LAKE O' THE PINES WATERSHED TMDL PROJECT DOCUMENTATION REPORT
TCEQ COMMENTS AND RESPONSE
July 25, 2003

COMMENT: 1) Typographical errors and suggested editorial changes are indicated on the hard copy of the report attached to these comments.

RESPONSE : OK

COMMENT: 2) Please include a Table of Contents for the report.

RESPONSE : OK

COMMENT: 3) Please include a summary of the steering committee's discussion of the TMDL project endpoint and the final endpoint selected.

RESPONSE : #3) (Insert as lead paragraph in Section 1)
The 303 (d) listing process has identified water quality and aquatic life impairments in the Lake O' the Pines watershed, and various basin stakeholders have identified additional concerns. However, the distribution of the adverse conditions, their severity, possible seasonal components, and their relationships to known or suspected sources of pollutants were initially poorly defined by preexisting data. Sources of impairments in the Lake O' the Pines watershed were not initially identified, but major possible candidates include poultry production and other agricultural operations, industrial and municipal wastewater discharges, lignite mining, and power plant operations. The primary uses of Lake O' Pines are recreation and public water supply, and demand for both uses is expected to continue to grow.

(Insert before subheading "**Critical Conditions"** in Section 2)

Target (Endpoint) Selection

The subject of the appropriate water quality endpoints, or targets, that we should seek to affect through the TMDL program was first raised during the September 22, 1999 Watershed Steering Committee meeting. TMDL Targets are the numerical expressions defining the water quality or biological conditions that a consensus of watershed stakeholders believe will allow achievement of the designated and desired uses of the basin waters. The TMDL Targets serve as the focus of the technical work to be accomplished during TMDL development, the goal that defines success for the process, and a criterion against which to evaluate future conditions.

The Lake O' the Pines watershed steering committee and the Cypress Creek Basin Clean Rivers Program steering committee both expressed the importance of protecting the water supply, recreational and aesthetic uses of Lake O' the Pines. There is a great deal of local concern over preserving those uses, as they are widely perceived to be threatened by activities in the watershed. Although grab sampling has indicated localized violations of the segment standard for dissolved oxygen concentrations, there is presently little direct evidence that those uses are now being impaired.

Several approaches to defining numerical endpoints, technical issues involved in the sampling and analysis of particular parameters, and the problem of linking quantitative measures of water quality impairment (e.g., segment standards) to their immediate biological effectors and watershed inputs potentially driving them were discussed extensively during subsequent communications with TCEQ staff.

A technical memorandum (with an executive summary) discussing these issues was prepared and provided to the stakeholders to prepare them for additional discussion of TMDL targets (or endpoints) during the July, 2000 steering committee meeting. This memorandum recommended a flexible strategy for developing an appropriate target(s) as we recognized that selection of particular parameters and numerical thresholds will be, to some extent, an ongoing process as our understanding of the system increases during TMDL development. In particular, the relationship between phosphorus loading and the biological response parameters, the possible extent of summer nitrogen limitation episodes, the definition of critical hydrometerological conditions, and the role of the shallow upper portion of Lake O' the Pines in nutrient deposition and regeneration may affect future decisions with respect to Target conditions.

****NEED MEETING MINUTES TO FINISH THIS RESPONSE****

COMMENT: 4) Segment numbers should include the leading zero.

RESPONSE : OK

COMMENT: 5) Please include a more detailed map (or maps) showing all significant water bodies and other points of interest to the project, including Big Cypress Creek, Lake O' the Pines, Lake Bob Sandlin, Lake Monticello, Welch Reservoir, Ferrels, Bridge Dam, State Highway 11, Hwy 259 bridge, SH 155, NETMWD Intake, Longview Intake, Arms Creek, Alley Creek, Hurricane Creek, Tankersley Creek, Dry Creek, Hart Creek, Prairie Creek, Lilly Creek, Boggy Creek, Frazier Creek, poultry houses, poultry litter application sites, sources of nonpoint source pollution, municipal jurisdictions, and permitted wastewater discharges. This should include all information developed for the TMDL GIS database as described under Task 11 in the project work plan.

RESPONSE :) Additional maps are being prepared for inclusion in the report

COMMENT: 6) The report states that the Lake O' the Pines watershed includes some of the leading dairy producing counties in the state. However, there is no additional discussion of dairy operations in the report. The report should include all information necessary to assess dairy operations located in the Lake O' the Pines watershed and their impacts on dissolved oxygen levels in the reservoir.

RESPONSE : (replace 7th paragraph in Section 1)

The Lake O' the Pines watershed includes some of the leading broiler and dairy producing counties in the state. Because most of the latter are located in the Sulphur River drainage basin, or they are in subwatersheds tributary to Lake Cypress Springs and Lake Bob Sandlin, dairies do not have significant direct impacts on Lake O' the Pines. Water quality assessments were prepaired for both reservoirs during the fall, 2002 and copies are available from Franklin County Water District and Titus County Fresh Water Supply District No.1. Station 10311, located between Fort Sherman Dam, and the mouth of the first tributary below Lake Bob Sandlin (Tankersley Creek), exhibits the lowest phosphorus and nitrogen levels on Segment 0404. The area around Pittsburg has experienced particularly intense development of poultry production facilities. The Poultry Farm and Litter Application Survey compiled by Pilgrim's Pride Corporation (1998) on behalf of the Cypress Basin Clean Rivers Program indicated that poultry production throughout the Cypress Creek Basin totaled approximately 99,000,000 birds during 1997, nearly 25% of statewide production. This activity generated 132,720 tons of litter, of which 114,511 tons were disposed of on 42,363 acres of disposal sites at application rates that varied from 1 to 5 tons/acre during 1997.

COMMENT: 7) The report cites census data from the 1990 census. Please update these with figures from the 2000 census. Please include population projections for the watershed.

RESPONSE : (replace ninth paragraph in Section 1)

The city of Mount Pleasant, in Titus County, recorded a population of almost 14,000 in the 2000 census, making it the largest urban concentration in the Lake O' the Pines watershed. The cities of Pittsburg, Daingerfield, Lone Star, and Ore City constitute the other major population centers. The total population projected for the Lake O' the Pines watershed in 2050, including estimates of the rural populations in those portions of eleven counties in the watershed, 80,808, an increase of about 37%[1]. Manufacturing and electric power generation accounts for the majority of water use within the watershed, with municipal water supply a distant third. Although most rural residents still depend on groundwater from the Carrizo-Wilcox and Queen City aquifers, the demand for treated surface water by rural basin residents and by population centers outside the Lake O' the Pines watershed (e.g., Longview) is increasing.

(Insert new table)

[1] Texas Water Development Board, 2002 Board Approved Population Predictions for the 2006 Regional Water Plan.

Table 1-1
Current and Projected Populations of Cities and Portions of Counties within the Lake O' the Pines Watershed

County	% County in Watershed	Urban Areas	2000 Urban Populations	2000 Estimated Rural Population	2000 Total Population	2050 Projected Urban Population	2050 Projected Rural Population	2050 Projected Total Population
Camp	75	Pittsburg	4,347	5424	9771	5327	8257	13584
Cass	1	Hughes Springs*	1856*	356		2117*	407	
		Avinger	464		820	463		870
Franklin	38			3589	3589		6020	6020
Gregg	0			0	0			0
Harrison	3	Marshall*	23935*	1269	1269	25073*	1932	1932
Hopkins	2			750	750		1069	1069
Marion	25			2728	2728		2848	2848
Morris	56	Daingerfield	2,517	4955	9103	2515	5286	8831
		Lone Star	1631			1030		
Titus	45	Mt. Pleasant	13,935	6448	20383	20844	10102	30946
Upshur	15	Ore City	1,106	4540	5646	1645	5733	7378
		Gilmer*	4799*			7248*		
Wood	5	Winnsboro	3,584	1505	5089	5228	2102	7330
		Totals			59149			80808

*Not in Lake O' the Pines watershed

COMMENT: 8) Historical Water Quality - A detailed map (or maps) showing all sampling locations should be presented in the body of the report.

RESPONSE : OK

COMMENT: 9) Historical Water Quality - In this, and all other discussions throughout the report, a clear distinction needs to be made between "gross" constituent loadings (i.e., at the source) and "net" constituent loadings (i.e., at instream locations).

RESPONSE : OK

COMMENT: 10) The report characterizes values of dissolved oxygen, pH, and Secchi depth measured in Lake O' the Pines during 1995 - 1999 as "extreme". Please elaborate on this statement.

RESPONSE : " extreme" removed

COMMENT: 11) Nitrate+Nitrite data is not presented. If it is available, it should be included.

RESPONSE : Not available

COMMENT: 12) Please explain the source of the data presented in the Table 1-4.

RESPONSE : Clean Rivers Program data - PPA. 2000. Cypress Creek Basin Summary Report. Prepared by Paul Price Associates, Inc. for submission to TNRCC, Austin, Texas.

COMMENT: 13) Please include summary of results from Rapid Bioassessment Studies to support the discussion presented on Page 12.

RESPONSE : (Insert Table 2-3 and reference)

Table 2-3
Summary of Rapid Bioassessment Protocol Results from Big Cypress Creek (Segment 0404)

25 August - 1 September 2000

	Tankersley Creek at FM 3417 10261	**Hart Creek at Titus Co. Rd 10266**	**Big Cypress Below Walkers 16457**	**Big Cypress at Gasline Crossing 16460**	**Big Cypress at Fish Camp 10307**
Habitat					
Total Score	19	18	22	21	17
Aquatic Life Use*	Intermediate	Intermediate	High	High	Intermediate
Nekton					
Total Score	44	46	48	52	47
Aquatic Life Use**	Intermediate	Inter./High	High	High	High/Inter.
Benthic Macroinvertibrate					
Total Score	24	27	34	29	25
Aquatic Life Use***	Intermediate	Intermediate	High	High	Intermediate
	Swauano Creek at SH 49	**Walkers Creek at US 271**	**Greasy Creek at FM 557**	**Dry Creek at Camp Co. Rd.**	**Big Cypress near Greasy**

	15738	**16454**	**16016**	**10274**	**16458**
Habitat					
Total Score	18	21	17	17	18.5
Aquatic Life Use*	Intermediate	High	Intermediate	Intermediate	Intermediate
Nekton					
Total Score	48	44	46	44	49
Aquatic Life Use**	High	Intermediate	Inter./High	Intermediate	High
Benthic Macroinvertibrate					
Total Score	23	28	24	26	30
Aquatic Life Use***	Intermediate	Intermediate	Intermediate	Intermediate	High

Table 2-3 Continued
August 6-8 2001

	Tankersley Creek at FM 3417 10261	Hart Creek at Titus Co. Rd 10266	Big Cypress Below Walkers 16457	Big Cypress at GaslineCrossing 16460	Big Cypress at Fish Camp 10307
Habitat					
Total Score	20	20.5	18.5	19.5	17
Aquatic Life Use*	High	High	Intermediate	High / Intermediate	Intermediate
Nekton					
Total Score	54	52	52	50	47
Aquatic Life Use**	High / Exceptional	High	High	High	High/Inter.
Benthic Macroinvertibrate					
Total Score	22	30	31	24	25
Aquatic Life Use***	Intermediate	High	High	Intermediate	Intermediate

	Swauano Creek at SH 49 15738 8 Aug 2001	Walkers Creek at US 271 16454 6 Aug 2001	Greasy Creek at FM 557 16016 7 Aug 2001	Dry Creek at Camp Co. Rd. 10274 8 Aug 2001	Big Cypress near Greasy 16458 7 Aug 2001
Habitat					
Total Score	20	21	18	14.5	18.5
Aquatic Life Use*	High	High	Intermediate	Intermediate	Intermediate
Nekton					
Total Score	50	48	52	34	49
Aquatic Life Use**	High	High	High	Limited / Intermediate	High
Benthic Macroinvertibrate					
Total Score	27	24	21	24	30
Aquatic Life Use***	Intermediate	Intermediate	Limited	Intermediate	High

Aquatic Life Use Point Score Ranges

	Limited	Intermediate	High	Exceptional
*Habitat	<13	14-19	20-25	26-31
**Nekton (fish)	<34	40-44	48-52	58-60
***Macroinvertebrates	<22	22-28	29-36	>36

COMMENT: 14) The report differentiates between TCEQ data and Clean River Program data. This is not accurate. The data should be referenced as TCEQ data.

RESPONSE : OK

COMMENT: 15) Please include only 303(d) list information pertaining to Segments 0403 and 0404.

RESPONSE : OK – but Segment 0408, Lake Bob Sandlin (Table 2-2) is part of the Lake O' the Pines watershed.

COMMENT: 16) The footnote for this Table is not clear. Is it more correct to say that the bold type indicates an occasion when the dissolved oxygen standard was violated?

RESPONSE : (Replace footnote to table 2-4 with:)

Bold type indicates an occasion when the dissolved oxygen standard was violated

COMMENT: 17) The report states on Pg 25 that phosphorus is too abundant to be exerting limits on production and respiration. This statement is contradicted on Pg 38 where the report states that phosphorous is in short supply for this system. There are additional seemingly contradictory statements in the report regarding the relative significance of nitrogen and phosphorous on photosynthetic activity in the reservoir. The report is confusing on this point and needs to be clarified.

RESPONSE : Although phosphorus may appear to be too abundant in Lake O' the Pines to be exerting limits or control on production and coupled respiration, this is not the case as summer total phosphorus concentrations primarily represent phosphorus tied up in living and dead organic material, phosphorus sorbed to mineral particles, or present as polyphosphate, all of which are of only limited availability for new growth. Dissolved phosphorus was rarely, if ever, detected in Lake O' the Pines summer baseflow samples (AWRL = 0.01 mg/l). Summer nitrogen likewise consisted almost entirely of total Kjeldahl nitrogen (TKN) and much smaller concentrations of ammonia, indicating that nitrogen was also present primarily as organic matter (biomass and detritus) and not in an immediately available form. In this condition of general nutrient abundance but limited availability, photosynthesis and respiration rates will tend to depend on the rates of regeneration of nitrogen and phosphorus from sediments or from living populations, given appropriate conditions of temperature, light, and other nutrients. Nutrient regeneration rates at any given time and location may depend on both physical factors, such as sediment redox potential, dissolved oxygen concentrations and pH of overlying water, and mixing events (e.g., wind stress, internal waves), and biological factors, including pathogen-induced lysis of algal cells, grazing by fish and macroinvertebrates, or direct excretion from growing algal populations under otherwise favorable environmental conditions.

COMMENT: 18) Section 2 should conclude with a clear, straight forward statement of the water quality problem identified in the preceding analyses and which is addressed by the TMDL.

RESPONSE : Violations of DO Standards, based on grab sampling, have been documented at Station 10300 in the Upper Reservoir. Extensive diurnal dissolved oxygen sampling conducted during 2000-2003 as part of the TMDL program, confirm that standards violations are occurring in the upper- and lowermost stations in the reservoir (Table 2-4). In addition, basin stakeholders are concerned that a declining DO trend has been detected at the lowermost station (10296) in the reservoir. Both conditions appear to have resulted from elevated nutrient concentrations throughout the reservoir which originate in the Big Cypress Creek drainage.

COMMENT: 19) Please include permit number, facility name, and name of permittee in the Table.

RESPONSE : See Table 3-1

COMMENT: 20) Please include permit number and permitted flow in the Table.

RESPONSE : See Table 3-2

COMMENT: 21) Please include permit number and permitted flow in the Table.

RESPONSE : See Table 3-1 and 3-2

COMMENT: 22) Please present the calculation of nutrient loads entering Lake O' the Pines from point sources in more detail.

COMMENT: 23) Please specify the relationship between the "gross" nutrient loadings from the point source discharges and the "net" nutrient loadings from point source discharges to the reservoir and/or explain the mechanism by which this relationship is determined.

RESPONSE : #22-23) (Insert following second para, Section 3 {Source Analysis})

Table 3-3 presents nutrient loads expected from the major point sources (>0.02 MGD) in the Lake O' the Pines watershed when operating at their respective maximum permitted discharge rates. As none of these facilities currently have nutrient limitations, the nutrient concentrations measured during the 1998 Intensive Survey were used with permitted flows to estimate maximum loads. Discharges into tributary impoundments (e.g., Welsh and Ellison Creek Reservoirs) are not included in this tabulation. Annual nutrient loads coming from these facilities (gross loads) would total 29,877 kg/year total phosphorus and 419,964 kg/year nitrogen. Reductions in phosphorus and nitrogen loads relative to the Intensive Survey results (Table 3-2) reflect the approximately 4.6 MGD discharge observed at the Mount Pleasant SW facility in August, 1998.

Figure 3-1 shows total phosphorus concentrations in Big Cypress Creek at Station 10308 and at Station 13631, the lowermost station in Segment 0403. The elevated phosphorus concentrations at Station 10308 during 1998-2000, weakly reflected at Station 13631, are likely related to excess discharges from the Mount Pleasant SW facility during that period. The differences in phosphorus concentration between the two stations represent a substantial 78% reduction, with average concentrations of 1.20 mg/l at 10308 and 0.26 mg/l at 13631.

Table 3-3
Major Point Source Nutrient Concentrations and Loads of Major Point Sources (≥ 0.200 MGD) Expected at Maximum Permitted Discharge

Source	Max. Permitted flow	Total Phosphorus		Total Nitrogen	
	(m^3/day)	mg/l	kg/day	mg/l	kg/day
Mount Pleasant SW	11,356.2	6.44	73.1	73.9	839.2
Mount Pleasant SE	11,015.5	0.241	2.6	23.1	254.4
Pittsburg – Sparks Branch	3,671.8	0.664	2.4	9.03	33.2
Pittsburg – Dry Creek	757.1	2.14	1.6	8.54	6.5
Daingerfield	2,649.8	0.54	1.4	5.72	15.2
Omaha	757.1	0.98	0.7	1.7	1.3
Source Total	30,207.5		81.8		1149.8

(replace para three through eight, Section 3)
Average annual nutrient loads at stations 10308 and 13631 were calculated by multiplying grab sample results by the monthly average flows for the months in which the sample was collected. Streamflow data was obtained for the USGS gage at Station 10308 and discharge at Station 13631 was calculated from the Station 10308 data by multiplying by the drainage area ratio. Monthly loads were averaged for each year, then multiplied by 12 to obtain an annual load. For the period 1979-2000, total phosphorus loads at Station 10308 averaged 112,824 kg/year, ranging from 4,370 kg in 1988 to 605,028 kg in 1994. At Station 13631, TP loads averaged 50,855 kg/year, with a low of 1,222 kg in 1979 and a high of 171,374 kg in 1993. The annual average phosphorus load at Station 13631 is 55% less than that at 10308. Although the difference in concentrations noted above might be ascribed to dilution by water of lower phosphorus content, the large reduction in load suggests assimilation or deposition during passage down Big Cypress Creek.

Nitrogen data is much more limited than that for phosphorus, with a particular paucity of measurements that correspond to available streamflow information. Recognizing the higher level of uncertainty, total nitrogen concentrations also vary substantially between these stations, averaging 12.01 mg/l at Station 10308 and 2.76 mg/l at Station 13631, a reduction of 77% (Figure 3-2). Nitrogen loads at the two stations average 2,490,614 kg/year at Station 10308 and 230,322 at Station 13631, a reduction of 91%.

The point source loads estimated in Table 3-3 provide annual estimates of 29,877 kg TP/year and 419,964 kg TN/year originating in the larger wastewater treatment plants in the Lake O' the Pines watershed. While the point sources in Mount Pleasant contribute 24% of the average phosphorus load observed at Station 10308, they account for only 16% of the average annual nitrogen load.

Application of SWAT (Soil and Water Assessment Tool) to simulate runoff and nutrient transport from the Lake O' the Pines watershed produced average annual loading estimates of 113,000 kg TP/year and 197,000 kg TN/year, without consideration of point source loads.[2] Natural, baseline, or landscape loads (e.g., existing land cover categories but without poultry litter or other fertilizer application) were calculated to average 18,200 kg TP/year and 75,400 kg TN/year.

The SWAT non point source estimates, like the point source loads calculated from the Intensive Survey data, or the maximum permitted discharges, are gross loadings deposited from the respective modeled land surfaces into the watercourses draining into Lake O' the Pines. Unlike the other major biologically active elements (carbon, hydrogen, oxygen, nitrogen and sulfur) phosphorus has no phases or compounds that are gases at ordinary temperatures and pressures. As a consequence, phosphorus introduced into an aquatic environment will remain there, and be potentially available for use by macrophytes and microbiota, until it is flushed out or buried in sediments beyond the depth of bioturbation. In the context of the Lake O' the Pines watershed, this implies that any phosphorus reaching the stream network will eventually be transported to the reservoir, assuming Big Cypress Creek is in steady-state equilibrium to the point at which it is affected by Lake O' the Pines backwater.[3] Although the reduction in average phosphorus load between Stations 10308 and 13631 demonstrated in the monitoring data appears to indicate that significant biological assimilation and sorption by fine-grained sediments are taking place in Big Cypress Creek, that data is subject to a low flow sampling bias that does not account for the transport of significant portions of the suspended and bed loads, which will carry the particulate phosphorus fraction. Water samples have generally been collected during periods of low to normal flow, whereas much of the actual transport of water, sediments and dissolved constituents takes place during high flow periods in response to rainfall events[4] We expect that, during low to

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[2] Ward, G. 2003. Application of SWAT to Basin-Scale Simulation of the Lake O' the Pines watershed. Technical Memorandum Submitted to TCEQ, Lake O' the Pines TMDL Project, February 2003.

[3] Gordon, N.D., et al.. 1992. Stream hydrology. John Wiley & Sons, New York.

[4] Allan, J.D. 1995. Stream Ecology, Structure and Function of Running Waters. Chapman and Hall, London, New York.

normal flow periods in Big Cypress Creek, phosphorus will accumulate in the stream, but will be transported downstream during high flow periods. These considerations lead us to the conclusion that the gross point and nonpoint source phosphorus loads (29,855 and 113,000 kg/year, respectively) are the appropriate net loads being delivered to Lake O' the Pines.

The nitrogen budget is not such a simple matter due to the variety of biological transformations it is subject to, and the circumstance that nitrogen may be both assimilated (nitrogen fixation) and lost (denitrification) as a result of biological processes in direct exchange with the atmosphere. During low and normal flow periods nitrogen, like phosphorus, will also tend to be assimilated and processed in Big Cypress Creek. The nitrogen, however will tend to be lost from the system through bacterial denitrification, which proceeds most rapidly in environments containing abundant organic material and having anaerobic and aerobic zones in close physical proximity, as at a sediment surface.[5] However, even the highest rates of denitrification reported for natural temperate waters cannot account for the nitrogen losses between stations 10308 and 13631 implied by the differences in monitored average annual loads, and would result in only a small (ca. 20%) reduction in the gross non point source load.[6] The difference may lie in the very limited Nitrogen data, and the particular paucity of measurements that correspond to available streamflow information (10 records at 10308, 14 records at 13631 during 1993-2000, only 4 in the same month at both stations).

Allocation of the loads entering Lake O' the Pines is summarized in Table 3-4. Big Cypress Creek was estimated to contribute about 80% of the total annual inflow to Lake O' the Pines, and about 88% of the total phosphorus load. This estimate of the importance of Big Cypress Creek contributions is consistent with the water quality conditions found to prevail in the upper and main reservoir basins, compared with the cove environments into which the minor tributaries flow.

Table 3-4
Net Nutrient Loads Entering Lake O' the Pines

	Total Phosphorus (kg/year)	Total Nitrogen (kg/year)
SWAT NPS Loads	113,000	197,000
Landscape Loads	18,200	75,400
Non-Point Source loads	94,800	121,600
Point Source Loads	29,877	336,000
Total Anthropogenic Loads	124,677	457,600
Total Loads	142,877	533,000

[5] Rheinheimer, G. 1991. Aquatic Microbiology. John Wiley & Sons, New York.
[6] Ford, T.E. (ed). 1993. Aquatic Microbiology; An Ecological Approach. Blackwell Scientific Publications, London, Boston.

COMMENT: 24) EPA requires TMDLs to analyze domestic discharges using the larger of either the maximum discharge allowed by the current permit or the discharge that would be needed to serve predicted populations. Please include these figures in the point source load calculations.

RESPONSE : See Table 3-1 and 3-2

COMMENT: 25) Please clarify the nature of the nutrient loads calculated by the SWAT model as being "gross" loadings at the point of discharge or "net" loadings to the reservoir. Please specify the relationship between the "gross" nutrient loadings from nonpoint sources and the "net" nutrient loading from nonpoint sources to the reservoir and/or explain the mechanism by which this relationship is determined.

RESPONSE : In SWAT the loads are computed as a land-use source, based upon soils, vegetation, season, precipitation, sunlight, air temp, etc., then further altered as a function of movement across the watershed surface, including effects of surface slope, soils, percolation, then combined with the same load calculation for other landuses to determine the load from a subwatershed. In the model, this is considered to be the load in the stream channel outlet from the subwatershed. The terms "gross" and "net" are not used in this context, and it's not clear to me where "gross" stops and "net" begins. In our SWAT modeling, we assumed no further alteration of the load in its traversal down the stream channel to Lake o' the Pines. Reality is that there would be two processes affecting the water column concentration of phosphorus: uptake by phytobiota, and exchange with sediments on the streambed. Unlike phosphorus, nitrogen may be lost to the system entirely through denitrification, or gained through nitrogen fixation. Neither pathway is likely to be substantial in Big Cypress Creek due to relatively short travel times to Lake O' the Pines. Biological uptake would represent a loss of dissolved phosphorus or nitrogen from the water column, but the organically bound nutrients would stay in the water column in the form of algal biomass, and eventually be deposited as organic detritus. The latter would be the net of loss due to sedimentation of sorbed phosphorus versus gain due to resuspension and mobilization from bed sediments. The bed sediments involved would be the very fine organics, clays and fine silts.

The latter is expected to be larger than the former. Indeed, except where the sediments are protected from high stream velocities, the sediment nutrients are expected to migrate downstream eventually. Although the cycle of sequestration and subsequent scour and transport probably occurs on a longer time scale on the floodplain than in the Big Cypress Creek channel, nutrients in this system can be assumed to eventually reach Lake O' the Pines. Our assumption to assume zero loss of phosphorus in the stream translates to neglecting true sequestration in the bed and floodplain sediments and temporary retention in biomass. The "net" load to the reservoir may therefore overestimated, and this overestimation is part of the implicit margin of safety.

COMMENT: 26) Please provide an assessment of atmospheric sources of nutrient loads to Lake O' the Pines.

RESPONSE : The atmospheric pathway has been found to be an important source of nitrogen compounds to a watershed. For phosphorus, while there is an atmospheric pathway, it is almost always minor, and negligible. For example, in the USGS SPARROW project, which is a thorough, detailed GIS-based evaluation of constituent loads into the nation's watercourses, including atmospheric pathways, Smith et al. (1997) state bluntly, "The atmosphere is assumed to be a negligible source of total phosphorus."

This fact notwithstanding, the runoff from Big Cypress watersheds includes any nutrient deposition on the watershed surface. The atmospheric load is therefore included in the nutrient concentrations in runoff in the automated water samples. The atmospheric load is also included implicitly, but not explicitly, in the model input specification. The SWAT-input parameters characterizing surface landuse (including vegetation) and soils (including surficial soils) are derived from field data and implicitly include all normal sources of nutrients to the landscape, one of which is the atmospheric pathway. Thus validation of the SWAT model implicitly includes validation of the atmospheric loading component. Unless we wished to consider a situation in which the atmospheric load is changed (which is not part of the present TMDL studies), there is no need to separate the atmospheric component and treat it as an independent input.

Atmospheric deposition of phosphorus in inland areas has been reported to commonly fall within the range of 10-100 $mg/m^{2*}year$, with the higher values associated with urban-industrial development and dust from aeolian erosion.[7] At the upper limit, a deposition rate of 100 mg/m^2*year would result in a total of 6847 kg/year of phosphorus added directly to Lake O' the Pines by precipitation and dry deposition, about 4.8% of the load from Big Cypress Creek. However, because of the general net transport of water downstream, only that portion of the deposition falling on the upper 3600 acre portion of the reservoir exhibiting low dissolved oxygen concentrations (21% of the surface area – effectively 1% of Big Cypress Creek loading) would be relevant to the problem addressed by this TMDL.

Nitrogen deposition in precipitation has been reported to average about 100 mg/m^2*year over the continental United States, and to range up to 350 $mg/m^2/year$ in the upper midwest. Dry deposition of ammonium and nitrate salts in the same region were reported to be even more important, bringing maximum observed atmospheric deposition rates up to 1000 g/m^2*year.[8] Other authors have indicated even greater atmospheric deposition potentials for nitrogen as nitrate concentrations in rainfall are reported to commonly fall into the range 0.4 – 1.3 mg/l (at an annual precipitation rate of 35 inches, deposition would range from 267 to 1156 mg/m^2*year), but no dry deposition rates were given.[9] Assuming a total atmospheric deposition rate for nitrogen compounds of 1500 mg/m^2*year implies an annual load to Lake O' the Pines of 102,707 kg, or nearly 20% of the Big Cypress Creek loading. Again, only a fraction of this load would seem relevant

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[7] Wetzel, R.G. 1983. Linmology. Saunders College Publishing, Philadelphia, Fort Worth.
[8] Wetzel, R.G. 1983. Linmology. Saunders College Publishing, Philadelphia, Fort Worth.
[9] Allan, J.D. 1995. Stream Ecology, Structure and Function of Running Waters. Chapman and Hall, London, New York.

to excessive nutrient conditions in the upper reservoir, although this magnitude of input is probably significant to the overall mass balance of nitrogen in Lake O' the Pines.

In addition to physical deposition of nitrogen compounds from the atmosphere, biological conversion of molecular nitrogen to ammonium ion (fixation), may be a significant source of nitrogen input to Lake O' the Pines during summer stratification. Nitrogen fixation during the summer may be carried out by blue-green algae (Cyanobacteria) in the aerobic epilimnion, by photosynthetic bacteria concentrated in the metalimnion, by heterotrophic bacteria in the anaerobic hypolimnion, and by benthic algae and bacteria, on shallow sediment surfaces within the euphotic zone. Aggregate rates of nitrogen fixation in lakes and reservoirs are reported to range from <100 to 800 mg/m^2*year, the higher value corresponding to an annual load of 54,777 kg added to Lake O' the Pines.[10]

[1] Wetzel, R.G. 1983. Linmology. Saunders College Publishing, Philadelphia, Fort Worth.
[1] Wetzel, R.G. 1983. Linmology. Saunders College Publishing, Philadelphia, Fort Worth.
[1] Allan, J.D. 1995. Stream Ecology, Structure and Function of Running Waters. Chapman and Hall, London, New York.
[1] Rheinheimer, G. 1991. Aquatic Microbiology. John Wiley & Sons, New York.

COMMENTS: 27) As discussed previously, the figures in the Table do not add up. Please correct the Table.

RESPONSE : Table(s) fixed

COMMENTS: 28) It is not clear how the discussion of the Refield ratio is useful to the analysis nor is the numerical information on which it is based presented in the report. Please provide further justification as to the purpose of the analysis and present the data on which the ratios were calculated.

RESPONSE : Paragraph removed from end of Section 3

COMMENTS: 29) Please explain the purpose of the "Linkage" section of the report.

RESPONSE : The Linkage Section of this report establishes the relationships between constituent loadings and the resultant water quality conditions in Lake O' the Pines.

COMMENTS: 30) Concentration values for nutrients should be reported in units of mg/l throughout the report.

RESPONSE : OK

[10] Rheinheimer, G. 1991. Aquatic Microbiology. John Wiley & Sons, New York.

COMMENTS: 31) The report states that total phosphorous concentrations average about 0.08 mg/l below SH155 and 0.217 mg/l in the headwaters of the reservoir. However, an average concentration of 0.9 mg/l for the entire reservoir was used the estimate the summer standing stock of total phosphorous. This appears to be too high. Please provide additional explanation for the assumed phosphorous concentration.

RESPONSE : (Insert at beginning of fourth paragraph in Section 4)
The upper reservoir is the direct receiving water for the nutrient loads carried by Big Cypress Creek (Table 3-4). Water quality monitoring data from the TCEQ TRACS database and that collected as part of the TMDL program indicated that phosphorus and nitrogen concentrations at Station 13631 have varied substantially over time (Figures 4-1 and 4-2). While total phosphorus averages 0.173 mg/l over the entire period of record, the 1997-2002 average shown in Table 4-2 reflects the high concentration event centered on January, 2000. Total nitrogen concentrations peaked slightly earlier (fall, 1999), but did not exhibit a unique event that substantially altered the long term average.

In Lake O' the Pines,…

(Replace sixth paragraph in Section 4)
A very rough estimate of the summer standing stock of total phosphorus and TKN (approximating total nitrogen) in Lake O' the Pines is presented in Table 4-3. Summer (May-September) nutrient concentrations in the epilimnion were based on the TCEQ TRACS and TMDL surface sample results for all Lake O' the Pines stations. Constituent concentrations in the epilimnion were calculated from surface grab samples from stations 10296, 16156, 10297, 17078, and 10300. Hypolimnion concentrations were based on bottom summer (May-September) samples collected at Stations 10296, 16156, and 13977. The boundry between the epilimnion and hypolimnion was assumed to occur at 5 m, giving an oxic water mass occupying over 80 % of the reservoir volume during summer stratification.[11] The physical characteristics of sediment cores collected from Lake O' the Pines stations in August, 1999 as part of a Clean Rivers Program special study are summarized in Table 4-3.[12] Sediment data is reported on a dry weight basis and includes a percent solids analysis. To calculate sediment constituents on an areal basis, one must also specify a sediment depth (in this case, 5 cm) and a sediment specific gravity. Two specific gravity numbers are used to span a reasonable range of sediment density. Table 4-4 presents the carbon, nitrogen and phosphorus content of those sediments based on subsamples taken from the surface and at 5, 10 and 20 cm depths. We assume that the phosphorus and nitrogen in the 0-5 cm surface layer in areas not isolated under a persistent hypolimnion is available for exchange with the epilimnion during the summer.

The estimates of atmospheric deposition and nitrogen fixation shown in Table 4-3 are based on the near maximum rates discussed in the preceeding section. Denitrification

[11] Texas Water Development Board. 1999. Volumetric survey of Lake O' the Pines. Hydrographic Survey Report, Austin, Texas.
[12] CRP. 2000. Targeted Monitoring in the Cypress Basin: Nutrient Study in Lake O' the Pines. Prepared for submission to TNRCC by Paul Price Associates, Inc. and Caddo Lake Institute, Austin, Texas.

was assumed to occur at a maximal literature rate (64 mg/m^2*day) for 100 days during summer on sediment surfaces under the hypolimnion.[13] These results indicate that phosphorus accumulated in Lake O' the Pines at a rate of 1938 mg/m^2 annually (132,677 kg/68471193 m^2) during the period monitored (1983-2002). The highest surface sediment phosphorus concentrations observed in Lake O' the Pines (ca.37,500 mg/m^3), would require the annual deposition of 3,538,053 m^3 of sediment, a layer 5 cm deep throughout the reservoir. This is equivalent to a sedimentation rate of 874 acre-feet/year, about three times the sedimentation rate estimated by the Texas Water Development Board, a high rate, but not impossibly so.[14] In spite of the large inputs of nitrogen, accumulation in Lake O' the Pines did not take place during the period monitored, instead the reservoir experienced an average net loss of total notrogen.

(…modify Table 4-2)

Table 4-2
Average Inflow and Summer Epilimnion Concentrations of Chlorophyll-*a* and Major Nutrients,1997-2002

Station Name	Dam*	Longview Intake	NETMWD Intake	Lone Star Landing	Big Cypress Inflow
Station Number	10296	16156	10297	10300	13631
Chlorophyll-*a* (µg/l)					
Average	8.12	8.00	14.02	14.42	
Standard Deviation	5.64	6.47	12.44	16.60	
n	23	13	13	13	
Total Phosphorus (mg/l)					
Average	0.069	0.042	0.121	0.130	0.289
Standard Deviation	0.101	0.065	0.217	0.061	0.302
n	23	13	13	12	23
Total Kjeldahl Nitrogen (mg/l)					
Average	0.626	0.564	0.819	1.019	2.623
Standard Deviation	0.264	0.162	0.153	0.220	2.750
n	24	13	13	12	23
N:P Ratio (g-atom basis)	20.1	29.7	15.0	17.4	20.1

*Data collected 1993 – 2002

[13] Ford, T.E. (ed). 1993. Aquatic Microbiology; An Ecological Approach. Blackwell Scientific Publications, London, Boston.
[14] Texas Water Development Board. 1999. Volumetric survey of Lake O' the Pines. Hydrographic Survey Report, Austin, Texas.

(…and add Table 4-3)

Table 4-3
Lake O' the Pines Nutrient Mass Flux

	TP	TN
Inflows (kg/year)	+142,877	+533,000
Dry/wet deposition and N fixation (up to kg/year)	+6,800	+150,000
Water – Epilimnion (kg)	23,004	182,838
- Hypolimnion (kg)	7,893	32,759
Sediment (kg, 0-20 cm)	289,222	754,826
Lake O' the Pines Total (kg)	320,119	970,423
Denitrification (up to kg/year)		-181,000
Outflows (kg/year)	-17,000	-780,000
Lake O' the Pines Net Annual Gain (Loss) (kg)	132,677	(278,000)

COMMENT : 32) Please include an explanation for the fact that there are two sets of sediment data presented.

RESPONSE : Sediment data is reported on a dry weight basis and includes a percent solids analysis. To calculate sediment constituents on an areal basis, one must also specify a sediment depth (in this case, 5 cm) and a sediment specific gravity. Two specific gravity numbers are used to span a reasonable range of sediment density.

COMMENT : 33) Please present the data from which the nitrogen-phosphorous ratios were calculated

RESPONSE : (Replace 7th paragraph Section 4)
Paired values of total nitrogen and total phosphorus collected during 2000-2002 are used in Table 4-6 to characterize the summer epilimnitic N:P ratios in Lake O' the Pines. Total nitrogen and total phosphorus represent the entire macronutrient pool of the summer reservoir waters, including the inorganic, immediately available nutrients, nitrogen and phosphorus bound to non-living organic and inorganic particulate material which is more slowly available, and that contained in the living tissue of primary producers and microconsumers, which together are performing the bulk of the observed reservoir metabolism. The living tissue fraction, particularly rapidly growing plankton populations, tends to exhibit a N:P ratio of 16:1 on an atom for atom basis, and is expected to take up those nutrients in that ratio for growth. What we find is that it is phosphorus that is in short supply in this system; the N:P ratios average 127, ranging from 32 to 203, a substantial oversupply of nitrogen relative to the amount of phosphorus present. Considering the values observed at the individual reservoir stations reveals a gradient in the N:P ratio consistent with our hypothesis that phosphorus is being

assimilated, driving metabolic activity resulting in violations of the dissolved oxygen criteria, and being deposited through sedimentation during transport through the reservoir.

Considering just inorganic nitrogen, N:P ratios average 31, the same pattern emerges, one that reflects the preferential assimilation of phosphorus as the nutrients move down the reservoir axis from their primary source in Big Cypress Creek.

Examination of the N:P (and carbon) ratios in the sediment samples shows that, in contrast to the water column, sediment phosphorus is abundant relative to nitrogen, the situation seen in the external nutrient sources, and represents the endpoint of phosphorus assimilation and sequestration by burial in deep sediment. It is significant that the phosphorus content of the sediments at the upper stations (10300 and 10297) are two to three times the levels in the lower stations, reflecting the more intense assimilation and sedimentation taking place at those locations. Net export of nitrogen in dam releases, and losses due to denitrification reflect the low N:P ratio of the sediments.

(Replace Table 4-6)

Table 4-6

Summer Epilimnion Nitrogen-Phosphorus Ratios in Lake O' the Pines

Station	Date	TN	TP	mg-atN/l	mg-atP/l	N:P
10300	7/24/02	1.4272	0.098	0.101943	0.003161	32
17087	6/20/02	1.135	0.069	0.081071	0.002226	36
			SH 155			
10297	7/19/00	0.928	0.02	0.066286	0.000645	103
10297	8/23/00	0.8666	0.01	0.0619	0.000323	192
			Lower Reservoir			
16156	8/23/00	0.7632	0.01	0.054514	0.000323	169
16156	6/20/02	1.057	0.015	0.0755	0.000484	156
10296	8/23/00	0.9184	0.01	0.0656	0.000323	203
10296	7/24/02	0.606	0.01	0.043286	0.000323	134
			Cove Stations			
16448	6/20/02	0.847	0.011	0.0605	0.000355	171
16450	6/20/02	0.6978	0.02	0.049843	0.000645	77

COMMENTS : 34) Please present the data and provide a graphic to support the discussion of paired values for chlorophyll-*a* and total phosphorous.

RESPONSE : (Insert Table 4-7, and reference to it)

Table 4-7

Paired Summer (May-September)Total Phosphorus (mg/l) **and Chlorophyll a** (μg/l)

Measurements From Lake O' the Pines

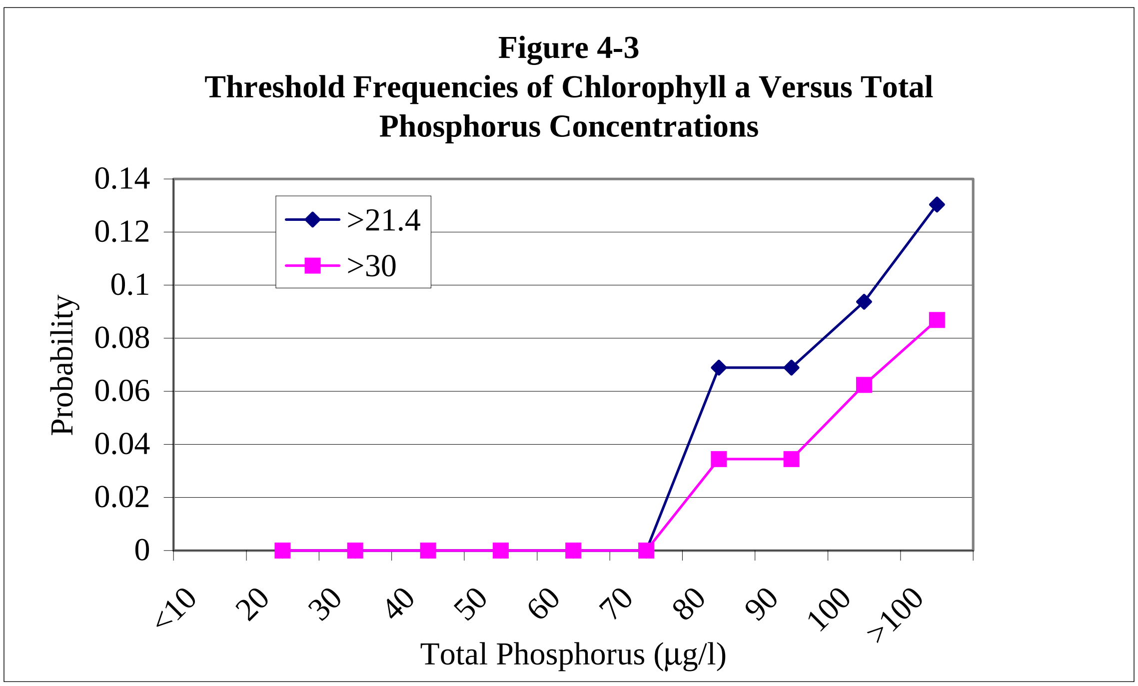
Station	Date	TP	Chl a
10296	09/16/97	0.03	12.5
10296	08/24/98	0.03	2.94
10296	09/27/99	0.03	4.27
10297	08/12/97	0.11	21.3
10297	06/29/99	0.06	6.34
10297	09/27/99	0.05	4.98
10297	07/31/01	0.08	26.4
10297	05/14/02	0.08	18.7
10297	08/21/02	0.08	35.6
10300	09/16/97	0.1	33
10300	05/11/98	0.07	3.47
10300	07/13/98	0.13	4.2
10300	06/28/99	0.28	2.49
10300	09/09/99	0.18	6.2
10300	09/27/99	0.14	10.1
10300	07/25/00	0.12	2.99
10300	07/31/01	0.15	31.2
10300	05/14/02	0.18	13.4
10300	08/21/02	0.16	58.5
13631	08/22/02	0.078	9.3
13977	05/18/99	0.13	13
16156	06/28/99	0.02	8.65
16156	09/27/99	0.04	4.27
10296	07/19/00	0.02	13
10296	08/22/02	0.016	7.3
10297	07/19/00	0.02	16
10297	07/13/01	0.5	10.7
10297	07/24/02	0.031	4
10297	06/20/02	0.063	3.3
10297	08/22/02	0.062	5.4
10300	07/24/02	0.098	8
10300	06/20/02	0.063	9.3
13631	07/19/00	0.04	3.3
13631	07/13/01	0.115	18
13631	07/24/02	0.098	9.3
13631	06/20/02	0.063	17

Table 4-7 continued

16156	07/19/00	0.25	15
16156	06/20/02	0.015	3.3

16156	08/22/02	0.022	6.7
16448	07/24/02	0.196	2.7
16448	06/20/02	0.011	3.3
16449	07/24/02	0.012	4
16449	06/20/02	0.019	2.7
16868	06/20/02	0.052	6.7
17087	07/24/02	0.068	5.3
17087	06/20/02	0.069	13

(Insert Figure 4-3 and reference)



COMMENTS : 35) As discussed previously, it is not clear how the Vollenwieder calculations were made. Please provide additional information on the calculation.

RESPONSE :) (Replace Vollenweider discussion)

To establish a quantitative relationship between phosphorus loading and concentrations in Lake O' the Pines, we can employ a simple empirical model developed by Vollenweider to relate landscape loading to lake or reservoir total phosphorus concentration:[15]

$$TP\ (mg/m^3) = \frac{\text{load}\ (mgTP/m^2*year)}{Z\ (\rho + \sigma)}$$

Where load refers to areal loading, or the mass of annual total phosphorus loading (from the SWAT simulation plus the point source load, Table 3-4), divided by reservoir area:

$$= (113{,}000 + 29{,}877\ kgTP/year)*1{,}000{,}000/68{,}471{,}193\ m^2$$
$$= 2087\ mgTP/m^2*year.$$

Z = average depth (reservoir volume/reservoir area, 4.34 m),[16]
ρ = flushing rate (reservoir volume/annual inflow, 1.89), and
σ = sedimentation coefficient (10/Z)

$$TP_{total} = 2087/4.34(1.89 + 10/4.34)$$
$$= 115\ mg/m^3\ \text{or}\ 0.108\ mg/l$$

The estimated load gives excellent agreement with the observed total phosphorus concentrations in the reservoir, recognizing that the model gives an average value over the phosphorus gradient characteristic of Lake O' the Pines. Total phosphorus averaged 0.114 mg/l using all data 1997-2002 and setting censored values to their respective detection limits. When censored values are set to zero, the average falls to 0.096 mg/l. The SWAT landscape load (18,200 kg/year, or 266 mg/m^2*year) can be used to examine the lower limit of average phosphorus concentration potentially achievable in Lake O' the Pines (without human activity in the watershed – not an actual, feasible lower limit):

$$TP_{Natural} = 266/4.34(1.89 + 10/4.34)$$
$$= 14.6\ mg/m^3\ \text{or}\ 0.015\ mg/l$$

To minimize the probability of algal blooms (either planktonic or periphytic), it will be desirable to reduce the average total phosphorus concentration in the upper reservoir to below 0.07 mg/l. Given that the current reservoir summer average is about 0.095 mg/l and the upper reservoir stations average about 0.125 mg/l, an approximately 50% reduction in average total phosphorus concentration (to 0.0475 mg/l) would be required. Solving the Vollenwieder model for the appropriate load gives:

$$Load_{desired} = TP*Z(\rho + \sigma)$$
$$= 47.5\ mg/m^3*4.34(1.89+10/4.34)$$
$$= 865\ mgTP/m^2*year\ \text{or}\ 59{,}200\ kg/year$$

This equals a reduction in the existing total phosphorus load by 83,677 kg/year, or 58%

[15] Cooke, D.G., et al. 1993. Restoration and Management of Lakes and Reservoirs. Lewis Publishers, Boca Raton.
[16] Texas Water Development Board. 1999. Volumetric survey of Lake O' the Pines. Hydrographic Survey Report, Austin, Texas.

(142,877 – 59,200 = 83,677 kg/year).

COMMENTS : 36) Please discuss the uncertainty associated with the analytical approach to the TMDL for the Lake O' the Pines (i.e., the QUALTX model, SWAT model, Vollenwieder model) more completely in this report.

RESPONSE : has been revised

COMMENTS : 37) The report is incorrect in stating that Segment 0404 was removed from the 303(d) list as a result of a change in the aquatic life use. Please correct the statement.

RESPONSE : has been revised