1994

LAKE AND WETLAND MONITORING PROGRAM

REPORT/SUMMARY

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Summary

The Kansas Department of Health and Environment (KDHE) Lake and Wetland Monitoring Program surveyed the water quality conditions of 25 Kansas lakes and wetlands during 1994. Eight of these lakes were federal reservoirs, three were major wetlands, and the remaining 14 represented State Fishing Lakes/State Parks, and city/county lakes.

Most of the surveyed lakes appeared to be constant to improved, as compared to their last surveys, with regard to their assigned trophic state. Eight lakes indicated reasonably constant trophic states since their last surveys, while 12 indicated an improved (lower) trophic state. In general, the improved lake trophic states indicated improved water quality conditions, but this may have been influenced by recovery processes from recent (1993) flood conditions in several waterbodies. Five lakes were surveyed in 1994 that indicated an increase in trophic state since their last water quality survey.

A total of 72 exceedences of the Kansas numeric water quality criteria, or Environmental Protection Agency (EPA) water quality guidelines, were documented in the surface waters of the 25 surveyed lakes. Thirty-four of these exceedences concerned aquatic life support criteria. Twenty-eight concerned water supply and human health related criteria. The remaining 10 exceedences concerned agricultural water uses.

Atrazine was the most often detected pesticide in Kansas lakes during 1994. Fourteen lakes had detectable concentrations of atrazine within their main bodies. These detections ranged in concentration from 0.31 to 16.0 ug/L. Dual (metolachlor) was detected in six lakes (concentration ranging from 0.26 to 4.2 ug/L), while alachlor was detected in five (concentration ranging from 0.16 to 3.0 ug/L). Concentrations of atrazine in eight lakes exceeded the applicable chronic criterion for aquatic life support (1.0 ug/L). Atrazine levels in five lakes exceeded the domestic water supply criterion (3.0 ug/L). Alachlor levels exceeded the domestic water supply criterion (2.0 ug/L) in one lake. Five lakes had detections of alachlor during 1994. Other pesticides detected in lakes during 1994 included propachlor, metribuzen (Sencor), carbofuran (Furidan), and cyanazine (Bladex).

TABLE OF CONTENTS

Page

Introduction 1

Development of the Lake and Wetland Monitoring Program . 1

Overview of the 1994 Monitoring Activities 1

Methods 5

Yearly Selection of Monitored Sites 5

Sampling Procedures 5

Taste and Odor/Algae Bloom Program 6

Results and Discussion 6

Lake Trophic State 6

Trends in Trophic State 9

Lake Stratification 9

Contact Recreation and Fecal Coliform Bacterial Counts . 14

Limiting Nutrients and Physical Parameters 14

Surface Water Exceedences of State
Water Quality Criteria 17

Pesticides in Kansas Lakes, 1994 20

Discussion of Nonpoint Sources of Pollution
For Selected Lakes 21

Taste and Odor/Algae Bloom Investigations and Other
Special Investigations in 1994 21

Conclusions 25

References 25

Lake Data Availability 27

TABLES

Page

Table 1. General information pertaining to lakes in 1994 2

Table 2. Present and past trophic states of lakes 8

Table 3. Algal community composition of lakes in 1994 10

Table 4. Change in lake trophic state for each basin over time 11

Table 5. Macrophyte community structure in nine of the surveyed lakes in 1994 12

Table 6. Stratification status of the lakes and wetlands surveyed during 1994 13

Table 7. Fecal coliform bacterial data for swimming areas in the surveyed lakes 16

Table 8. Factors limiting algae production in the surveyed lakes 17

Table 9. Exceedences of aquatic life support criteria in surveyed lakes 18

Table 10. Exceedences of human health criteria in surveyed lakes 19

Table 11. Pesticide detections in lakes, 1994 22

Figures

Page

Figure 1. Locations of the lakes and wetlands surveyed during 1994 3

Figure 2. Locations of the lakes and wetlands within the KDHE Lake and Wetland Monitoring Program. 4

INTRODUCTION

Development of the Lake and Wetland Monitoring Program

The Kansas Department of Health and Environment (KDHE) Lake and Wetland Monitoring Program was established in 1975 to fulfill the requirements of the 1972 Clean Water Act (Public Law 92-500) by providing Kansas with background water quality data for water supply and recreational impoundments, by determining regional and time trends for those impoundments, and by identifying pollution control and/or assessment needs within individual lake watersheds.

Program activities originally centered around a small sampling network comprised mostly of federal lakes, with sample stations at numerous locations within each lake. In 1985, based on the results of statistical analyses, the number of stations per lake were reduced to a single station within the main body of each impoundment. This, and the elimination of parameters with limited interpretive value, allowed expansion of the lake network to its present 117 sites scattered throughout all the major drainage basins and physiographic regions of Kansas.

In 1989, KDHE initiated a Taste and Odor/Algae Bloom Technical Assistance Program for public drinking water supply lakes. This was done to assist water suppliers in identifying and controlling taste and odor problems, in finished drinking water, that result from ecological processes and algae blooms in water supply lakes.

Overview of the 1994 Monitoring Activities

Staff of the KDHE Lake and Wetland Monitoring Program visited 25 Kansas lakes during 1994. Of the 25 surveyed sites, eight were large federal lakes last sampled in 1991, eight were State Fishing Lakes (SFLs)/State Parks/Game Management Areas, six were city/county lakes (CLs and Co. lakes, respectively), and three were major wetland/wildlife management areas (WMAs). Eleven of the 25 lakes serve as either primary or back-up public water supplies (PWSs). In addition to these routine activities, program staff were engaged in an EPA Clean Lakes Program Phase 1 project at two urban lakes, and initiated a project to investigate the role of small point source dischargers on lake water quality. This later project was funded, in part, through an EPA mini-grant for Total Maximum Daily Load (TMDL) development.

Table 1 compiles some general information on the lakes surveyed during 1994. Figure 1 depicts the locations of the 25 lakes and wetlands surveyed during 1994. Figure 2 depicts the locations and status of all currently active sites within the Lake and Wetland Monitoring Program. In addition to routine lake monitoring, several public lakes and private ponds were investigated as part of the Taste and Odor/Algae Bloom Technical Assistance Program.

Table 1. General Information Pertaining to Lakes Surveyed in 1994.

Lake	Basin	Authority	PWS(*)	Last Surveyed
Bourbon Co. SFL	MC	State		1988
Cedar Bluff Lake	SS	FMPR		1991
Cheyenne Bottoms	LA	SWWA		1991
Clinton Lake	KR	FMPR	*	1991
Council Grove City L.	NE	Local	*	1989
Douglas Co. SFL	KR	State		1989
Geary Co. SFL	SS	State		1986
Harvey Co. East Lake	WA	Local		1988
Herington Reservoir	SS	Local	*	1991
Kanopolis Lake	SS	FMPR	*	1991
Lyon Co. SFL	MC	State		1989
Milford Lake	KR	FMPR	*	1991
Mission Lake	KR	Local	*	1989
Montgomery Co. SFL	VE	State		1989
Mound City Lake	MC	Local	*	1988
Neosho Co. SFL	NE	State		1988
Perry Lake	KR	FMPR	*	1991
Pottawatomie Co. SFL 1	KR	State		1989
Pottawatomie Co. SFL 2	KR	State		1988
Quivera Big Salt Marsh	LA	FWWA		1991
Quivera Little Marsh	LA	FWWA		1991
Tuttle Creek Lake	KR	FMPR	*	1991
Webster Lake	SO	FMPR		1991
Wilson Lake	SS	FMPR		1991
Yates Center Lake	VE	Local	*	1993

CI = Cimarron
KR = Kansas/Lower Republican
LA = Lower Arkansas
MC = Marais des Cygnes
MO = Missouri
NE = Neosho
SO = Solomon
SS = Smoky Hill/Saline
UA = Upper Arkansas
UR = Upper Republican
VE = Verdigris
WA = Walnut

FMPR = Federal Multipurpose Reservoir

WMA = Wildlife/Game Management Area

SFL = State Fishing Lake

SWWA = State Wetland/ Wildlife Area

FWWA = Federal Wetland/ Wildlife Area

Figure 1. Locations of the 25 lake and wetland sites surveyed during 1994 by the KDHE Lake and Wetland Monitoring Program.

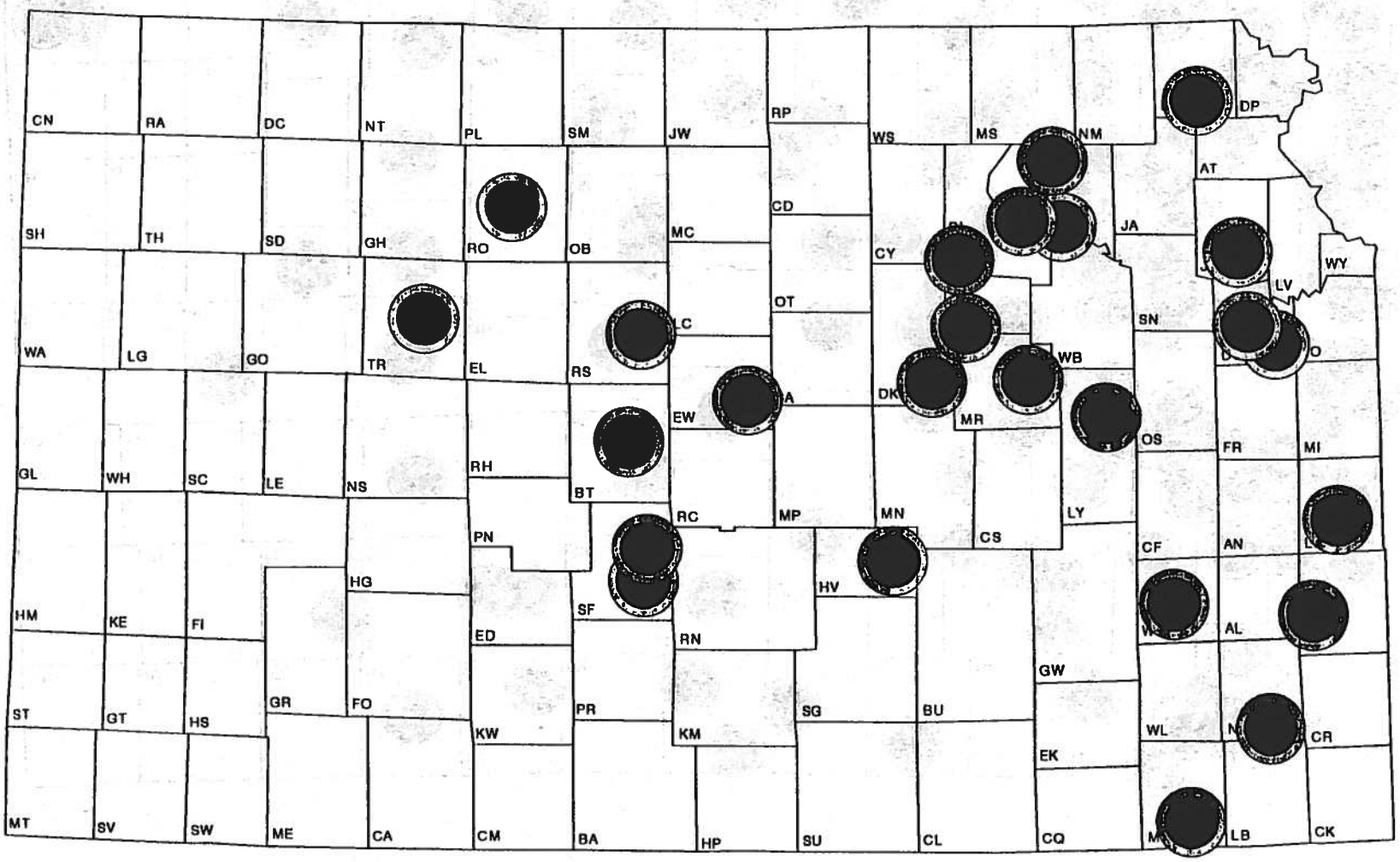
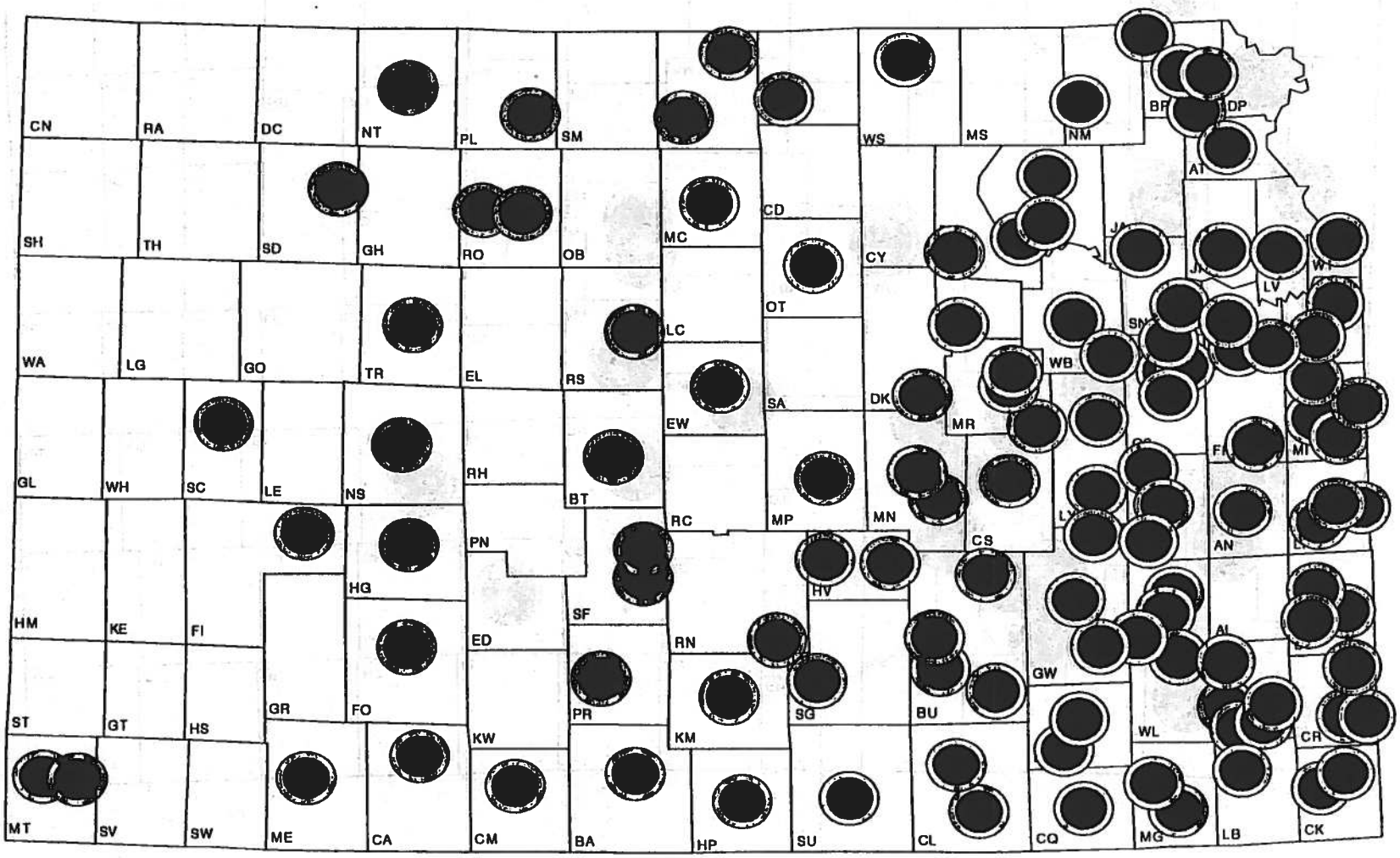


Figure 2. Locations of all currently active lake and wetland sampling sites within the KDHE Lake and Wetland Monitoring Program.



Constructed lakes are usually termed "impoundments" or "reservoirs," based on whether or not they serve as water supplies. Likewise, many parts of the country routinely term small lakes as "ponds," based on arbitrary surface area cut-offs. To allow consistency, this report uses the term "lake" to define all non-wetland bodies of standing water within the state. The only exception is when more than one lake exists with the same general name. For example, the city of Herington, Kansas, has two water supply lakes under their jurisdiction. The older one is routinely referred to as Herington City Lake, while the newer one is given the name of Herington Reservoir to distinguish it from its sister waterbody.

METHODS

Yearly Selection of Monitored Sites

Since 1985, the 24 large federal lakes in Kansas have been arbitrarily partitioned into three groups of eight. Each group is sampled once during a three year period of rotation. Up to 25 smaller lakes are sampled each year in addition to that year's block of eight federal lakes. These smaller lakes are chosen each year for sampling based on three considerations: (1) Is there recent data available (within the last 3-4 years)?; (2) Is the lake showing indications of pollution that require enhanced monitoring?; or (3) Have there been water quality assessment requests from other administrative or regulatory agencies (state, local, or federal)? Some lakes have been added to the program site list to serve as "ecoregional" reference sites, based on the relatively un-impacted nature of their watersheds.

Sampling Procedures

At each lake, a boat is anchored over the inundated stream channel near the dam. This point is station 1 for each lake, and should represent the area of maximum depth. Duplicate water samples are taken by Kemmerer sample bottle at 0.5 meters below the surface for determination of inorganic chemistry (basic anions and cations), algal community composition, chlorophyll-a, nutrients (ammonia, nitrate, Kjeldahl nitrogen, and phosphorus), and metals (aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, silver, thallium, vanadium, and zinc). Duplicate water samples are also taken at 0.5-to-1.0 meter above the lake substrate for the determination of inorganic chemistry, nutrients, and metals. In addition, a single pesticide sample is taken at 0.5 meter and duplicate surface bacterial samples (fecal coliform and fecal streptococci) are taken at either the public swimming area or main boat ramp/courtesy dock/fish cleaning station area (KDHE, 1995).

Beginning with the 1992 sampling year, macrophyte surveys have been conducted at each of the smaller lakes (<300 acres) within the KDHE Lake and Wetland Monitoring Program sampling network. The survey consists of the selection of 10-20 sampling points, plotted on a field map, in a regular pattern over the lake surface. At each sampling point, the boat is stopped and a grappling hook cast to rake the bottom for submersed aquatic plants. This, combined with visual observations at each station, determines presence or absence of macrophytes at the station. If present, macrophyte species are identified and recorded on site. Those species that can't be identified in the field are placed in plastic bags, on ice, for identification at the KDHE Topeka office. Presence/absence data, and species specific presence/absence data, are used to calculate a "percent distribution" estimate for each lake (KDHE, 1995).

At each lake, measurements are made at station 1 for temperature and dissolved oxygen profiles, pH, and Secchi disk depth. All samples are preserved and stored in the field in accordance with KDHE quality assurance protocols (KDHE, 1995). Field measurements, chlorophyll analysis, and algal taxonomy are conducted by staff of KDHE's Office of Science and Support. All other analyses are carried out by the KDHE Health and Environmental Laboratory (KDHE, 1995).

Taste and Odor/Algae Bloom Program

In 1989, KDHE initiated a formal Taste and Odor/Algae Bloom Technical Assistance Program. Technical assistance concerning taste and odor incidences in water supply lakes, or algae blooms in lakes and ponds, may take on varied form. Investigations may simply involve identification of algal species present within a lake, or they may entail the measurement of numerous physical, chemical, or biological parameters including watershed land use analysis to identify nonpoint pollution sources. Investigations are generally initiated at the request of treatment plant personnel, local authorities, or personnel at a KDHE District Office. While lakes used as public water supplies are the primary focus, a wide variety of samples related to algae, lake odors, and fishkills, from both streams and lakes, are accepted for analysis.

RESULTS AND DISCUSSION

Lake Trophic State

Calculation of the Carlson Chlorophyll-a Trophic State Index (TSI) remains a useful tool for comparison of lakes in regard to general ecological functioning and level of productivity (Carlson, 1977). Table 2 presents TSI scores for the 1994 lakes, previous TSI scores for lakes with past data, and an indication of the extent that individual lakes were dominated by submersed and floating-leaved

vascular plant communities (macrophytes). Since chlorophyll TSI scores are based on the planktonic algal community, a dominance by macrophytes "bumped" the trophic state classification to the next highest level than that assigned by TSI score alone. The system used to assign trophic state, based on the TSI score, is given below. It represents an in-house modification of the Carlson TSI system to account for macrophytic productivity. Trophic state classification is adjusted for macrophytes where percent areal cover is estimated at 30% or greater.

TSI score of 0-39 = Oligo-Mesotrophic = O/M.

O/M = A lake with a low level of planktonic algae and no significant macrophyte community. In a number of Kansas lakes, this condition is related to high turbidity. In such cases, nutrient availability remains high, but is not translated into biological productivity or biomass due to light limitation. Lakes with such high turbidity and nutrient levels, but such low algal production, may be called "argillotrophic" (Naumann, 1929) rather than oligo-mesotrophic. The argillotrophic class is identified by the letter "A" within this report.

TSI score of 40-49 = Mesotrophic = M.

M = A lake with only a moderate planktonic algal community, or a small algal community combined with a sizeable macrophyte community.

TSI score of 50-63 = Eutrophic = E.

E = A lake with a large planktonic algal community or a moderate algal community combined with a sizeable macrophyte community. This category is further divided as follows:

TSI = 50-54 = slightly eutrophic = SE,
TSI = 55-59 = fully eutrophic = E,
TSI = 60-63 = very eutrophic = VE.

TSI score of 64 or greater = Hypereutrophic = H.

H = A lake with a very large planktonic algal community or a large algal community combined with a large macrophyte community.

Table 2. Current and past TSI scores, and trophic state classifications for the 1994 lakes. The abbreviations used previously for trophic state levels (O/M, A, M, SE, E, VE, H) apply here. An asterisk appearing after the name of a lake denotes that the lake was macrophyte dominated. In such a case, the trophic state based solely on TSI score is given, followed by the macrophyte-adjusted TSI score in parentheses.

Lake	1994 TSI & Status		Previous Status
Bourbon Co. SFL	50.2	SE	M
Cedar Bluff Lake	51.2	SE	VE
Cheyenne Bottoms	70.7	H	H
Clinton Lake	56.5	E	VE
Council Grove City Lake	47.2	M	M
Douglas Co. SFL	54.6	SE	H
Geary Co. SFL	51.5	SE	VE
Harvey Co. East Lake	73.6	H	H
Herington Reservoir	59.6	E	VE
Kanopolis Lake	46.7	M	M
Lyon Co. SFL*	50.4	SE(E)	M
Milford Lake	41.6	M	SE
Mission Lake	54.5	SE	VE
Montgomery Co. SFL	61.0	VE	H
Mound City Lake*	59.6	E(VE)	H
Neosho Co. SFL	67.6	H	H
Perry Lake	47.0	M	SE
Pottawatomie Co. SFL 1	38.9	O/M	VE
Pottawatomie Co. SFL 2*	41.6	M(SE)	M
Quivera Big Salt Marsh	88.9	H	VE
Quivera Little Marsh	78.1	H	H
Tuttle Creek Lake	35.2	A	A
Webster Lake	35.2	O/M	VE
Wilson Lake	49.9	M	M
Yates Center Lake*	54.0	SE(E)	SE

All Carlson chlorophyll TSI scores are calculated by the following formula, where C is the phaeophytin corrected chlorophyll-a level in ug/L (Carlson, 1977):

$$TSI = 10(6-(2.04-0.68\ln(C))/\ln 2).$$

The composition of the algal community often gives a better ecological picture of a lake than relying solely on a trophic state classification. Table 3 presents both total algal cell count and percent composition of several major algal groups for the lakes surveyed in 1994. Lakes in Kansas that are nutrient enriched tend to be dominated by green or blue-green species, while those dominated by diatom communities may not be so enriched. Certain species of blue-green, diatom, or dinoflagellate algae may contribute to taste and odor problems, when present in large numbers, in lakes or streams that serve as public drinking water sources.

During 1993, flood inflows caused large impacts on resident algae communities in a number of lakes in Kansas. It should be considered that flood recovery processes might have influenced water quality/trophic state conditions in these lakes that were sampled during 1994.

Trends in Trophic State

Trends in trophic state, among most of these 25 lakes, appeared to be stable-to-improving since the last surveys. Table 4 presents the results of the comparison of current trophic state to past records.

Of the 25 lakes surveyed in 1994, five indicate a degrading condition, as evidenced by increases in lake trophic state. Nearly 50% of lakes sampled during 1994 show some improvement since the last survey (12 lakes) while eight lakes remained stable over time.

As can be seen in Table 5, four of the nine macrophyte surveys resulted in no macrophytes being found. This may mean that cover was non-existent, or it may merely indicate that macrophyte presence was so sparse as to preclude detection using the current technique. Of the five lakes with measurable macrophyte communities, the common plant species were various forms of pondweed (*Potamogeton* spp.), water naiad (*Najas* sp.), and stonewort algae (*Chara* and *Nitella* spp.).

Lake Stratification

Stratification is a natural process that can occur in any standing body of water, whether that waterbody is a natural lake, pond, artificial reservoir, or wetland pool (Wetzel, 1983).

Table 3. Algal communities present in the 1994 lakes at the time of sampling. The value in the count column is in cells/uL. "Other", in the far right column, refers to euglenoids, cryptophytes, dinoflagellates, and other single-celled flagellates. A "*" next to a number indicates that the percent of total, based on a biomass consideration, would be significantly above the percent of total shown, which is based on cell numbers.

Lake	Total Count (cells/uL)	Percent Composition			
		green	bluegreen	diatoms	other
Bourbon Co. SFL	2.52	23	25	10	*42
Cedar Bluff Lake	9.26	45	31	19	*5
Cheyenne Bottoms	48.51	26	55	17	2
Clinton Lake	11.40	48	36	10	*6
Council Grove CL	4.73	17	67	13	2
Douglas Co. SFL	22.43	3	97	<1	0
Geary Co. SFL	4.66	47	0	53	0
Harvey Co. East L.	23.44	33	50	6	*11
Herington Res.	11.59	24	63	2	11
Kanopolis Lake	1.58	64	0	28	*8
Lyon Co. SFL	2.33	38	0	3	*59
Milford Lake	1.45	65	0	0	*35
Mission Lake	5.42	31	47	0	*22
Montgomery Co. SFL	26.15	6	73	18	3
Mound City Lake	5.86	40	22	28	10
Neosho Co. SFL	22.74	5	83	6	6
Perry Lake	1.89	27	0	70	3
Pott. Co. SFL #1	1.01	50	0	50	0
Pott. Co. SFL #2	3.21	53	39	4	4
Quivera BSM	81.27	71	0	*28	1
Quivera LSM	354.06	9	91	0	<1
Tuttle Creek Lake	0.50	25	0	63	12
Webster lake	0.82	62	0	8	*30
Wilson Lake	7.18	42	0	56	2
Yates Center Lake	20.79	20	77	2	<1

Table 4. Trends over time for lake trophic state classification, within each major river basin in Kansas, for those sites surveyed during 1994.

Basin	Number of Lakes Constant	Improving	Degrading
Kansas/Lower Republican	0	7	1
Lower Arkansas	2	0	1
Marais des Cygnes	0	1	2
Neosho	2	0	0
Solomon	0	1	0
Smoky Hill/Saline	3	2	0
Verdigris	0	1	1
Walnut	1	0	0
Totals	8	12	5

Lake stratification occurs when sunlight (heat energy) penetrates into the water column. Due to the thermal properties of water, high levels of sunlight (combined with calm winds during the spring-to-summer months) cause layers of water to form with differing temperatures. The cooler layer remains near the bottom of the lake (hypolimnion) while the upper layer (epilimnion) develops a higher ambient temperature. The middle layer (metalimnion) displays a rapid drop in temperature with depth (the thermocline), compared to conditions within the epilimnion and hypolimnion.

Once these layers of water with differing temperatures form, they tend to remain stable and do not easily mix with one another. The net result is no re-oxygenation from the atmosphere within the hypolimnion, at least for the duration of the summer. In many cases, this causes hypolimnetic waters to be depleted of oxygen and unavailable for fish and other aquatic life as habitat. Stratification eventually breaks down in the fall when surface waters cool. Once epilimnetic waters cool to temperatures comparable to hypolimnetic waters, the lake will mix completely once again. The fall time of lake mixing is called "lake turnover." Many of our large lakes, created by the impoundment of major streams, display "polymictic" behavior. In these lakes, thermal stratification may form and collapse several times during a given summer instead of remaining stratified for the entire growing season.

Lake turnover can cause fishkills, aesthetic problems, and taste and odor problems in drinking water if the hypolimnion comprises a significant volume of the lake. This is because such a sudden mixing combines oxygen-poor, nutrient-rich hypolimnetic waters with

Table 5. Macrophyte community structure in 10 of the lakes surveyed during 1994. Macrophyte community in these surveys refers to submersed and floating-leaved aquatic plants, but not to the emergent shoreline community. The percent species cover is the abundance estimate for each documented species (Note: due to overlap in species cover, the percentages under community composition may not equal the percent total cover.).

Lake	% Total Cover	% Species Cover and Community Composition	
Douglas Co. SFL	0%	0%	none present
Geary Co. SFL	7%	7%	Potamogeton foliosus
		7%	Najas guadalupensis
		7%	Ceratophyllum demersum
Harvey Co. East Lake	0%	0%	none present
Herington Reservoir	0%	0%	none present
Lyon Co. SFL	67%	33%	Nitella flexilis
		33%	Chara globularis
		20%	Najas guadalupensis
		7%	Potamogeton nodosus
		7%	Nelumbo lutea
Mission Lake	0%	0%	none present
Mound City Lake	?%	?%	not sampled but large community present
Pott. Co. SFL #2	47%	27%	Nitella flexilis
		20%	Ceratophyllum demersum
		13%	Najas guadalupensis
Yates Center Lake	59%	59%	Najas guadalupensis
		41%	Chara globularis
		12%	Chara braunii
		12%	Potamogeton diversifolius
		6%	Potamogeton foliosus

epilimnetic waters that are lower in nutrients and richer in dissolved oxygen. This often results in explosive algae growth, lowering of overall lake dissolved oxygen levels, sudden fishkills, and often imparts objectionable odors to the lake water and tastes or odors to drinking water produced from the lake. Therefore, this lake process is important in lake management, the ability of the waterbody to support aquatic life, and the ability of the waterbody to support sport fisheries.

Presence or absence of stratification is determined by the depth profiles taken in each lake for temperature and dissolved oxygen concentration. Table 6 presents this data. Any temperature change

Table 6. Lake and wetland stratification status for the 25 sites surveyed during 1994. Rates are calculated for the entire water column.

Lake	Date Sampled	Temperature Decline Rate (degrees/meter)	Dissolved Oxygen Decline Rate (mg/L per meter)	Thermocline Depth (meters)	Maximum Depth Recorded (meters)
Bourbon Co. SFL	July 19	na	na	na	>7
Cedar Bluff Lake	June 6	-0.58	-0.52	6-7	12
Cheyenne Bottoms	June 28	na	na	na	<1
Clinton Lake	June 15	na	na	na	>7
Council Grove CL	July 6	-1.04	-0.54	6-7	12.5
Douglas Co. SFL	June 21	-2.00	-1.00	2-4	9
Geary Co. SFL	August 1	-1.13	-0.90	6-9	9
Harvey Co. East L.	June 27	-0.22	-1.20	4-4.5	4.5
Herington Res.	June 20	-0.50	-1.24	3-4	8
Herington Res.	August 22	-0.11	-0.56	none present	9
Kanopolis Lake	June 7	-0.45	-0.61	6-7	10
Lyon Co. SFL	July 6	-1.08	-1.08	4-5	6.5
Milford Lake	June 13	-0.54	-0.35	none present	13
Mission Lake	May 31	-1.25	-1.63	4	4
Montgomery Co. SFL	July 19	na	na	na	>7
Mound City Lake	July 19	na	na	na	>7
Neosho Co. SFL	July 19	na	na	na	5-7
Perry Lake	June 15	na	na	na	>7
Pott. Co. SFL #1	June 1	-1.60	-1.54	3-4	5
Pott. Co. SFL #2	July 11	-1.43	-0.67	4-5	10.5
Quivera BSM	June 27	na	na	na	<1
Quivera LSM	June 27	na	na	na	<1
Tuttle Creek Lake	June 13	-0.21	-0.24	none present	14
Webster Lake	June 6	-0.06	-0.09	none present	8.5
Wilson Lake	June 7	na	na	na	>7
Yates Center Lake	July 5	-1.68	-0.69	4-6	9.5

greater than -1.0 degree Celsius per meter depth is considered evidence of strong thermal stratification (Hutchinson, 1957; Wetzel, 1983), although rates may be considerably lower during the initiation phase of stratification. Presence of a significant oxycline is also used to determine stratification.

Contact Recreation and Fecal Coliform Bacterial Counts

Beginning in 1992, the Lake and Wetland Monitoring Program discontinued collecting bacterial samples from the open waters of network lakes. Past data strongly indicates that fecal coliform counts are typically low in the open water of typical Kansas lakes. This condition is likely due to predation by protozoan organisms and the fact that limnetic environments are hostile to the survival of gut bacteria in general. In preference to open water samples, fecal bacteria counts were made, during 1994, from either the main swimming beach (first priority) or the main boat ramp area (secondary priority). The selection of the boat ramp area as an alternate sampling site was made since it is one of the most likely sites for contact recreation, whether or not facilities exist for swimming. On occasion, samples near fish cleaning stations (third priority for sampling) may be taken for comparative purposes with past cleaning station data, if no swimming beaches exist and the cleaning station is in close proximity to the boat ramp area.

Table 7 presents the bacterial data collected during the 1994 sampling season. All counts are compared to the 200 colonies/100 mL standard for contact recreation within the Kansas Surface Water Quality Standards (KDHE, 1994).

Four lakes, out of the 25 surveyed, had fecal coliform bacterial counts that exceeded the 200 colonies/100 mL criterion for contact recreation. These four locations were the courtesy dock area at Mission Lake, the State Park beach at Webster Lake, Cheyenne Bottoms, and the fish cleaning station at Mound City Lake. The high bacterial counts at Cheyenne Bottoms might be attributable to natural sources as the samples were collected early in the morning, near the outlet of the main pool in the wetland complex. The causes of higher counts at the other three locations are not known, but may be due to human recreational activity prior to the survey or due to leakage from restroom facilities near the lake.

Limiting Nutrients and Physical Parameters

The determination of which nutrient, or physical characteristic, "limits" phytoplankton production is of primary importance in lake management. If certain features can be identified, which exert exceptional influence on lake water quality, those features can be addressed in lake protection plans to a greater degree than less important factors. In this way, lake management can be made more

efficient.

The concept of limiting nutrients, or limiting factors, is often difficult for the layman to grasp. The following analogy is provided in an attempt to clarify the concept:

> A person is given 10 spoons, 9 knives, and 5 forks. They are then asked to place sets of utensils at each place at a table. Further, only complete sets of utensils are to be placed, with a complete set including all three tools. The question is, "What utensil is the limiting factor?"
>
> In this example, the number of forks available "limits" the number of place settings that can be made. Therefore, forks become the limiting factor for this scenario.

In a lake ecosystem, the level of algal production is the "place setting," while plant nutrients and light availability are the "spoons, forks, etc." Common factors that limit algal production in lakes are the levels of available nutrients (primarily phosphorus and nitrogen) and the amount of light available to power photosynthesis. Less common limiting factors in lakes include, but are not limited to, available levels of carbon, iron, temperature, and vitamins.

The use of nutrient ratios are commonly employed to estimate which major plant nutrients are limiting factors in lakes. These ratios take into account the relative needs of algae cells for the different chemical nutrients. Typically, total nitrogen/total phosphorus (TN/TP) mass ratios that are above 12 indicate phosphorus limitation. Conversely, TN/TP ratios below 7 indicate nitrogen limitation. Ratio numbers within the 7-to-12 range indicate that both, or neither, of these major plant nutrients may be limiting to phytoplankton production (Wetzel, 1983).

Table 8 presents limiting factor determinations for the lakes surveyed during 1994. It should be kept in mind that these determinations reflect the time of sampling and may not apply to other times of the year. Also, the assumption was made that no unusual circumstances or conditions, present at the time of sampling, influenced which nutrient or factor became the limiting one. While nutrient ratios have been, and are, routinely used to assess limiting nutrients in lakes, it should be noted that the ratios do not provide complete proof of which nutrient is limiting for an entire growing season.

Table 7. Fecal coliform bacterial counts from the 25 lakes and wetlands surveyed during 1994. Since wetlands are not considered "attainable" for contact recreational use, those values are given for informational purposes only. It should also be kept in mind that these are one time grab samples taken during the week, not during the weekends which should be higher use periods. All units are in "number of colonies per 100 mL of lake water."

Lake	Site Location	Fecal Coliform Count
Bourbon Co. SFL	fish cleaning station	10
Cedar Bluff Lake	swim beach	50
Cheyenne Bottoms	open water	850
Clinton Lake	State Park beach	65
Council Grove City Lake	swim beach	<10
Douglas Co. SFL	boat ramp	<10
Geary Co. SFL	boat ramp	<10
Harvey Co. East Lake	swim beach	<55
Herington Reservoir	fish cleaning station	<10
Kanopolis Lake	State Park beach	10
	Corps of Eng. beach	10
Lyon Co. SFL	swim beach	10
Milford Lake	Corps of Eng. beach	<35
Mission Lake	boat ramp	40
	courtesy dock	450
Montgomery Co. SFL	boat ramp	85
Mound City Lake	fish cleaning station	350
Neosho Co. Lake	fish cleaning station	10
Perry Lake	State Park beach	70
Pottawatomie Co. SFL #1	courtesy dock	50
	boat ramp	10
Pottawatomie Co. SFL #2	fish cleaning station	<10
Quivera Big Salt Marsh	open water	75
Quivera Little Marsh	open water	100
Tuttle Creek Lake	River Pond Park beach	20
Webster Lake	south swim beach	10
	State Park beach	1,900
Wilson Lake	State Park beach	<10
Yates Center Lake	boat ramp	40
	fish cleaning station	10

Table 8. Limiting factor determinations for the 25 surveyed lakes in 1994, including TN/TP ratios. Factors are listed in descending order of importance.

Lake	TN/TP Ratio	Limiting Factors Present
Bourbon Co. SFL	38.8	Phosphorus
Cedar Bluff Lake	>19.8	Phosphorus
Cheyenne Bottoms	5.4	Nitrogen
Clinton Lake	>21.6	Phosphorus
Council Grove City L.	>2.0	Nitrogen, Phosphorus
Douglas Co. SFL	>5.4	Nitrogen
Geary Co. SFL	133.7	Phosphorus
Harvey Co. East Lake	12.7	Phosphorus
Herington Reservoir	>21.1	Phosphorus
Kanopolis Lake	>22.5	Phosphorus
Lyon Co. SFL	8.6	Phosphorus, Nitrogen
Milford Lake	19.3	Phosphorus
Mission Lake	26.4	Phosphorus
Montgomery Co. SFL	39.2	Phosphorus
Mound City Lake	18.6	Phosphorus
Neosho Co. SFL	15.2	Phosphorus
Perry Lake	>25.0	Phosphorus
Pott. Co. SFL #1	>25.9	Phosphorus
Pott. Co. SFL #2	184.0	Phosphorus
Quivera Big Salt Marsh	16.1	Phosphorus
Quivera Little Marsh	24.6	Phosphorus
Tuttle Creek Lake	9.0	Light, Phosphorus, Nitrogen
Webster Lake	14.4	Phosphorus
Wilson Lake	>19.9	Phosphorus
Yates Center Lake	58.0	Phosphorus

As can be seen from the data in Table 8, phosphorus is the primary limiting factor for lakes surveyed during the summer of 1994. Twenty-one of the 25 lakes were primarily phosphorus limited or were limited by both nitrogen and phosphorus. Three lakes were limited primarily by nitrogen. One lake was identified as limited by both nutrient and light availability.

Surface Water Exceedences of State Water Quality Criteria

All numeric water quality criteria referred to in this section are taken from Chapter 28 of the Kansas Administrative Regulations (K.A.R. 28-16-28b through K.A.R. 28-16-28f), or from EPA water quality criteria guidance documents (EPA 1972, 1976; KDHE, 1994). Copies of the Standards may be obtained from the Office of Science and Support, KDHE, Building 283, Forbes Field, Topeka, Kansas 66620.

Tables 9 and 10 present documented exceedences of state surface water quality criteria during the 1994 sampling season. These data were generated by comparison of a computer data retrieval, for 1994 Lake and Wetland Monitoring Program ambient data, to the state surface water quality standards. Only samples from the upper 3.0 meters of the water column were used to document standards violations, as a majority of samples below 3.0 meters were from hypolimnetic waters. In Kansas, lake hypolimnions generally constitute a small percentage of total lake volume and, while usually having a greater number of pollutants present in measurable quantities (compared to surface waters), do not pose a significant water quality problem for the lake as a whole.

Table 9. Chemical parameters exceeding chronic and acute aquatic life support criteria in lakes surveyed during 1994. Chemical symbols are from the Periodic Table of the Elements. Aquatic life support is abbreviated ALS, while dissolved oxygen is abbreviated as DO. Atrazine is abbreviated as Atz, while TSS stands for total suspended solids. Only those lakes that displayed some type of documented exceedence are included in Tables 9 and 10.

	Chronic ALS									Acute ALS	
Lake	Cu	Se	Sb	Hg	DO	pH	Atz	Cl	TSS	Cu	Cl
Cedar Bluff Lake		x									
Cheyenne Bottoms					x			x	x		
Clinton Lake							x				
Council Grove C.L.				x							
Douglas Co. SFL						x	x				
Harvey Co. East Lake							x				
Herington Reservoir							x				
Kanopolis Lake		x						x			
Milford Lake							x				
Mission Lake							x				
Montgomery Co. SFL						x					
Neosho Co. SFL						x					
Perry Lake							x				
Pott. Co. SFL #1		x		x							
Pott. Co. SFL #2			x								
Quivera Big Marsh						x		x	x		x
Quivera Little Marsh						x		x			x
Tuttle Creek Lake							x				
Wilson Lake		x						x			
Yates Center Lake	x	x			x					x	

Table 10. Exceedences of human use criteria and/or EPA guidelines within the surface waters of the lakes surveyed during 1994. Some symbols are taken from the Periodic Table of the Elements. Atz = atrazine, Ala = alachlor, TDS = total dissolved solids, and SO4 = sulphate. The food procurement use refers to water quality that is considered protective for consumption of harvested aquatic life. Only lakes with documented exceedences are included within the table. An "x" indicates that the exceedence occurred for a use presently existing, or likely to exist in the future, at the given lake. An "*" indicates that the exceedence occurred where the indicated use does not presently exist.

Lake	Water Supply						Irrigation		Food Procur.	Livestock Water
	Atz	Ala	Cl	SO4	TDS	Sb	TDS	F	Hg	TDS
Cedar Bluff Lake				*	*					x
Cheyenne Bottoms			*	*	*		*			
Council Grove C.L.									x	
Douglas Co. SFL	*									
Harvey Co. East Lk.	*									
Herington Reservoir	x									
Kanopolis Lake			x	x	x		x			
Mission Lake	x									
Perry Lake	x									
Pott. Co. SFL #1									x	
Pott. Co. SFL #2						*				
Quivera Big Marsh			*	*	*		*	*		*
Quivera Little Mar.			*		*		*			*
Tuttle Creek Lake	x	x								
Webster Lake				*	*		x			
Wilson Lake			x	x	x		x			

With respect to the aquatic life support use, selenium, chloride, high pH, and atrazine constituted the majority of the exceedances of numeric water quality criteria during 1994. Out of 20 lakes and wetlands with exceedences, eight exceeded the chronic criteria for atrazine. Next, in terms of frequency, were the seven exceedences of the chronic and acute chloride criteria, followed by five exceedences, each, of the chronic criterion for selenium and the general criterion for pH. All pH exceedences were for values above 8.5 standard pH units. In all cases, these high values were attributed to primary production within the algae and macrophyte communities, rather than to outside pollution sources. Likewise, all low dissolved oxygen exceedences were attributed to the shallow stratification of a few of the surveyed lakes. These shallow stratification situations were due to the existing, site specific, weather conditions during the early summer. They do not represent the effects of outside pollution sources.

As shown in Table 10, drinking water supply use was most impacted by exceedences for pesticides and salinity during 1994. Irrigation uses were considered impaired due to the salinity of water in several western lakes. The two exceedences for mercury, under the human health use, represent trace detections. These may be due to atmospheric deposition.

Pesticides in Kansas Lakes, 1994

Fourteen lakes had detectable levels of pesticides within the main body of the lake during 1994. Table 11 lists these lakes and the pesticides that were detected, along with the level detected and analytical quantification limit. Seven different pesticides were detected in total.

Atrazine continues to be the most often detected pesticide in lakes in Kansas (KDHE, 1991). Atrazine was identified in all fourteen lakes with detectable levels of pesticides. Six lakes had detections of Dual (metolachlor), and five lakes had detections of alachlor. Single detections were recorded for cyanazine (Bladex), metribuzen (Sencor), propachlor (Ramrod), and carbofuran (Furidan) at two of the surveyed lakes.

In all cases, the detection of these pesticides indicates impacts from agricultural nonpoint source pollution. The sites of most concern during 1994 were Tuttle Creek Lake and Mission Lake. These lakes exceeded both the chronic aquatic life support and drinking water supply criteria for atrazine by wide margins. In addition, both lakes contained a relatively large variety of detectable pesticides when sampled.

Lakes of secondary concern, due to exceedence of the drinking water supply criterion for atrazine, were Herington Reservoir, Douglas Co. SFL, and Harvey Co. East Lake. Of these three lakes, only

Herington Reservoir actually serves as a water supply lake.

Discussion of Nonpoint Sources of Pollution for Selected Lakes

Certain lakes and wetlands were chosen for further discussion, based on the number and type of surface water quality standards exceedences that were observed. A waterbody was chosen if 1) three, or more, parameters experienced exceedences of chronic criteria of the aquatic life support use, 2) more than one parameter experienced exceedences of acute criteria of the aquatic life support use, or 3) more than one parameter exceeded irrigation, water supply, livestock watering, or human health criteria.

Based on these considerations, nine lakes and wetlands were chosen for further discussion regarding the sources of their use impairments. The nine waterbodies identified were Cedar Bluff Lake, Cheyenne Bottoms, Kanopolis Lake, Quivera Big and Little Salt Marshes, Tuttle Creek Lake, Webster Lake, Wilson Lake, and Yates Center Lake.

In the case of Tuttle Creek Lake, impairments are due to high pesticide levels in the water. The pesticide problem in Tuttle Creek Lake has been documented for many years and is due to agricultural runoff from corn and sorghum crops. Based on stream water quality data collected near the border, a significant portion of the pesticide load entering Tuttle Creek Lake originates in the neighboring state of Nebraska. Yates Center Lake has several heavy metal related impairments with copper being the most obvious. The water quality problems may be due to natural geologic contributions, or may relate to copper sulphate treatments for taste and odor problems in water supply lakes. However, the history of copper sulphate use in Yates Center Lake is not known.

For the other seven lakes and wetlands, impairments revolve around various aspects of salinity. In all seven cases, these waterbodies are located in western Kansas. Some likely have higher salinity due to natural geologic conditions, while others may be impacted by irrigation return flow or evaporative concentration of salts in the lake/wetland proper.

Taste and Odor/Algae Bloom Investigations and Other Special Investigations in 1994

During the period of October 1, 1993 to September 30, 1994, ten investigations were undertaken within the auspices of the Taste and Odor/Algae Bloom Program. Six of the investigations were related to fishkills while the other four were related to taste and odor problems in drinking water, aesthetic complaints, or potential algal toxicity. Each will be discussed individually within the

Table 11. Pesticides detected during 1994 in Kansas lakes. All values are in ug/L. Analytical quantification limits are as follows for the eight detected pesticides: atrazine = 0.3 ug/L, metolachlor (Dual) = 0.25 ug/L, alachlor = 0.1 ug/L, 2,4-D = 0.80 ug/L, propachlor (Ramrod) = 0.25 ug/L, metribuzen (Sencor) = 0.10 ug/L, cyanazine (Bladex) = 0.50 ug/L, and carbofuran (Furidan) = 0.70 ug/L. The "exceeded" column refers to whether atrazine concentrations exceeded chronic aquatic life support (ALS) levels (1.0 ug/L), or the current MCL of 3.0 ug/L for water supply (WS), or whether the water supply MCL for alachlor was exceeded (2.0 ug/L).

Lake	Pesticide								Exceeded	
	Atrazine	Dual	Alachlor	2,4-D	Ramrod	Sencor	Bladex	Furidan	ALS	WS
Cedar Bluff Lake	0.41									
Cheyenne Bottoms	0.31									
Clinton Lake	1.60	0.38							xxxx	
Douglas Co. SFL	3.50		0.64						xxxx	xxx
Harvey Co. East Lake	4.40	0.33	0.16						xxxx	xxx
Herington Reservoir	3.40	0.26							xxxx	xxx
Lyon Co. SFL	0.89									
Milford Lake	2.80								xxxx	
Mission Lake	13.00	3.20	1.90					0.9	xxxx	xxx
Montgomery Co. SFL	0.52									
Mound City Lake	0.43									
Neosho Co. SFL	0.89									
Perry Lake	2.00	0.51	0.16						xxxx	
Tuttle Creek Lake	16.00	4.20	3.00		0.39	0.23	1.60		xxxx	xxx

remainder of this section.

On February 25, 1994, algae samples were submitted from the KDHE Southeast Kansas District Office from the pre-sedimentation basin at the LaCygne, Kansas, water treatment plant. The public had reported a diesel fuel-like odor in the finished drinking water. Algae was not identified as the problem. Rather, a recent fuel pipeline break, upstream in the Marais des Cygnes River Basin, was identified as the cause of the problem. Diesel fuel is reported to impart a detectable taste/odor in concentrations as low as 0.5 parts per billion.

On March 21, 1994, a sample from the Princeton, Kansas, lagoon was examined. The reported problem was that the lagoon had turned red in color. The sample contained a large community of rotifers (Brachionus spp.) which were identified as the likely cause of the red coloration.

On May 18, 1994, algae samples were examined from a fishkill at Eck Lake in Wichita, Kansas. The samples contained a moderately large community of algae dominated by Chrysochromulina sp., a very small alga which is occasionally found in Kansas. While the literature does have references about this algae producing toxins in marine habitats, it was not the most likely cause of the fishkill. The presence of considerable numbers of amoeba and other protozoans suggested that the pond had undergone some stress. Physical data, taken during the fishkill investigation, indicated a large temperature difference (10° Celsius) between the east and west shore of this small lake. This large temperature difference could be attributable to recent storm inflows, or rapid solar heating of shallow areas on one side of the lake. This stress, combined with possible lowered dissolved oxygen levels was suggested as the cause of the fishkill.

On June 9, 1994, algae samples were examined from a fishkill at an impoundment on Dry Creek, in Wichita, Kansas. All the samples had large communities of blue-green algae, dominated by Microcystis aeruginosa. The large algae community, combined with other field observations suggested that organic enrichment, from sewer discharges or leakage, was the cause of the fishkill.

On June 14, 1994, algae samples were examined from a fishkill at a small, private pond in southwest Harvey County. A small blue-green algae community was present, but was not identifiable as a likely cause of the fishkill. KDHE Southcentral District Office staff expressed a belief that pesticides had entered the pond during storm runoff.

On July 25, 1994, algae samples were examined from the Delaware River as part of a fishkill investigation. While the algae community consisted of >500,000 cells/mL of Microcystis aeruginosa, a known toxin producer, diel oxygen swings were identified as the

likely cause of the fishkill. The large blue-green algae community appeared to have been washed from a small watershed lake upstream of the fishkill location. This watershed lake lies about one mile downstream from the Sabetha Wastewater Treatment Plant, and thus serves as a *de facto* tertiary treatment system. This situation serves as an example of the need for planning and watershed pollution assessments prior to lake design and construction.

On July 25, 1994, an algae sample was examined from a fishkill at a private pond west of Mayetta, Kansas. The fishkill was attributed to the diel oxygen swings that the pond was experiencing, but the algae community itself was of special interest. The community was dominated by Lyngbya wollei, a blue-green algae of considerable importance as a nuisance species throughout the southeast United States. This was the first known identification of this algae in Kansas. Lygnbya wollei is a very large filamentous species of blue-green algae that forms tough mats on the lake substrate which can break loose and float on the surface. The surface of floating mats are often yellow-orange in color as direct sunlight causes cellular damage and decoloration. The underside of the mats are purple-black in color due to the production of phycobilin pigments by the algae. These features are diagnostic of the algae. The odor produced by the algae during this fishkill was horrific, being reminiscent of raw sewage combined with the aroma of decaying flesh.

On July 26, 1994, an algae sample was examined from the clarifier at the Midwest Grains wastewater treatment system near Atchison, Kansas. Company staff were concerned about the presence of filamentous algae growing in the clarifier, and whether this might cause NPDES permit total suspended solids violations in their effluent if enough filaments broke off. The algae was identified as Oscillatoria sp., a filamentous blue-green algae. Given the unusually high water clarity in the system, such growths were not surprising. The question of whether such forms of suspended solids in the effluent should be identified as a permit violation has been the subject of much discussion over the last few years.

On September 8, 1994, algae samples were examined from a fishkill at Lake Waltana, west of Wichita, Kansas. The sample revealed not algae but Wolffia sp., a very small form of duckweed. Apparently the lake hosted a large cover of this tiny plant, which likely caused very low dissolved oxygen levels in the water under this cover. The lake has been the site of numerous complaints about odors and fishkills due to the failing septic systems around the lake. Until these septic systems are repaired or replaced, further problems can be expected.

On September 22, 1994, an algae sample was examined from a citizen complaint at Harrison Park Lake in Wichita, Kansas. No fishkill was reported, but local residents had noted a large algae community in the lake. The sample revealed a very large community of blue-

green algae, composed of Microcystis aeruginosa and Anabaena sp. Small, urban lakes such as this appear to be predisposed to large blue-green blooms on a regular basis. As such algae blooms die, the result is often a fishkill due to low oxygen conditions.

CONCLUSIONS

The following conclusions are offered, based upon the lake monitoring data obtained during 1994.

1. Trophic state conditions suggest that most lakes surveyed in 1994 were improved in terms of past trophic state compared to current condition. Flushing and recovery from flood impacts during 1993 may have influenced the 1994 sampling data in a number of these lakes.

2. Exceedences of surface water quality criteria revolved primarily around two parameter groups. These were pesticides (atrazine and alachlor exceedences of chronic aquatic life support and drinking water supply criteria, respectively) and salinity (chloride, sulphate, and total dissolved solids exceedences of irrigation, livestock watering, or drinking water supply criteria).

3. Fourteen of the 25 surveyed lakes (56% of the total) had detectable concentrations of agricultural pesticides during the summer of 1994. Atrazine was the most commonly encountered pesticide.

4. Most impacts of the 1993 flood on lake water quality appear to have been very transitory. The most lasting impacts will likely be the physical damage caused by floodwaters and the extra silt loads deposited behind dams.

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LAKE DATA AVAILABILITY

Lake data are available for all lakes included in the Kansas Lake and Wetland Monitoring Program. Water quality data may be requested by writing to the Office of Science and Support, KDHE, Building 283, Forbes Field, Topeka, Kansas 66620-0001. All data referenced within this report are also accessible on STORET.