Trophic Classification of Texas Reservoirs

2008 Texas Water Quality Inventory and 303(d) List

(March 19, 2008)

Reservoirs and lakes become more eutrophic as they age. Eutrophication of reservoirs and lakes in southern states is enhanced due to warm, fertile climates. Human activities can accelerate the process by increasing the rate at which nutrients and organic substances enter the impoundments and their surrounding watersheds. Sewage discharges, agricultural and urban runoff, leaking septic tanks, and erosion of stream banks can increase the flow of nutrients and organic substances into reservoirs and lakes. These pollutants can over-stimulate the growth of algae and aquatic plants, creating conditions that interfere with contact recreation (swimming), boating (noncontact recreation), and the health and diversity of native fish, plant, and animal populations. Over-production of bacteria, fungi, and algae may also impart foul odors and tastes to the water.

Section 314 of the CWA of 1987 requires all states to classify lakes and reservoirs according to trophic state. The trophic state of a reservoir refers to its nutritional status. Various classification schemes or indices have been developed that group reservoirs into discrete quality (trophic) states along a continuum from oligotrophic (poorly nourished) to hypereutrophic (over nourished). The basis for the trophic state index concept is that in many reservoirs the degree of eutrophication may be related to increased nutrient concentrations. Typically, phosphorus is the nutrient of concern and an increase in its concentration may trigger a responding increase in the amount of algae (estimated by chlorophyll *a*) in the reservoir. Due to increased algal biomass, water transparency (as measured by a Secchi disk or submarine photometer), decreases.

Table 1 - 1. Types of Trophic States in Reservoirs and Lakes

Trophic State	Water Quality Characteristics
Oligotrphic	Clear waters with extreme clarity, low nutrient concentrations, little organic matter or sediment, and minimal biological activity.
Mesotrophic	Waters with moderate nutrient concentrations and, therefore, more biological productivity. Waters may be lightly clouded by organic matter, sediment, suspended solids or algae.
Eutrophic	Waters extremely rich in nutrient concentrations, with high biological productivity. Waters clouded by organic matter, sediment, suspended solids, and algae. Some species may be eliminated.
Hypereutrophic	Very murky, highly productive waters due to excessive nutrient loading. Many clearwater species cannot survive.

Major Texas reservoirs have been evaluated and ranked by the TCEQ using Carlson's Trophic State Index (TSI). Carlson's Index was developed to compare among reservoirs Secchi disk depths, chlorophyll *a* concentrations, and total phosphorus concentrations obtained by in-reservoir sampling (Carlson, 1977). These three variables are highly correlated and are considered estimators of algal biomass. By using regression analysis, Carlson related Secchi disk depth to total phosphorus concentration and to chlorophyll *a* concentration. The TSI is determined from any of the three computational equations:

TSI (Secchi Disk) = 60 - 14.41 ln (*SD)*, where *SD* is mean secchi disk depth in meters.

TSI (Chlorophyll *a*) = 9.81 ln(*Chla)* + 30.6, where *Chla* is mean chlorophyll *a* in ug/L.

TSI (Total Phosphorus) = 14.42 ln(*TP)* + 4.15, where *TP* is mean total phosphorus in ug/L.

Although chlorophyll *a* is the most direct measure of algal biomass, Carlson used Secchi disk depth as the primary indicator. The index was scaled, so that TSI = 0 represents the largest measured Secchi disk depth (64 m) among reservoirs. Each halving of transparency represents an increase of 10 TSI units (Table 1-2). The relationships between Secchi disk and chlorophyll *a* was nonlinear, so a 10-unit TSI (Chl *a*) change does not correspond to a factor-of-two change for chlorophyll *a*. Instead, chlorophyll *a* approximately doubles for each 7-unit increase in TSI (chl *a*).

Table 1 - 2. Carlson's Trophic State Index and Associated Parameters

Trophic State Index	Secchi Disc (m)	Total Phosphorus (ug/L)	Chlorophyll *a* (ug/L)
0	64	0.75	0.04
10	32	1.5	0.12.
20	16	3	0.34
30	8	6	0.94
40	4	12	2.6
50	2	24	6.4
60	1	48	20.0
70	0.5	96	56
80	0.25	192	154
90	0.12	384	427
100	0.062	768	1,183

Carlson's Index provides a useful tool for assessing a reservoir's current condition and monitoring for change over time. For instance, the index would provide a quantitative estimate of the degree of improvement for a reservoir in which the TSI (Chl *a*) decreased from 60 to 40 units following implementation of restoration measures. The index provides useful information in cases where the values are different, e.g., if TSI (TP) > TSI (Chl *a*), phosphorus is probably not the limiting nutrient; TSI (SD) > TSI (Chl *a*) indicates the presence of non-algal turbidity. Carlson's Index has the advantage of presenting trophic state on a continuous numeric scale and can approximate the oligotrophic-hypereutrophic nomenclature required by the EPA. Secchi disk depths and total phosphorus and chlorophyll *a* concentrations are routinely determined at TCEQ and CRP fixed monitoring stations on reservoirs and lakes, so input data are readily available for computation of Carlson's Index. The index does not perform well for certain water quality conditions: (1) where transparency is affected by suspended erosional materials rather than phytoplankton, (2) where primary production is controlled by attached algae or aquatic macrophytes rather than phytoplankton, and (3) when phosphorus is not the nutrient limiting phytoplankton growth.

Although the index can be used to classify and rank Texas reservoirs by trophic state, priority ranking for restoration is difficult. Carlson's Index is not the same as a water quality index. Assessment of reservoir water quality depends to a large degree on the assignment of beneficial uses and determinations to evaluate if the uses are being maintained and/or impaired. For this reason, the 305(b) assessment and 303(d) list provide a ranking of priorities for protection and restoration for all water bodies including reservoirs.

Texas reservoirs are ranked in Appendix A according to Carlson's TSI for chlorophyll *a* as an average calculated from 10 years of SWQM data (December 1, 1999 - November 30, 2006). In order to maximize comparability among reservoirs, data from the station nearest the dam in the main pool of each reservoir were utilized if available. For many reservoirs, these are the only sites monitored by the TCEQ and Clean Rivers Program. Chlorophyll *a* was given priority as the primary trophic state indicator because it is best for estimating algal biomass in most reservoirs. A minimum of four chlorophyll *a* measurements, two total phosphorus and two Secchi disk measurements were required for a reservoir to be included in the ranking. Out of 190 reservoir stations surveyed, 102 had enough data to be included in the ranking. Based on this assessment, all 102 reservoirs are considered mesotrophic through hypereutrophic, showing a range of eutrophication (Table 1 - 3). No reservoirs are considered oligotrophic. Rankings are also provided for total phosphorus (TP) and Secchi disk transparency (SD). This analysis permits comparison of individual TSI indicators for each reservoir, provides indications of the clearest reservoirs (low TSI SD), and identifies reservoirs with low and high total phosphorus concentrations.

Table 1 - 3. Number of Texas Reservoirs Assessed in Each Trophic Class

Trophic Class	TSI (Chl a) Index Range	Number of Texas Reservoirs
Oligotrophic	0 - 35	0
Mesotrophic	>35 - 45	13

Trophic Class	TSI (Chl a) Index Range	Number of Texas Reservoirs
Eutrophic	>45 - 55	48
Hypereutrophic	>55	41

Reservoirs with the clearest water (highest Secchi disk transparency) occur primarily in the central portion of the state and are listed in descending order: Stillhouse Hollow Lake (1216), Lake Travis (1404), Lake Alan Henry (1241A), Possum Kingdom Reservoir (1207), and Canyon Lake (Segment 1805). Reservoirs with the poorest light transparency (lowest Secchi disk transparency) listed in descending order are: Rita Blanca Lake (Segment 0105), Springfield Lake (1253A), Lake Wichita (0219), Cox Lake (2454A), and Country Club Lake (1209A).

Reservoirs with the lowest total phosphorus concentrations listed in descending order are: Toledo Bend Reservoir (Segment 0504), Greenbelt Reservoir (0223), Ellison Creek Reservoir (Segment 0404), Medina Lake (1909), and Lake Meredith (0102). Reservoirs enriched with the highest total phosphorus concentrations listed in descending order are: Rita Blanca Lake (Segment 0105), Lake Tanglewood (Segment 0230), Lake Woodlands (1008F), Squaw Creek (Segment 1229A), and Country Club Lake (Segment 1209).

Water Quality Trends in Reservoirs

Carlson's TSI Chl *a* values for 102 reservoirs from the 2006 and 2008 reporting cycles were compared to indicate temporal trends (Appendix A). Trends could not be calculated for 12 reservoirs (12%), due to the lack of reporting information. The 2006 period of record was December 1, 1994 - November 30, 2004; for 2008, the period of record was December 1, 1996 - November 30, 2006.

TSI Chl *a* values, which estimate the amount of algal biomass, can indicate improvement when values decrease. However, changes in data reporting and improved laboratory detection of low – level chlorophyll *a* may be a significant cause in for decreasing TSI Chl a values in 48 of 102 (47%) reservoirs. Reservoirs with the largest trends for decreasing algal content are Lake Nacogdoches (0611Q), Lake Jacksonville (0614), Lake Coleman (1419), Canyon Lake (1805) and Lake Kickapoo (0213). Increases in algal biomass (increase in TSI Chl *a* values) are indicated in 37 of 102 (36%) reservoirs. Reservoirs with the largest trends for increasing algal content (substantial positive TSI Chl *a* values) are Lake Whitney (1203), Rita Blanca Lake (Segment 0105), Granger Lake (1247), and Lake Gladewater (0506). These changes are for a two-year period and may not represent longer term trends. Five reservoirs (5%) exhibited no change in TSI Chl *a*.

A reservoir's trophic rank may differ from that in the last assessment due to changes in data reporting rather than changes in water quality. Many individual values in the SWQMIS water quality database are reported as less than analytical reporting limits (non-detects). There is no generalized way to determine the true value for an individual result in the range between zero and the reporting limit. For the trophic classification assessment of Texas reservoirs, 50 percent of an analytical reporting limit is computed for these results. This is done to include as many individual data points in the analysis as possible, and to indicate the level of monitoring effort.

For more information please contact the Surface Water Quality Monitoring Team at monops@tceq.state.tx.us.

Reservoir Control Programs

Texas employs several reservoir pollution control procedures to ensure high-quality water for recreational, domestic, and industrial uses. Surface water quality standards have been adopted for significant reservoirs throughout the state. The standards establish designated uses for classified segments and presumed uses for unclassified segments and include numerical criteria to protect those uses. Designated uses are determined by taking into account the reservoir's physical and biological characteristics, natural water quality, and existing uses. Criteria, depending on parameter, are based on background levels or accepted levels for protection of human health and aquatic life. TMDLs are conducted to determine the assimilative capacity of the segment and to determine discharge treatment levels and nonpoint source loads necessary to meet the criteria. These treatment levels are then required when issuing wastewater permits to dischargers. In some cases, TMDLs may recommend no discharge of wastewater. Compliance with wastewater permits is monitored through on-site inspections by TCEQ personnel and through self-reporting procedures. When noncompliance with permits is found, enforcement actions may be required to attain compliance. The uses, criteria, TMDLs, and permits are periodically reviewed and, if necessary, revised. Each major reservoir is routinely monitored to assess the overall condition of the water body and determine short- or long-term water quality trends. Reservoirs with non-supported uses are placed on the State of Texas 303(d) List.

The TCEQ has several specific rules that prescribe permit limitations for discharges of domestic wastewater into reservoirs. Chapter 309 of the effluent standards portion of the TCEQ rules requires discharges located within five river miles upstream of certain reservoirs to achieve a minimum effluent quality of 10 mg/L BOD_5 and 15 mg/L TSS as a 30-day average. This rule applies to reservoirs that are subject to private sewage facilities regulation or that may be used as a source for a public drinking water supply. Currently, 92 Texas reservoirs are designated for the public water supply use. Additional rules under Chapter 311, Watershed Protection, have been promulgated that protect specific reservoirs:

Subchapter D: §§311.31- .36.

This rule requires all domestic and industrial permittees in the entire Lake Houston watershed to meet effluent limitations equal to or commensurate with 10 mg/L BOD_5, 15 mg/L TSS, and 3 mg/L NH_3-N as a 30-day average. All wastewater effluents disposed of on land shall meet an effluent quality of 20 mg/L BOD_5 and 20 mg/L TSS. Domestic facilities must submit a solids management plan. Additionally, all domestic and industrial facilities with gaseous chlorination disinfection systems must have dualfeed chlorination systems and must meet a minimum chlorine residual of 1 mg/L and a maximum chlorine residual of 4.0 mg/L.

Subchapter A, B and F: §§311.1-.5, 311.11-.15 and 311.51-.55.

These rules apply to a series of reservoirs on the Colorado River, which are commonly referred to as the Highland Lakes, including Lake Austin (Segment 1403), Lake Travis (Segment 1404), Lake Marble Falls (Segment 1405), Lake LBJ, (Segment 1406), Inks Lake (Segment 1407), and Lake Buchanan (Segment 1408). Water quality areas, those portions of the watersheds within 10 river miles of the reservoirs, were established for each reservoir. New wastewater facilities constructed in these areas will be issued no-discharge permits, which means that treated

wastewater will not be discharged to surface waters. Any existing facility that requires a permit amendment for expansion or is not meeting permit requirements because of sewage overloading will be issued a no-discharge permit. Proposed new or expanded treatment facilities in the watersheds of these reservoirs will be issued no-discharge permits unless the applicant can establish that any alternative proposed wastewater disposal will protect and maintain the existing quality of the reservoirs.

Subchapter G: §§311.61.-311.66.
This rule applies to Lakes Worth, Eagle Mountain, Bridgeport, Cedar Creek, Arlington, Benbrook, and Richland-Chambers. With the exception of oxidation pond systems, domestic discharges within the water quality areas of the watersheds of these reservoirs are required to meet advanced treatment limits of 10 mg/L BOD_5, and filtration is required to supplement suspended solids removal by January 1, 1993. In addition to water quality monitoring and creation of rules to regulate the permitting of wastewater discharges to reservoirs, the TCEQ maintains an extensive inspection program of wastewater treatment facilities. When permit limitations are not being met, the appropriate enforcement action is pursued.

Reservoir and Lake Restoration Efforts

Section 314 of the Clean Water Act makes federal grant funds available to states under the Clean Lakes Program. The TCEQ is currently not administering any grant funding under this program.

Low pH in Texas Waterbodies

One reservoir, eight freshwater streams, and one tidal stream have shown low pH (high acidity) in at least one assessment location. Most of these waterbodies are located in the eastern portion of the state, where natural geologic buffering capacity is limited. TCEQ is continuing routine monitoring and initiating a project to identify waterbodies requiring special studies to determine if a TMDL or review of the standard is needed. In some cases, the pH standard may not be accurate.

Table 1 - 4. Texas Waterbodies with Low pH

Segment Number	Reservoir Name
0401	Caddo Lake
0402	Big Cypress Creek below Lake O' the Pines
0406	Black Bayou
0407	James Bayou
0508	Adams Bayou
0511	Cow Bayou Tidal

Segment Number	Reservoir Name
0606	Neches River above Lake Palestine
0608	Village Creek
0608A	Beech Creek
1407A	Clear Creek

High pH in Texas Waterbodies

Eight reservoirs and one freshwater stream have shown elevated pH (high basicity) in at least one assessment location. A likely cause of elevated pH is consumption of dissolved CO_2 by photosynthesis. Excessive amounts of photosynthetically active algae and macrophytes can increase consumption of CO_2 during the day, increasing pH in the water column. All of these waterbodies are included in the project to determine if a TMDL or review of the standard is needed.

Table 1 - 5. Texas Waterbodies with High pH

Segment Number	Reservoir Name	Trophic Class
0105	Rita Blanca Lake	Hypereutrophic
0229	Upper Prairie Dog Town Fork of Red River	Unknown
0302	Wright Patman Lake	Eutrophic
0307	Cooper Lake	Too few samples to determine
0507	Lake Tawakoni	Hypereutrophic
0605	Lake Palestine	Hypereutrophic
0803	Lake Livingston	Hypereutrophic
0818	Cedar Creek Reservoir	Too few samples to determine
1212	Lake Somerville	Hypereutrophic

Appendix A. Trophic Classification of Major Texas Reservoirs Using Carlson's Trophic State Index (TSI)

Segment	Station	Reservoir	Chla Rank	Chla Records	Chla Mean (ug/L)	Chla TSI	Trend	Secchi Rank	Secchi Records	Secchi Mean (Meters)	Secchi TSI	TP Rank	TP Records	TP Mean (mg/L)	TP TSI
0611Q	15801	LAKE NACOGDOCHES	1	10	2.36	39	-10.70	28	9	1.56	53.62	72	11	0.06	62.4
1249	12111	LAKE GEORGETOWN	2	11	2.38	39.04	-1.20	11	65	2.22	48.48	35	22	0.04	55.3
0408	10329	LAKE BOB SANDLIN	3	8	2.64	40.12	-5.64	32	8	1.44	54.7	19	8	0.02	52.9
0811	10970	LAKE BRIDGEPORT	5	6	3.4	42.58	0.00	46	6	1.22	57.12	45	6	0.04	57.3
1404	12302	LAKE TRAVIS	5	41	3.4	42.58	+0.88	4	34	3.42	42.28	66	51	0.04	59.8
0102	10036	LAKE MEREDITH	6	19	3.44	42.66	-4.68	9	21	2.4	47.42	5	19	0.02	50.1
0223	10173	GREENBELT RESERVOIR	7	20	3.44	42.68	-4.12	10	22	2.22	48.44	2	23	0.02	49.5
1909	12825	MEDINA LAKE	8	22	3.56	43.04	-5.42	8	17	2.5	46.76	4	26	0.02	49.7
1419	12398	LAKE COLEMAN	9	14	3.72	43.44	-6.26	34	10	1.44	54.78	9	13	0.02	50.6
0213	10143	LAKE KICKAPOO	10	4	3.88	43.86	-5.98	87	4	0.66	65.84	52	4	0.04	58.2
1220	11921	BELTON RESERVOIR	11	12	3.96	44.08	-3.22	14	66	2.14	49	33	24	0.04	54.9
1216	11894	STILLHOUSE HOLLOW LAKE	12	10	4	44.16	-5.50	3	77	3.54	41.76	34	30	0.04	55
0611	17824	LAKE STRIKER	13	9	4.18	44.6	-4.80	50	10	1.18	57.74	94	10	0.1	70.3
0834	11063	LAKE AMON G. CARTER	14	8	4.44	45.18	-2.12	22	8	1.8	51.48	36	9	0.04	55.4
1418	12395	LAKE BROWNWOOD	15	19	4.5	45.34	-4.16	51	14	1.16	57.82	70	18	0.06	61.2

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0614	10639	LAKE JACKSONVILLE	16	27	4.58	45.48	-6.40	17	30	2.04	49.74	9	31	0.02	50.6
0840	17834	RAY ROBERTS LAKE	17	7	4.76	45.88	-3.72	40	26	1.3	56.22	49	14	0.04	58
1231	11979	LAKE GRAHAM	18	13	4.78	45.92	-5.18	74	15	0.78	63.46	28	16	0.04	54.1
1403	12294	LAKE AUSTIN	19	42	4.8	45.96	+1.66	19	33	1.9	50.72	60	48	0.04	59.1
1247	12095	GRANGER LAKE	20	11	5.06	46.48	+4.70	103	62	0.48	70.3	60	22	0.04	59.1
1433	12511	O H IVIE RESERVOIR	21	25	5.14	46.62	-4.14	13	28	2.16	48.88	69	26	0.06	60.9
1233	12002	HUBBARD CREEK RESERVOIR	22	13	5.18	46.7	-4.52	35	13	1.38	55.28	17	15	0.02	52.4
0504	10404	TOLEDO BEND RESERVOIR	23	55	5.2	46.74	-1.70	16	112	2.06	49.6	1	6	0.02	45.9
0204B	15447	MOSS LAKE	24	19	5.38	47.1	-5.44	36	20	1.36	55.54	31	21	0.04	54.7
1805	12597	CANYON LAKE	25	16	5.52	47.34	-6.12	7	19	2.82	45.08	15	20	0.02	52.3
0210	10139	FARMERS CREEK RESERVOIR/NOCONA LAKE	26	16	5.6	47.48	-2.08	45	14	1.26	56.74	22	17	0.04	53.2
0404A	14473	ELLISON CREEK RESERVOIR	27	10	5.64	47.56	-1.08	42	13	1.28	56.56	3	9	0.02	49.6
0302	10213	WRIGHT PATMAN LAKE	28	8	5.68	47.6	-1.22	84	8	0.7	65.12	95	8	0.1	70.5
0610	14906	SAM RAYBURN RESERVOIR	29	58	5.72	47.66	NA	15	86	2.08	49.46	79	89	0.06	65.1
0217	10159	LAKE KEMP	30	14	5.84	47.88	-1.02	18	15	1.96	50.3	17	15	0.02	52.4

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1429	12476	TOWN LAKE	31	38	6.3	48.62	-1.08	21	24	1.8	51.46	22	41	0.02	53.2
1230	11977	LAKE PALO PINTO	32	18	6.56	49	-5.12	72	20	0.8	63.12	43	20	0.04	56.7
0605	17575	LAKE ATHENS	33	13	6.9	49.5	-3.78	24	17	1.66	52.7	12	16	0.02	51.6
0212	10142	LAKE ARROWHEAD	34	15	7.18	49.92	+0.08	76	14	0.76	64.1	105	15	0.18	79.3
1224	11939	LEON RESERVOIR	35	15	7.34	50.14	-0.96	30	16	1.48	54.34	42	17	0.04	56.4
1405	12319	LAKE MARBLE FALLS	36	40	7.44	50.26	+0.32	39	33	1.34	55.88	6	47	0.02	50.2
1207	11865	POSSUM KINGDOM RESERVOIR	37	4	7.5	50.34	NA	6	67	2.94	44.48	53	16	0.04	58.6
0613	10638	LAKE TYLER	38	36	7.64	50.52	-2.72	47	33	1.2	57.4	12	35	0.02	51.6
0603	10582	B A. STEINHAGEN RESERVOIR	39	26	7.78	50.7	-2.72	106	28	0.42	72.72	83	28	0.08	66.5
1408	12344	LAKE BUCHANAN	40	41	8.02	50.98	+1.80	20	33	1.82	51.3	71	49	0.06	61.9
1413	12367	LAKE J B THOMAS	41	9	8.06	51.04	+0.22	110	11	0.38	74.22	57	10	0.04	59
1254	12127	AQUILLA RESERVOIR	42	28	8.12	51.12	-1.32	85	34	0.7	65.16	39	31	0.04	55.8
0836	15168	RICHLAND-CHAMBERS RESERVOIR	43	5	8.22	51.24	0.00	56	5	1.06	59.28	54	5	0.04	58.9
0228	10188	LAKE MACKENZIE	44	21	8.5	51.56	-0.40	37	22	1.36	55.66	42	22	0.04	56.4
2303	13189	FALCON LAKE	45	17	8.9	52	NA	102	18	0.5	70.16	86	16	0.08	67.6

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1418A	12178	HORDS CREEK RESERVOIR	46	6	9.02	52.14	-2.24	57	6	1.04	59.32	24	6	0.04	53.6
1406	12324	LAKE LYNDON B JOHNSON	47	40	9.04	52.16	+0.94	45	31	1.26	56.74	57	49	0.04	59
0215	10157	DIVERSION LAKE	48	13	9.16	52.3	+1.04	48	15	1.18	57.54	7	14	0.02	50.4
1225	11942	LAKE WACO	49	18	9.24	52.38	+1.30	68	113	0.84	62.36	93	105	0.1	69.7
1240	12027	WHITE RIVER LAKE	50	21	9.26	52.4	-2.06	100	27	0.5	69.86	68	23	0.04	60.1
0405	10312	LAKE CYPRESS SPRINGS	51	28	9.42	52.56	-1.60	41	31	1.3	56.24	18	30	0.02	52.8
0817	10981	NAVARRO MILLS RESERVOIR	52	19	9.78	52.94	-1.94	104	18	0.48	70.48	78	21	0.06	64.1
0401	10283	CADDO LAKE	53	31	9.8	52.96	NA	73	115	0.8	63.28	88	34	0.08	67.9
1235	12006	LAKE STAMFORD	54	10	9.88	53.04	-1.28	98	8	0.58	67.68	80	10	0.06	65.2
1241A	18414	LAKE ALAN HENRY	55	8	10.02	53.18	NA	5	4	3.38	42.46	26	9	0.04	53.7
0403	10296	LAKE O THE PINES	56	36	10.26	53.4	+0.88	55	38	1.12	58.48	30	39	0.04	54.4
1229	17110	SQUAW CREEK RESERVOIR	57	11	10.34	53.5	-2.28	26	9	1.56	53.52	110	11	0.48	93.1
0813	10973	HOUSTON COUNTY LAKE	58	25	10.42	53.56	+0.32	31	27	1.46	54.5	26	28	0.04	53.7
1423	12422	TWIN BUTTES RESERVOIR	59	18	10.76	53.88	-1.24	70	23	0.84	62.4	84	23	0.08	67.1
1422	12418	LAKE NASWORTHY	60	45	10.94	54.04	-1.42	99	51	0.56	68.44	68	50	0.04	60.1

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0816	10980	LAKE WAXAHACHIE	61	20	11.08	54.16	-1.54	82	19	0.7	65.06	62	23	0.04	59.2
0832	11061	LAKE WEATHERFORD	63	17	12.34	55.22	-0.82	78	18	0.74	64.32	62	18	0.04	59.2
2454A	12514	COX LAKE	63	21	12.32	55.22	NA	112	24	0.34	75.98	108	22	0.28	85.7
1426A	12180	OAK CREEK RESERVOIR	64	11	12.76	55.56	-3.66	96	32	0.6	67.22	48	12	0.04	57.9
1002	11204	LAKE HOUSTON	65	41	12.8	55.58	+3.28	107	41	0.4	73.44	102	171	0.18	78.7
0512	10458	LAKE FORK RESERVOIR	66	53	12.9	55.66	+1.06	29	119	1.52	53.92	47	3	0.04	57.7
0807	10942	LAKE WORTH	67	6	13.04	55.76	-1.28	86	6	0.7	65.24	64	6	0.04	59.6
1407	12336	INKS LAKE	68	40	14.06	56.5	+1.76	28	33	1.56	53.62	46	44	0.04	57.5
0409	17478	LAKE GILMER	69	19	14.14	56.56	-2.10	53	21	1.14	58.02	52	21	0.04	58.2
1434C	17020	LAKE BASTROP	70	36	14.34	56.7	NA	33	28	1.44	54.72	40	46	0.04	56.2
1236	12010	LAKE FORT PHANTOM HILL	71	4	14.58	56.86	NA	71	3	0.8	63.1	76	4	0.06	63.8
0104	17465	LAKE FRYER	72	16	14.66	56.9	-0.20	101	19	0.5	69.9	91	19	0.1	69.2
0803	10899	LAKE LIVINGSTON	73	61	15.32	57.34	+0.38	75	75	0.78	63.6	97	54	0.14	75.8
0506	17585	LAKE GLADEWATER	74	14	15.36	57.38	+3.84	81	16	0.72	64.58	50	17	0.04	58.1
1203	11851	LAKE WHITNEY	75	13	15.5	57.46	+6.96	25	68	1.6	53.26	13	16	0.02	51.9

Appendix A. Trophic Classification of Major Texas Reservoirs Using Carlson's Trophic State Index (TSI)

Segment	Station	Reservoir	Chla Rank	Chla Records	Chla Mean (ug/L)	Chla TSI	Trend	Secchi Rank	Secchi Records	Secchi Mean (Meters)	Secchi TSI	TP Rank	TP Records	TP Mean (mg/L)	TP TSI
1209A	11792	COUNTRY CLUB LAKE	76	12	16.4	58.02	+0.82	111	11	0.36	74.64	109	12	0.4	90.7
0815	10979	BARDWELL RESERVOIR	77	20	16.46	58.04	+0.32	93	20	0.62	67	63	22	0.04	59.4
0830	15151	BENBROOK LAKE	78	6	16.8	58.24	0.00	77	6	0.74	64.26	78	6	0.06	64.1
1222	11935	PROCTOR LAKE	79	16	16.98	58.36	+2.18	90	59	0.64	66.42	87	20	0.08	67.7
2312	13267	RED BLUFF RESERVOIR	80	20	17.62	58.7	+2.58	67	22	0.86	62.14	15	22	0.02	52.3
1416A	12179	BRADY CREEK RESERVOIR	81	13	17.84	58.84	+1.20	80	25	0.72	64.56	37	23	0.04	55.7
1242N	18457	TRADINGHOUSE CREEK RESERVOIR	82	6	18.76	59.32	NA	66	9	0.86	62.06	29	9	0.04	54.2
1008F	16482	LAKE WOODLANDS	83	7	21	60.44	NA	109	63	0.38	73.88	111	28	0.94	102.9
1012	11342	LAKE CONROE	84	8	21.06	60.46	+2.96	43	12	1.26	56.58	65	87	0.04	59.7
1209B	11798	FIN FEATHER LAKE REET	85	15	21.42	60.62	+0.42	59	12	0.98	60.24	107	15	0.26	84.3
1411	12359	E V SPENCE RESERVOIR	86	10	22.1	60.94	+1.00	38	12	1.34	55.78	27	11	0.04	54
0820	10998	LAKE RAY HUBBARD	87	8	22.3	61.02	0.00	62	29	0.94	60.9	73	14	0.06	62.7
0605	16159	LAKE PALESTINE	88	29	22.46	61.1	+0.60	64	31	0.92	61.26	32	32	0.04	54.8
0809	10944	EAGLE MOUNTAIN RESERVOIR	89	5	24.46	61.94	0.00	61	5	0.94	60.86	85	5	0.08	67.2
1402G	17017	FAYETTE RESERVOIR	90	37	25.84	62.48	NA	52	28	1.16	57.9	57	49	0.04	59

Appendix A. Trophic Classification of Major Texas Reservoirs Using Carlson's Trophic State Index (TSI)

Segment	Station	Reservoir	Chla Rank	Chla Records	Chla Mean (ug/L)	Chla TSI	Trend	Secchi Rank	Secchi Records	Secchi Mean (Meters)	Secchi TSI	TP Rank	TP Records	TP Mean (mg/L)	TP TSI
0229A	10192	LAKE TANGLEWOOD	91	35	27.3	63.02	+2.10	63	35	0.92	61.06	112	38	1.18	106.2
1425	12429	O C FISHER RESERVOIR	92	18	27.52	63.08	+0.32	105	24	0.46	71.38	98	23	0.16	76.9
1253	16247	SPRINGFIELD LAKE	93	32	29.7	63.84	+1.24	114	31	0.3	77.72	103	35	0.18	78.9
0507	10434	LAKE TAWAKONI	94	62	29.82	63.88	+2.20	60	149	0.94	60.76	81	17	0.08	65.4
2103	12967	LAKE CORPUS CHRISTI	95	5	31.76	64.5	NA	54	30	1.14	58.12	104	25	0.18	79.2
1412A	12167	LAKE COLORADO CITY	96	4	37.2	66.04	+0.54	95	24	0.6	67.18	89	4	0.08	68.6
0509	10444	LAKE MURVAUL	97	22	38.3	66.34	+3.14	94	23	0.6	67.14	74	25	0.06	63.4
1212	11881	LAKE SOMERVILLE	98	12	42.14	67.26	+3.46	79	63	0.74	64.36	92	18	0.1	69.3
1242A	16781	OLD MARLIN CITY LAKE	99	21	42.96	67.46	-1.48	108	19	0.38	73.82	100	23	0.16	77
1241A	11529	BUFFALO SPRINGS LAKE	100	8	55.08	69.9	+0.66	88	8	0.66	66.12	83	9	0.08	66.5
0219	10163	LAKE WICHITA	101	9	107.02	76.42	+0.70	113	9	0.32	76.86	106	9	0.22	81.9
0105	10060	RITA BLANCA LAKE	102	14	349.78	88.04	+5.56	117	18	0.08	98.2	113	17	3.36	121.2

* Reservoirs are ranked in priority by TSI (Chl). A true rank was used which can result in a tied rank for reservoirs with the same TSI (Chl) The rank resumes with subsequent rank value.
** The Carlson's TSI (Chl), (TP), and (SD) were computed for each reservoir by calculating the arithmetic average for the TSI values from each sample date. The effect of these computations is that the ranking of Carlson's TSI (Chl), (TP), and (SD) values may vary slightly from a ranking based on the arithmetic average of chlorophyll *a*, total phosphorus, and Secchi disk values.
*** Some ranking assignments are skipped by the computational data model.
**** A minus(-) preceding a value in the trend column indicates decreased algal content between the 2006 and 2008 reporting cycles; a plus (+) indicates increased algal content; NA indicates a comparison cannot be made due to absence of comparable data.

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