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TCEQ Water Quality Planning Division

Trophic Classification of Texas Reservoirs

Draft 2022 Texas Integrated Report for Clean Water Act Sections 305(b) and 303(d)

The primary productivity of reservoirs, as indicated by the amount of nutrients (phosphorus and nitrogen) and the extent of algae (suspended, floating, and attached) and rooted aquatic plants, can have a significant effect on water quality. Up to a point, nutrients promote ecosystem production and healthy growth of algae, larger plants, and fish and other aquatic organisms. However, excess nutrients and algae in reservoirs can have a deleterious effect on water quality, and algae can reach nuisance levels that potentially (1) create nuisance aesthetic conditions, (2) cause taste and odor in drinking water sources, (3) contribute to reduced dissolved oxygen as algae decay, and (4) ultimately reduce the ability of a water body to support healthy, diverse aquatic communities.

Eutrophication refers to an overall condition characterized by an accumulation of nutrients that support relatively elevated growth of algae and other organisms. Eutrophication is primarily influenced by the physical and hydrological characteristics of the water body and can be affected by natural processes and human activities in the surrounding watershed. Human activities can accelerate the eutrophication process by increasing the rate at which nutrients and organic substances enter impoundments and surrounding watersheds. Discharges of treated sewage, agricultural and urban runoff, leaking septic tanks, and erosion of stream banks can increase the flow of nutrients and organic substances into reservoirs. In comparison to natural lakes in northern states, the eutrophication process in southern reservoirs is often enhanced by (1) warm climates with long growing seasons, (2) soils and geologic substrates that create high concentrations of sediment and nutrients in rainfall runoff, and (3) relatively high river inflows on main stem impoundments. As a result, some reservoirs in Texas can be relatively eutrophic even where nutrient loadings due to human activities are not relatively large.

The trophic state of a reservoir refers to its nutritional status that is indicated by measurements of nutrients and algae. Section 314 of the U.S. Clean Water Act (CWA) requires all states to classify lakes and reservoirs according to trophic state. Assessing water body condition based on algae is accomplished by evaluating indicators that reflect nutrient dynamics that drive primary production. Various classification schemes (Table 1-1) 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

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concentrations. Typically, phosphorus is the nutrient of concern and changes in its concentration may trigger a response that influences the amount of algae, as estimated by chlorophyll *a* (Chl *a*) in the reservoir. For example, increases in phosphorus can result in higher algal biomass, which in turn decreases water transparency (as measured by a Secchi disk or submarine photometer).

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

Trophic State	Water Quality Characteristics
Oligotrophic	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 relatively rich in nutrient concentrations, with high biological productivity. Waters more clouded by organic matter, sediment, suspended solids, and algae.
Hypereutrophic	Murkier, highly productive waters. Dense algae, very high nutrient concentrations.

(Adapted from a variety of descriptions of trophic state characteristics)

Major Texas reservoirs have been evaluated and ranked every two years by TCEQ using Carlson's Trophic State Index (TSI). Carlson's Index was developed to compare reservoirs using in-reservoir sampling data (Carlson, 1977; Carlson and Simpson, 1996). Secchi disk depths, chlorophyll *a* concentrations, and total phosphorus concentrations are three variables that are highly correlated and considered estimators of algal biomass. The Carlson Index uses regression analysis to relate these three parameters to determine trophic state. 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*) = $9.81 \ln(\text{Chl } a) + 30.6$, where Chl *a* is mean chlorophyll *a* in µg/L.

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

Although chlorophyll *a* is the most direct measure of algal biomass, the TSI uses 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). Since the relationship between Secchi disk and chlorophyll *a* was nonlinear a 10-unit TSI (Chl *a*) change does not correspond to a doubling of 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 (µg/L)	Chlorophyll *a* (µg/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

(Adapted from Carlson, 1977; and Carlson and Simpson, 1996)

Carlson's Index provides a useful tool for assessing a reservoir's condition and evaluating changes over time. For example, 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 which explains possible causes of the water body condition. For example, 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 provides a simple model for evaluating condition which provides both advantages and disadvantages. The trophic state is developed on a continuous numeric scale and is useful for approximating the oligotrophic-hypereutrophic nomenclature required by EPA. Secchi disk depths, total phosphorus, and chlorophyll *a* concentrations are routinely determined at fixed monitoring stations on reservoirs and lakes, so data is 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 does not replace the need to use attainment determinations. Carlson (1977) points out that trophic state is not equivalent to an index of water quality. Assessment of reservoir water quality depends heavily on the assignment of beneficial uses and determinations to evaluate if the uses are being maintained and/or impaired. 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, 2010 - November 30, 2020).

To maximize comparability among reservoirs, data from the monitoring station nearest the dam, with the most available data, in the main pool of each reservoir were utilized if available. In some cases, multiple stations situated close to one another were also used. For many reservoirs, these are the only sites monitored by TCEQ and the Clean Rivers Program. Chlorophyll *a* was given priority as the primary trophic state indicator because it has proven to be most useful 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. Of the 143 reservoirs surveyed, 139 had sufficient data to be included in the ranking. Based on this assessment, the 139 reservoirs show a range of eutrophication, from oligotrophic to hypereutrophic (Table 1 - 3). Rankings are also provided for total phosphorus (TP) and Secchi disk transparency (SD). Comparing TSI indicators between the reservoirs 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 – 40	6
Mesotrophic	>40 – 50	24
Eutrophic	>50 – 70	104
Hypereutrophic	>70	5

Adapted from Carlson and Simpson (1996)

Reservoirs with the clearest water (highest mean Secchi disk transparency), listed in descending order are as follows: Canyon Lake (4.60 m), International Amistad Reservoir (4.08 m), Lake Travis (3.62 m), Medina Lake (3.58 m) and Tyler State Park Lake (3.24 m). Reservoirs with the poorest light transparency, (lowest mean Secchi disk transparency), listed in ascending order are as follows: Rita Blanca Lake (0.10 m), Cox Lake (0.12 m), Palo Duro Reservoir (0.24 m), White River Lake (0.26 m), and Lake Wichita (0.28 m).

Thirty-one reservoirs share the lowest mean total phosphorus concentration of 0.02 mg/L. Reservoirs with the highest mean total phosphorus concentrations, listed in descending order are as follows: Rita Blanca Lake (3.04 mg/L), O. C. Fisher Lake (1.42 mg/L), Lake Tanglewood (1.02 mg/L), Lake Woodlands (0.90 mg/L), Palo Duro Reservoir (0.32 mg/L) and Lake Corpus Christi (0.32 mg/L).

Water Quality Differences in Reservoirs

Carlson's TSI Chl *a* values for 103 reservoirs from the 2012 and 2022 reporting cycles were compared to indicate temporal differences (Appendix A). Differences could not be calculated for 36 reservoirs (26%), due to the lack of comparable reporting information from 2012. The 2012 period of record was December 1, 2000 - November 30, 2010; for 2022, the period of record was December 1, 2010 - November 30, 2020.

TSI Chl *a* values, which estimate the amount of algal biomass, can indicate water quality improvement when values decrease. There were decreases in TSI Chl *a* values in 34 (33%) of the comparable reservoirs between 2012 and 2022 report cycles. Reservoirs with the largest decrease in mean TSI Chl *a* values, listed in descending order are as follows: Lake Alan Henry (-11.76), Canyon Lake (-8.22), Twin Buttes Reservoir (-6.24), Lake Texoma (-5.24), and Lake Ratcliff (-5.22). Increases in algal biomass (increase in TSI Chl *a* values) are indicated in 69 (67%) of the comparable reservoirs, which may be indicative of natural or cultural eutrophication. Reservoirs with the largest differences for increasing algal content (substantial positive TSI Chl *a* values), listed in descending order are as follows: Lake Somerville (+12.16), Greenbelt Lake (+10.74), O.C. Fisher Lake (+10.46), Lake Meredith (+9.86), and Farmers Creek Reservoir (+8.58).

It should be noted that a reservoir's trophic rank may differ from that in the last assessment due to improvements in data reporting and analytical capabilities or a change in monitoring station(s) 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 or censored data). 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 censored results. This is done to maximize the amount of data used in this analysis and to indicate the level of monitoring effort. For more information, please contact the Surface Water Quality Monitoring Team at swqm@tceq.texas.gov.

Reservoir Control Programs

Texas implements several reservoir pollution control procedures to ensure high-quality water for recreational, aquatic life, domestic, and industrial uses. Surface water quality standards have been adopted for significant reservoirs throughout the state in Title 30, Texas Administrative Code (30 TAC), Chapter 307, Texas Surface Water Quality Standards. The Standards establish uses for classified segments and unclassified water bodies and include numerical criteria to protect those uses. Designated uses are determined by considering 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. TCEQ issues Texas Pollutant Discharge Elimination System permits that include limits designed to protect these uses. Each major reservoir is routinely monitored to assess the overall condition of the water body in comparison to the criteria and determine short-term or long-term water quality trends. Reservoirs with non-supported uses are placed on the State of Texas 303(d) List. This includes Sub-category 5n, which is established to focus management actions that address nutrients in reservoirs with numeric Chl *a* criteria. When a water body is identified as impaired and in need of remedial efforts, in some cases a total maximum daily load (TMDL) is conducted to determine the assimilative capacity of the water body for a pollutant under consideration. A TMDL allocates waste loads for permits and load allocations from unregulated sources to ensure attainment with water quality standards. 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, TMDL implementation plans, and permits are periodically reviewed and, if necessary, revised.

TCEQ has several specific rules that prescribe permit limitations for discharges of domestic wastewater into reservoirs. The rules in 30 TAC, Chapter 309 Domestic Wastewater Effluent Limitation and Plant Siting, specifically Section 309.3(c), require discharges within five stream miles upstream of certain reservoirs to achieve a minimum effluent quality. For example, a 5-day biological oxygen demand (BOD_5) of 10 mg/L, and total suspended solids (TSS) of 15 mg/L; both expressed as a 30-day average. This rule applies to reservoirs that are subject to on-site/private sewage facility regulation or that may be used as a source for a public drinking water supply. Currently, 95 reservoirs are designated for the public water supply use in Section 307.10, Appendices A and B of the Standards. Additional rules under 30 TAC, Chapter 311, Watershed Protection protect specific reservoirs:

Subchapter A, B, and F: Sections 311.1-6, 311.11-16, and 311.51-56

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, meaning 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. Allowable stormwater runoff and certain non-stormwater discharges that may be authorized by a Texas Pollutant Discharge Elimination System (TPDES) or National Pollutant Discharge Elimination System (NPDES) permit are also included in these watershed rules.

Subchapter D: Sections 311.31-36

This rule requires all domestic and industrial permittees in the entire Lake Houston (Segment 1002) watershed to meet effluent limitations as specified in the rule. For example, 10 mg/L of carbonaceous $BOD_{5,}$ 15 mg/L of TSS, and 3 mg/L of ammonia-nitrogen (NH3-N); all expressed as a 30-day average (domestic discharges). All wastewater effluents disposed of on land must meet an effluent quality as specified in

Sections 309.1-309.4 and 311.34. Domestic facilities must submit a solids management plan. Additionally, all domestic and industrial facilities with gaseous chlorination disinfection systems must have dual-feed chlorination systems and meet a minimum chlorine residual of 1 mg/L and a maximum chlorine residual of 4.0 mg/L (instantaneous grab sample).

Subchapter G: Sections 311.61-311.67

This rule applies to Lakes Worth (Segment 0807), Eagle Mountain (Segment 0809), Bridgeport (Segment 0811), Cedar Creek (Segment 0818), Arlington (Segment 0828), Benbrook (Segment 0830), and Richland-Chambers (Segment 0836). Except for oxidation pond systems, domestic discharges within the water quality areas of the watersheds of these reservoirs must meet advanced treatment limits. For example, BOD_5 of 10 mg/L and 15 mg/L TSS (30-day average), and filtration is required to supplement suspended solids removal by January 1, 1993. Section 311.67 specifies effluent limitations to control nutrients from certain new domestic wastewater facilities or discharge permit amendments to increase permitted flow (after January 1, 2015) discharging to the Benbrook Lake watershed and Benbrook Lake water quality area. Based on the discharge point location and size of discharge, permittees must meet a daily effluent limit for TP of 1.0 mg/L, based on a 30-day average.

Reservoir and Lake Restoration Efforts

Section 314 of the Clean Water Act makes federal grant funds available to states for Clean Lakes Program purposes. TCEQ is currently not administering any grant funding under this program. There are several lakes and reservoirs throughout the state where restoration efforts are currently under way to improve water quality. In addition to TMDLs, watershed protection plans (WPPs) and watershed characterizations may be developed to protect high-quality waters, to address threatened waters before they become impaired, or to restore water bodies for which TMDLs are not practical. The lakes and reservoirs with ongoing restoration efforts include the following:

Lake O’ the Pines — TMDL Implementation Plan
E.V. Spence Reservoir — TMDL Implementation Plan
Lake Austin — TMDL Implementation Plan
Lake Worth — TMDL Implementation Plan
Lake Houston — TMDL Implementation Plan
Aquilla Reservoir — TMDL Implementation Plan
Mountain Creek Lake — TMDL Implementation Plan
Lake Como — TMDL Implementation Plan
Fosdic Lake — TMDL Implementation Plan
Echo Lake — TMDL Implementation Plan
Donna Reservoir — TMDL Implementation Plan
Lake Arlington/Village Creek — Watershed Protection Plan
Lake Granbury — Watershed Protection Plan
Lake Lavon — Watershed Protection Plan
Joe Pool Lake — Watershed Protection Plan

High and Low pH in Texas Water Bodies

The trophic status of a water body can impact several water quality parameters, including pH. Photosynthesis, respiration, and decomposition all contribute to pH fluctuations due to their influences on available carbon dioxide levels in the water column. Elevations in pH are typically highest in mid-afternoon, and lowest just before sunrise. Section 314 of the CWA requires states to include methods and procedures to evaluate and mitigate pH as part of the trophic classification.

Instantaneous and diel pH data collected as part of routine water quality monitoring and special studies are evaluated to determine attainment with site-specific water quality standards for high and low pH as part of the Integrated Report. If impaired, TCEQ considers this information when developing restoration strategies such as TMDLs and Watershed Protection Plans (WPPs), to determine if the pH impairment is related to excessive enrichment.

Low pH in Texas Water Bodies

Data from one freshwater stream and one tidal stream (Table 1-4) have indicated low pH (high acidity) in at least one assessment location, resulting in the water bodies being included in the 2022 Index of Water Quality Impairments. During respiration, dissolved carbon dioxide reacts with water to form carbonic acid, which may lower pH. Most of these water bodies are in the eastern portion of the state, where natural geologic buffering capacity is limited.

Table 1 - 4. Texas Water Bodies with Low pH

Segment Number	Water Body Name
0511	Cow Bayou Tidal
1407A	Clear Creek

High pH in Texas Water Bodies

Data from nine reservoirs and three freshwater streams (Table 1-5) have indicated elevated pH (high basicity) in at least one assessment location resulting in the water bodies being included on the 2022 Texas 303(d) List. A likely cause of elevated pH is consumption of dissolved carbon dioxide by photosynthetic processes. Excessive amounts of photosynthetically active algae and macrophytes can increase consumption of carbon dioxide during the day, increasing pH in the water column. Many of these water bodies are in the eastern portion of the state, where natural geologic buffering capacity is limited.

Table 1 - 5. Texas Water Bodies with High pH

Segment Number	Water Body Name	Trophic Class
0105	Rita Blanca Lake	Hypereutrophic

0229	Upper Prairie Dog Town Fork Red River	Unknown
0302	Wright Patman Lake	Eutrophic
0306	Upper South Sulphur River	Unknown
0403	Lake O' the Pines	Eutrophic
0405	Lake Cypress Springs	Eutrophic
0514	Big Sandy Creek	Unknown
0605	Lake Palestine	Eutrophic
0818	Cedar Creek Reservoir	Eutrophic
0826	Grapevine Lake	Eutrophic
1212	Somerville Lake	Eutrophic
1252	Lake Limestone	Eutrophic

Appendix A. Carlson's Trophic State Index (TSI)

Chl *a* – chlorophyll *a*

TP – total phosphorus

The Carlson's TSI (Chl *a*), (TP), and (Secchi) 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 *a*), (TP), and (Secchi) values may vary slightly from a ranking based on the arithmetic average of chlorophyll *a*, total phosphorus, and Secchi disk values.

Segment	Station ID	Reservoir	Chl *a* Rank[1]	Chl *a* Records	Chl *a* Mean (µg/L)	Chl *a* TSI	Chl *a* TSI (2010)	10 Year Change[2]	Secchi Rank	Secchi Records	Secchi Mean (m)	Secchi TSI	TP Rank	TP Records	TP Mean (mg/L)[3]	TP TSI
1805	12597	CANYON LAKE	1	34	1.6	35.18	43.4	-8.22	1	32	4.6	37.98	2	32	0.02	37.4
1904	12825, 12826	MEDINA LAKE	2	14	1.64	35.4			4	37	3.58	41.66	2	36	0.02	37.4
1241B	18414	LAKE ALAN HENRY	3	20	1.86	36.7	48.46	-11.76	6	22	3.2	43.26	105	21	0.08	67
2305	13835	INTERNATIONAL AMISTAD RESERVOIR	4	28	1.88	36.84			2	26	4.08	39.72	3	25	0.02	40.5
1909	18407	MEDINA DIVERSION LAKE	5	9	2.08	37.74	39.94	-2.2	27	11	1.56	53.66	8	10	0.02	43.2
0302G	20813	TP LAKE	6	17	2.4	39.2			30	25	1.52	54.02	90	18	0.06	62.4
0506M	21823	TYLER STATE PARK LAKE	8	15	2.82	40.8			5	17	3.24	43.02	8	16	0.02	43.2
1404	12302	LAKE TRAVIS	8	71	2.82	40.8	42	-1.2	3	71	3.62	41.46	4	71	0.02	41.7
0611R	17824	LAKE STRIKER	9	34	2.94	41.16	44.14	-2.98	70	38	0.9	61.5	69	34	0.04	58.1
1216	11894	STILLHOUSE HOLLOW LAKE	10	52	3.26	42.18	41.16	1.02	9	52	2.74	45.52	38	52	0.04	54
0404N	17337	LAKE DAINGERFIELD	11	13	3.44	42.7			8	16	2.76	45.32	55	16	0.04	56.6
0614	10639	LAKE JACKSONVILLE	12	29	3.62	43.24	45.34	-2.1	10	38	2.58	46.38	5	30	0.02	42.2

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[1] Reservoirs are ranked in priority by TSI (Chl *a*). A true rank was used which can result in a tied rank for reservoirs with the same TSI (Chl *a*). Therefore, some ranking assignments are skipped by the computational data model. The rank resumes with subsequent rank value.

[2] A positive value indicates increased algal content; A negative value indicates decreased algal content; missing values indicate a comparison cannot be made due to absence of comparable data.

[3] Total phosphorus concentrations converted from µg/L to mg/L.

Segment	Station ID	Reservoir	Chl *a* Rank[1]	Chl *a* Records	Chl *a* Mean (µg/L)	Chl *a* TSI	Chl *a* TSI (2010)	10 Year Change[2]	Secchi Rank	Secchi Records	Secchi Mean (m)	Secchi TSI	TP Rank	TP Records	TP Mean (mg/L)[3]	TP TSI
1234	12005	LAKE CISCO	13	19	4.06	44.36	44.6	-0.24	85	21	0.8	63.18	57	20	0.04	56.7
1604	15377	LAKE TEXANA	14	39	4.72	45.82			134	111	0.32	76.7	129	39	0.18	78.8
0506I	14422	LAKE HAWKINS	15	34	5.28	46.94	48.06	-1.12	11	35	2.52	46.7	9	29	0.02	44.3
1249	12111	LAKE GEORGETOWN	16	49	5.7	47.66	44.46	3.2	22	49	1.64	52.82	36	49	0.04	53.6
1220	11921	BELTON LAKE	17	38	5.7	47.68	45.8	1.88	14	39	2.02	49.9	23	38	0.02	50.9
0611Q	15801	LAKE NACOGDOCHES	18	38	5.94	48.08	44.08	4	23	38	1.64	52.92	32	37	0.04	53.3
0610	14906	SAM RAYBURN RESERVOIR	19	34	5.96	48.1	48.66	-0.56	19	37	1.72	52.12	79	30	0.06	60.6
0505E	13703	BRANDY BRANCH RESERVOIR	20	36	6.02	48.2			7	40	2.88	44.8	14	35	0.02	46.9
1233	12002	HUBBARD CREEK RESERVOIR	21	20	6.14	48.4	46.6	1.8	57	23	1.02	59.74	26	20	0.02	51
1426A	12180	OAK CREEK RESERVOIR	22	23	6.32	48.7	53.18	-4.48	26	21	1.56	53.64	17	20	0.02	47.7
1403	12294	LAKE AUSTIN	23	64	6.42	48.86	44.14	4.72	17	64	1.76	51.88	11	63	0.02	45.4
0228	10188	MACKENZIE RESERVOIR	24	26	6.64	49.18	54.08	-4.9	47	27	1.14	58.14	13	23	0.02	46.7
0811	10970	BRIDGEPORT RESERVOIR	25	44	6.7	49.26			59	44	1	59.98	30	41	0.02	51.5
0840	14039, 17834	RAY ROBERTS LAKE	26	52	6.72	49.28	47.18	2.1	45	38	1.18	57.64	21	51	0.02	49.3
1418C	12178	HORDS CREEK RESERVOIR	27	7	6.76	49.36	50.88	-1.52	46	9	1.16	57.78	12	9	0.02	45.7
0504	10404	TOLEDO BEND RESERVOIR	28	108	6.88	49.52	47.98	1.54	15	109	1.86	51.02	45	107	0.04	55.3
0204B	15447	MOSS LAKE	30	27	6.94	49.6	48.64	0.96	39	27	1.3	56.32	26	26	0.02	51
0213	10143	LAKE KICKAPOO	30	33	6.94	49.6			131	34	0.34	75.14	100	33	0.06	64.1
0203	15440, 20545	LAKE TEXOMA	31	103	7.44	50.28	55.52	-5.24	42	87	1.22	57.1	72	103	0.04	58.8
0202Q	16945	PICKENS LAKE	32	26	7.48	50.32			18	27	1.74	52.08	75	26	0.04	59.5
0605F	17575	LAKE ATHENS	33	35	8.4	51.48	50.96	0.52	13	39	2.14	49.08	6	32	0.02	42.6
1419	12398	LAKE COLEMAN	34	20	8.88	52.02	46.7	5.32	73	22	0.9	61.66	33	21	0.04	53.5
1433	12511	O. H. IVIE RESERVOIR	35	18	9.1	52.26	47.2	5.06	33	19	1.46	54.62	26	19	0.02	51
1418	12395	LAKE BROWNWOOD	36	17	9.78	52.98	48.24	4.74	58	20	1	59.88	42	17	0.04	55
1207	11865	POSSUM KINGDOM LAKE	37	115	9.86	53.06	54.1	-1.04	12	116	2.32	47.88	40	114	0.04	54.5

Segment	Station ID	Reservoir	Chl *a* Rank[1]	Chl *a* Records	Chl *a* Mean (µg/L)	Chl *a* TSI	Chl *a* TSI (2010)	10 Year Change[2]	Secchi Rank	Secchi Records	Secchi Mean (m)	Secchi TSI	TP Rank	TP Records	TP Mean (mg/L)[3]	TP TSI
0612G	21435	LAKE NACONICHE	38	25	10.04	53.22			35	27	1.42	54.88	18	26	0.02	48.2
1230	11977	LAKE PALO PINTO	39	9	10.04	53.24	49.74	3.5	80	7	0.84	62.4	61	9	0.04	57.3
0836	15168	RICHLAND-CHAMBERS RESERVOIR	40	43	10.08	53.28			60	43	1	60.04	49	42	0.04	56.3
1408	12344	LAKE BUCHANAN	41	71	10.12	53.3	52.08	1.22	25	71	1.56	53.62	22	71	0.02	50
0603	10582	B A. STEINHAGEN LAKE	42	36	10.3	53.48	52.5	0.98	127	36	0.36	74.34	103	31	0.06	65
1429	12476	LADY BIRD LAKE (FORMERLY TOWN LAKE)	43	48	10.62	53.78	51	2.78	21	47	1.66	52.74	91	36	0.06	62.8
1231	11979	LAKE GRAHAM	44	22	10.64	53.8	49.64	4.16	98	22	0.7	65.3	69	20	0.04	58.1
0217	10159	LAKE KEMP	45	33	10.84	53.98	51.72	2.26	49	34	1.12	58.46	36	33	0.04	53.6
1423	12422	TWIN BUTTES RESERVOIR	46	23	11.04	54.16	60.4	-6.24	77	23	0.86	62.24	47	22	0.04	56
0613	10637	LAKE TYLER	47	31	11.22	54.32	54.94	-0.62	28	36	1.52	53.9	15	30	0.02	47.1
0408	10329, 17059	LAKE BOB SANDLIN	48	35	11.46	54.54			16	37	1.78	51.74	10	32	0.02	44.4
0212	10142	LAKE ARROWHEAD	49	36	11.58	54.64	53.48	1.16	115	36	0.5	70.22	127	34	0.16	77.6
0604T	17339	LAKE RATCLIFF	50	38	12	54.98	60.2	-5.22	92	36	0.76	64.02	88	35	0.06	62
0506L	18847	LAKE HOLBROOK	51	22	12.52	55.4			31	23	1.48	54.42	20	20	0.02	48.8
0834	11063	LAKE AMON G. CARTER	52	19	12.62	55.48	48.32	7.16	53	19	1.08	58.84	31	16	0.02	53.1
0613	10638	LAKE TYLER EAST	53	31	12.76	55.58	53.34	2.24	36	36	1.42	54.92	19	30	0.02	48.4
0223	10173	GREENBELT LAKE	54	31	12.78	55.6	44.86	10.74	81	31	0.84	62.62	58	31	0.04	56.8
1203	11851, 13987	WHITNEY LAKE	55	31	13.58	56.18	57.42	-1.24	24	41	1.56	53.54	29	30	0.02	51.3
1247	12095	GRANGER LAKE	56	52	13.6	56.2	55.08	1.12	119	51	0.44	71.66	55	52	0.04	56.6
1406	12324	LAKE LYNDON B. JOHNSON	57	69	13.62	56.22	52.72	3.5	34	70	1.44	54.8	26	70	0.02	51
0303A	16856	BIG CREEK LAKE	58	34	13.74	56.3	60.16	-3.86	121	33	0.42	72.56	116	30	0.1	69.4
1012	11342	LAKE CONROE	59	37	13.78	56.34	58.82	-2.48	65	113	0.94	60.84	103	111	0.06	65
0214H	20162	NORTH FORK BUFFALO CREEK RESERVOIR	60	14	14.02	56.5			117	14	0.46	71.24	120	13	0.1	71.2
0512	10458	LAKE FORK RESERVOIR	61	107	14.28	56.68	54.48	2.2	41	112	1.24	56.92	74	107	0.04	59.2

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0830	15151	BENBROOK LAKE	62	47	14.44	56.8			86	47	0.8	63.32	65	45	0.04	57.5
1407	12336	INKS LAKE	63	69	14.94	57.12	57.52	-0.4	38	69	1.32	56.06	61	69	0.04	57.3
1225	11942	WACO LAKE	64	37	14.98	57.16	58.36	-1.2	88	37	0.78	63.6	70	34	0.04	58.2
2454A	12514	COX LAKE	65	33	15.44	57.44	54.36	3.08	140	34	0.12	89.96	133	28	0.22	82.3
1405	12319	MARBLE FALLS LAKE	66	68	15.48	57.48	52.56	4.92	32	68	1.46	54.48	83	68	0.06	61.1
0208	10137	LAKE CROOK	67	35	15.7	57.62			136	37	0.3	77.62	126	35	0.16	76.5
0816	10980	LAKE WAXAHACHIE	68	36	15.82	57.7	58.22	-0.52	112	45	0.52	69.6	52	40	0.04	56.5
0506H	17062	LAKE GLADEWATER	69	37	15.96	57.78	60.52	-2.74	66	40	0.92	61.16	65	33	0.04	57.5
0818	16748, 16749	CEDAR CREEK RESERVOIR	71	89	16.06	57.84			67	84	0.92	61.3	65	88	0.04	57.5
0826	11035, 17827	GRAPEVINE LAKE	71	52	16.08	57.84			75	38	0.86	62.06	61	48	0.04	57.3
1254	12127	AQUILLA RESERVOIR	72	36	16.32	57.98	54.68	3.3	109	36	0.56	68.22	73	32	0.04	59
0307	13855	JIM L. CHAPMAN LAKE (FORMERLY COOPER LAKE)	73	36	16.38	58.02			104	38	0.64	66.44	106	35	0.08	67.1
0209	16343	PAT MAYSE LAKE	74	38	16.5	58.1			50	39	1.1	58.52	36	34	0.04	53.6
1411	13863	E. V. SPENCE RESERVOIR	76	15	16.86	58.32	61.76	-3.44	43	14	1.22	57.22	92	15	0.06	62.9
1422	12418	LAKE NASWORTHY	76	24	16.86	58.32	55.1	3.22	97	23	0.7	65.14	71	24	0.04	58.4
0809	10944	EAGLE MOUNTAIN RESERVOIR	77	44	17.02	58.4			79	45	0.86	62.3	81	45	0.06	60.8
0818J	17949	PURTIS CREEK STATE PARK LAKE	78	12	17.12	58.46			52	16	1.1	58.7	112	14	0.08	68.2
2312	13267	RED BLUFF RESERVOIR	79	18	17.24	58.54	55.68	2.86	89	17	0.78	63.64	26	15	0.02	51
2103	12967	LAKE CORPUS CHRISTI	80	40	17.44	58.64	57.18	1.46	133	41	0.32	76.4	135	40	0.32	86.9
0817	10981	NAVARRO MILLS LAKE	81	33	17.46	58.66	53.98	4.68	113	35	0.5	69.78	97	31	0.06	63.8
1236	12010	FORT PHANTOM HILL RESERVOIR	82	27	17.52	58.68			100	27	0.68	65.62	100	23	0.06	64.1
0813	10973	HOUSTON COUNTY LAKE	83	34	17.7	58.78	54.14	4.64	44	37	1.2	57.38	46	30	0.04	55.6
0806G	22142	MARINE CREEK RESERVOIR	84	5	18.44	59.18			68	5	0.9	61.4	16	5	0.02	47.5
0409D	17478	LAKE GILMER	85	36	18.5	59.22	58.36	0.86	29	38	1.52	53.96	52	30	0.04	56.5
0401	10283	CADDO LAKE	86	38	18.64	59.3	54.5	4.8	96	140	0.7	65.12	105	36	0.08	67

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0215	10157	DIVERSION LAKE	87	25	18.72	59.34	54.18	5.16	106	26	0.62	66.82	50	26	0.04	56.4
0828	13904	LAKE ARLINGTON	88	46	19.02	59.5			95	46	0.74	64.48	86	46	0.06	61.8
1224	11939	LEON RESERVOIR	89	21	19.28	59.62	52.44	7.18	56	21	1.02	59.66	48	17	0.04	56.2
0210	10139	FARMERS CREEK RESERVOIR (ALSO KNOWN AS LAKE NOCONA)	90	35	19.44	59.72	51.14	8.58	91	34	0.76	63.94	55	34	0.04	56.6
0214G	17947	LAKE IOWA PARK	92	14	19.5	59.74			128	14	0.36	74.36	111	13	0.08	67.9
2116	13019, 13020	CHOKE CANYON RESERVOIR	92	49	19.52	59.74			116	49	0.48	70.44	118	49	0.1	70.1
0102	10036	LAKE MEREDITH	93	32	19.94	59.96	50.1	9.86	79	35	0.86	62.3	39	30	0.04	54.4
0701D	10642	SHALLOW PRONG LAKE	94	34	20.04	60.02	57.74	2.28	111	39	0.54	68.9	115	32	0.08	69
0505F	13601	MARTIN CREEK RESERVOIR	95	32	20.26	60.12	56.74	3.38	51	35	1.1	58.58	44	31	0.04	55.2
0815	10979	BARDWELL RESERVOIR	96	35	20.56	60.26	58.82	1.44	126	44	0.38	74.04	83	39	0.06	61.1
1242H	18457	TRADINGHOUSE RESERVOIR	97	37	20.62	60.28	60.14	0.14	76	36	0.86	62.22	77	36	0.04	59.7
1232D	17941	LAKE DANIEL	98	20	20.98	60.46			125	24	0.38	73.66	117	21	0.1	69.8
1413	21614	LAKE J. B. THOMAS	99	15	21.32	60.62	54.44	6.18	84	15	0.82	62.96	89	15	0.06	62.2
0807	10942	LAKE WORTH	100	46	21.58	60.74			102	46	0.66	66.16	78	46	0.04	60.5
2303	13189	INTERNATIONAL FALCON RESERVOIR	101	29	21.7	60.8	55.68	5.12	55	31	1.02	59.64	95	28	0.06	63.6
0820	10998	LAKE RAY HUBBARD	102	53	22.06	60.96	61.82	-0.86	64	39	0.94	60.76	59	54	0.04	57.1
1237	12021	LAKE SWEETWATER	103	20	22.3	61.06			90	22	0.78	63.74	87	20	0.06	61.9
0803	10899	LAKE LIVINGSTON	104	35	22.46	61.12	57.72	3.4	123	36	0.42	72.84	119	36	0.1	70.6
1008F	16482	LAKE WOODLANDS	105	39	23.38	61.52	63	-1.48	120	117	0.42	72.4	137	40	0.9	102.2
1228	11974	LAKE PAT CLEBURNE	106	37	23.7	61.66	59.96	1.7	101	39	0.66	65.92	77	34	0.04	59.7
1428K	20161	WALTER E. LONG LAKE	107	24	23.86	61.72	59.34	2.38	37	24	1.34	55.72	63	15	0.04	57.4
0405	10312	LAKE CYPRESS SPRINGS	108	36	24.02	61.78	57.26	4.52	48	38	1.14	58.22	41	34	0.04	54.7
0821	15685	LAVON LAKE	109	59	24.18	61.84			107	63	0.62	67.08	94	63	0.06	63.1
1434C	17020	LAKE BASTROP	110	59	24.14	61.84	59.48	2.36	40	59	1.26	56.62	113	58	0.08	68.3

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1205	11860	LAKE GRANBURY	111	114	24.68	62.04	61.34	0.7	69	113	0.9	61.48	52	113	0.04	56.5
1252	12123	LAKE LIMESTONE	112	70	26.24	62.66	59.16	3.5	93	74	0.76	64.14	84	72	0.06	61.5
0605	16159	LAKE PALESTINE	113	38	27.6	63.16	63.46	-0.3	62	40	0.98	60.32	67	31	0.04	57.6
0403	10296	LAKE O' THE PINES	114	36	28.28	63.38	58.3	5.08	73	39	0.9	61.66	43	36	0.04	55.1
1240	12027	WHITE RIVER LAKE	115	35	28.38	63.42	56.3	7.12	138	41	0.26	79.36	101	35	0.06	64.9
1235	12006	LAKE STAMFORD	116	25	29.8	63.9	56.46	7.44	118	26	0.46	71.4	108	23	0.08	67.2
0832	11061	LAKE WEATHERFORD	117	40	30.68	64.18	59.32	4.86	108	39	0.58	68.04	80	37	0.06	60.7
1002	11204	LAKE HOUSTON	118	32	31.34	64.4	60.1	4.3	124	33	0.4	73.06	132	32	0.22	81.8
1416B	12179	BRADY CREEK RESERVOIR	119	24	32.22	64.66	59.24	5.42	82	24	0.84	62.64	97	24	0.06	63.8
0507	10434	LAKE TAWAKONI	120	104	32.32	64.7	64.42	0.28	71	108	0.9	61.6	86	104	0.06	61.8
0827	11038	WHITE ROCK LAKE	121	35	33.38	65.02	64.46	0.56	110	38	0.56	68.28	108	36	0.08	67.2
0509	10444	MURVAUL LAKE	122	36	34.56	65.36	67.02	-1.66	94	40	0.74	64.2	93	35	0.06	63
1210	17586	LAKE MEXIA	123	37	35.04	65.48			130	42	0.36	75.02	128	35	0.16	77.8
0199A	10005	PALO DURO RESERVOIR	124	20	35.5	65.62	61.68	3.94	139	21	0.24	80.28	136	19	0.32	87.1
0302	10213, 14097	WRIGHT PATMAN LAKE	125	79	35.78	65.7			105	169	0.64	66.6	110	65	0.08	67.6
1222	11935	PROCTOR LAKE	126	19	37.38	66.12	64.58	1.54	114	20	0.5	69.82	123	19	0.12	73.7
0515A	17948	LAKE QUITMAN	127	38	38.56	66.42	66.52	-0.1	87	37	0.8	63.38	98	28	0.06	63.9
0803G	16953	LAKE MADISONVILLE	128	11	40.04	66.8			122	10	0.42	72.64	124	11	0.14	74.6
1212	11881	SOMERVILLE LAKE	129	33	40.2	66.84	54.68	12.16	103	34	0.64	66.36	121	28	0.12	72
0804J	17951	FAIRFIELD LAKE	130	33	41.82	67.22	72	-4.78	74	37	0.86	62.04	122	32	0.12	73
1241C	11529	BUFFALO SPRINGS LAKE	131	20	44.32	67.8	69.5	-1.7	83	22	0.84	62.68	109	21	0.08	67.3
1402G	17017	CEDAR CREEK RESERVOIR/ LAKE FAYETTE	132	59	44.6	67.86	62.22	5.64	63	57	0.96	60.6	125	58	0.14	75.1
1242A	16781	NEW MARLIN CITY LAKE	133	38	46.28	68.22	70.58	-2.36	132	38	0.34	75.62	130	34	0.22	81.6
0202M	21032	LAKE BONHAM (BONHAM CITY LAKE)	134	67	50.58	69.08			129	61	0.36	74.66	114	68	0.08	68.6
0229A	10192	LAKE TANGLEWOOD	135	30	65.66	71.64	69.7	1.94	61	34	0.98	60.3	138	25	1.02	104

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1253A	16247	SPRINGFIELD LAKE	136	38	74.3	72.86	67.52	5.34	135	39	0.3	77.26	132	36	0.22	81.8
0219	10163	LAKE WICHITA	137	33	92.6	75.02	75.28	-0.26	137	28	0.28	78.04	134	35	0.3	86.6
1425	12429	O. C. FISHER LAKE	138	17	242.18	84.46	74	10.46	99	16	0.68	65.36	139	17	1.42	108.8
0105	10060	RITA BLANCA LAKE	139	22	789.94	96.06	95.56	0.5	141	25	0.1	93.18	140	22	3.04	119.8

Works Cited

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