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State Water Resources Control Board
P.O. Box 100
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Subject: Comments on statistical issues in draft Water Quality Control Policy regarding Section 303(d) List

Dear Mr. Wilson:

I have been asked by Flow Science Incorporated to offer my expert opinion about the proposed use of a statistical approach to the decision process involved in listing and de-listing water bodies as required in Section 303(d). My professional background as a statistician began with my research specialization in the field for my Ph.D. in mathematics from Cornell in 1966. Since that time, I have been continuously engaged in teaching statistics at Northwestern University, UC Berkeley, and the California Institute of Technology (Caltech), where I have been Professor of Mathematics since 1977 and department head since 2003. In recognition of my research contributions I was elected in 1973 as a Fellow of the professional society called the Institute of Mathematical Statistics, and throughout my academic career I have been active as a statistical consultant not only for scientific and engineering colleagues, but also for various governmental agencies and private companies. I have also served as a statistical expert witness in a variety of legal and regulatory matters.

I have read carefully the section entitled "Issue 6: Statistical Evaluation of Numeric Water Quality Data" in the December 2, 2003 SCRCB draft policy for listing and de-listing. My opinion is that the approach described is quite sensible and provides a sound framework for the decision-making required by Section 303(d). Here are my principal reasons:

1) It is clear that the sampling and testing on which listing decisions are made are subject to many types of variability—measurement error, analytical error, space-time variabilities, and so on—and, accordingly, the only scientifically sound way to interpret the results is as what statisticians call "random variables". The advantage of using a statistical approach to decision making is that it provides a rational method to evaluate a set of individual results that are mutually contradictory—e.g. some showing pollutant concentration limits exceeded and some showing non-exceedance.

2) The so-called "Exact Binomial Method" is a good choice for the statistical analyses required because it avoids the use of questionable probability models for the underlying data and relies instead upon clear, unambiguous classification

of test results as "acceptable" or "unacceptable". The proposed Critical Exceedance Rate of 10% seems reasonable to me, but the choice of this percentage should be based on the judgment of environmental scientists, reflecting their experience with the frequency of "false positive" findings of impairments.

3) The proposal not to require a minimum sample size for listing decisions is a wise one, in my opinion, since it permits decision-makers to use small datasets when the results are conclusive. I assume that to be considered conclusive, a dataset must have a sufficient range over space and time to be considered a representative sample and a suitable basis for a listing decision.

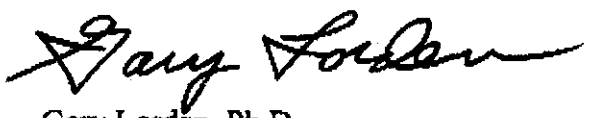
4) The proposed maximum Type I error probability of 10% seems to me a reasonable choice, given the multiplicity of hazard analyses to be performed and the repeated use of the Exact Binomial Test in cycle after cycle. In any event, it is certainly good practice to investigate and seek to balance the two types of error ("incorrect listing" and "failure to correctly list") in judging a water body.

I regard the proposed policy as a good start on the development of a well-designed process for making listing and de-listing decisions, but there are issues that merit further consideration and work. One is the use of a "planning list" (cited in the Draft Policy, page 165, as implemented in Florida and included in California's July 2003 draft policy) to impose closer monitoring on bodies of water that have marginal or questionable impairments. This type of "intermediate decision" is widely recommended by statisticians in scientific and engineering practice to reduce probabilities of error by making sure that enough high quality data are taken when the ultimate decision is difficult or a "close call". In particular, if a set of measurements is considered not to meet a standard of "sufficient range over space and time" as I discussed in point 3) above, then it might sensibly be used as a basis for a decision to place the water body on a planning list and to establish a sampling plan for monitoring it.

Another worthwhile consideration in my opinion is the question of what statistical specifications are wisest for "de-listing" decisions. The draft policy suggests using a (worst-case) "erroneous de-listing" probability of 10%-- i.e. a 90% worst-case probability of "erroneous failure to de-list"-- for such decisions. This seems too stringent unless standards for subsequent data collection are imposed to monitor closely possible improvements in impairment levels. To be effective, such monitoring would probably require more sophisticated statistical sampling designs than the "fixed n" design of the Exact Binomial Test.

Whatever its final form, I firmly believe that a sound, effective process to meet the statutory requirements for listing impairments of water bodies must use the science of statistics in the same way that many other rational human processes do: to recognize and quantify the variability in different sources of information so as to make decisions whose possible errors have been weighed and balanced in the most intelligent possible fashion. Although I have recommended some minor modifications, I believe that the statistical methods proposed in California's December 2003 draft policy are reasonable and appropriate as a basis for making Section 303(d) listing and de-listing decisions.

Sincerely,



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