Potential Impact of Phosphorus Control on Low DO in the SJR DWSC:

Supplemental Information for May 10, 2001 TAC Meeting

G. Fred Lee, PhD, DEE

May 19, 2001

The May 10, 2001 SJR DO TMDL TAC meeting included discussion of the potential benefits of controlling phosphorus added to the SJR and its tributaries as a means of reducing the oxygen demand load to the SJR DWSC. At the TAC meeting, I mentioned some of the work that Chris Foe, Erwin Van Nieuwenhuyse (of the US Fish and Wildlife Service and a regular participant in TAC meetings who has worked on phosphorus control issues in other areas of the country) and I have been doing on this issue. These discussions arose from the comments made by CALFED Directed Action proposal peer reviewers, which were raised by TAC members, to the effect that nutrient control would not be a viable method of controlling the DO depletion in the Deep Water Ship Channel. The basic premise advanced by some of those who claim that nutrient (phosphorus) control would not be effective is that the algal available phosphorus concentrations in the SJR and the DWSC are well above algal growth rate limiting concentrations of a few micrograms per liter P.

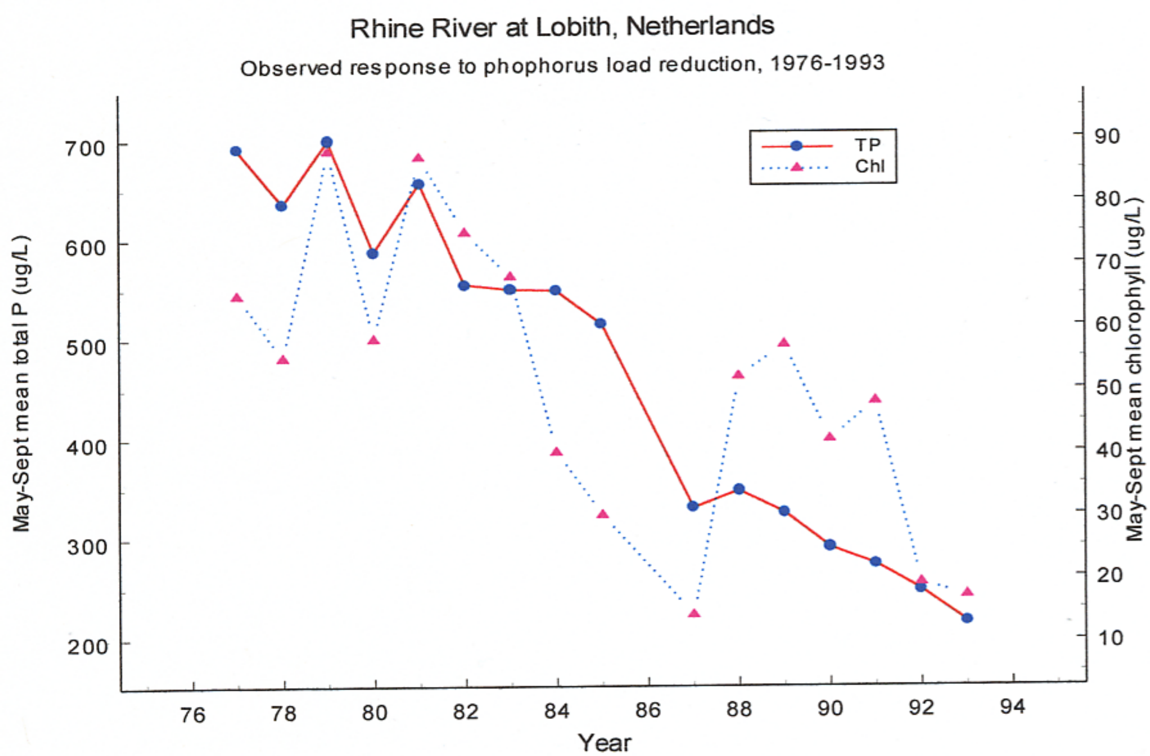
Review of the Literature.

At the May 10, 2001 TAC meeting, when this issue was raised by TAC members, I indicated that there was literature on the issue of the potential benefits of controlling phosphorus in waterbodies to reduce algal growth under conditions where, both before and after phosphorus control, the concentrations of available phosphorus in the waterbody are surplus of those needed to limit algal growth rates. I mentioned that I had published a paper on this topic, and that Erwin had previously provided the TAC with a plot of the Rhine River phosphorus and chlorophyll relationships.

Since this is a recurring issue, that is of considerable importance to developing an oxygen demand control program for the DWSC, I wish to provide additional background information on this issue that may be of interest to the SJR watershed stakeholders.

Rhine River Studies. Several TAC meetings ago, Chris Foe, Erwin Van Nieuwenhuyse and I discussed the issue of the potential benefits of phosphorus control in land runoff/discharges and waste discharges on reducing the algal related oxygen demand load to the DWSC. At that meeting, Erwin again mentioned the experience on the Rhine River, where there was a direct correlation between the phosphorus control in the Rhine River watershed in Europe and the planktonic algal chlorophyll present in the Rhine in the Netherlands – i.e., just before the Rhine enters the sea. Previously, Erwin has provided the TAC with a plot of the chlorophyll-phosphorus concentration relationships for the Rhine. I have recently scanned this plot. The attached plot (Figure 1) was developed by the Dutch Governmental Institute on Inland Water Management and Waste Water Treatment. Examination of Figure 1 demonstrates a strong correlation between reducing the phosphorus concentrations in the Rhine River and the planktonic algal chlorophyll present in the Rhine River. It is important to note that the concentrations of phosphorus found in the Rhine River are all well above algal growth rate limiting concentrations.

Figure 1



Source, Dutch Governmental Institute on Inland Water Management and Waste Water Treatment (1994)

OECD Eutrophication Studies. I mentioned in those discussions that the issue of the potential benefits of phosphorus control on controlling excessive fertilization of waterbodies was a topic to which I devoted considerable attention in the 1960s, 1970s and early 1980s. As part of the post-International OECD Eutrophication Studies, in the early 1980s my graduate students and I developed a review paper on the world's literature experience on the impact of phosphorus control on reducing planktonic algal biomass in waterbodies. This paper,

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),

is available from my website, www.gfredlee.com, in the Excessive Fertilization/Eutrophication section. . The key figure from this paper is attached (Figure 2). The abscissa in this figure is the normalized phosphorus loading term that was developed by Vollenweider.

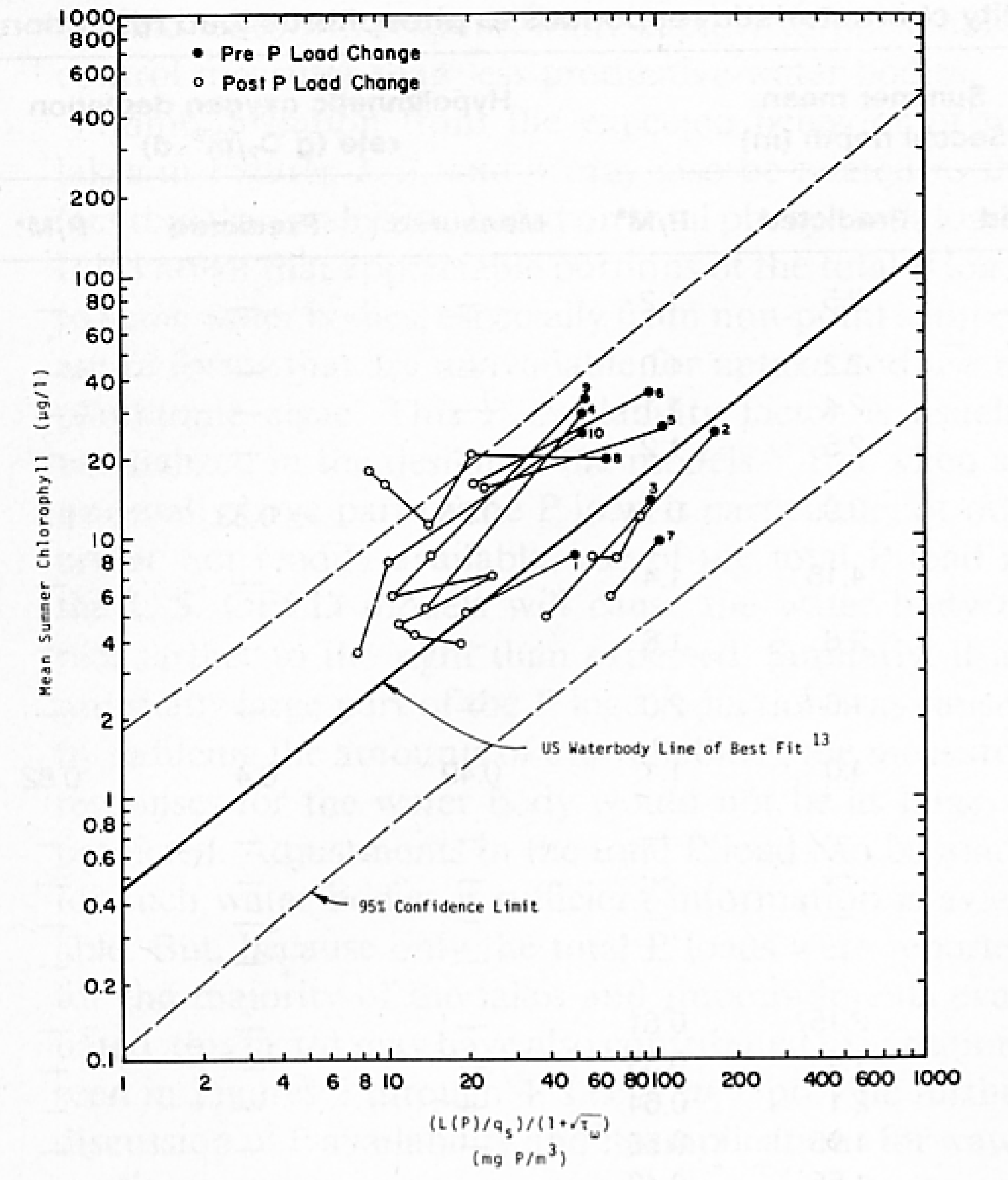


Figure 2—Phosphorus loading: Chlorophyll couplings before and after P load changes (see Table 1 for water body identification).

Rast, et al. (1983)

As discussed in my papers, this term normalizes the phosphorus loads (in grams P per square meter of waterbody surface per unit time) to waterbodies based on their hydrologic (hydraulic residence time) and morphologic (mean depth) characteristics. This term is approximately equivalent to the average in-waterbody phosphorus concentration. It has been shown, through a review of the data for about 750 waterbodies located throughout the world, that the normalized phosphorus load to a waterbody is strongly correlated with the planktonic algal chlorophyll, algal-related Secchi depth and hypolimnetic oxygen depletion rates. Further information on this issue is available on my website.

As discussed in the paper, waterbodies that have had a change in their phosphorus loads should track changes in the planktonic algal chlorophyll parallel to the line of best fit .for the normalized phosphorus load-planktonic algal chlorophyll relationship. As shown in the attached figure, with few exceptions, this is what has been found. The exceptions can be explained based on other issues that control algal growth in the waterbody.

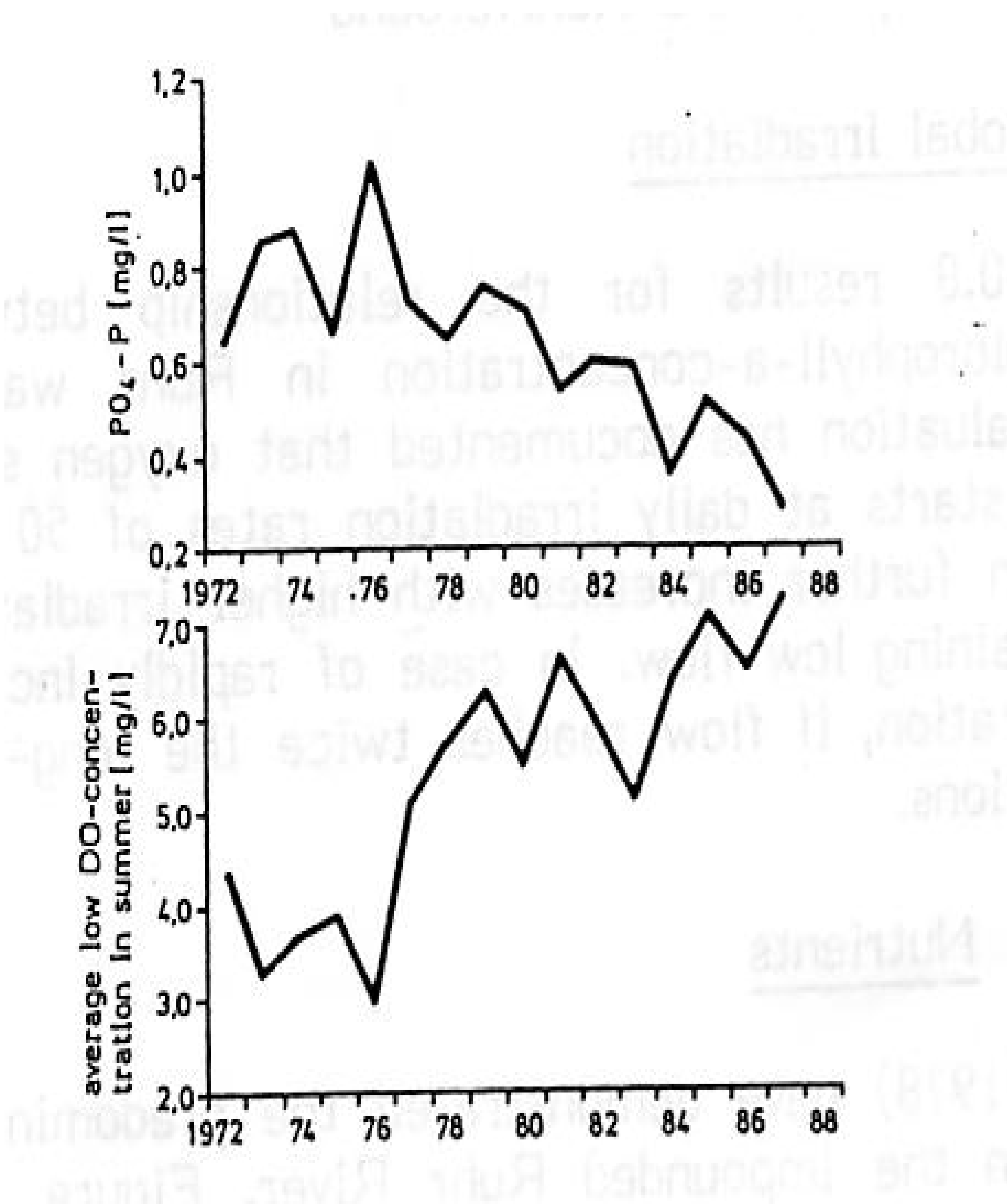
An important issue in this review is that the final phosphorus concentration in the waterbody is well above any algal growth rate-limiting concentration. This means that, as part of an algae control program based on phosphorus control, it is not necessary to decrease the phosphorus concentrations in the waterbody to growth rate-limiting concentrations to have significant impact on the planktonic algal chlorophyll, and their impact on water quality, such as DO depletion.

Ruhr River Studies. At the recent TAC meeting Erwin provided me with a copy of a paper,

Albrechtl, Detlef R, "Results of Fifteen Years of Continuous Monitoring of Water Quality in the Ruhr River Heavily Affected by Residual Point and Nonpoint Pollution," American Water Resources Association's *Nonpoint Pollution: 1988 – Policy, Economy, Management, and Appropriate Technology*, pp. 271-280, November (1988).

This paper discusses the fact that, as phosphorus is controlled from various sources for the Ruhr River in Europe, the low DO problems in the River and algae decreased. A plot of these relationships is shown in Figure 3. Again, as with other situations, the final phosphorus concentration was not growth-rate limiting. Yet, clearly reducing phosphorus concentrations reduced the algal caused oxygen demand.

I mentioned at the TAC meeting that I had received an invitation to present a paper at the American Chemical Society national meeting that will be held in Chicago in the last week of August 2001, devoted to assessing the potential benefits of controlling phosphorus in ag runoff on eutrophication-related water quality. This paper, entitled "Assessing the Water Quality Impacts of Phosphorus Runoff from Agricultural Lands," will be presented in the AgroChemicals Division at the American Chemical Society national meeting in Chicago in the symposium, "Environmental Impact of Fertilizer Products – Life Cycle of Crop Nutrients."



From Albrecht (1988)

Implications for Effectiveness of P-Control in SJR Watershed.

As I indicated at the TAC meeting, the algal biomass that develops under growth-rate limiting concentrations is only an issue of time. Just because phosphorus is present at a surplus concentration compared to the growth-rate limiting concentration of a few micrograms per liter soluble ortho-P, does not mean that the biomass cannot increase or decrease upon altering available phosphorus concentrations in the waterbody. Given sufficient time, the algae will grow proportional to the phosphorus. In a light-limited situation, such as the SJR and its tributaries, growth will be controlled by light penetration. Again, the issue of primary concern is the time available for growth. In rivers such as the SJR and its tributaries, the algae gain sufficient light, through periodic exposure near the surface, to continue to grow. In the Deep Water Ship Channel, where the algae can be in permanent darkness in the mid- to lower depths, they will not continue to grow, and therefore die, and the biomass will decrease as it does down the Deep Water Ship Channel from Channel Point to Columbia Cut.

The situation is clearly that controlling algal available phosphorus in waterbodies, under conditions where there is considerable surplus phosphorus compared to algal growth rate needs, will reduce the planktonic algal biomass in the waterbody. This is the technical basis for approximately 100 million people in the world having their domestic waste waters treated for phosphorus removal in order to reduce planktonic algal growth in the waterbodies receiving the treated waste waters. With respect to the SJR watershed the issue that needs to be addressed is an assessment of the magnitude of the algal caused oxygen demand which reaches the DWSC decrease can be achieved through implementable phosphorus control from the sources within the SJR watershed.

Some stakeholders are using the peer reviewers and some TAC members' comments in an attempt to justify having the Regional Board not consider nutrient control as a means of controlling oxygen demand loads from various sources in the watershed. This approach is technically invalid and will not likely be accepted by the Regional Board. Nutrient control will likely be part of the mix of control programs that will be part of the fix for controlling low DO in the Deep Water Ship Channel. The focus of nutrient control, however, will be an attempt to control nutrients not in the main stem of the SJR or DWSC, but in the headwaters of the tributaries, such as Mud and Salt Sloughs, the SJR upstream of Landers Avenue and other tributaries, to limit the amount of algal growth that occurs in the tributary before it reaches the main stem.

As Chris Foe's work with the Strawman has shown, the three tributaries at the headwaters – Mud and Salt Sloughs and the SJR above Landers – contributed approximately 75 percent of the oxygen demand load that was present at Vernalis during the summer-fall 2000. If nutrient control in the tributaries can be implemented, then the oxygen demand load that actually reaches Vernalis (and, subsequently, the DWSC) will be reduced. This will reduce the magnitude of required aeration/recirculation flow of the SJR through the DWSC to prevent DO depletion below water quality objectives.

It is important to note that there are significant questions about whether commitments on flow and the funding of aeration can be achieved by June 2003, when the Regional Board has to report the TMDL to the US EPA. It is possible that, by that time, the implementation plan for the

DWSC, because of the lack of assured recirculated flow and funding for aeration, will have to focus almost completely (if not completely) on controlling oxygen demand sources, which will include algal growth within the DWSC watershed.

Algal Culture Studies.

Chris Foe and I have been developing information that will be pertinent to a supplemental proposal for funding to address the issue of assessing the potential benefits of controlling phosphorus concentrations in the tributaries to the SJR. I have designed an experimental approach for conducting studies of this type that is patterned after the work that I did in the 1960s and 1970s. The experiments will include removing phosphorus from tributary water through the use of alum and examining the growth of algae as a function of the phosphorus content of the water. Since there are not funds within the Directed Action proposal for these studies, this will have to be done through supplemental funding. These studies should be initiated this summer, in order to allow adequate time to conduct the studies on each of the major SJR tributaries and within each tributary to assess the potential significance of each of the major phosphorus sources and the potential benefits of controlling these sources to a certain degree in reducing the oxygen demand load to the DWSC.

Recently, I have established contact with Dr. Rick Zechman, Assistant Professor of Biology at CSU Fresno, regarding his interest and ability to undertake algal culture studies to assess the potential benefits of removing phosphorus from SJR tributary waters on the algal growth that would occur in these waters. Dr. Zechman has been doing some algal taxonomy/ecology studies in the SJR watershed. He has algal culture capabilities and is interested in working with Dr. Jones-Lee and my self in these studies. I have recently been appointed a member of the CSU Fresno faculty as a Research Engineer. My wife (Dr. Anne Jones-Lee, who has also been appointed a member of the CSU Fresno faculty as a Research Scientist) and I could be working with Dr. Zechman in these studies, if we can find funding for them.

These studies are important to the Steering Committee-stakeholders/CVRWQCB in establishing a technically valid approach for managing excessive oxygen demand loads to the DWSC. By focusing on those sources of phosphorus in the watershed that lead to the high algal load that reaches the DWSC during the summer-fall period, it will be possible to use the financial resources available for oxygen demand control, beyond that which can be achieved through assured recirculated flow, in the most technically valid, cost-effective manner. These studies can potentially provide the information needed to determine where the financial resources available for algal-caused oxygen demand control should be focused. They can also potentially provide the information needed to determine whether funds should be spent on oxygen demand control (phosphorus control) or on additional aeration as the most cost-effective approach for controlling the oxygen demand that reaches the DWSC from upstream algal sources.

Comments or questions regarding this discussion may be directed to G. Fred Lee.