
74/11/09	10 55	0.672	0.900	0.060	0.010	0.010	
74/12/14	10 25	0.256	0.900	0.035	0.015	0.060	
75/01/09	15 16	0.296	1.100	0.048	0.010	0.060	
75/02/11	11 10	0.590	0.600	0.016	0.008K	0.050	
75/03/12	12 25	0.368	0.400	0.012	0.008K	0.030	
75/04/16	11 25	0.220	0.800	0.070	0.005	0.030	
75/05/03	16 00	0.125	0.250	0.015	0.005K	0.030	
75/05/18	13 30	0.300	1.250	0.045	0.010	0.060	
75/06/16	15 20	0.370	0.850	0.025	0.010	0.060	
75/06/29	18 55	0.135	0.650	0.030	0.010	0.040	
75/07/12	12 45	0.010	0.600	0.050	0.010	0.050	
75/07/30	12 15	0.010	1.150	0.040	0.010	0.070	
75/08/28	15 10	0.040	1.600	0.010			
75/09/20	12 30	0.025	0.700	0.015	0.010	0.090	

K VALUE KNOWN TO BE
 LESS THAN INDICATED

STORET RETRIEVAL DATE 76/05/04

2013AA TF2013AA P001200
 38 09 00.0 096 08 00.0 4
 MADISON
 20 GREENWOOD CO.
 T/TORONTO RES. 100392
 VERDIGRIS RIVER
 11EPALES 2141204
 0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 N02&N03 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT INST MG/L P	50051 FLOW RATE MG/L	50053 CONDUIT FLOW-MGD MONTHLY
75/06/04	11 30		3.450	22.000	4.200	4.200		7.100	
75/06/30	14 00		4.200	15.000		6.900		10.500	
75/07/17	10 00		9.600	17.000	2.800	7.500		8.100	
75/08/05	15 00		23.000	15.500	1.700	7.500		10.500	
75/09/19	14 00		28.000	14.800	4.400	10.000		10.800	
75/10/15	15 30		9.300	27.000	10.000	10.500		12.000	
75/10/30	11 15		17.500	30.000	10.500	8.700		10.500	
75/11/19	14 00		15.400	29.000	10.500	11.500		16.500	
75/12/05	11 30		12.600	32.000	12.000	6.200		13.500	
76/01/16	11 30		4.000	38.000		8.300		11.500	
76/02/04	15 00			25.000					
76/02/25	14 00			27.500					

STORET RETRIEVAL DATE 76/05/04

2013AB TF2013AB P000458
 37 48 00.0 095 57 00.0 4
 TORONTO
 20 7.5 TORONTO
 T/TORONTO RES. 100391
 VERDIGRIS RIVER
 11EPALES 2141204
 0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 N02&N03 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
75/02/11	11 00								
CP(T)-			5.040	1.400	0.100	1.800	2.400		
75/02/11	16 00								
75/03/27	11 00								
CP(T)-			5.280	3.900	0.360	0.980	1.500		
75/03/27	16 00								
75/04/30	11 00								
CP(T)-			93.000	7.000	0.310	4.500	5.600		
75/04/30	16 00								
75/05/28	11 00								
CP(T)-			10.500	1.800	0.240	2.400	2.400		
75/05/28	16 00								
75/06/24	11 00								
CP(T)-			12.600	2.400	0.050	2.630	2.630		
75/06/24	16 00								
75/07/22	11 00								
CP(T)-			22.500	5.300	0.050K	4.600	5.300		
75/07/22	16 00								
75/08/08	11 00								
CP(T)-			24.000	8.900	0.290	4.850	6.100		
75/08/08	16 00								
75/09/26	11 00								
CP(T)-			22.000	10.500	0.160	7.200	7.700		
75/09/26	16 00								
75/10/22	11 00								
CP(T)-			9.000	27.000	5.800	9.200	9.200		
75/10/22	16 00								
75/11/21	11 00								
CP(T)-			10.500	21.000	7.300	4.700	8.100		
75/11/21	16 00								
75/12/01	11 00								
CP(T)-			9.800	15.000	4.700	6.800	7.900		
75/12/01	16 00								
75/12/22	11 00								
CP(T)-			8.800	29.000	12.000	3.400	9.800		
75/12/22	16 00								

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/05/04

2013CA PD2013CA P000363
37 59 35.0 096 09 10.0 4
HAMILTON
20 GREENWOOD COUNTY
T/TORONTO RES 100391
WILLOW CREEK
11EPALES 2141204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL	00625 TOT KJEL N	00610 NH3-N TOTAL	00671 PHOS-DIS ORTHO	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
75/05/13	13 30		0.050	6.500	0.080	2.000	2.400		
75/07/25	14 00		0.075	3.600	0.025K	0.980	1.800		
75/08/04	09 00		0.025	21.500	0.075	1.700	3.500		
75/09/10	10 00		0.075	4.900	0.110	1.400	1.800		

K VALUE KNOWN TO BE
LESS THAN INDICATED