Comments on the US EPA's proposed "National Strategy for the Development of Regional Nutrient Criteria

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Via Express Mail

August 21, 1998

Nicholas A. Baer
Hlth and Ecol Criteria Div (4304)
Off of Sci and Tech; Off of Water
US EPA
401 M Street SW
Washington, DC 20460

Dear Mr. Baer:

Please find enclosed my comments on the US EPA's proposed "National Strategy for the Development of Regional Nutrient Criteria." As discussed, this is a topic area that I have worked on for nearly 40 years. I find that the US EPA has not adequately incorporated what is known about eutrophication impacts, assessment and management in formulating this Strategy. The timetable proposed for developing regional, waterbody-general-type, chemical-specific, nutrient criteria is far too short to develop technically valid criteria that can be used to cost-effectively identify excessive fertilization problems and develop appropriate management programs. Unless the Agency is careful, it could readily cause such a massive outpouring of anti-US EPA sentiment by urban dwellers and agricultural interests so as to call for the termination of the Agency management. There is need to develop a more appropriate approach for regulating chemicals in aquatic systems than exists today which focuses on chemical impacts rather than chemical concentrations.

I strongly urge that the US EPA abandon the chemical-specific approach and focus on a nutrient impact approach, i.e. controlling the problems of eutrophication rather than the chemicals that are in some loose, often ill-defined way related to excessive fertilization problems.

If there are questions or comments about the attached comments, please contact me. If I can help the Agency develop a more appropriate approach, please let me know.

Sincerely yours,

G. Fred Lee, PhD, PE, DEE

GFL:oh
Enclosure

Comments on "National Strategy for the Development of Regional Nutrient Criteria" Developed by the US EPA Office of Water, June 1998

Submitted by

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August 20, 1998

Presented herein are comments on the US EPA's June 25, 1998 "National Strategy for the Development of Regional Nutrient Criteria."

Overall Assessment

Overall, the draft National Strategy for the Development of Regional Nutrient Criteria fails to properly incorporate key information from the substantial literature that was developed in the 1960s and 1970s on reliably managing the excessive fertilization of waterbodies.

One of the most significant deficiencies in this Strategy is the failure to address the two most significant national water quality problems associated with excessive fertilization of waterbodies, namely impacts on domestic water supply raw water quality and impacts on the recreational use of waterbodies. More people are impacted by algal related tastes and odors and increased cost of domestic water supply treatment than any other water quality problem. The taste and odor problems associated with water supplies is a substantial national problem that needs to be addressed through a national eutrophication management strategy. The impairment of the recreational use of waterbodies through excessive growths of aquatic plants is one of the most important national water quality problems. The US EPA's national nutrient strategy must be focused on addressing this problem in a technically valid, cost-effective manner. Rather than the Agency focusing

on developing a national nutrient strategy that addresses eutrophication related water quality problems of limited national interest as is apparently being done based on the draft Strategy listing of problem areas, the Agency should focus its national strategy on the national eutrophication problems of concern to most of the people in the US.

The Agency's proposed approach of developing numeric chemical specific water quality criteria for nitrogen and phosphorus compounds as they may impact the excessive fertilization of various types of waterbodies in various parts of the country can readily lead to technically invalid nutrient management programs. If the Agency persists with this approach, it will almost certainly cause the US public and private interests to spend large amounts of funds in misdirected nutrient management programs.

The Agency should immediately abandon any attempts to develop numeric chemical specific nutrient based criteria for regulating nutrient inputs to waterbodies. The focus of the national eutrophication management program should be on controlling nutrient impacts, not nutrient concentrations that are in some poorly defined way related to the excessive fertilization of waterbodies. The US (Rast and Lee, 1978, 1981; Lee *et al.*, 1978) and international Eutrophication Studies (OECD 1982) of the 1970s provide a technical base for formulating technically valid, cost- effective phosphorus control programs for waterbodies in which phosphorus is the key limiting element governing the magnitude of deteriorated water quality due to planktonic algae in lakes and reservoirs. At this time there is an insufficient understanding of nutrient load eutrophication response relationships to develop technically valid, cost-effective nutrient management programs for waterbodies in which phosphorus is the limiting element where the excessive aquatic plant growth is manifested as attached algae and/or floating or attached macrophytes. Further, at this time, the relationship between nitrogen loads to waterbodies and the eutrophication response for all types of aquatic plant growth is such that it is not possible to establish reliable numeric chemical specific nitrogen based criteria.

Rather than developing a crash program to develop chemical specific nutrient criteria for types of waterbodies in various parts of the US, the US EPA should reactivate the eutrophication research program that was terminated in the 1970s to develop the necessary information base needed to formulate technically valid, cost-effective nutrient control programs for the US. The elements of developing a technically valid, cost-effective eutrophication management program for waterbodies is included within this discussion.

Qualifications of Commentors

The issue of appropriate regulation of aquatic plant nutrients (nitrogen and phosphorus) is an area to which the authors have devoted considerable attention throughout their professional careers. Beginning in the 1960s, Dr. G. Fred Lee became involved in establishing excessive fertilization - nutrient control programs for lakes and reservoirs located in the upper Midwest, including the US/Canadian Great Lakes. During the 1970s and 1980s he and Dr. Jones worked on these issues for lakes, reservoirs, and estuaries principally in the Southeast and Southwest. During the 1990s he and Dr. Jones-Lee have

been active in this topic area for lakes, reservoirs, estuaries, and nearshore marine waters primarily in California. Further, throughout this time, they have been involved in work on these topics in most parts of the world.

For 30 years, while he held university graduate-level environmental engineering and environmental science teaching and research positions, he devoted a considerable part of his professional activities to aquatic plant nutrient water quality management issues. He has conducted over several million dollars in research on this topic and has published extensively on it. He has worked on this issue throughout the US and in a number of other countries, including serving as the US representative to the international Organization for Economic Cooperation and Development (OECD) Eutrophication Studies that took place in the 1970s. During the 1970s, Dr. Lee was chosen to develop the synthesis report for the US EPA's components of the OECD international eutrophication studies. These studies represented a five-year, $50 million effort involving 22 countries in western Europe, North America, Japan and Australia examining the nutrient load eutrophication response of lakes and reservoirs and some estuarine and marine waters. In addition to developing a synthesis report for the US part of these studies, Dr. Lee represented the US in the international OECD eutrophication studies advisory board.

Beginning in the mid-1970s, Dr. Anne Jones-Lee (Dr. Jones) and Dr. Lee worked together as a team on these issues. Her biological background, coupled with her PhD dissertation devoted to assessing the role of sediments as a phosphorus source for excessive fertilization of waterbodies, and his expertise and experience in environmental engineering and environmental sciences, aquatic chemistry of nutrients and other constituents and consulting experience with governmental agencies and industry throughout the world, provides a high degree of expertise/experience in addressing excessive fertilization problems.

Following the completion of the international OECD studies in the late 1970s, Drs. Lee and Jones-Lee continued this work where they expanded the normalized phosphorus load eutrophication response relationships originally suggested by Vollenweider and verified in the OECD studies, to 750 waterbodies located in various parts of the world. They have published several synthesis reviews on this issue, as well as a number of other papers and reports, several of which are appended to these comments and others are listed and available from the authors, either through their web site (http://members.aol.com/gfredlee/gfl.htm) or upon request.

In addition to extensive work on eutrophication management in lakes and reservoirs, Drs. G. F. and Jones-Lee have considerable experience addressing excessive fertilization problems in tidal fresh water, estuarine, nearshore marine waters, as well as streams and rivers. With respect to rivers, they served as advisors to the French government on excessive fertilization of French rivers (Lee and Jones-Lee, 1988). They have also served as advisors to governmental agencies in Norway, The Netherlands, Israel, South Africa, Tunisia, Japan, Spain, Italy, Jordan, India, and Canada.

The authors are pleased to find that the US EPA is finally, after about a 20-year lapse, beginning to address one of the most significant causes of water quality use impairment in the US-excessive fertilization of the nation's waters. However, as discussed herein, the authors are concerned that the strategy proposed by the US EPA in June 1998 can readily lead to inappropriate approaches for managing excessive fertilization problems. Specific comments on issues that need to be addressed by the US EPA and the states in developing a technically valid, cost-effective nutrient management strategy are presented below. These comments include, as an attachment, a number of the authors' papers and reports pertinent to this topic. Many of the attachments to these comments have previously been provided to part of the US EPA team that developed this Strategy.

Specific Comments

Page iii, fifth paragraph, "Preface," states

"*EPA is also to work with States and Tribes to adopt criteria (i.e. numeric concentration levels) for nutrients, including nitrogen and phosphorus, as part of enforceable State water quality standards under the Clean Water Act.*"

It has been known for over 20 years that chemical-specific nutrient criteria similar to those that the US EPA has promulgated for potentially toxic constituents are not a reliable basis for developing technically valid, cost-effective nutrient control programs. Work done in many parts of the world in the 1960s and 1970s clearly demonstrated that there is no single numeric criterion value for nitrogen and/or phosphorus for managing excessive fertilization in various types of waterbodies such as streams, rivers, lakes, estuaries, etc., for various geographical regions. As discussed in publications of the authors which review the extensive literature on this topic, there are a wide variety of factors that influence how a particular concentration of a nutrient, such as nitrogen or phosphorus, impacts the water quality - beneficial uses of a waterbody. The US EPA and the states will be making a significant error if they proceed along the path which apparently is the focal point of this proposed national nutrient control strategy of developing chemical-specific nutrient concentrations that will serve as criteria that will be implemented into state water quality standards and NPDES discharge limits.

The Agency's attempts to develop nutrient based criteria similar to the existing "Gold Book" criteria for potentially toxic chemicals fails to recognize and address the significant problems that the Agency is now encountering in trying to use its chemical specific "Gold Book" criteria as a basis for developing technically valid, cost-effective management of chemical constituents that are potentially toxic to aquatic life. There is widespread growing recognition across the US by professionals within the water quality management field, that in the mid 1980s the Agency made a significant mistake in adopting numeric chemically based water quality criteria as a regulatory approach for managing potentially toxic chemicals. While that approach has often been said to have been highly successful, in fact it is fundamentally flawed. When the cost-effectiveness of the approach is critically examined it is found that it traps the US public into massive

expenditures for chemical constituent control beyond that needed to protect the beneficial uses of a waterbody.

That approach, when applied to urban area stormwater runoff under current regulatory requirements, will cause the public to ultimately have to spend hundreds of billions of dollars across the US treating urban area stormwater runoff associated constituents to meet US EPA worst case based numeric chemical specific water quality criteria and state standards based on these criteria in order to control certain heavy metals and organics in urban area and highway stormwater runoff so that the concentrations in the runoff waters do not cause exceedance of water quality standards by any magnitude more than once every three years. This is the current US EPA urban stormwater runoff water quality management program that is now being implemented across the US. The basic problem with this program is that it fails to recognize the significantly different physical, chemical and biological response characteristics between the conditions that exist in urban area and highway stormwater runoff and those that were used to develop the worst case based criteria. There are a number of studies that have shown that the heavy metals in typical urban area and highway stormwater runoff are in non-toxic/non-available forms, and while they cause administrative exceedances of water quality standards in the runoff waters, these exceedances do not represent real water quality use impairments of concern to the public. As discussed by Lee and Jones-Lee (1995a, 1996a, 1998a), there is growing recognition that the Agency should abandon its numeric chemical specific approach for regulating constituents as they may impact water quality and focus the regulatory programs on chemical impacts, not chemical concentrations.

The Agency is now proposing to expand its failed numeric chemical specific approach for technically valid, cost-effective regulation of potentially toxic chemicals in urban area stormwater runoff to include nitrogen and phosphorus compounds in the runoff and from other sources as they may impact the excessive fertilization of waterbodies. The proposed national nutrient strategy could well perpetuate a technically invalid approach of focusing on chemical concentrations of nitrogen and phosphorus compounds rather than on chemical impacts as measured by excessive growths of aquatic plants and/or the impacts of these growths on the beneficial uses of waterbodies. While the chemical concentration approach, i.e., numeric chemical specific criteria/standards, is bureaucratically simple to administer, it is often technically invalid and can readily lead to massive public expenditures for chemical constituent control which have little or no impact on the excessive fertilization of waterbodies. The chemical concentration approach fails to properly incorporate the physics and chemistry of constituents as they may impact aquatic life and other beneficial uses for potentially toxic chemicals. This problem will even be more severe when applied to nutrients because of the far more complex coupling between the concentration of a nutrient in water and the development of aquatic plants that impair the beneficial uses of a waterbody.

Recently, the US EPA has had to admit that its efforts over the last ten years to develop numeric, chemical-specific, sediment quality criteria have had to be abandoned in favor of sediment quality guidelines. The same situation could readily occur for the nutrient water quality criteria where because of the complexity of the aqueous environmental

chemistry of nutrients and the variety of other factors that influence aquatic plant production and the impacts of this production on beneficial uses of waterbodies, ultimately the Agency will have to abandon the basic foundation of its currently proposed National Nutrient Strategy in favor of nutrient guideline values for various types of waterbodies. Even guideline values are highly dangerous in that they tend to be utilized at the state and local levels as not-to-be-exceeded concentrations without regard to their limitations.

It has been our experience that there is limited ability among the regulatory community to properly incorporate the aqueous environmental chemistry, physical and other factors that must be considered in developing technically valid, cost-effective eutrophication control programs. We are already seeing regulatory agencies at the federal and state level ignore available forms of phosphorus and the hydraulic residence time of nutrients in a waterbody in formulating TMDLs for nutrients (Lee, 1998). This situation will almost certainly become worse than it is if the US EPA promulgates numeric chemical specific criteria for nutrients. These criteria will be misused as state standards and NPDES discharge limits. As discussed by Lee and Jones-Lee (1988, 1996b), the appropriate approach for developing a technically valid, cost-effective eutrophication management program is to develop a watershed-based assessment of available forms of nutrients as they may impact the beneficial uses of various parts of a waterbody, as well as the overall waterbody. This requires a site specific examination of nutrient loads eutrophication response relationships. Outside of using the OECD Eutrophication Study results for phosphorus limited waterbodies where the excessive fertilization problem is manifested as planktonic algae, there is no reliable basis for developing a national nutrient strategy. Considerable research needs to be done before such a strategy can be properly formulated and implemented.

An outline of a watershed-based excessive fertility control program is incorporated in these comments. This is the approach that the Agency should be promoting where it develops information that could be used by stakeholder groups to formulate and implement technically valid, cost-effective eutrophication/nutrient control programs that are in tune with the stakeholders' desires for eutrophication-related water quality in the waterbody of concern and their financial resources to achieve this water quality. As discussed in a subsequent section, the ultimate control of nutrients - eutrophication of waterbodies will be met with opposition by sports fisheries and some other groups who will want to maintain the productivity of the waterbody in order to support a high level of sports fishing and other wildlife productivity.

Page iv, second paragraph, states

"*In the case of nutrients, however, there is a great deal of variability in inherent nutrient levels and nutrient responses throughout the country. This natural variability is due to differences in geology, climate, and waterbody type.*"

This statement fails to properly present the information in the vast literature on this topic. The issue is not only waterbody type, such as lake, river, stream, etc., geology and

climate, the issue is the waterbody's morphological characteristics and hydrology. It is inappropriate to group all lakes and reservoirs into one waterbody type and try to establish a nutrient criterion for this type within a geographical/climatic region. Such an approach will almost certainly over-regulate nutrient discharges to a waterbody if the typical US EPA worst-case-based approach that is used to establish the national water quality criteria is followed.

This paragraph also states,

"*EPA believes that distinct geographic regions and types of waterbodies need to be evaluated differently and that recommended nutrient concentration levels need to reflect geographic variation and waterbody types.*"

The issue is not geography or climate; nutrient load eutrophication response relationships are controlled by morphological and hydrologic and other characteristics of the waterbody. As demonstrated in our work as part of the OECD Eutrophication Study Program conducted in the 1970s, the phosphorus load eutrophication response relationships for lakes and reservoirs ranging from an antarctic lake through desert reservoirs is the same when the nutrient loads are normalized based on hydrologic and morphologic characteristics (Jones-Lee and Lee, 1993).

On page iv of the "Preface," several timetable deadlines for the development of the nutrient criteria are established which include the states having adopted nutrient criteria that support states' designated uses by 2003. Based on almost 40 years of work on nutrient load eutrophication response issues and how states and the US EPA develop criteria and standards and implement them into control programs, 2003 is too short a time to properly develop technically valid, cost-effective nutrient criteria for nitrogen. The work done during the 1960s and 1970s under the sponsorship of the US EPA and its predecessor organizations which was culminated in the OECD eutrophication studies provides the technical base for developing an approach for nutrient criteria (not single numeric chemical specific values), but a regulatory approach which properly reflects how nutrients impact the eutrophication-related water quality of a waterbody for lakes and reservoirs where the problem is manifested as planktonic algal growth. 2003 is too short a time to develop nutrient criteria to address attached and floating macrophytes and attached algae that are controlled by phosphorus loads to a waterbody. Considerable additional research is needed before appropriate nutrient criteria can be developed to control these types of eutrophication-related water quality problems.

Page v, second paragraph, states,

"*Once adopted as part of State or Tribal water quality standards, the nutrient criteria in State standards will become the basis for identifying waters where nutrients result in impairment of water quality and making many management decisions to reduce excessive nutrient levels in these waters."*

The US EPA must immediately abandon this approach, which is more of its ill-founded, chemical-specific criteria approach, in favor of chemical impact control programs. As discussed in the enclosed reports/papers, those familiar with nutrient load eutrophication response relationships know that the focus of the control programs has to be on the problems caused by excessive fertilization, namely excessive aquatic plant growth or hypolimnetic oxygen depletion, etc. It should not be on nutrient concentrations as proposed by the Agency. The coupling between nutrient concentrations and excessive fertilization response as manifested by excessive aquatic plant growth is poorly understood for all areas, except phosphorous-limited waterbodies where the excessive growths of algae are manifested as planktonic algae. There is substantial literature developed in the 1960s and 1970s that provides far greater insight into these issues than is demonstrated in this proposed strategy.

As proposed, the nutrient control strategy can cost the public many billions of dollars in unnecessary, inappropriate nutrient control because of the failure of the US EPA and the states to properly incorporate into the criteria and their implementation approach and standards what has been developed through many years of research prior to the time that the US EPA abandoned nutrient-caused water quality problems as a significant area of emphasis in the mid-1970s. Over the last 20 years, there has been a massive void of lack of research on these issues. Before any meaningful strategy can be developed, the Agency must again develop a credible, national research program to reliably investigate nutrient load eutrophication response relationships, especially for nitrogen-limited waterbodies and waterbodies where the primary problems are associated with attached algae, and floating and attached macrophytes.

Page 1, third paragraph, states,

"Symptoms include an overabundance of primary producers, decreased biological diversity, algal blooms (some toxic), low dissolved oxygen, episodic anoxia, loss of vascular plant life, and fish kills."

Several of these so-called impacts are not necessarily valid or national problems. While it is often stated that there is decreased biological diversity in eutrophic waters, in fact, the diversity in eutrophic or hypereutrophic lakes and reservoirs is as high as in oligotrophic waterbodies. What happens is that certain types of organisms develop to a greater extent; this does not necessarily rule out the development of a wide variety of other organisms, however.

With respect to toxic blooms, this is a red herring that is not a national problem that can be meaningfully addressed through this Strategy. I have worked on toxic bloom issues at several locations in the US and in other countries for over 30 years. The conditions that lead to toxic blooms are so poorly understood as to make any attempt to control them through a eutrophication control program highly remote.

The low dissolved oxygen issue rarely occurs in surface waters; it is related to thermal or salinity stratification. Our work on the US OECD Eutrophication Study Program

developed a nutrient load hypolimnetic oxygen depletion rate relationship that can be used to predict, for certain types of waterbodies, the impacts of nutrient loads on the oxygen resources of a waterbody. The key issue that is driving excessive fertilization control in some parts of California is not anoxia, but diel dissolved oxygen depressions, which at certain times during the day, under certain climatic conditions, lead to excursions of the dissolved oxygen levels below state water quality standards for DO. This is a much more subtle and difficult problem to address. It could become one of the most important impacts of eutrophication since it does represent a violation of water quality standards.

An even more significant eutrophication problem that is not generally recognized is the cause of sediment toxicity. Dissolved oxygen depletion in sediments is the most important cause of sediment toxicity, through either the loss of oxygen or, more importantly, the production of ammonia and hydrogen sulfide. Lee and Jones-Lee (1996c) have reviewed the impacts of eutrophication on sediment toxicity.

The so-called loss of vascular plant life mentioned here is somewhat of a misnomer in that vascular plants will and do develop in hypereutrophic waterbodies. In fact, the development of vascular plants is one of the major problems impairing the use of waterbodies associated with waterbody enrichment. Several parts of the country are experiencing excessive growths of water hyacinth and other floating macrophytes, which severely impact the beneficial uses of waterbodies. The relationship between nutrient loads and floating macrophytes is poorly understood, and one that needs considerable research. This is a national problem that needs to be addressed, which cannot be reliably addressed within the time frame that the US EPA has allowed for implementation of this Strategy. As discussed by Lee (1973) the issue of concern in attached vascular plant development in lakes and reservoirs is the change in light penetration due to planktonic algal growth as it may impact the growth of attached macrophytes and attached algae. Again, there is an insufficient understanding of these issues to enable them to be meaningfully addressed in the time frame that the US EPA has proposed for developing numeric chemical specific nutrient criteria.

With respect to fish kills in eutrophic waterbodies, these are rare. They do occasionally occur. However, this is not a major national problem. Further, the actual cause of the fish kills in some areas is poorly understood. There is no reliable basis for assessing what constitutes excessive nutrients in a waterbody that will necessarily lead to fish kills.

The real national problems of eutrophication which are not mentioned in the Strategy are the impacts on the aesthetic quality of the waterbody for recreational and domestic water supply purposes. The hypereutrophication of waterbodies results in floating algal scums, excessive growths of attached algae which interfere with contact and other recreation, decreased water clarity, severe odors and significant water quality problems for domestic water supply associated with taste and odor production, shortened filter runs and in some, apparently rare, situations, increased trihalomethane precursors. The Agency's listing of eutrophication related water quality problems, where they have focused on issues that are not necessarily national problems, and certainly not ones that can be addressed in the

implementation of this Strategy, is deficient, especially in light of the fact that the major eutrophication problems of the US are not mentioned.

Page 1, fifth paragraph, indicates that US EPA is headed toward "*Legally, a nutrient criterion is the numeric value which supports a particular beneficial designated use in defining a water quality standard."* where a chemical-specific criterion will be developed for nitrogen and phosphorus for various types of waterbodies. As discussed herein, this approach has been known to be technically invalid for over 20 years.

With respect to the next sentence, *"Scientifically, a nutrient criterion is meant to encompass both causal and response variables (e.g., nitrogen or phosphorus levels), as well as aquatic community response parameters such as but not limited to algal biomass, chlorophyll a, and secchi depth."* this approach ignores the attached algae and floating and attached macrophyte problem. Further, it is well-known that nitrogen and phosphorus levels are not appropriate parameters for judging excessive fertilization. The focus must be on the eutrophication response, not the nutrients which often in a very complex way can influence this response.

Page 1, sixth paragraph, states, *"Similarly, in this text the problem of* eutrophication *is used to describe an increase of nutrients in a waterbody which results in an overabundance of plant biomass (Flemer, 1972)."* Eutrophication is well-defined in the limnological literature. It is not, contrary to the statement made herein, and evidently by Flemer, an overabundance of plant biomass; it is an enrichment. This enrichment may or may not result in an overabundance of aquatic plants in a particular waterbody. Eutrophication is a process, not the result of the process, i.e., eutrophic or hypereutrophic waters.

On the bottom of page 1 and top of page 2, it is stated,

"In all aquatic ecosystems some general processes determine whether N or P is the limiting macronutrient and can be expressed as the nitrogen-to-phosphorus ratio (N:P). The Redfield ratio *of N:P for primary producers in marine systems is approximately 16:1 on a molar scale (Redfield, 1958). In freshwater systems the phosphorus limitation tends to be greater at an N:P ratio of up to about 26:1. Ecosystems that deviate substantially from these ratios are likely to experience nutrient limitation of either N or P (i.e., if the ratio in marine or estuarine waters is less than 16, N could be limiting; if the ratio is greater than 16, P is probably the limiting nutrient)."*

Contrary to the statement made, Redfield numbers as presented in this paragraph are not reliable indicators of limiting nutrients. The limiting nutrient in a eutrophication management program is the nutrient that limits the rate of growth of the aquatic plants to a sufficient extent to limit the water quality impacts of the growth. The mechanical use of Redfield numbers as presented in this paragraph will, in many situations, lead to incorrect conclusions regarding limiting nutrients. A nutrient is limiting only when the concentration of available forms of the nutrient are less than those that are needed for the optimum growth of the aquatic plant. Most hypereutrophic waterbodies have surplus

nitrogen and phosphorus compared to that needed for algal growth, with the result that neither nitrogen or phosphorus is limiting. Under these conditions large amounts of nitrogen and phosphorus removal can occur at considerable expense to the public without significant impact on excessive fertility of the waterbody. This section ignores the basic biochemistry of how nutrients are used by algae. Attached is a report entitled, "Determination of Nutrient Limiting Maximum Algal Biomass in Waterbodies," (Lee and Jones-Lee, 1998b) which evolved from work by the American Water Works Association Quality Control in Reservoirs Committee, which discusses how to properly assess limiting nutrients under conditions where the aquatic plant growth is manifested as planktonic algae. Under conditions where there is attached algae, or macrophytes, the issue of limiting nutrients still needs to be investigated. Limiting nutrients for these types of plants are different than planktonic algae.

Lee and Jones(1992) and Lee and Jones-Lee (1992) have developed guidance for formulating the minimum monitoring program that will provide the kind of information that is needed to implement the OECD Vollenweider eutrophication modeling results. This program evolved from the experience of the five-year, 200-waterbody nutrient load eutrophication response studies that were conducted in the OECD Eutrophication Study Program as well as their experience in conducting studies of this type in several parts of the world.

Page 2, fourth paragraph, states

"Sources historically associated with nutrient overenrichment are fertilizers, sewage treatment plants, detergents, septic systems, combined sewer overflows, sediment mobilization, animal manure, atmospheric deposition and internal nutrient recycling from sediments."

Contrary to the statement made, the phosphorus in detergents has not been a cause of excessive fertilization of waterbodies. As has been documented in the literature, the amount of phosphorus in detergents has not been and is not now sufficient to cause increased fertility in waterbodies that the public can perceive. This issue was addressed in a paper developed by the authors, "Detergent Phosphate Bans and Eutrophication," Lee and Jones (1986) and Lee and Jones-Lee (1995b), where the authors developed a relationship which showed that at least a 25% reduction of available phosphorus loads in a waterbody is necessary in order for the public to perceive a change in the planktonic algal chlorophyl that is present in the waterbody. For hypereutrophic waterbodies, much larger changes in phosphorus loads are necessary to cause an improvement in the eutrophication related water quality of the waterbody.

With respect to the internal nutrient cycling being a significant source of nutrients that maintains excessive fertility of the waterbody independent of the nutrient loads, again this is a bugaboo that is often presented as a major cause of excessive fertilization of waterbodies. However, it was well-documented in the 1960/1970s, through the use of phosphorus residence time models, (Sonzogni *et al.* 1976) that the internal nutrient cycling in a waterbody is not a major factor in contributing to the excessive fertilization

of the waterbody. As has been demonstrated in the literature (Rast *et al.,* 1983), controlling the external sources of phosphorus to a waterbody results in a rapid decrease in the excessive fertility of the waterbody proportional to the amount of phosphorus control for phosphorus limited waterbodies. The time needed to achieve this decrease is governed by the phosphorus residence time in the waterbody. While similar information is not available for nitrogen-limited waterbodies, it is expected that the same situation would occur. The sediments of a waterbody are sinks for nutrients which do not control excessive fertilization. Excessive fertilization is controlled by the nutrient loads to the waterbody, not by internal nutrient cycling.

With respect to the statement that sediment suspension releases nutrients, that statement is true for ammonia associated with sediment interstitial waters. It is not generally true for phosphorus. Jones and Lee (1981) summarized the results of Dr. Jones' dissertation devoted to the release of phosphorus from aquatic sediments upon suspension in the water column. They reported that, while there is some phosphorus in the interstitial waters of sediments that is released to the water column upon sediment resuspension, these same waters contain ferrous iron, which upon contact with oxygen is oxidized to ferric hydroxide which co-precipitates any phosphorus released from the sediment interstitial water. Therefore, contrary to the statement made in the Strategy, the suspension of sediments generally does not result in phosphorus release to the water column.

Page 2, same paragraph, states

"Other factors that can influence overenrichment are light attenuation, land-use practices, and imbalance of primary, secondary, and tertiary producers and consumers (plankton, macrophytes, epiphytes, grazers, predators, and decomposers)."

Light attenuation, except in severely light-limited conditions (secchi depth less than 0.2 m) caused by high levels of natural color or suspended solids - turbidity is not a factor in controlling excessive fertilization of waterbodies. As discussed by Lee *et al.* (1995a), while light limitation due to planktonic algae can slow down the rate at which planktonic algae reach maximum biomass, it does not control the severity of the algal blooms that can occur except under severe light limitation conditions.

With respect to land use practices influencing the fertility of waterbodies, Rast and Lee (1984), using the US OECD Eutrophication Study data base (Rast and Lee, 1978) developed national nutrient export coefficients for various types of land use. These coefficients, when combined with the OECD phosphorus load eutrophication response relationships described by Jones and Lee (1982, 1986) enable predictions to be made of the impact of altering land use on the eutrophication related water quality. This is an extremely powerful tool that can be used in developing eutrophication management programs for rapidly developing areas.

The issue of the numbers and types of primary, secondary and tertiary producers and consumers mentioned in the Strategy is not an "imbalance" problem. It is a factor that

must be considered in site specific examination of nutrient load eutrophication response water quality relationships. It is well established that introduced species can significantly impact how aquatic plant production impacts water quality. This is another of those issues for which the US EPA will not be able to adequately consider in the time frame allowed in formulating numeric chemical specific water quality criteria for nutrients.

Page 3, in the box at the top of the page, lists the number of states that have no water quality standards for various forms of nutrients. While the US EPA, in the draft Strategy, implies that this is a deficiency on the part of the states who do not have nutrient standards, there is a justified reason for this situation. The US EPA in the 1970s abandoned work on nutrients - excessive fertilization and chose to focus its regulatory and research efforts on chasing rodent carcinogens as listed in the Priority Pollutants. This resulted in the US EPA's mid-1970s management shutting down a highly credible eutrophication study program which, if it had been allowed to continue, would have now developed the information that is needed to develop credible nutrient control programs for those areas for which there is a lack of technical information. The Agency should not now issue an edict that nutrient criteria will be developed by the states within a few years without having the technical base of information that is needed to formulate technically valid criteria for managing excessive fertilization in various types of waterbodies.

With respect to 17 states having no water quality standards for nitrate and nitrate/nitrites, the states that have such standards based on nutrients have adopted technically invalid approaches since there is not adequate technical information today to develop appropriate nitrate/nitrite nutrient-based criteria.

With respect to 21 states having no water quality standards for phosphorus, again unless the states become familiar with the OECD Eutrophication Study results, they probably have developed technically invalid approaches for limiting phosphorus concentrations in waterbodies. The OECD eutrophication studies, which were supported by the US EPA, clearly demonstrate that single numeric values are not appropriate for phosphorus, even when grouped by region and waterbody type.

With respect to the statement, *"Many States have narrative standards only,"* narrative standards are appropriate for excessive fertilization since the primary impacts of excessive fertilization are aesthetics, i.e. excessive growths of algae that impair recreational use. The appropriate approach for developing nutrient control programs should be based on a narrative standard in which the people of the region of a waterbody who are concerned about the effects of excessive fertilization on the waterbody's beneficial uses need to determine that the waterbody is excessively fertile, not based on nutrient concentrations but excessive growths of aquatic plants that interfere with use. This is a local regional issue that varies widely in various parts of the country. In Wisconsin and in Minnesota where there are many thousands of lakes available for recreational pursuits, the public has the opportunity to examine oligotrophic vs. eutrophic waterbodies for various aspects of recreational pursuits. However, in many other parts of the country, such as in the Tennessee Valley Authority where the authors have worked, what is judged to be excessive fertility in Wisconsin is acceptable fertility in the

Tennessee Valley. This is related to the fact that the people in that region do not have the opportunity to experience low fertility waters. As a result, the nutrient levels that are judged to be excessive in Wisconsin will be significantly different for the same type of waterbody than in Tennessee or Texas or many other parts of the country. This issue is discussed in the attached reports (Lee *et al.*, 1995b,c) devoted to properly assessing the trophic state of waterbodies.

Page 3, in the box at the top, states, *"10 States have adopted EPA criteria unrelated to eutrophication (e.g., 10 mg/L for nitrate, or 0.10 µg/L elemental phosphorus).*" To list this as an issue along with the failure of states to adopt nutrient criteria is inappropriate. As discussed in the National Academies of Science and Engineering "Blue Book of Water Quality Criteria," released in 1973, the US EPA "Red Book of Water Quality Criteria" released in 1976 and the American Fisheries Society critique of the "Red Book" released in 1978, there is justification for listing concentrations of nitrate-nitrogen above 10 mg/L and elemental phosphorus above 0.10 µg/L P based on toxicity to aquatic life for humans. These criteria are based on different non-nutrient impacts and are appropriate.

Page 4, first bulleted item, "Nonpoint Sources: Picking Up the Pace; A National Strategy for Strengthening Nonpoint Source Pollution Management (draft, September 1997)," states

"This strategy envisions that all States/Tribes, with the active assistance and participation of all stakeholders, will implement dynamic and effective nonpoint source pollution programs to achieve and maintain beneficial uses of water by the end of calendar year 2013."

This statement does not reflect the situation that exists today on controlling non-point source pollution from agricultural/rural runoff. Thus far, there has been limited significant progress to eliminating the pollution of the nation's surface and groundwaters by agricultural runoff and infiltration. As discussed by Lee (1997), agricultural interests in some parts of the US have been able to effectively stop all efforts to reduce the pollution of surface and groundwaters by nutrients, pesticides, etc. While 2013 represents 14.5 years, it is unlikely that the political power of agricultural interests and agricultural chemical interests will be sufficiently neutralized by that time to enable the development of effective nutrient, pesticide and other agricultural-oriented water quality control programs to be implemented. Congress has thus far and almost certainly will continue in the future to prohibit the US EPA and, at the state level, state pollution control agencies, from developing meaningful effective pollution control from agricultural sources in many parts of the country. Until such control is, in fact, implementable, the US EPA cannot develop a reliable national nutrient control program.

One of the issues that is missing from the draft Strategy that must be an important component of it, is the need to focus nutrient control programs on available forms of nutrients rather than total nutrients. Work by the senior author and his graduate students in the 1970s, as well as many others subsequently, have demonstrated that most of the

particulate phosphorus present in erosional runoff from agricultural areas and in urban area and highway stormwater runoff is in a non-algal available form. On behalf of the International Joint Commission for the Great Lakes, the authors and their associates (Lee *et al.*, 1980) developed a review devoted to the importance of focusing nutrient control programs on available forms of nutrients. While this issue has been well documented, regulatory agencies in various parts of the country are focusing nutrient control programs on non-algal available forms of nutrients. Such an approach can readily lead to large scale inappropriate use of public and private funds in implementing nutrient control programs that will have far less impact on the excessive fertilization of a waterbody than those typically predicted, where the predictions use total phosphorus and total nitrogen loads rather than available loads. The net results is that the public will be mislead with respect to the potential benefits of spending funds to control nutrient input, since, for some situations, a large part of the funds will be devoted to nitrogen and phosphorus that are not nutrients for algae and other aquatic plants.

On page 4, the second bulleted item, "Strategy for Addressing Environmental Public Health Impacts from Animal Feeding Operations (AFOs) (draft, March 1998)," does not mention dairies as a source of nutrients. Dairies are a significant cause of surface and groundwater pollution by nutrients (nitrogen for surface and groundwaters and phosphorus for surface waters). The situation in California with respect to regulating dairies is typical of what occurs in many areas where large amounts of nitrogen and phosphorus are discharged to surface and groundwaters with little control, since the pricing structure for milk in many areas, such as California, is such that it is not possible for dairies to increase the cost of milk to cover the cost necessary to control the pollution of the environment by nitrogen and phosphorus compounds. Until this issue is effectively addressed, the ability to control dairy inputs of nitrogen and phosphorus to surface and groundwaters will be limited.

Page 5, first paragraph, mentions the ANPRM. The authors are providing separate comments on the appropriateness of the ANPRM with respect to nutrients issues. Many of the issues discussed herein will be discussed in the comments on the needs for revisions of the US EPA's approach for developing, and, most importantly, implementing water quality criteria into state standards and NPDES permitted discharges.

Page 5, middle of the page, states,

"The groups developing the strategies are all investigating related problems...land use-nutrient loading relationships, ecological responses, and appropriate mitigation activities. As all of these strategies progress, it will be essential to coordinate the information and activities that result so that consistent policy is developed."

It should be noted that the primary eutrophication impact issues, namely the aesthetic quality of waters impacted by excessive fertility and the impact on domestic water supplies is apparently not being included as problems of concern by the US EPA and the other agencies developing the Strategy. These are the issues that affect most Americans. They are the issues that need to be addressed in a meaningful nutrient-control strategy.

While there are some localized atypical significant eutrophication problems, such as in Chesapeake Bay, these are not national problems that should cause the Agency to develop a crash program for controlling nutrient inputs to lakes, reservoirs, rivers and many other waterbodies located throughout the country.

Page 5, mid-paragraph, under "EPA National Strategy for Developing Regional Nutrient Criteria," states, *"This Strategy proposes to build on the work accomplished to date and to establish an objective, scientifically sound basis for assessing nutrient overenrichment problems."* The authors have little confidence that the US EPA can develop such an approach based on the work that the Agency has done as manifested by comments made in this proposed Strategy. The Strategy does not adequately and reliably present the substantial literature that was developed prior to the time that the US EPA shut down research on nutrient load eutrophication response relationships in the nation's waters in the mid-1970s. The first step in developing a credible strategy is to become familiar with the large amounts of work that was developed in the 1960s and 1970s that was directed to the specific issues that are finally now being addressed by the Agency.

Page 5, under "EPA National Strategy for Developing Regional Nutrient Criteria," states that the *"EPA will develop 'nutrient criteria guidance' for nitrogen, phosphorus, and other nutrient parameters such as chlorophyll a, secchi depth, and algal biomass."* As discussed herein, chemically-based nutrient criteria for waterbody types as proposed by the Agency will not be technically valid since this approach has been known for over 20 years to be inappropriate. Chlorophyll a is a regional applicable eutrophication response parameter for some types of waterbodies, which is a measure of greenness of the water. The public's response to chlorophyll a depends on geographical location. A certain greenness in Wisconsin is significantly different to the public than the same greenness in Tennessee or other parts of the TVA (Newbry *et al.*, 1979).

With respect to the use of secchi depth as a eutrophication parameter, caution must be exercised in the use of this parameter since natural color and inorganic turbidity can significantly impact the secchi depth of a waterbody. Further, unless there is severe light limitation the planktonic algal chlorophyl that develops as peak biomass in the waterbody will be the same as in waterbodies where the secchi depth is controlled by planktonic algae. A report, "Secchi Depth as a Water Quality Parameter," (Lee *et al.*, 1995a) covering the appropriate use of secchi depth in eutrophication management programs is attached to these comments.

There are several other parameters, such as the extent of areal coverage by floating macrophytes, macroalgae, and attached algae, which cause major national eutrophication related water quality problems, that should be part of the parameters that need to be addressed in any credible national nutrient control strategy. However, as discussed herein, these problems do not lend themselves to developing chemical specific numeric nutrient criteria. The information base on nutrient concentrations vs. eutrophication response does not exist for these kinds of problems. Without this information base, any selection of a critical nutrient concentration will be largely arbitrary and either fail to

adequately address the problems that are of concern to the public, or over-regulate nutrients resulting in a mis-use of public funds.

The statement in the latter part of this paragraph about focusing on waterbody types, such as streams and rivers; coastal waters and estuaries; lakes and reservoirs; and wetlands, as discussed herein, will not lead to technically valid, cost-effective eutrophication management programs. It is inappropriate for the US EPA to develop nutrient criteria for all lakes and reservoirs, estuaries, etc., within a given geographical region. Each one is individual, and there is need to consider the morphological and hydrologic characteristics of the waterbody in developing nutrient management programs.

Page 6, item 2, states, *"These 'nutrient criteria' will be based on EPA's nutrient criteria guidance or other scientifically defensible methods and will be incorporated into the States' water quality standards."* Repeatedly over the years, the US EPA has claimed that its criteria are based on scientifically defensible approaches. While in most cases this statement is appropriate, the implementation of the criteria into standards and their use to limit point and non-point source discharges often lacks scientific and engineering credibility. The Agency should stop the mechanical approach fostered on the states for implementation of its criteria into standards and NPDES discharge limits and focus considerable efforts on developing appropriate discharge limits that will protect the designated beneficial uses of waterbodies from excessive fertilization without significant unnecessary cost to public and private interests.

On page 8, under "Nutrient Criteria and Standards Development," the statement is made,

"Upon completion of all the waterbody-type guidance documents, EPA expects all States and Tribes to adopt and implement numerical nutrient criteria into their water quality standards within three years of publication of waterbody type guidance documents and to complete adoption of nutrient criteria for all waterbodies in the State by no later than December 31, 2003."

This timetable is far too short to develop technically valid nutrient criteria based on the current state of information that is available today in this topic area.

Page 15 lists a number of parameters that have been suggested as possible indicators. Several of these are not technically valid and even those that are valid are valid under limited conditions. The bottom-line issues for most eutrophication situations are not listed such as the frequency and severity of nuisance algal blooms or tastes and odors in domestic water supplies. Also, the areal extent of coverage of the waterbody by macrophytes and attached algae should be a parameter that is listed. This Strategy is significantly deficient in addressing the real eutrophication water quality problems as they affect the majority of the public.

Many of the chemical parameters listed under "Chemical/Biomass Parameters" can yield unreliable estimates of the eutrophication characteristics of a waterbody.

At the bottom of page 15, why is "TN" listed as an indicator of plankton-dominated systems for streams and rivers? It is not a valid parameter. Similarly, the top of page 16 contains a number of parameters that are listed that can readily lead to inappropriate assessments of the extent of excessive fertilization of rivers and streams and, most importantly, the impact on the public.

An issue that is not addressed in this Strategy that will likely become important in several areas of the country is the impact of significant control of nutrient inputs to waterbodies on the quality of fisheries within the waterbody. Lee and Jones-Lee (1991) have discussed the relationship between nutrient loads to waterbodies and fish production within the waterbodies. For many waterbodies there is a coupling between the available phosphorus loads to a waterbody and the fish biomass produced within the waterbody. Therefore, when the available limiting nutrient load to the waterbody is significantly decreased, the amount of fish present in the waterbody will decrease. This situation is already occurring in Lake Erie, where the sports fishermen are complaining about the significant decrease of the fisheries in the lake, and are blaming this decrease on the reduced phosphorus loads to the lake. Lake Erie is responding as it should, with respect to decreasing the phosphorus loads, decreasing the phytoplankton, which through the food web decreases the fish biomass. Some sports fishing groups are calling for adding phosphorus to Lake Erie to restore the quality of the fisheries.

A similar situation is projected to occur (Lee and Jones-Lee, 1998c) in the Sacramento/San Joaquin River Delta, where there are severe excessive fertilization problems as manifested by water hyacinth growth within the Delta and excessive growths of planktonic algae in water supply reservoirs that utilize Delta waters as a raw water source. The algae in these reservoirs cause severe taste and odor problems for water utilities that provide domestic water supplies for about 20 million people in California. The water utilities would like to see the nutrients input to the Delta decreased. However, fisheries' interests are opposed to this approach because of the potential adverse impact on fisheries.

The formulation of a technically valid national nutrient control strategy by the US EPA must include developing an approach for addressing the conflict of interest between fisheries groups and those that want to minimize eutrophication related water quality.

Overall, the US EPA is trying to make up for 20 years of neglect of the excessive fertilization area by initiating a crash program on developing chemically-based nutrient criteria. This approach could meet with such opposition to call for Congress to terminate the appointment of the US EPA Administrator in an effort to develop an organization that can more appropriately address the water quality problems than the Agency is proposing to do for nutrients. Unless the Agency is careful, it will have essentially all urban dwellers and all agricultural interests vigorously opposing the US EPA's existence. A considerable part of this opposition could be justified since it will not be possible for the Agency to reliably implement its proposed strategy in accord within the timeframe allowed in a technically valid, cost-effective manner for regulating the excessive fertilization problems of this country.

Development of a Water Quality Management Program for Excessive Fertility in Waterbodies

Presented below are the elements of a watershed-based aquatic plant nutrient control program to manage excessive fertility in waterbodies. Jones-Lee and Lee (1998) provide additional detail on the development of technically valid, cost-effective aquatic plant nutrient control programs.

Organize the waterbody's watershed stakeholders into a public group to address the excessive fertility problems.

Appoint a Technical Advisory Committee (TAC) to provide technical guidance to the stakeholders on the development of a technically valid, cost-effective excessive fertility management program

The TAC is to organize and supervise the implementation of the technical components of the excessive fertilization management program

Technical components of the eutrophication management program

Review existing data on waterbody and watershed pertinent to excessive fertilization water quality problem

Consider data quality and adequacy to define:

The magnitude of the excessive fertilization problems and

How the excessive eutrophication water quality problems impact the public's use of the waterbody.

Factors causing and controlling the excessive fertilization,

Define the limiting nutrient(s)/factors

Sources of total and algal available nutrients

Potential for controlling limiting nutrient input to the waterbody

Develop a conceptual model of the excessive fertilization problem, its causes and potential control approaches

Use the model to help organize the excessive eutrophication management program

The model should not become a computer game

Develop a monitoring/evaluation program to fill information gaps

Conduct a highly focused information collection monitoring/evaluation program.

Review the data as collected and adjust the program to maximize the useful information gained for the monitoring funds available.

Refine the conceptional model of the eutrophication problem to develop a best estimate nutrient load - eutrophication-related water quality response

Use this model to make an estimate of the impact of controlling the input of the limiting nutrient to a certain degree on the magnitude of the excessive fertilization water quality problem

When adequate data/information is available to reliably define the eutrophication-related water quality problems, their causes and potential control programs, work with the stakeholders in developing the eutrophication management program that is appropriate for the waterbody and the watershed.

- Define the desired eutrophication-related water quality
- Assess the resources available to implement the eutrophication control program
- Assess the potential adverse consequences of eutrophication management on the fisheries and others aquatic life resources of the waterbody.

Do not rely on numeric chemical-specific nutrient water quality criteria/standards to establish eutrophication management goals

Such criteria/standards will not likely be reliable for cost-effective management of a waterbody's excessive fertilization water quality problems

Develop a stakeholder consensus on the appropriate eutrophication management program appropriate for the waterbody and watershed

Monitor the implementation of the eutrophication management program.

Based on the results, adjust the program as more is learned about the nutrient load-eutrophication response relationship for the waterbody of concern.

Review with the stakeholders the previously adopted consensus of the desirable goals for eutrophication management in the waterbody of concern

Adjust the goals for the eutrophication management program to reflect what can be accomplished with the funds available for eutrophication management as well as the stakeholders' consensus of desired degree of excessive eutrophication management based on the new information available from the monitoring of the implementation of the eutrophication management program.

Adoption of this approach for excessive eutrophication management will lead to a technically valid, cost-effective eutrophication control program that will meet the needs and resources of the stakeholders for the waterbody and watershed of concern.

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Summary Biographical Information

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Anne Jones-Lee, PhD

Dr. G. Fred Lee is president and Dr. Anne Jones-Lee is vice president of G. Fred Lee & Associates, an environmental consulting firm located in El Macero, California. For 30 years, Dr. G. Fred Lee held university graduate level teaching and research positions at several major US universities, including a Distinguished Professorship of Civil and Environmental Engineering at the New Jersey Institute of Technology. Dr. Anne Jones-Lee taught graduate level environmental engineering and environmental sciences courses and conducted research for 11 years. She held an associate professorship in civil and environmental engineering at the New Jersey Institute of Technology. In 1989, Dr. G. Fred Lee and Dr. Jones-Lee assumed full-time consulting activities through G. Fred Lee & Associates.

Dr. G. Fred Lee holds a PhD degree from Harvard University in Environmental Engineering and Environmental Sciences and a Master of Science in Public Health degree from the University of North Carolina. He obtained a bachelors degree from San Jose State University. Dr. Anne Jones-Lee holds a bachelors degree from Southern Methodist University and a masters and PhD degree in environmental sciences from the University of Texas at Dallas. She has published over 200 professional papers and reports.

Dr. G. Fred Lee has conducted over $5 million in research on various aspects of water quality and solid and hazardous waste management. He has published over 650 papers and reports on this work. He has served as an advisor to numerous governmental agencies and industries in the US and other countries on water quality and solid and hazardous waste management issues. Dr. G. Fred Lee and Dr. Anne Jones-Lee have extensive experience in developing approaches that work toward protection of water quality without significant unnecessary expenditures for chemical constituent control. They have been active in developing technically-valid, cost-effective approaches for the evaluation and management of chemical constituents in rivers, lakes, impoundments, estuaries, near-shore marine waters, and groundwaters, domestic and industrial wastewater discharges, contaminated sediments, urban stormwater runoff, solid and hazardous waste, and hazardous chemicals since the 1960s. The management of the excessive fertilization of waterbodies has been one of the primary areas of Drs. G. F. Lee's and Jones-Lee's

research advisory activities. They have presented short-courses and lectures on this topic at many locations in the US and in several other countries. Dr. Lee is a registered professional engineer in the state of Texas and a Diplomate in the American Academy of Engineers.

Further information on their experience and expertise in water quality evaluation and management is available on their web site (http://members.aol.com/gfredlee/gfl.htm) or from them upon request.

EUTROPHICATION RELATED WATER QUALITY PUBLICATIONS OF G. FRED LEE and ANNE JONES-LEE

Listed below are the publications, bulletins, reports and books prepared for public distribution by G. Fred Lee and Anne Jones-Lee since 1981 devoted to eutrophication assessment and management. A copy of the available reprints, bulletins, reports and publications may be obtained upon request. Also, a list of publications prepared prior to 1981 is available upon request.

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