Comments on

Lake Shaokatan Phosphorus Total Maximum Daily Load Report Prepared for the Yellow Medicine River Watershed District 2009

Prepared by

David J. Schuler Schuler Environmental Engineering, 12/02/2009

Comments submitted by

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Prepared for

Minnesota Agricultural Water Resources Coalition

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The Minnesota Agricultural Water Resources Coalition requested that we conduct a review of the Lake Shaokatan Phosphorus Total Maximum Daily Load (TMDL) Report prepared for the Yellow Medicine River Watershed District 2009 by David J. Schuler, Schuler Environmental Engineering, dated 12/02/2009. With Dr. G. Fred Lee's more than five decades of work on the water quality impacts of excessive input of phosphorus to waterbodies and his experience in the development of TMDLs for agricultural runoff sources, we have reviewed the TMDL report and related documents. Our comments on the adequacy and reliability of that report to serve as the basis for implementation of a TMDL to control excessive fertilization of Lake Shaokatan are presented in this report.

Overall Findings

From our experience in conducting studies on many waterbodies to establish allowable phosphorus loads to control excessive planktonic algal growth water quality impacts, it is our finding that the Schuler phosphorus TMDL report does not provide an adequate or reliable technical basis for the establishment of a TMDL to control the input of phosphorus from Lake Shaokatan's watershed to achieve the Minnesota Pollution Control Agency (MPCA) TMDL water quality targets for that lake.

- The studies that served as the basis for developing the proposed total phosphorus loading limit of 1537 kg P/yr do not adequately or reliably identify, characterize, and quantify the current P sources and loads to and within the lake.
- They do not adequately define the hydrology of the lake system necessary to understanding the use of nutrient in the production of algae and aquatic weeds.
- They do not characterize the water quality problems of concern. While the TMDL target goals focus on planktonic algal chlorophyll, there is indication that also of concern is the growth of nuisance aquatic weeds.
- They do not describe the cause-and-effect relationship between the P loading to the lake and its nutrient-related water quality characteristics. A reliable characterization of this cause-and-effect relationship over the range of typical conditions of the watershed and lake is critical for developing a reasonable expectation of the water quality improvements that will occur if money is spent and practices altered to achieve the target load, and, indeed, for

instilling confidence that achieving the target P load will, in fact, result in achieving the water quality characteristics of the lake.

- They do not discuss the anticipated allocation of the 1537 kg P/yr loading among the external and internal sources contributing P to the lake, much less demonstrate that agricultural sources of P can meet their allocations while maintaining viability.
- They do not adequately consider or investigate the apparently accepted concept that the internal loading of P contributes substantially, and unusually, to the P load and the eutrophication-related water quality problems of the lake. If it does, this loading should have been investigated and quantified, and consideration be given to how to allocate load from this source in the TMDL.

The complex nature of the watershed sources of P and the response of Lake Shaokatan to the external and internal P loads mandates that an initial allocation of each of the major P source loads and the responsibility for control of the source allocation including the internal P source be part of the TMDL development process. Only with this information can an understanding be developed by all interests that a TMDL to control P loads to the lake and within the lake can potentially be implemented to achieve the TMDL water quality targets.

The Schuler TMDL report for Lake Shaokatan falls far-short of meeting the requirements outlined in the MPCA's "Lake Nutrient TMDL Protocols and Submittal Requirements" of March 2007. While the topics of items on the MPCA TMDL Protocol checklist have apparently been addressed, the information provided in response to those items is not adequate to develop an implementable P control TMDL from the external watershed P sources and the in-lake internal P load derived from the lake sediments.

Major information gaps in the TMDL studies include the lack of hydrologic information on the lake, the limited information on phosphorus concentrations in watershed land runoff for part of a year under the climatic conditions that occur in this lakes watershed. The hydraulic residence time (filling time) of waterbodies is a primary factor influencing the extent to which the P load to a waterbody is used in the production of planktonic algal chlorophyll. Studies have shown that the water residence time of a lake greatly impacts how much P load can be allowed in order to achieve given allowed planktonic algal chlorophyll in the waterbody. Not only do the hydrologic characteristics of the waterbody need to be well-understood for the 2005 TMDL study year, but also the variability in those characteristics need to be defined for the range of common hydrological and meteorological conditions for the lake and its watershed.

Because of the variability of rainfall-runoff and the transport of P in that runoff from year to year, several years' worth of high-quality data should be collected to develop an adequate information base upon which to develop a phosphorus TMDL for a waterbody. Continuous monitoring of flows and reliable sampling and analysis of the runoff waters are needed over several years to develop an adequate database for flow, residence time, and nutrient concentration/load upon which to reliably estimate the external P loads from a watershed. The TMDL study period incorporated only part of 2005, which is inadequate to characterize the P loads to the lake, the factors influencing those loads, as well as the response of the lake to the P load input from the watershed and from the lake sediments. Furthermore, as far as we have been able to determine, there is no definitive, quantitative information regarding what has been indicated to be a significant internal P load in this lake. This needs to be defined before reliable controls on external P loads can be evaluated.

In the 1960s when he held the position of Professor of Water Chemistry in the Department of Civil and Environmental Engineering at the University of Wisconsin, Madison Dr. Lee initiated some of the early studies on the excessive fertilization of lakes geared toward management of water quality problems. Shortly after joining that faculty he became vice chairman of the Lake Mendota Problems Committee. While Lake Mendota was at that time one of the most studied lakes in the world, and hundreds of limnological and fisheries studies had been conducted on the lake, some of which were devoted to excessive fertilization, Dr. Lee and his graduate students were among the first to conduct engineering-type studies to define how land use in the watershed impacted the eutrophication-related water quality of the lake. In the 1970s, under a US EPA contract, he examined the amounts of aquatic plant nutrients derived from land runoff from various types of land uses in the watersheds of about 100 lakes across the country. Based his several decades of study, he found, as have others, that there can be significant season-to-season, and year-to-year variation in the amounts of P and N contributed in land runoff. That work has made it clear that at least three years of comprehensive data must be collected to adequately characterize the P load exported from a particular type of land-use and to assess the impact of the P in that runoff on eutrophication-related water quality of receiving waters.

In addition to the problems with the approach employed for estimating loads during the sampling periods, the 2005 TMDL study included collection of data on P load from the Lake Shaokatan watershed for only part of the year in which summer water quality impact was assessed. While some monitoring of the nutrient concentrations in some of the lake's watershed were conducted in 2006 and 2007 no flow measurements were made at the time of sample collection. Those concentration data, therefore, cannot be used to estimate P loads from a watershed or to the lake. In addition, during those 2006 and 2007 studies the only response parameter measured in the lake was Secchi depth; no planktonic algal chlorophyll measurements were made. From the information available it appears that both the MPCA and the US EPA approved this study plan and its implementation.

Even with the limitations on data for the 2005 TMDL study year, the P load–water quality response characteristics for Lake Shaokatan can be compared, to some extent, with those common to waterbodies around the world. The 700-waterbody Vollenweider–OECD normalized P load – planktonic algal chlorophyll response model can be applied in a general way to Lake Shaokatan. That exercise shows that the P loading–planktonic algal chlorophyll response for this lake is similar to that of lakes around the world with similar characteristics. This means that this modeling approach may be useful for quantifying the water quality significance of various sources of P to Lake Shaokatan and expected improvements in planktonic algal chlorophyll that may result from given alterations in the P loading. Additional information on this approach is provided in Appendix A to these comments.

Another significant problem with the draft TMDL is that it is directed at the total P load rather than algal-available P (i.e., the P that is in a form that can support algal growth, or can convert to a form that can support algal growth). The TMDL report claims that all TP is available to support algal growth. That claim, however, ignores the governing aqueous environmental chemistry of P, as well as the numerous laboratory and whole-lake studies that show that many waterbodies with high loads of inorganic P produce fewer planktonic algae than those without those types of loads. While the 2005 TMDL study period was characterized by exceptionally high rainfall, the TMDL report claims that there was limited runoff from that rainfall and limited soil erosion during the study period. If those claims are accurate, those conditions and associated P load computations should not be considered to be normal for inorganic P loading from watershed sources. While the MPCA water quality criterion for this lake is expressed as TP, that criterion can be in significant error when applied to waterbodies with large amounts of inorganic, non-algal-available P in the water column.

It has been found that, in general, the Secchi depth for Lake Shaokatan is within the range reported for lakes around the world whose clarity is controlled primarily by planktonic algal chlorophyll. However there were several instances in which non-algal particulate matter is causing the lake to be more turbid than expected based only on planktonic algal chlorophyll. This means that this lake at times contains elevated levels of particles in the water column that cause the lake to be more turbid, and have a lower Secchi depth value, than expected for waterbodies located throughout the world where the Secchi depth is controlled by planktonic algae. This condition is likely due to the input of erosional material to the lake from the watershed, the suspension of sediment particles into the water column associated with boats and wind mixing. The elevated level of particulates in the water column is likely to consist to some extent of inorganic particulate P that is not available for algal growth as well as organic particulate P that only slowly converts to algal-available P through mineralization.

During the times when Secchi depth in Lake Shaokatan is not controlled by planktonic algal chlorophyll, Secchi depth is not a reliable TMDL water quality target, and a response that is not amenable to control by P load reduction. Implementing a Secchi depth TMDL could force watershed interests to achieve TMDL P load reductions to meet a water quality target that cannot be achieved through P load reduction. That would cause expenditure of large amounts of money to achieve an unachievable target.

TP is also not an appropriate TMDL water quality target for Lake Shaokatan. Phosphorus is only of concern to the extent that it contributes to the planktonic algal chlorophyll which is the water quality concern of focus in the TMDL. TP is only a reliable TMDL water quality target when it has been adequately demonstrate that all of it is in a form that is available to support algal growth. Part of the TP in Lake Shaokatan is not controlled by algal available P loads within the watershed and in the lake and does not contribute to the development of chlorophyll. Under the current situation efforts directed to the control of TP that is not and does not convert to algal-available P which could result in large expenditures for meeting P load allocations without concomitant improvement in the lake's water quality/beneficial uses of concern to the public.

Lake Shaokatan experiences large growths of aquatic macrophytes (rooted aquatic weeds) that not only impair the lake's water quality-related beneficial uses but also apparently contribute substantially to the release of P from lake's sediments which, in turn, results in increased TP and planktonic algal chlorophyll in the lake during mid to late summer. Although not documented, it was estimated in the TMDL report that up to about 50% of the lake's total P load is derived from the sediments. It is critical that the contribution from that source be quantified and taken into proper account in the TMDL P load allocations, in the assessment of the achievability of the TMDL P load allocations, and in the expectations of the water quality improvements that may be attained through achieving the TMDL target goals.

A very high internal P load could be expected to be due in part to the dam's impeding water flow through the lake. While the dam increased the lake elevation and volume, it also created a lake that typically does not flush accumulations of nutrients in the water column. This is important for Lake Shaokatan wherein aquatic weeds pump sediment-P into the water column and greatly increase the algal-available P load to the lake resulting in increased planktonic algal chlorophyll late in the summer beyond that which would be supported by external P loads. This has been demonstrated by the reported finding that when the lake has flushed – i.e., water that entered the lake from the watershed was sufficient to cause water to flow over the dam spillway – water quality in the lake greatly improved for a period, even though the additional inflow from the watershed increased the TP load to the lake.

The technical valid TMDL water quality target parameters that are quantifiably related to nutrient load amenable to control under a P load TMDL, are planktonic algal chlorophyll and the area and density of aquatic macrophytes in the lake. Those are the two water quality parameters that are of concern to the public in terms of impairing their use of the lake.

Estimations of water and P loads from watershed with intermittent flow and variable P concentration can be in significant error, especially if they are based on periodic grab samples of water and periodic flow gage readings without reliable interpolation between sampling points. Information is available on how the loads and flows were estimated between sampling dates.

Insufficient information was presented to evaluate the reliability of the modeling used to relate P loads from the various external sources, and in-lake sources, within resultant in-lake P concentrations and water quality target values for chlorophyll and Secchi depth. It is clear that the measurements made during 2005 are inadequate to make such correlations and verify their cause-and-effect coupling. This information is needed to evaluate the reliability of the modeling that has been done and to reliably allocate loads to various sources to meet TMDL water quality targets.

Overall the TMDL studies of Lake Shaokatan are seriously deficient in providing a reliable database upon which to develop a TMDL to control the excessive fertilization of the lake under current lake and watershed conditions. The previous studies of the early 1990s were conducted under significantly different conditions than exist today. The studies that have been conducted thus far are inadequate to develop a reliable TMDL for controlling the excessive fertilization of Lake Shaokatan in a technically valid, cost-effective manner.

Summary of Experience in Support of These Comments

Dr. G. Fred Lee has been active in investigating the impacts of nutrients on waterbodies since the early 1960s. A summary of his experience and areas of activity is appended to these comments. Dr. Anne Jones-Lee has worked with Dr. Lee on these issues beginning in the 1970s. They have developed a substantial body of papers and reports on their work on the impact of nutrients on water quality, many of which are on their website, www.gfredlee.com, in the Excessive Fertilization/Eutrophication section [http://www.gfredlee.com/pexfert2.htm].

Specific Comments

Page 14 devoted to "**3.0 Water Quality Standards**" discusses the MPCA's applicable water quality standard for Lake Shaokatan. Section 3.1 states, "*Applicable Minnesota Water Quality Standards Minnesota's standards for lakes limit the quantity of nutrients, which may enter waters. Minnesota's standards at the time of listing (Minnesota Rules 7050.0150(3)) stated that in all Class 2 waters of the State (i.e., "…waters…which do or may support fish, other aquatic life, bathing, boating, or other recreational purposes…") "…there shall be no material increase in undesirable slime growths or aquatic plants including algae…*"

This standard focuses on protecting the beneficial uses of a waterbody. This section also states, "*The numeric translators established numeric thresholds for phosphorus, chlorophyll-a, and clarity as measured by Secchi depth.*" By using the Carlson Trophic state index approach, MPCA has followed a "limnological" study rather than problem-solution approach to developing nutrient criteria. Lee et al. (1995) discussed the development of a trophic state classification based on water quality considerations, i.e., based on the impacts of nutrients on the beneficial uses of waterbodies.

> Lee, G. F., Jones-Lee, A. and Rast, W., "Alternative Approaches for Trophic State Classification for Water Quality Management, Parts I and II: (Suitability of Existing Trophic State Classification Systems and Application of Vollenweider-OECD Eutrophication Modeling Approach)," Report of G. Fred Lee & Associates El Macero, CA (1995). Available from gfredlee@aol.com as EF011

As they pointed out a major problem with the Carlson Trophic State Index approach in that it mixes the nutrient impact parameter of planktonic algal chlorophyll with a nutrient concentration, total P. Total P itself does not impact water quality, unless and until it stimulates the production of sufficient aquatic plant/algal biomass that impacts the beneficial uses of the waterbody. Phosphorus in a waterbody does not necessarily translate to planktonic algal chlorophyll, especially in those waterbodies with high inorganic P loads from erosion of soil-bound phosphorus from the watershed or stirred up from the sediments. Therefore, including total P in the nutrient criteria can skew the trophic state classification of a waterbody and make the nutrient criteria unreliable for assessing water quality impairments associated with nutrient additions.

Some of these problems also arise with using Secchi depth in a trophic state classification and in nutrient criteria for those waterbodies in which there is an elevated level of inorganic or organic non-algae suspended solids to the waterbody. While Secchi depth is an appropriate nutrient response parameter in those waterbodies in which planktonic algae are the primary cause of decreased light penetration, it is not a reliable parameter for waterbodies such as Lake Shaokatan in which, at times, inorganic suspended solids, especially sediments, stirred into the water column are a significant cause of decreased water clarity. Thus while Secchi depth is a reliable water quality parameter (where water clarity, whatever the source, is deemed to be a problem) it is not necessarily an appropriate response parameter for nutrient-related water quality response.

The MPCA nutrient criteria applied to Lake Shaokatan are somewhat skewed owing to their incorporation of both total P and Secchi depth as nutrient-related "impacts." The valid nutrient-related water quality response parameters for Lake Shaokatan are planktonic algal chlorophyll and the area and density of aquatic macrophytes (water weeds) that develop in the lake.

Based on our experience, a 30 µg/L target for average summer planktonic algal chlorophyll is a suitable water quality goal for minimizing the impacts of planktonic algae on the beneficial uses of the lake. The non-algae turbidity that causes the lower-than-normal Secchi depth affects the public's perception of planktonic algal chlorophyll levels and their impact on the lake's water quality. It should be understood, however, that this average planktonic algal chlorophyll will not preclude the occurrence of some large algal blooms that will significantly adversely affect the water contact-related beneficial uses of the lake as well as the public's perception of "water quality" during bloom periods.

Page 14 under "**4.0 Stream and Lake Data Assessment"** states:
"Ortho phosphorus is often referred to as soluble phosphorus when in fact it is particles that pass through a 1 micron filter in laboratory filtration techniques. These very small particles are the majority of the problem in the transport of phosphorus from the watershed to the lake."

No reference was provided for that statement; that statement is not in keeping with the analytical chemistry of phosphorus. Dr. G. Fred Lee has a strong background in analytical chemistry and more than four decades of work on the analysis of pollutants in water. For about 30 years he taught graduate-level water and wastewater analysis courses, and has served on Standard Methods for Examination of Water and Wastewater ("Standard Methods") analytical committees, including the phosphorus committee, for more than five decades. Typically the filter pore-size employed to distinguish between "soluble" and "particulate" pollutants is 0.45 µ, not the 1 µ size that was evidently used in these studies. While some particulate matter can pass through a 1 µ pore-size filter, it is highly inappropriate to claim that the majority of the phosphorus that passes through such a filter is particulate, as was done in the TMDL report. The key factor would be whether or not the filtered samples were turbid, and/or whether or not high-G centrifugation of the filtered samples would reduce the P content of the samples by settling the particulate P. As discussed in writings referenced above in the summary of our qualifications, laboratory chemical analyses and algal assay studies for samples from many areas by various investigators have shown that particulate inorganic phosphorus is not available for algal growth and does not convert to algal-available P.

Page 19 in "**4.0 Stream and Lake Data Assessment**" contains a map of the sampling locations used in the 2005 studies. When we compare this map with that provided in the previous version of this TMDL report we find that station 4 was omitted in the most recent version of the TMDL report. Station 4 is a particularly important station in that it is at the dam outlet of the lake. If there was no flow out of the lake during the 2005 study period that should have been stated. We understand that in some years there is flow out of the lake.

The report is confusing with regard to the hydrologic conditions that occurred in 2005, the primary study year. It states on page 20,
"The flows at monitored sites were far below the average conditions for the Lake Shaokatan watershed and were not representative of the typical flow regime."

However, Figure 15 shows that the rainfall in 2005 was over 30 in while the normal in recent years is just over 20 in. While not stated in the report it is understood that the rainfall measurements are made at an airport located about 20 miles away from the lake. The report states on page 26, "*During the 2005 sampling season, rainfall in excess did occur. However, the antecedent moisture conditions were low. Combined with overall mild rainfall intensity in 2005, the result was low runoff.*"

Page 22 "**Table 5: 2005 Stream Summary"** presents the OP and TP analytical results for the watershed samples collected in 2005. Those data show that the lower runoff than normal years of 2005, smaller than expected amounts of the total P is particulate. This may indicate that the tile drain flows are likely lower in particulate P than runoff from more normal precipitation. The statement on the same page,
"*At nearly every monitoring station, the majority of the total phosphorus was measured as ortho phosphorus, which would be highly available for algal growth."* can be in error, as discussed above, due to the larger-than-normal filter pore-size used in for those analyses.

Page 24 in "***5.0 Pollutant Assessment***
There are various sources of phosphorus in the Lake Shaokatan watershed. Timing and budget constraints did not allowed this project to conduct an intensive source inventory but past studies and local information sources allow some conclusions and estimates to be developed."

That statement is an acknowledgement that inadequate funds were made available to conduct the needed studies to account for year-to-year variability in P load transport and to define over several years the amounts of P contributed from various sources. As a result, agricultural interests could be required to spend large amounts of money to try to control P derived from their lands based on inadequate and unreliable presumptions and data collected in the TMDL study year.

Page 24 under, "**Lake Sediment Release (Internal Loading)**"
The TMDL report states that up to about 50% of the total P load was due to P derived from the lake sediments. The first paragraph on page 26 discusses the proposed mechanisms for release of P from lake sediments. We have had extensive experience in the release of P from sediments; that paragraph fails to properly present the situation that occurs in shallow oxygenated waterbodies with respect to the anoxic release of P from lake sediments. In the 1970s with about $1-million of US Army Corps of Engineers support we examined the release of about 30 potential pollutants from about 100 sediments taken from waterways from throughout the US. It was found, as would be expected based on the aquatic chemistry of P, that under anoxic conditions (no oxygen) iron-bound phosphate can be solubilized, with the release the P. However, in the oxygenated water column the released ferrous iron is quickly oxidized to ferric iron, which scavenges the phosphate that had been released to the water column in the anoxic sediments. Further, it is well-known that ferric phosphate compounds are not available to support algal growth.

The statement in that paragraph, "*Several metal species such as iron and sulfate can be reduced and become soluble."* does not reflect an understanding of aquatic chemistry. Sulfate is a non-metal and is soluble in freshwaters.

Page 26 in the last paragraph presents a discussion of the flushing time for the lake. That paragraph states,

"Lake flushing seems to require substantial rainfall for at least two to three consecutive seasons to occur. Figure 18 shows the annual rainfall for Lake Shaokatan from 1991-2007. Substantial lake flushing occurred during the period 1992-1996, but sustained inter-year rainfall has not occurred since. From Figure 15, it appears that consecutive annual rainfall in the neighborhood of 30 inches or more a year needs to occur to drive lake flushing. During the 2005 sampling season, rainfall in excess did occur. However, the antecedent moisture conditions were low. Combined with overall mild rainfall intensity in 2005, the result was low runoff. Under these conditions, Lake Shaokatan tends to accumulate large amounts of phosphorus in the sediments that is later released to the overlying water column at large rates. These conditions promote excessive summer mean lake phosphorus concentrations exceeding 100 ug/L."

From the information available the high flows that lead to lake flushing are important factors in impacting the lake's water quality.

Another of the highly significant deficiencies in the study of Lake Shaokatan as part of developing a P TMDL is the failure to develop comprehensive information on the hydrology of the lake and its watershed. The hydraulic residence time of a waterbody is key to the use of P input in the production of planktonic algae in a waterbody. It is a key normalizing factor in the Vollenweider normalized phosphorus loading term that quantitatively relates P load to planktonic algal chlorophyll. The Vollenweider phosphorus loading term is $[(L(P)/q_S)/(1+\sqrt{T_{\omega}})]$ in which the term, L(P), is the areal annual P load, q_s is the mean depth divided by the hydraulic residence time, and $T\omega$ is the hydraulic residence time. It has been found there is a good correlation between the normalized P load to a lake and the planktonic algal chlorophyll that develops in the waterbody. We have used this relationship to examine the impact of hydraulic residence on the planktonic algal chlorophyll that would be expected in the Lake Shaokatan given various P loads. We found that the coupling between this lake's estimated P loading, based on in-lake total P, and average summer chlorophyll level is about the same as that for lakes and reservoirs located throughout the world that have similar normalized P loadings. See Appendix 1 for further discussion of this issue.

It is well-established that the flushing time of a waterbody is an exponential function of the hydraulic residence time; 95% flushing of a lake's conservative (non-reactive) chemicals like chloride is three-times the hydraulic residence time. However, for non-conservative chemicals like phosphate, the flushing time is a function of chemical residence time. The chemical residence time is the total mass of the chemical in the lake divided by the annual load. These relationships are discussed in the following paper:

> Sonzogni, W. C., Uttormark, P. C., and Lee, G. F., "A Phosphorus Residence Time Model: Theory and Application," Journ. Water Res. 10:429-435 (1976).
> http://www.gfredlee.com/Nutrients/P-ResidenceTime.pdf

The phosphorus residence time in a lake is typically a few months to a few years for very large lakes such as Lake Michigan.

Page 30 **6.0 TMDL and Allocations** presents information on the modeling that was done to determine the allowed P loading to achieve the MPCA P standard for this lake. Figure 17 presents the results of the modeling calculations for several years. The discussion of that figure stated,

"It is reasonable to assume the phosphorus sediment release rate is variable both within a given growing season and especially year to year. The lake does not flush on a regular basis and is a function of the particular rainfall pattern and volumes for a given year, and to a large extent, seems to be highly related to the preceding ground water levels. The internal loading is much more difficult to assess in terms of rate and magnitude of loading, and as such, is not included directly in this modeling. Nevertheless, the target for cumulative loading from both watershed and internal sources is 1,537 kg/yr."

According to the statement in the next paragraph the 1,537 kg/yr P cumulative load is equivalent to 4.2 kg day.

That statement, again, points to the need for a properly conducted, several-year hydrologic study of the lake and the watershed as part of establishing allowed P loads. The mentioning of groundwater levels as a factor without any definitive characterization of the groundwater table elevation is another serous omission in that study. If the internal loading is not known, how can the cumulative target load be developed? It is the allowed loads from the watershed that need to be established as those are the loads that can potentially be controlled. The modeling that has been done only attempts to relate a total internal and watershed load to an in-lake phosphorus concentration. What is needed, but was not determined, is the relationship between the external P load and planktonic algal chlorophyll that results from that load. This is the type of information that can be effectively used to determine how best to manage the external loads to achieve the desired lake water quality in terms of planktonic algal chlorophyll. The Vollenweider–OECD normalized P load chlorophyll relationship focuses on external loads, and through the normaling factors of morphology and hydrology of the lake, accounts for the internal loads that develop for a particular waterbody.

Page 30 under 6.0 TMDL and Allocations states,

"*The quantification of phosphorus sources within a watershed and the subsequent lake response is very complex. Despite the complexity, this report draws in previous Lake Shaokatan studies, inflow and in-lake data, and a widely used modeling package (FLUXBATHTUB) to establish a total maximum daily load of phosphorus consistent with Lake Shaokatan meeting state water quality standards."*

No information was presented in the final TMDL report on the details of that modeling. The original TMDL report contains an appendix with two tables of data that is evidently related to this modeling. However no information was presented on the modeling and other information that was presented in that appendix. Such information is essential to evaluating the reliability of the modeling to establish the allowed P external and internal loads.

The information in the original TMDL report appendix indicates that the modeling to establish the allowed P load apparently only used flows into the lake in 2005 between April 15, 2005 and October 12, 2005. The flow diagrams for sites 1, 3 and 7 show that that is the period of measured flows. This approach ignores the load to the lake from the culverts between mid-October and mid-April. That flow, unless it is very small, will be important in determining the allowed P load since it impacts not only the P load, but also the hydraulic residence time of the lake which, in turn, impacts the allowed P load to achieve the planktonic algal chlorophyll goal.

Appendix 1 shows that at the beginning of the modeling the lake level was 0.8 ft but at the end was 3.1 ft., apparently indicating that the lake level rose by about two feet during the study period. No reference point for those lake levels was provided. The range of changes in lake level in wet and dry years should be provided.

Page 30 states, "*The lake does not flush on a regular basis and is a function of the particular rainfall pattern and volumes for a given year, and to a large extent, seems to be highly related to the preceding ground water levels.*"
The technical basis for that statement with regard to the influence of groundwater on algal growth was not provided. If that statement is correct, it reflects another significant deficiency in the 2005 study; apparently no measurements were made of groundwater elevation or flow.

From what we see now, the monitoring and modeling was inadequate for establishing a reliable target external P load necessary for achieving target in-lake water quality characteristics.

Appendix A
Summary of OECD Eutrophication Study Results.

While we have investigated the impacts of nutrient loads on excessive fertilization of many waterbodies, our most comprehensive effort was associated with the Organization for Economic and Development (OCED) international eutrophication study, and our independent follow-on studies. The 5-year OECD eutrophication study, conducted in the 1970s, focused on evaluating and quantifying the relationships between nutrient loading and water quality response based on data from 200 waterbodies of varying character in 22 countries in Western Europe, North America, Japan, and Australia. Through that study, R. Vollenweider developed an empirical relationship (model) between mean summer chlorophyll concentration and annual phosphorus load normalized by waterbody area, mean depth, and hydraulic residence time. That model demonstrated and quantified the importance of waterbody morphology and hydrology in controlling the use of P in the production of planktonic algal chlorophyll.

G. Fred Lee was selected by the US EPA to evaluate, and develop the synthesis report for, the US part of the OECD eutrophication study. Using Vollenweider's model concepts, he and his colleagues described empirical relationships between normalized P load and eutrophication-related water quality characteristics for a diverse group of lakes and reservoirs across the US, relationships that were in keeping with those subsequently developed upon the entire OECD study database.

His synthesis report was published as:

> Rast, W. and Lee, G. F., "Summary Analysis of the North American (US Portion) OECD Eutrophication Project: Nutrient Loading-Lake Response Relationships and Trophic State Indices," EPA 600/3-78-008, US EPA-Corvallis (1978).

A summary paper covering that report was published as a feature article in:

> Lee, G. F.; Rast, W. and Jones, R. A., "Eutrophication of Water Bodies: Insights for an Age-Old Problem," Environ. Sci. & Technol. 12:900-908 (1978).
> http://www.gfredlee.com/Nutrients/Eutrophication-EST.pdf

The final overall OECD report was published in 1982:

> OECD, "Eutrophication of Waters, Monitoring, Assessment, and Control," Organization for Economic Cooperation and Development, Paris (1982).

More recent summaries of Lee and Jones-Lee's work on excessive fertilization of waterbodies were published in:

> Jones, R. A. and Lee, G. F., "Use of Vollenweider-OECD Modeling to Evaluate Aquatic Ecosystem Functioning," Functional Testing of Aquatic Biota for Estimating Hazards of Chemicals, ASTM STP 988, Amer. Soc. Test. & Mat., Philadelphia, pp. 17-27 (1988).
> http://www.gfredlee.com/Nutrients/EcosystemFunctionOECD.pdf

> Jones-Lee, A., and Lee, G. F., "Eutrophication (Excessive Fertilization)," Water Encyclopedia: Surface and Agricultural Water, Wiley, Hoboken, NJ pp 107-114 (2005).
> http://www.gfredlee.com/Nutrients/WileyEutrophication.pdf

Concurrent with and following his involvement in the OECD eutrophication study, Dr. Lee and his associates continued the evaluation and expansion of the underlying concepts of Vollenweider and empirical Vollenweider–OECD models developed through the US and international OECD studies. That work included discussion and demonstration of the use of the modeling approach for water quality evaluation and management, documentation of the predictive capability of the models, expanding the database for the models, and evaluating and expanding the water quality parameters for which the approach has applicability.

Lee and his associates expanded the international OECD eutrophication study database to more than 700 waterbodies located in many areas of the world. They expanded the original concepts proposed by Vollenweider to include several additional eutrophication-related water quality response measures including water clarity and hypolimnetic oxygen depletion rates of waterbodies, discussion of which was included in the Rast and Lee report of the US part of the OECD eutrophication study.

Review papers discussing the expanded database include:

> Jones, R. A., and Lee, G. F., "Recent Advances in Assessing the Impact of Phosphorus Loads on Eutrophication-Related Water Quality," Journ. Water Research 16:503-515 (1982). http://www.gfredlee.com/Nutrients/RecentAdvWaterRes.pdf
>
> Jones, R. A. and Lee, G. F., "Eutrophication Modeling for Water Quality Management: An Update of the Vollenweider-OECD Model," World Health Organization's Water Quality Bulletin 11:67-174, 118 (1986).
> http://www.gfredlee.com/Nutrients/voll_oecd.html

Lee and Jones-Lee have further expanded the modeling approach to the quantification of fish production in waterbodies as a eutrophication-related water quality response parameter.

> Lee, G. F. and Jones, R. A., "Effects of Eutrophication on Fisheries," Reviews in Aquatic Sciences, 5:287-305, CRC Press, Boca Raton, FL (1991).
> http://www.gfredlee.com/Nutrients/fisheu.html

The work discussed in that paper demonstrated that, as expected, altering the phosphorus load to a waterbody impacts the fish production in the waterbody. Also discussed was the importance of considering the impacts on fish production associated with nutrient load reductions and nutrient criteria for waterbodies.

Rast et al. reviewed of the capability and reliability of the Vollenweider–OECD modeling approach for assessing and quantifying the changes in planktonic algal chlorophyll that would be expected to result from given changes in the P load to a waterbody in the paper:

> Rast, W., Jones, A., and Lee, G. F., "Predictive Capability of US OECD Phosphorus Loading-Eutrophication Response Models," Journ. Water Pollut. Control Fed. 55(7):990-1003 (1983). http://www.gfredlee.com/Nutrients/PredictiveCapabilityOECD.pdf

The literature contains a number of papers/reports on “uncertainty” issues in the use of the Vollenweider P loading–chlorophyll relationships. Our reports and papers include careful consideration and extensive discussion of the limitations and appropriate use of those relationships. They cannot be mechanically applied without regard to specific character of the subject waterbody. However, if properly used they can provide a useful tool to help guide the development management approaches for excessively fertile lakes and reservoirs.

A key issue in the Lee et al. studies of the impact of phosphorus on waterbodies was the role of total phosphorus versus algal-available phosphorus in impacting the fertilization of waterbodies. This issue was specifically discussed in:

> Lee, G. F., Jones, R. A., and Rast, W., "Availability of Phosphorus to Phytoplankton and its Implications for Phosphorus Management Strategies," IN: Phosphorus Management Strategies for Lakes, Ann Arbor Science Publishers, Inc., Ann Arbor, MI (1980).
> http://www.gfredlee.com/Nutrients/Avail-P.pdf

Some of Dr. Lee’s more recent papers/reports discuss the technical errancy of the US EPA’s position that all forms of particulate phosphorus are available or become available to support algal growth. We have become involved in the issues of the development of appropriate approaches for controlling phosphorus from agricultural land runoff to improve the eutrophication-related water quality conditions of receiving waters, focusing in part on the comparative effects of controlling total phosphorus versus algal-available P in runoff waters. The following reviews constitute some of Lee’s writings on this issue:

> Lee, G. F., “Assessing Algal Available Phosphorus,” Submitted for Inclusion in the Proceedings of US EPA Science Symposium: “Sources, Transport, and Fate of Nutrients in the Mississippi River and Atchafalaya River Basins,” Minneapolis, MN, November 7-9 (2006). http://www.gfredlee.com/Nutrients/AvailPEPASymp06.pdf
>
> Lee, G. F., “A Proposal for Assessing Algal-Available Phosphorus Loads in Runoff from Irrigated Agriculture in the Central Valley of California,” Report of G. Fred Lee & Associates, El Macero, CA, November (2006).
> http://www.gfredlee.com/Nutrients/AlgalAssayAvailP.pdf
>
> Lee, G. F., "Assessing Algal Available Phosphorus," Proceedings of US EPA Science Symposium: Sources, Transport, and Fate of Nutrients in the Mississippi River and Atchafalaya River Basins, Minneapolis, MN, November 7-9 (2006).
> http://www.gfredlee.com/Nutrients/AvailPEPASymp06.pdf
>
> Cowen, W. F., and Lee, G. F., "Phosphorus Availability in Particulate Materials Transported by Urban Runoff," Journ. Water Pollut. Control Fed. 48(3):580-591 (1976).
> http://www.gfredlee.com/Nutrients/AvailPParticulatesCowen.pdf

Additional discussion can be found in the Stormwater Runoff Water Quality Newsletters NL- 1-2, 1-5, 4-3/4, 5-1, 6-1, 6-2, 7-6/7, 9-1/2, 9-7, 9-8, 9-10, 10-1, 10-2, 10-4, 10-5, 10-6, 10-13, 11-2, 11-5, 11-7/8, 11-9,11-10, 12-3, 12-5, 12-6, 12-7/8 which are available online at:
http://www.gfredlee.com/newsindex.htm. As discussed, the literature shows that the US EPA position of requiring that total phosphorus, rather than algal-available P, be regulated is not technically valid and can cause agricultural and urban interests to spend large amounts for phosphorus control beyond that needed to control excessive fertilization-related water quality impacts.

In 2002 Lee and Jones-Lee published a discussion of how nutrient criteria/standards should be established:

> Lee, G. F. and Jones-Lee, A., "Developing Nutrient Criteria/TMDLs to Manage Excessive Fertilization of Waterbodies," Proceedings Water Environment Federation, TMDL 2002 Conference, Phoenix, AZ, November (2002). http://www.gfredlee.com/Nutrients/WEFN-Criteria.pdf

That paper addresses problems with the technical foundation of the US EPA's statistical approaches for developing nutrient criteria and describes the technical advantages and strengths of a site-specific approach that considers the waterbody characteristics and water quality management objectives. The latter approach has been adopted by the California State Water Resources Control Board as discussed in:

> SWRCB, "Estuarine Nutrient Numeric Endpoint Coastal Stakeholder Advisory Group (Coastal SAG) Meeting May 1, 2009," PowerPoint Slides, SWRCB, Sacramento, CA, May (2009). http://www.gfredlee.com/Nutrients/CoastalSAGMeeting5-1-2009.pdf

> SWRCB, "Estuarine NNE Project - NNE STRTAG Meeting Conference Call August 17, 2009," California State Water Resources Control Board (SWRCB) Coastal Nutrient Development Program Sacramento, CA, August 17 (2009). http://www.gfredlee.com/Nutrients/STRTAG8-17-09Mtg.pdf

An important finding that evolved from the Vollenweider et al. work in the OECD eutrophication studies is the relationship between the normalized annual phosphorus load to a waterbody and the waterbody's average phosphorus concentration. Vollenweider found that the phosphorus load, normalized as he prescribed by the waterbody's area, mean depth, and hydraulic residence time (filling time), is approximately equal to the average in-waterbody phosphorus concentration. In his book, "Surface Water Quality Modeling," Chapra (1997) confirmed that relationship.

Many of Lee's other papers and reports pertinent to these issues are available in www.gfredlee.com in the Excessive Fertilization/Eutrophication section [http://www.gfredlee.com/pexfert2.htm]. It is with this background that we present our conclusions on the adequacy of the Lake Shaokatan TMDL studies to serve as a technical basis for establishing the allowed P loads from the watershed and the apportionment of these loads to the various sources in the watershed.

Appendix B
Dr. G. Fred Lee's Experience in Evaluating Excessive Fertilization/Eutrophication of Lakes, Reservoirs, Estuaries and Near-Shore Marine Waters

A substantial portion of Drs. Lee and Jones-Lee's professional work continues to be in the area of evaluation and management of the impacts of aquatic plant nutrients (nitrogen and phosphorus) on water quality/beneficial uses of waterbodies, including lakes, reservoirs, coastal marine waters, as well as riverine systems. Excessive fertilization (eutrophication) causes adverse impacts on recreational uses and aesthetics, raw water supply water quality (tastes & odors and THM formation), and fisheries resources through, among other things, oxygen depletion associated with algal decomposition. As discussed below, their work focuses on the causes, manifestation, and control of the wide range of excessive fertilization problems.

Dr. Lee's work in eutrophication evaluation and management began in the 1960s when he established, developed, and directed the Water Chemistry Program in the Department of Civil and Environmental Engineering at the University of Wisconsin, Madison. During the 13 years under his direction, that program was highly involved in lake and reservoir water quality investigation and management; approximately 100 of his graduate students did their Masters theses or Ph.D. dissertations on various aspects of lake and reservoir water quality. One of the principal focal points of that work was excessive fertilization issues. Dr. Lee pioneered in the development of approaches for evaluating the impact of a various sources of nutrients, including activities and conditions in a waterbody's watershed, on waterbodies' water quality.

In 1960, Dr. Lee was appointed vice-chair of the Lake Mendota Water Quality Management Committee. Lake Mendota is one of the most intensively studied waterbodies in the world due to the long history of limnological research conducted by the University of Wisconsin, Madison, faculty and students. From 1960 through the early 1970s many of the water chemistry studies conducted on Lake Mendota were under the direction of Dr. Lee. During that time Dr. Lee was also involved in Great Lakes water quality issues, and served as an advisor to the International Joint Commission for the Great Lakes and the US EPA on excessive fertilization issues. Over the years he has been an investigator or advisor on eutrophication-related water quality issues in many areas of the US as well as in the Netherlands, Norway, Italy, Spain, Israel, Jordan, Japan, the USSR, Dominican Republic, South Africa, Argentina, and Antarctica.

On behalf of the Water Resources Center at the University of Wisconsin, Madison, Dr. Lee developed the first comprehensive overview of the causes, processes, implications, and management of the eutrophication of waterbodies in the paper:

> Lee, G.F., "Eutrophication," University of Wisconsin Eutrophication Information Program Occasional Paper no. 2, 32 pp (1970) [also published in Transactions of the Northeast Fish and Wildlife conference, pp 39-60 (1973), and available upon request from gfredlee@aol.com as EF014]

More recently, he and Dr. Jones-Lee were asked to contribute the following review of eutrophication:

Jones-Lee, A. and Lee, G. F., "Eutrophication (Excessive Fertilization)," In: Water Encyclopedia: Surface and Agricultural Water, Wiley, Hoboken, NJ, pp 107-214 (2005). [available at: http://www.gfredlee.com/Nutrients/WileyEutrophication.pdf]

Those reviews discuss the roles of nitrogen, phosphorus and other constituents in causing excessive fertilization-related water quality problems, as well as, and most importantly, approaches that can be used to manage excessive fertilization and evaluate the effectiveness of management strategies. Those two writings remain the most comprehensive reviews of eutrophication and its management.

Dr. Lee was also involved in the lake and reservoir management studies conducted by the state of Wisconsin in the late 1960s to early 1970s. As part of that program, whole-lake experimental approaches were used to assess the efficacy of a variety of strategies for evaluating and managing water quality in excessively fertile lakes; strategies evaluated included adding alum to the lake to remove phosphorus, aeration of the lake to mix the hypolimnion and epilimnion, hypolimnetic aeration, aquatic plant harvesting, among others. Dr. Lee was involved in a number of additional projects in the state of Wisconsin in which alum was used to treat whole lakes for phosphorus removal; he supervised the master thesis work of one of his students on this topic. Dr. Lee has developed specific guidance for discerning situations in which alum treatment for phosphorus removal can be effective, and where it should not be used. Critical to this assessment is the relative role of phosphorus in controlling excessive fertilization in the waterbody.

For a number of years beginning in the 1970s, Dr. Lee was a member of the American Water Works Association's national 'Quality Control in Reservoirs' Committee. During that time, the committee specifically addressed the value of mixing of lakes, either by aeration or pumping, for the purpose of managing eutrophication-related water quality problems. It was the committee's conclusion, supported by the fundamental chemistry of nutrients, that aeration of a whole waterbody could be significantly adverse to improving eutrophication-related water quality characteristics. Oxygenation of the hypolimnion, however, could be effective in maintaining cold-water fisheries and improving water supply water quality by reducing nutrient transport from the hypolimnion to the epilimnion. In 1965 Dr. Lee published a paper,

Lee, G.F. and Harlin, C.C., "Effect of Intake Location on Water Quality," Industrial Water Engineering 2:36-40 (1965). [available upon request to gfredlee@aol.com as publication DW003].

which specifically addressed the importance of evaluating domestic water supply water quality as a function of depth, and how, through selective withdrawal, water utilities can optimize their water quality in a thermally stratified waterbody.

While working with the state of Wisconsin Department of Conservation, Dr. Lee studied the impact of aeration of Comstock Reservoir on water quality. He examined the impact of aeration not only on chemical and biological characteristics of the reservoir, but also on the fisheries of the waterbody. Dr. Lee has had extensive experience in the evaluation of the impacts of various types of chemicals used to control algae and other aquatic weeds, including copper and diquat, on a waterbody's water quality and fisheries. Further, he is familiar with regulatory issues associated with the use of chemicals for aquatic plant control and their impact on non-target aquatic life. More recently, in support of the DeltaKeeper and the California State Water

Resources Control Board, Dr. Lee developed guidance for evaluating the water quality impact of herbicides used to control excessive growths of aquatic weeds, on non-target organisms:

Lee, G. F., “Developing a Reliable Program to Monitor Water Quality Impacts of Aquatic Pesticides,” Report of G. Fred Lee & Associates, El Macero, CA (2004). [available at: http://www.gfredlee.com/Nutrients/Aq-Pest-MonPgm.pdf]

Dr. Lee has had extensive experience in assessing and managing the couplings among eutrophication, eutrophication control, and fish and other aquatic organisms. He and Dr. Jones-Lee published what has become recognized as one of the most comprehensive reviews of the impacts of eutrophication and water quality management on fish populations:

Lee, G.F. and Jones R.A., "Effects of Eutrophication of Fisheries," Reviews in Aquatic Sciences, 5:287-305, CRC Press, Boca Raton, FL (1991), [http://www.gfredlee.com/Nutrients/fisheu.html]

That paper reviews how managing algae-related water quality in a reservoir can influence the fisheries of the waterbody.

During the 1970s, Dr. Lee was awarded the US EPA contract to develop a synthesis report for the US part of the Organization for Economic Cooperation and Development (OECD) eutrophication studies. The approximately $50-million OECD eutrophication studies examined the nutrient load—eutrophication-related water quality response relationships in about 200 waterbodies located in 22 countries (in western Europe, North America, Japan, and Australia) over a five-year period. Dr. Lee served as an advisor to the overall international studies, as well as developed the US OECD report synthesizing the data on about 40 US waterbodies. Dr. Lee's primary contribution to this effort was in the development, evaluation, and application of empirical nutrient load—eutrophication-response relationships that can be used by water utilities and others to examine how land use in a waterbody's watershed influences nutrient transport to the waterbody from the watershed and then, the waterbody's water quality. Drs. Lee and Jones-Lee and their associates have published extensively on this topic including several comprehensive reviews such as,

Lee, G. F., Rast, W. and Jones, R. A., "Eutrophication of water bodies: Insights for an age-old problem," Environmental Science & Technology 12:900-908 (1978). http://www.gfredlee.com/Nutrients/Eutrophication-EST.pdf

Jones, R. A. and Lee, G. F., "Eutrophication Modeling for Water Quality Management: An Update of the Vollenweider-OECD Model," World Health Organization's Water Quality Bulletin 11(2):67-74, 118 (1986). http://www.gfredlee.com/Nutrients/voll_oecd.html.

Jones, R. A. and Lee, G. F., "Chlorophyll-A Raw Water Quality Parameter," Journal American Water Works Association 74:490-494 (1982). [available upon request from gfredlee@aol.com].

Key to the development and evaluation of effective nutrient/eutrophication control strategies is the ability to reliably assess the improvement in water quality that can result, or has resulted, from various control strategies. One of the important results of their work with the Vollenweider-OECD eutrophication modeling approach was their demonstration of the predictive capability and reliability of the models using data collected before and after nutrient load alterations. That work was discussed in:

Rast, W., Jones, R. A. and Lee, G. F., “Predictive Capability of US OECD Phosphorus Loading-Eutrophication Response Models,” Journ. Water Pollut. Control Fed. 55:990-1003 (1983). [http://www.gfredlee.com/Nutrients/PredictiveCapabilityOECD.pdf]

While serving as chairman of the AWWA national Quality Control in Reservoirs Committee, Drs. Lee and Jones-Lee developed several committee reports that were designed to assist water utilities in managing their raw water quality:

Lee, G. F. and Jones, R. A., "Study Program for Development of Information For Use of Vollenweider-OECD Eutrophication Modeling in Water Quality Management for Lakes and Reservoirs," G. Fred Lee & Associates, El Macero, CA (1992). [available as EF007 upon request from gfredlee@aol.com].
]

Dr. Lee was asked by the organizers of a University of California Water Resources Center conference devoted to water supply source water quality issues, to develop a review of water quality issues in the Sacramento/San Joaquin Delta in the Central Valley of CA. This resulted in Drs. Lee and Jones-Lee’s publication of a paper and report:

Lee, G. F. and Jones, R. A., “Managing Delta Algal-Related Drinking Water Quality: Tastes and Odors and THM Precursors,” Published in “Protecting Drinking Water Quality at the Source,” proceedings of a Conference, Univ. of California Water Resources Center, Report no. 76, October (1991).

Lee, G. F. and Jones, R. A., “Regulating Drinking Water Quality at the Source,” Presented at Univ. of California Water Resources Center Conference, “Protecting Drinking Water Quality at the Source,” Sacramento, CA, April 3-4 (1991). http://www.gfredlee.com/WSWQ/wswqsour.htm

Those publications specifically discuss issues of how land use within and upstream of the Delta influences the quality of the domestic water supply derived from the Delta. Further, as part of the CA/NV AWWA Section Source Water Quality Committee, Dr. Lee developed a review for the committee on the impact of the drought in the late 1980s - early 1990s on domestic water supply water quality:

Lee, G. F. and Jones, R. A., "Impact of the Current California Drought on Source Water Supply Water Quality," Presented at CA/NV AWWA Fall conference, Anaheim, CA, 30pp, October (1991). [available upon request from gfredlee@aol.com].

That paper reviewed how the algae-related quality of the water derived from the Delta adversely impacts domestic water supply water quality through taste and odors and THMs.

Much of Dr. Lee's work on excessive fertilization of waterbodies has focused on eutrophic/hypertrophic waterbodies in which blue-green algae dominate the flora. Blue-green algae can be a significant source of tastes and odors in domestic water supplies. A number of Dr. Lee’s graduate students did their Ph.D. dissertations on water quality issues associated with blue-green algae; topics investigated included nitrogen fixation by blue-green algae, the role of thermocline migration and erosion in the transference of hypolimnetic nutrients to surface waters where they stimulate blue-green algal blooms, and the role of sediments and other sources of nitrogen and phosphorus compounds in controlling blue-green algae dominance in waterbodies.

Dr. Lee has been involved in several major projects on behalf of water utilities specifically designed to examine how land use in a water supply reservoir's watershed influences raw water quality. In what is believed to be one of the most comprehensive studies of this type ever undertaken, Dr. Lee conducted a multi-year, several hundred-thousand-dollar project on behalf of the city of Dallas, Texas, water utility. That study specifically addressed the issues of how changes in land use in the watershed of Lake Ray Hubbard, one of the primary water supply reservoirs for the city of Dallas, influenced taste- and odor-related water quality. The study considered not only algae but also actinomycetes as sources of taste and odors. Dr. Lee and one of his graduate students published a paper on the results of that investigation:

> Archibald, E. M. and Lee, G. F., "Application of the OECD Eutrophication Modeling Approach to Lake Ray Hubbard, Texas," Journal American Water Works Association, 73:590-599 (1981). http://www.gfredlee.com/Nutrients/OECDLakeRayHub.pdf

Dr. Lee conducted a similar study for the Olathe, Kansas, water utility, in which he examined the relationship between land-use practices in Lake Olathe's watershed and the waterbody's raw water quality.

Dr. Lee also conducted a study on behalf of the Lubbock, Texas, water utility related to controlling THMs in its finished water by controlling the sources of organic carbon in its raw water derived from Lake Meredith. That was an unusual situation in that a freshwater sponge was growing in the raw water transmission line between the reservoir and the water utility; it developed to a thickness of a foot or more inside the pipe. The sponge was obtaining its nutrients from organics derived from in-line open reservoirs along the transmission line.

One of the areas that Dr. Lee has pioneered is the development of guidance to water utilities and others on how to design a water supply reservoir to minimize raw water quality problems. He presented a paper on this topic:

> Lee, G. F. and Jones, R. A., "Predicting Domestic Water Supply Raw Water Quality in Proposed Impoundments," IN: Proc. American Water Works Association 1984 Annual Conference Proceedings, pp 1611-1630 (1984).
> http://www.gfredlee.com/WSWQ/RawWQProposedImp84.pdf

Drs. Lee and Jones-Lee assisted the Municipal Water Supply Authority for Santo Domingo in the Dominican Republic to evaluate the adequacy of a proposed water treatment plant for treating the waters derived from a yet-to-be-developed water supply reservoir on a river. They were able to develop predictions of the raw water quality in the proposed reservoir based on land use in the reservoir's watershed. From that prediction, they concluded that the proposed water treatment plant would not be able to produce high-quality water, and recommended changes in the design of the treatment plant to more appropriately address the water quality characteristics that would be expected based on the proposed reservoir's watershed.

Dr. Lee has been active for many years in work on the impacts of releases from reservoirs on downstream water quality. For example he served as an advisor to the Tennessee Valley Authority and other agencies on the impact of reservoir releases on downstream water quality and co-authored a review on this topic:

Krenkel, P. A., Lee, G. F. and Jones, R. A., "Effects of TVA Impoundments on Downstream Water Quality and Biota," IN: The Ecology of Regulated Streams, Plenum Press, New York, pp 289-306 (1979). [available upon request from gfredlee@aol.com.]

Another major concern about the impact of excessive fertilization on water quality is the utilization of dissolved oxygen in the bacterial decomposition of algae, which can lead to low dissolved oxygen or anoxic conditions in waterbodies. Drs. Lee and Jones-Lee served as the coordinating principal investigators for a $2-million CALFED project devoted to evaluating the cause and developing control programs, for the low dissolved oxygen problem in the San Joaquin River (SJR) Deep Water Ship Channel (DWSC) near the Port of Stockton. One of the primary causes of the dissolved oxygen depletion there is the oxygen utilization in the decomposition of algae that had developed upstream in the SJR. Upon entering the DWSC the algae settle, die and decompose; the decomposition depletes the oxygen resources of the channel. They developed a comprehensive synthesis report and supplementary discussion on that situation:

Lee, G. F. and Jones-Lee, A., "Synthesis and Discussion of Findings on the Causes and Factors Influencing Low DO in the San Joaquin River Deep Water Ship Channel Near Stockton, CA: Including 2002 Data," Report Submitted to SJR DO TMDL Steering Committee and CALFED Bay-Delta Program, G. Fred Lee & Associates, El Macero, CA, March (2003). http://www.gfredlee.com/SJR-Delta/SynthesisRpt3-21-03.pdf

Lee, G. F. and Jones-Lee, A., "Supplement to Synthesis Report on the Low-DO Problem in the SJR DWSC," Report of G. Fred Lee & Associates, El Macero, CA, June (2004). http://www.gfredlee.com/SJR-Delta/SynthRptSupp.pdf

They have become involved in the issues of the development of appropriate approaches for controlling phosphorus from agricultural land runoff to improve those conditions, focusing in part on the comparative effects of controlling total phosphorus versus algal-available P in runoff waters. Dr. Lee's reviews,

Lee, G. F., "A Proposal for Assessing Algal-Available Phosphorus Loads in Runoff from Irrigated Agriculture in the Central Valley of California," Report of G. Fred Lee & Associates, El Macero, CA, November (2006).
http://www.gfredlee.com/Nutrients/AlgalAssayAvailP.pdf

Lee, G. F., "Assessing Algal Available Phosphorus," Proceedings of US EPA Science Symposium: Sources, Transport, and Fate of Nutrients in the Mississippi River and Atchafalaya River Basins, Minneapolis, MN, November 7-9 (2006).
http://www.gfredlee.com/Nutrients/AvailPEPASymp06.pdf

address those issues.

Drs. Lee and Jones-Lee have reviewed the excessive fertilization of the Upper Mississippi River, examining the relative roles of agricultural land runoff and domestic wastewater sources in contributing to the problems. They are also working with the California Central Valley Regional Water Quality Control Board on the development of guidance for evaluating the water quality impact nitrogen and phosphorus in agricultural runoff/discharge and presented their findings in,

Lee, G. F. and Jones-Lee, A., "Assessing the Water Quality Significance of N & P Compound Concentrations in Agricultural Runoff," Invited presentation to the

Agrochemical Division, American Chemical Society national meeting, San Francisco, CA, September (2006). http://www.gfredlee.com/Nutrients/N-PRunoffACS.pdf

Lee, G. F., and Jones-Lee, A., "Assessing Water Quality Significance of N & P Compound Concentrations in Agricultural Runoff," PowerPoint Slides for Invited Paper Presented at Agrochemical Division, American Chemical Society National Meeting, San Francisco, CA, September (2006). http://www.gfredlee.com/Nutrients/N-PSlidesACS.pdf

With support of the California State Resources Board they developed,

Lee, G. F., and Jones-Lee, A., "Managing Nutrient (N & P) Water Quality Impacts in the Central Valley, CA," [Excerpts from: Lee, G. F. and Jones-Lee, A., "Review of Management Practices for Controlling the Water Quality Impacts of Potential Pollutants in Irrigated Agriculture Stormwater Runoff and Tailwater Discharges," California Water Institute Report TP 02-05 to California Water Resources Control Board/Central Valley Regional Water Quality Control Board, 128 pp, California State University Fresno, Fresno, CA, December (2002)], Report of G. Fred Lee & Associates, El Macero, CA (2002). http://www.gfredlee.com/SJR-Delta/CentralValleyNutrientMgt.pdf

That report presents a comprehensive review of nutrient evaluation/management issues. More recently, Drs. Lee and Jones-Lee worked with the California Water Environmental Modeling Forum to develop and present a workshop devoted to Delta Nutrient Water Quality Issues. Information on that workshop is available in

Lee, G. F., and Jones-Lee, A., "Delta Nutrient Water Quality Modeling Workshop — Background Information," Report of G. Fred Lee & Associates, El Macero, CA, September (2007). [available at:
http://www.gfredlee.com/Nutrients/NutrWorkshopRev4.pdf]

Our comments of the lack of validity of the US EPA former nutrient criteria development approach mentioned on the bottom of page 30 in,
"U.S. EPA. 2000a. Nutrient Criteria Technical Guidance Manual: Lakes and Reservoirs. Office of Water, Washington, DC. EPA-822-B-00-001.

U.S. EPA. 2000b. Nutrient Criteria Technical Guidance Manual: Rivers and Streams. Office of Water, Washington, DC. EPA-822-B-00-002.

U.S. EPA. 2001. Nutrient Criteria Technical Manual: Estuarine and Coastal Marine Waters. Office of Water, Washington, DC. EPA-822-B-01-003), and wetlands (U.S. EPA, 2007). in the RTAG and our comments as reference.

The State of California has Water Resources Control Board rejected the US EPA RTAG statistically based approach in favor of a site-specific approach for coastal waterbodies. These issues have been discussed in our Stormwater Runoff Water Quality Newsletters, NL-1-3, 5-1, 9-1/2, 9-8, 10-4, 10-5, 10-6, 10-7, 10-13, 11-2, 11-5, 11-9, 12-3, 12-5, 12-6, and 12-7/8.

As discussed by Lee and Jones-Lee in several papers and reports on their website, the US EPA approach for attempting to develop nutrient criteria over the past ten or so years involving statistical approaches is not valid. It often fails to incorporate cause and effect relationships in developing nutrient criteria that evolve from this approach. As an example is the US EPA's recent attempt to develop nutrient criteria for streams based on statistical correlations. We have provided comments on the fundamentally flawed nature of mechanically using statistics to develop so called relationships between total phosphorus and nitrogen concentrations and the impact of these chemicals a streams ecosystem. The NAS NRC review of this approach has concluded that this approach is a valid approach for developing nutrient criteria. Our comments on these issues are provided in,

Lee, G. F., and Jones-Lee, A., "Comments on 'US EPA "Empirical Approaches for Nutrient Criteria Derivation" Prepared by US EPA, Office of Water, Office of Science and Technology, Science Advisory Board Review, Draft August 17, 2009'," Report of G. Fred Lee & Associates, El Macero, CA, September 4 (2009).
http://www.gfredlee.com/Nutrients/EPA_Empirical_CritDevel.pdf

Hall, J., "Request for Peer Review of New EPA Region III Approach to Developing Instream Standards for Nutrients," Letter with attachments to Stephen Johnson, Administrator, US EPA, Washington, DC, Submitted by Hall & Associates, Washington, DC, August 21 (2008).
http://www.gfredlee.com/Nutrients/Hall_Cond_Prob_Eval.pdf

Lee, G. F., and Jones-Lee, A., "Comments on US EPA's Conditional Probability Approach for Developing Phosphorus Nutrient Criteria," Report of G. Fred Lee & Associates, El Macero, CA, September 26 (2008).
http://www.gfredlee.com/Nutrients/PCriterionCondProb.pdf

A list of their publications concerning eutrophication evaluation and management is available on this website. For further information, contact G. Fred Lee at gfredlee@aol.com