

**NUMERICAL STANDARD ON TOTAL PHOSPHORUS
FOR SCENIC RIVERS IN OKLAHOMA**

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INTRODUCTION

This document was prepared for Gerald Hilsher, Commissioner of OSRC; Save the Illinois River, Inc. (STIR); and Concerned Citizens for Green Country Conservation (CCGCC).

On December 18, 2001 the Oklahoma Scenic Rivers Commission unanimously passed a resolution to recommend to the Oklahoma Water Resources Board that a numerical standard for total phosphorus (TP) of 0.020 milligram per liter (20 microgram per liter) be adopted for the Scenic Rivers of Oklahoma. This document is part of the scientific information that fully supports this recommendation and emphasizes the urgent need for the adoption and enforcement of that standard.

The use of total phosphorus as a limiting nutrient in the growth of excessive algae and the need to adopt measures to reduce the total phosphorus in threatened waters around the world has long been recognized. (1,2) In 1967 the sewage discharges into Lake Washington were collected and diverted to restore and protect the water quality of that lake. The success of that action to reduce total phosphorus has been well reported. (3,4) In 1978 the Tahoe-Truckee Wastewater Treatment plant was placed on line with a discharge limit on total phosphorus of 0.15 milligram per liter. A wastewater treatment plant in Northern Virginia met a discharge limit for total phosphorus of 0.1 milligram per liter more than a decade ago. In 1984, considered a year of typical performance, the median effluent quality on total phosphorus for this plant was 0.03 milligram per liter. (5) These are some of the numerous examples of actions taken in other areas of the United States to protect recreational waters from phosphorus pollution.

At this time the State of Oklahoma has not set numerical limits for total phosphorus on any of the surface waters of the state. Nutrient overload and the associated problems of eutrophication are well established in many of the "clear" streams and lakes of Eastern Oklahoma. (6,7,8) The public health hazards associated with eutrophication and hypereutrophication of surface water have also been reported. (9,10) The six Scenic Rivers are considered one of the important water resources of the State. They need our special efforts to reverse the nutrient pollution that is now limiting their uses.

Numerous sources of scientific information and carefully collected data are available for use to determine the proper concentration of total phosphorus that will protect the Scenic Rivers. In brief, the information and data are clear that total phosphorus must be limited to a value in the range of 10 to 20 microgram per liter to assure that the high quality of the water in our Scenic Rivers is restored and maintained. The adoption of a limit of 20 microgram per liter as an instream numerical standard is recommended. This level of total phosphorus would improve the current water quality and provide time to further assess the special conditions of the Scenic Rivers of Oklahoma to provide the option to "fine tune" the need should lower levels be required.

Some of the important scientific information and data used in determining the needed level of TP are: a)--water quality reported for rivers and streams (11), b) the levels of TP in lakes that have been successfully restored (4), and c) the direct determination of the TP levels in clear streams which provide control of the algal growth (12, 13).

In addressing the question of what level of TP is required to protect the Scenic Rivers it is also appropriate to ask the related question of what level of TP is required to protect the downstream uses of the waters. For example, what level of TP is needed to protect the Illinois River and then what level is needed to protect Lake Tenkiller?

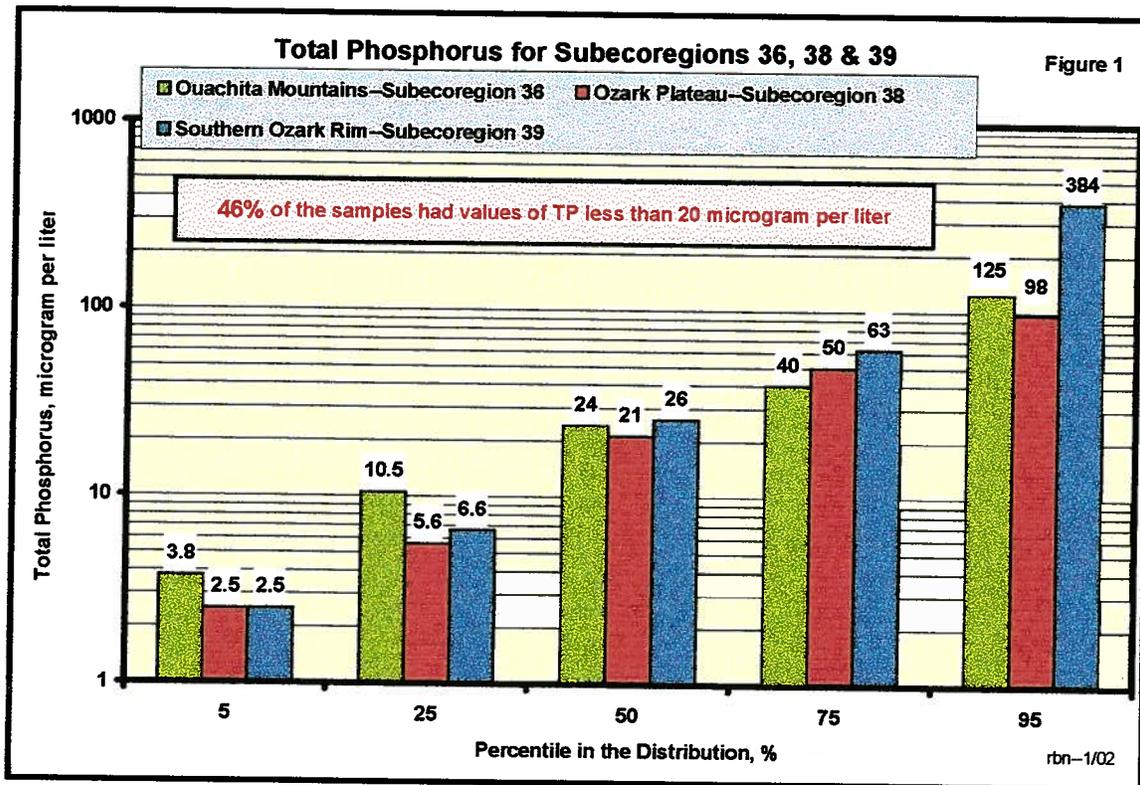
**DATA PRESENTATION AND ANALYSIS FROM
NUTRIENT ECOREGIONS**

In December 2000, the EPA published data and methodology for use in determining the nutrient levels needed to protect the water quality in rivers and streams in Ecoregion XI. (11) This is a region consisting of 8 Subcoregions. Three of the Subcoregions--36, 38, and 39-- are directly reflective of the conditions that should be used for reference in establishing the needed conditions for the Scenic Rivers of Oklahoma. Subcoregion 36 consists of the Ouachita Mountains in Oklahoma and Arkansas. Subcoregion 38 consists of the Ozark Plateau area of Missouri, Oklahoma and Arkansas. Subcoregion 39 consists of the Southern Rim of the Ozark Mountains and is in Arkansas and Oklahoma. Water samples were collected from 437 streams and rivers over the decade of 1990-99. A summary of the distribution of the streams and the sampling over the Subcoregions is shown in the following Table I.

TABLE I--THREE SELECTED SUBCOREGIONS OF ECOREGION XI				
	36	38	39	TOTAL
Number of Named Streams	112	67	258	437
Number of Stream Sample Stations	185	117	560	862
Number of Records of Total Phosphorus	3390	1644	8166	13200

It is clear from the information in the table that the database is large and covers many streams and rivers over the sampling period of 1990-99 for all four seasons--fall, winter, spring and summer. In the following graphical presentation of the data and the analysis, the three Subcoregions are kept separate to highlight any differences.

Figure 1 shows the distribution of the sample analyses for all three of the Subcoregions. The distribution of the data shows that the streams do not reflect pristine or minimally impacted conditions when over 25 percent of the data have total phosphorus concentrations greater than 40 microgram per liter.



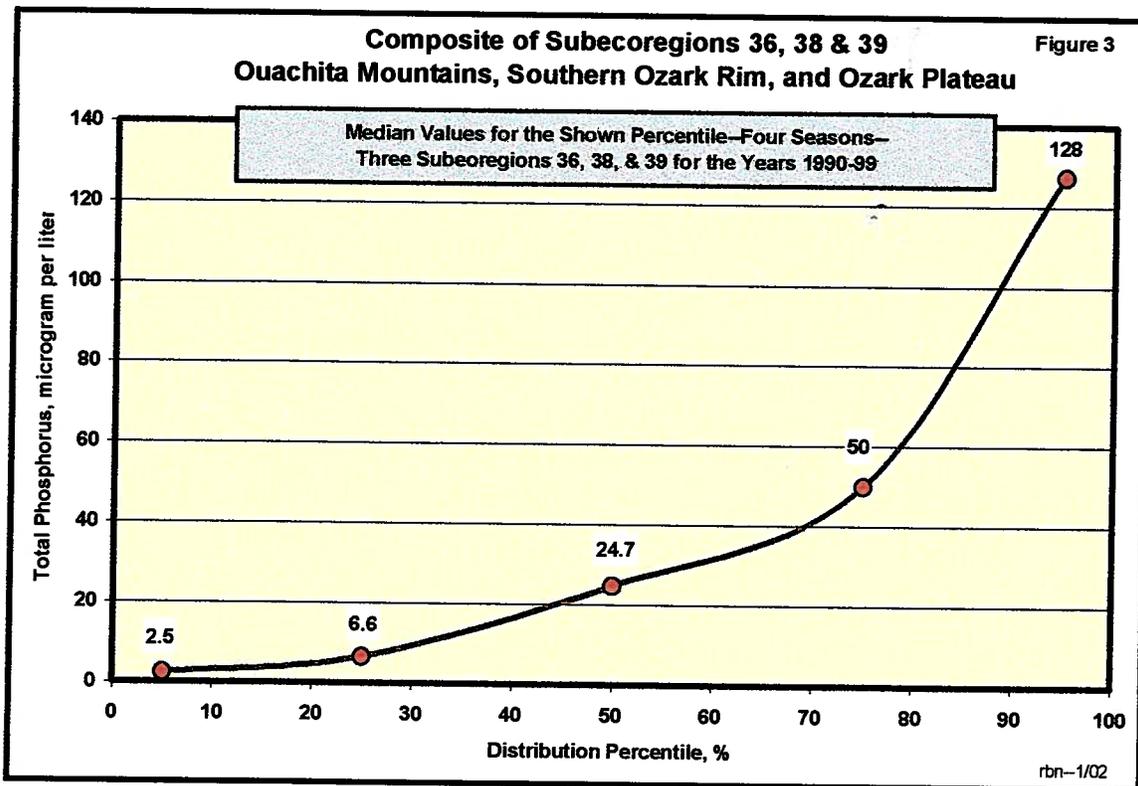
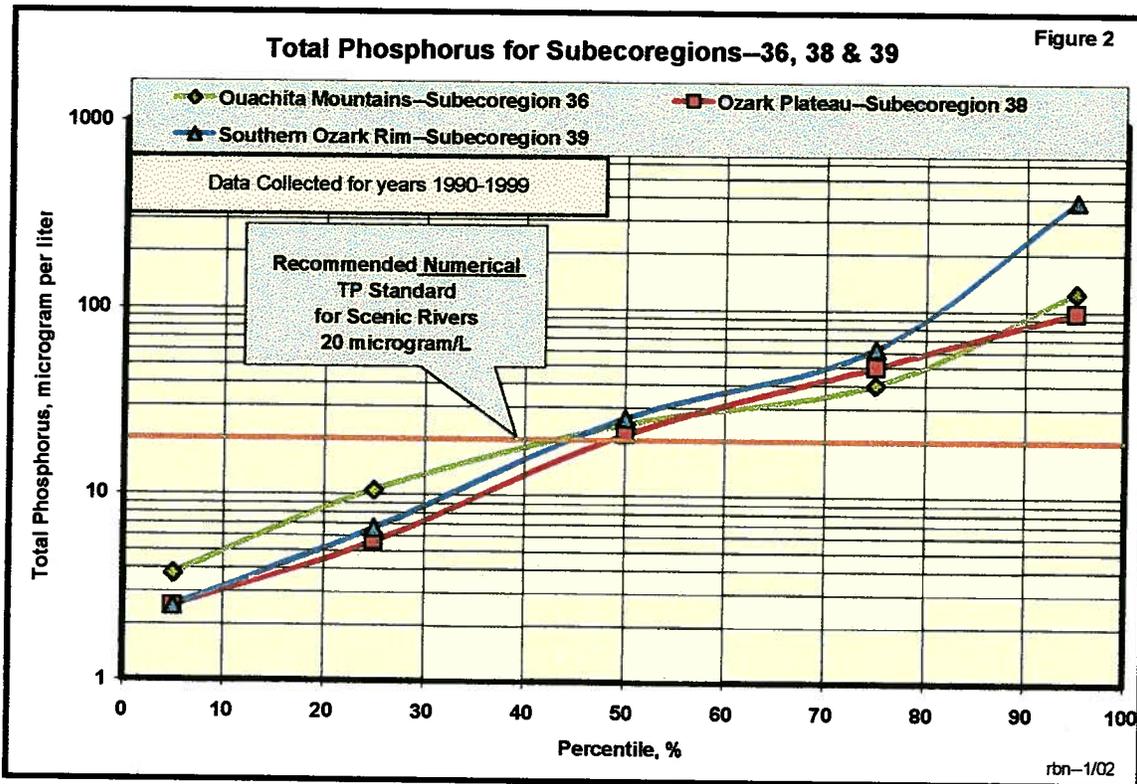
In addition, the rivers and streams in each of the Subcoregions follow the same general pattern. The most notable difference in the distributions is for Subcoregion 36 at the low concentrations. There, significantly higher values were obtained.

The most important observation that can be made from the figure is that 46 percent of all of the data collected is below 20 microgram per liter, the value recommended for adoption as a standard for the Scenic Rivers of Oklahoma. Figure 2 shows the same point by comparing the recommended standard with the data from each of the three Subcoregions.

Figure 3 shows a composite of the data from all three of the Subcoregions.

Using one of the two methodologies proposed by the EPA for selection of reference criteria for nutrients, the value of 6.6 microgram per liter would be selected as the reference condition for the streams in this area. For comparison, the reference condition for the Aggregate Nutrient Ecoregion XI is 10 microgram per liter. The area included in Ecoregion XI is the three Subcoregions presented above plus five additional Subcoregions located in the Appalachian Mountains.

The two methodologies recommended by the EPA for selection of the reference criteria for nutrients are:



First Method--Choose the upper 25th percentile (75th percentile) of a reference population of streams. This is the preferred method to establish a reference condition. The 75th percentile was chosen by EPA since it is likely associated with minimally impacted conditions, will be protective of designated uses, and provides management flexibility.

When reference streams are not identified as in the present situation for our Scenic Rivers, then the second methodology is adopted.

Second Method--Determine the lower 25th percentile of the population of all streams within a region. The 25th percentile of the entire population was chosen by EPA to represent a surrogate for an actual reference population. Data analyses to date indicate that the lower 25th percentile from an entire population roughly approximates the 75th percentile for a reference population. Case studies have been conducted to present evidence for this methodology.

All of the data for Aggregate Nutrient Ecoregion XI and each of the Subcoregions show that the reference concentration for total phosphorus is in the range of 5.6 to 10.5 microgram per liter. That same range is represented in the three Subcoregions--36, 38 & 39--that are most reflective of the conditions of the Oklahoma Scenic Rivers. One way to put these concentrations into perspective is to consider that they are the concentrations of total phosphorus where it is assured that maximum biodiversity and beneficial uses are maintained. In addition, there is no shift in either the flora or fauna of the rivers and streams as a result of excessive nutrients.

It should especially be noted that the recommended standard for total phosphorus of 20 microgram per liter is much higher than any reference condition within the above range--5.6 to 10.5 microgram per liter. In selection of the recommended standard of 20 there is some risk that this higher concentration of total phosphorus will adversely affect the conditions of the Scenic Rivers. We must rely on other studies to help assure that a value of 20 can be safely adopted as a standard.

A corresponding database on lakes and reservoirs in the Aggregate Nutrient Ecoregion XI was developed. Using the same methodology as presented above, the total phosphorus concentration for a reference condition for lakes and reservoirs is 8 microgram per liter. This is a reference value that would be applicable to downstream uses such as in Lake Tenkiller.

**Clark Reference--Nutrient Concentrations and Yields in
Undeveloped Stream Basins of the United States (14)--**

One method reported as being considered by some of the Staff of the OWRB for the determination of a standard for the Oklahoma Scenic Rivers is based on the Clark Reference. (14) As I understand the method would use the 75th percentile of the data presented in the reference, which is 37 microgram per liter. The flaw of using this method with this data as a basis for determining a standard for TP in our area is that the variations in the factors controlling the TP levels do not match the conditions in Oklahoma where

the subject scenic rivers are located. Also, the data are relatively sparse--representing only 85 sites over the entire United States for the years of 1990-95. A very critical factor against this method is that the data also include basins in the Western United States where higher levels of TP are found as a natural process of the geology in that area.

In contrast, the information presented in EPA 822-B-00-020 is more extensive and can be tailored to individual regions of the country giving a far more scientific basis for the determination of a TP standard. (11) For example, the Subcoregions 36, 38 and 39 alone represent 437 streams sampled over the time period of 1990-99 and all are located in Oklahoma, Missouri and Arkansas. None of these sample sites included the high phosphorus surface geology of the West. An area with naturally high levels of phosphorus would not be representative of the conditions of Oklahoma's Scenic Rivers.

TOTAL PHOSPHORUS LEVELS REQUIRED FOR CONTROL OF ALGAL GROWTH

A study was conducted on the Clark Fork River in Montana to determine the concentration of nutrients required for control of benthic chlorophyll to an acceptable level for the recreational uses. (13) The factors dictating the need to control the levels of algae for the Clark Fork River have many of the same characteristics that are applicable to the Scenic Rivers of Oklahoma. The Clark Fork has high value recreational activities that depend on the control of the algae. The sources of the nutrients are both point sources and non-point sources that will require actions to limit their impact. Therefore, there were extensive efforts made to collect background data on specific causes of the excessive growth of algae for this specific river. A corresponding effort was made to adapt the results of over 200 studies worldwide to forecast the levels of nutrients required to control the algal growth.

The results of the extensive research efforts are that the level of total phosphorus forecasted that would control algal growth, based on the worldwide studies, was 35 microgram per liter. Actual levels of total phosphorus which were measured in portions of the Clark River where algal growth was controlled to acceptable levels was 20.5 microgram per liter.

An additional finding of the study was that the most useful parameters for the forecasting of the control of algal growth were total nitrogen and total phosphorus. The numerous other parameters were not statistically significant in forecasting control. This is a very important finding since we often hear the cry for more time to measure more "scientific data" before standards are set, even when the need is urgent.

For the Clark Fork River, the data are clear that a concentration of 20.5 milligram per liter controls the growth of algae to acceptable levels for the recreational uses of the river. This is a good indicator that the algal growth in the Scenic Rivers can be controlled in a similar manner. This is good evidence for the standard of 20 microgram per liter for Oklahoma's Scenic Rivers.

LAKE RESTORATION AND PROTECTION

Over the past four decades many lakes and reservoirs have been restored and protected from excessive enrichment with nutrients. These results can be used to help determine the concentrations of total phosphorus that will result in the control of algal growth to obtain and maintain full biodiversity and all beneficial uses, especially recreational activities. (4) One of the most reported case histories was the restoration of Lake Washington by the collection and diversion of the sewage discharges. (3, 4). It was reported that in 1957 the sewage effluent was 57 % of the phosphorus load to the lake. Because of the impact on the state of the lake, it was decided to divert the sewage effluent around the lake and the work started in 1963 and was completed in 1968. The impact on the condition of the lake was very dramatic and the results were apparent very soon after diversion started. Figure 4 shows the historical deterioration in the condition of the lake and its recovery.

The first point from the case history is that the recovery of the lake was more rapid than is usually seen. This is due to the fact that the phosphorus pollution occurred only for a very short time before the sewage was diverted. This prevented the buildup of a large internal supply of phosphorus to continue to recycle after the input was limited. Second, the water in the lake has a short residence time and is therefore replaced frequently. This allows the former phosphorus laden water to be displaced rapidly. All of the three parameters measured--TP, chlorophyll a, and water transparency--reflected the deteriorating condition of the lake before the diversion of the sewage effluent was undertaken. The same three parameters tracked the recovery of the Lake.

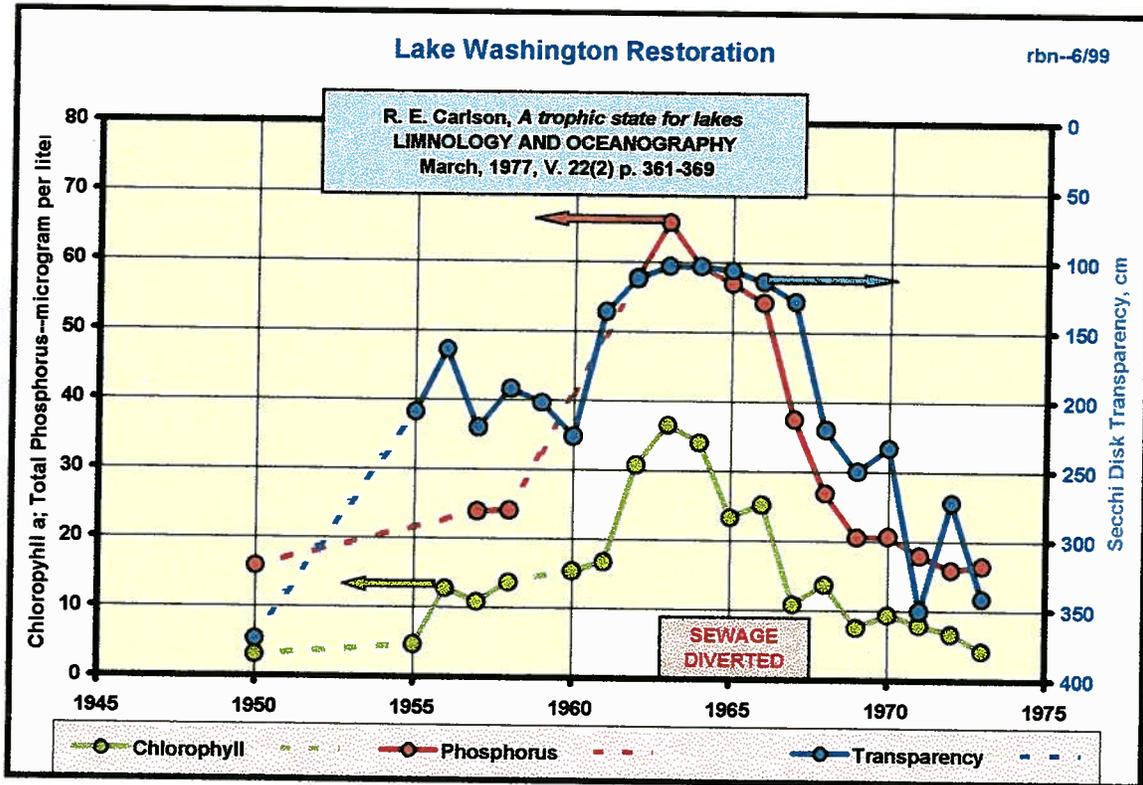
The water quality in Lake Washington was restored when the concentration of total phosphorus reached a level of 15 to 20 microgram per liter.

In considering the TP levels and the benefits of achieving low levels, the experience of Lake Washington should be expanded at this point. After the sewage was diverted, the TP levels declined to a 7-year mean of 19 microgram per liter. Subsequently, the level of TP stayed at about this level, yet the Secchi disk transparency more than doubled, reaching nearly 7 meter. This further increase in clarity was attributed to the return of *Daphnia* and its dominance of the zooplankton. The reduction in TP had decreased the occurrence of blue-green algae (*Oscillatoria*) and its interference with the filtering process of *Daphnia*. Thus there can be synergistic benefits in the low levels of TP in benefiting nature's biological control of the algal growth in healthy lakes and streams. (4)

Many other examples of the restoration of lakes and reservoirs are available. In general, when the starting condition of the lake is not too deteriorated so that the efforts to control total phosphorus concentration results in lowering the value to a level of 10 to 20 microgram per liter, then the results are considered an unqualified success.

The lessons to be adopted from the work done to restore lakes and reservoirs is that total phosphorus concentrations in the range of 15 to 20 are important to achieve high levels of beneficial uses in waters used for recreation. This fact has been clearly recognized for more than three decades.

The science is already available to show that decreasing the concentration of total phosphorus to a level of 15 to 20 microgram per liter would produce dramatically improved results for Lake Tenkiller.



Another, closer to home, case history is now in the making. Missouri is working to restore the water quality in Lake Taneycomo by limiting TP. As part of that effort the discharge permit for the wastewater treatment system at Hollister has a TP limit of 0.5 milligram per liter, the most strict discharge permit in Missouri in this aspect. At the time--in 1999, the level of TP in the lake had been limited to about 40 microgram per liter and at that level had not had the desired affect on the limit of algal growth. (19) With the close interrelationship of TP with the concentrations of Chlorophyll a, it is clear that further reduction of TP will continue to have direct benefit in reducing the algal growth. If a concentration of 20 microgram had been achieved, the lesson of Lake Washington would predict that great improvement in the condition of Lake Taneycomo could be expected.

**TECHNOLOGY CURRENTLY AVAILABLE FOR ACCOMPLISHMENT
 OF RECOMMENDED TOTAL PHOSPHORUS STANDARD**

Wastewater Treatment

Wastewater treatment is one of the key technologies needed to successfully limit the total phosphorus in surface waters. In reaching low concentrations of total phosphorus, both the technologies of biological phosphorus removal and chemical precipitation coupled

with efficient filtration are very important. The performance levels of 0.1 milligram per liter can be consistently achieved in many of the technologies. (5, 15) In some specific technologies the use of chemical precipitation and high quality filtration is consistently achieving an average concentration of total phosphorus of 0.03 milligram per liter.

For illustration of this point, the Upper Occoquan Sewage Authority Regional Water Reclamation Plant is a 15 million gallons per day advanced wastewater treatment facility that treats commercial wastewater to extremely high levels for discharge to the Occoquan Reservoir, the principal water supply reservoir in Northern Virginia. The permit limit on total phosphorus for the facility is a weekly average of 0.1 milligram per liter. In 1984, considered a typical performance year, the facility performance on total phosphorus was 0.03 milligram per liter.

For example, if such a performance capability were now available at the Fayetteville wastewater plant then the total phosphorus in that discharge could be reduced by approximately 90 percent. Since the discharge permit for Fayetteville is currently 1 milligram per liter for total phosphorus, significant phosphorus removal is already being required. My point is that even with the current level of phosphorus removal from the discharge, there is technology available to further decrease the discharge of phosphorus by 90 percent. And, that technology has been demonstrated in full-scale facilities for two decades.

The performance capability demonstrated by the Upper Occoquan Sewage Plant would result in discharge of total phosphorus of one-fourth pound for each million gallons of water treated. Currently, it is estimated that Fayetteville is discharging 2 to 3 pounds of total phosphorus per million gallons of treated water.

Management of Non-point Sources

Technology to limit total phosphorus from non-point sources is another key capability that has been studied for many years and is now being updated into improved management techniques. (7, 8, 16, 17) Briefly the current status of the technology is to identify the critical sources of phosphorus as the combined occurrence of a source of phosphorus and a transport mechanism. Once the critical sources are identified, then a wide range of options for intervention can be considered. (17) In general, areas where phosphorus has been land applied as commercial fertilizer or animal manure in amounts needed to support plant growth, the impact on surface waters is minimal. However, where phosphorus has been applied in great excess, phosphorus pollution of the nearby streams can be expected. In these cases the phosphorus is transported both in association with particles and as the water-soluble form.

Constructed Wetlands

Wetlands can be effective in improving the quality of the water from both discharges from point sources as well as from non-point sources. (16, 18) Although surface flow wetlands are most studied, a lot of research is currently being conducted on the use of constructed subsurface flow wetlands. In Oklahoma, some subsurface wetlands were improperly constructed using a reactive substrate--crushed limestone. These applications

caused the flow channels to change within the wetland resulting in unacceptable performance. These systems have been removed and this experience causes some reluctance for installing new wetlands in applications where they could be effective. (19)

<u>SUMMARY TABLE</u>	
INFORMATION SOURCE	TOTAL PHOSPHORUS microgram per liter
EPA Reference Criteria for Streams and Rivers in Subcoregions 36, 38 & 39	5.6 to 10.5
EPA Reference Criteria for Streams and Rivers in Aggregate Nutrient Ecoregion XI	10
EPA Reference Criteria for Lakes and Reservoirs in Aggregate Nutrient Ecoregion XI	8
Clark Fork River Case Study--Measured Result	20.5
Model Forecast from 200 Studies Worldwide	35
Lake Restoration Results--Lake Washington	15-20
OSRC Recommendation	20

CONCLUSIONS

- 1-- It is recommended that a concentration of total phosphorus of **20** microgram per liter be adopted and enforced as a numerical standard for the Scenic Rivers of Oklahoma.
- 2-- EPA recommended reference criteria for total phosphorus for rivers and streams in Nutrient Ecoregion XI, which includes Subcoregions 36--the Ouachita Mountains, 38--the Ozark Plateau, and 39--the Southern Rim of the Ozark Mountains is **10** microgram per liter, significantly below 20 microgram per liter.

- 3-- Reference Criteria for total phosphorus for rivers and streams in Subcoregions 36, 38 and 39 range from **5.6** to **10.5** microgram per liter, significantly below 20 microgram per liter.
- 4-- EPA recommended reference criteria for total phosphorus for lakes and reservoirs in Nutrient Ecoregion XI is **8** microgram per liter, significantly below 20 microgram per liter.
- 5-- Studies of restored lakes where nutrient pollution has been diverted show levels of total phosphorus needed for full support of lake uses to be about **15** to **20** microgram per liter.
- 6-- Direct measurement of total phosphorus required to control excessive algal growth in the Clark Fork River of Montana shows **20.5** microgram per liter. Computer models developed from over 200 studies from around the world forecasted that a level of **35** microgram per liter would be adequate.
- 7-- A wide range of technologies is available and demonstrated which can achieve the recommended level of total phosphorus required for protection of the Scenic Rivers of Oklahoma. These systems have been successfully operated for over a decade and many for much, much longer.

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