This document was prepared in October 2005 and presents EOA's responses to comments in a September 26, 2005 letter from John Plummer (Friends of Lake Merced) to John West (RWQCB). Responses are inserted below in italics.

Dear John:

It is two years since the study of effects of diverting stormwater from the Vista Grande Canal into Lake Merced, using a riparian buffer to remove contaminants, was initially proposed. Earlier this month the first (draft) report on the results of this study was released*. This report suggests a number of questions (in addition to that of delay in public reporting) regarding the adequacy of the study design and analyses. I hope that we can all work together to assure that these questions are adequately considered before additional testing goes forward.

Before discussing this report, however, let me again point out that the question of public health and safety is not insignificant. The report states, "(F)ull body water contact recreation is prohibited at Lake Merced," implying that this consideration may not be important. However, Water Contact Recreation is a designated beneficial use, and full body contact does occur, usually inadvertently, when a kayak, shell or sailboat flips boaters into the lake. Fishing, which is being encouraged at the lake, is also considered to be contact recreation. Maintaining a safe boating and fishing environment is then an important concern.

It is not clear what the concern is, since the draft report conservatively compares study data to full body water contact recreation criteria. However, we will add a footnote to the report stating that infrequent full body contact may occur due to accidental capsizing of boats in the lake. Also, please note that while it is true that fishing is considered contact recreation, ingestion of lake water during this activity is unlikely.

On to the study design and analyses:

1) The report recognizes that bacteria die-off and dilution are factors contributing to reduction in coliform between the stormwater feedstock and the lake. However, no attempt is made to evaluate the contribution of these factors; we do not, then, know whether the result would have been significantly different had stormwater simply run through a pipe and into the lake.

Some level of treatment by the riparian buffer is likely (see the attached document prepared by Michael J. Casteel, Ph.D., SFPUC Research Microbiologist). Additional engineering analysis would be needed to address this issue further. Such analysis was beyond the scope of the pilot study.

2) Metals were observed in the stormwater, but not in the ground in the riparian buffer and not in the lake. Where did they go? Does the absence of metals in the ground indicate that there was little if any percolation of the stormwater? What is the sustained injection of metals into the lake, if any? It seems risky to assume that no contamination has resulted simply because we can't figure out what the answers to these questions might be.

A number of physical, biological and chemical processes potentially govern the fate of metals in the stormwater runoff diverted to the riparian buffer/lake. Such potential processes include

* A copy of this report, *Preliminary Water Quality Screening Results; Lake Merced Pilot Stormwater Enhancement Project*, is available on our web site at http://www.lakemerced.org/Plans/Water/VistaGrande/lakemercedpilotstudydraftreport.pdf

accumulation in the riparian buffer soils (with any changes in soil concentrations potentially masked by natural variability), removal by biological uptake in the buffer or the lake, and adsorption to particles in the lake system. Transformations among species of individual metals are also likely. Characterization of the fate of the metals would require additional monitoring data and engineering analysis. Such monitoring and analysis were beyond the scope of the pilot study.

3) The report acknowledges the inadequacy of the statistical analysis that has been conducted: "The monitoring design could address filling some current data gaps in the project and reducing uncertainty in some statistical analyses." My observation is that this is the inevitable result of not having prepared an adequate study plan in the first place. This must be corrected by detailing future test designs much more thoroughly. Simply suggesting that additional testing might fill some gaps is not good enough.

NSMCSD and SFPUC (2004a and b) clearly detailed the monitoring design. However, monitoring projects are almost always constrained by budget considerations and rarely collect sufficient environmental data to fully characterize a site or system. Typically a trade-off must be made between using budget for monitoring vs. other important priorities. We do agree that any future increases in diversion volume would require vigilant monitoring. Before any additional diversions to the lake occur, we will carefully design and document additional monitoring activities.

4) Some description is provided regarding the flora found on the riparian buffer, and the characteristics of the soil in that area. However, no data is provided that would indicate the expected or likely effectiveness of this buffer as a bio-filter, nor is any analysis provided that would contribute to the understanding of these effects for future researchers and practitioners.

The attached document prepared by Michael J. Casteel, Ph.D. (SFPUC Research Microbiologist) provides documentation that the riparian buffer is likely to provide some level of treatment. Additional engineering analysis would be needed to further address this issue. Such analysis was beyond the scope of the pilot study.

5) There is some delay between a storm event and the delivery of treated stormwater to the test site. No analysis is presented indicating the degree to which the ground has become saturated during this interval. How much water does the buffer absorb? How much runs off directly into the lake? I am sure that these factors can be measured only approximately; however, some effort should be made. The absence of metals in the soil may indicate that in fact little of the stormwater is actually being treated by the riparian buffer.

Additional engineering analysis would be needed to address this issue. Such analysis was beyond the scope of the pilot study.

6) Since average rainfall during diversion events was significantly greater than during back-ground events the control group did not accurately reflect the conditions under which the sample group was tested. Assessment of other differences is then, unfortunately, largely little more than conjecture. Obviously, it is not possible to anticipate the size of storm events with full accuracy. However, some forecast is possible prior to the event. Rather than select the control group in predetermined sequence it might be better to use this forecast as one selection criterion.

The fact that average rainfall during diversion events was greater than during background

events makes the analysis conservative. This is because a greater volume of local stormwater runoff from the surrounding watershed and associated bacteria entered the lake during diversion storm events than background storms.

7) The report acknowledges the effect of mixing on reduced coliform counts, and estimates the impact if complete mixing in the entire lake were achieved. However, as the report also states, complete mixing within the time period being evaluated is extremely unlikely. The amount of mixing likely to occur in the zone near the test site is left unaddressed, (Might observed increase of metals in the water provide an index of the rate of mixing?), with the result that any health hazard in the test area is not adequately evaluated. Further, the data indicates that E-coli concentrations in the test area have risen to levels near acceptable limits. (See Figure 3. Probability Plot of E. Coli Concentrations in Lake Merced During Storm Events)

Additional engineering analysis would be needed to address the mixing issue. Such analysis was beyond the scope of the pilot study. In addition, stating that Figure 3 indicates that E. coli concentrations in the test area have risen to levels near acceptable limits is a misinterpretation of this probability plot. What is really indicated is that there is an approximate 98.5% probability that a sample from the population characterized by the distribution in Figure 3 will have a concentration lower than the single sample maximum criteria of 576 MPN/100mL for full body contact recreation. Of most importance, however, is that all total coliform, E. coli and enterococci concentrations were less than single sample maximum concentration criteria.

8) One would need a fuller description of the statistics applied to adequately comment on the analysis itself. However, these observations appear to be relevant:

a) Sample sizes seem to be very small, using a t-test in this environment is generally acknowledged to be a risky endeavor. For example, as the report states, the t-test assumes Normality of the data distributions. Testing for Normality with 3 sample points is impossible, and even 6 sample points is very suspect. Perhaps some consideration should be given to grouping this data.

Data groups from this study with a sample size of six passed normality tests. While it is true that normality cannot be tested for with a sample size of three, it is reasonable to assume the underlying population distribution is lognormal, since other data from this study were lognormally distributed and, in general, most environmental data are reasonably represented by a lognormal distribution. The report does acknowledge that small sample sizes lead to some uncertainty in the results of the statistical analyses.

b) The acceptance criterion has been established that results will be considered significant if the probability of those results occurring as a random event is less that 5%. While significance is generally claimed, a great many of the probabilities provided are well away from this threshold.

We only claimed statistical significance when $P \leq 0.05$.

c) There are repeated attempts to identify a linear relationship where it is quite evident none exists. (See especially Figure 4, Probability Plot of Enterococcus Concentrations and Appendix H, Surrogate Indicator Regression Plots.)

It is true that the data in Figure 4 do not show a linear relationship, though the data in Figures 2 and 3 are closer to linear. Although the regression line in Figure 4 was not used for any analysis and in no way influenced the conclusions of the report, we will remove it and add an

explanatory footnote. With regard to the figures in Appendix H, showing that the data did not demonstrate a linear relationship was actually the point of the exercise. As stated in the text, correlations were weak in all cases ($r^2 < 0.6$). Thus data from this study suggested that nitrate, TSS, TDS and conductivity are not effective indicators of fecal contamination in South Lake Merced following diversion of stormwater runoff.

9) The t-test is appropriate for evaluating a single hypothesis. It is not, however, appropriate to make a long list of tests to be conducted, then to use the t-test to evaluate the significance of each. Obviously, if one is using a 95% confidence limit one can expect to see one test out of twenty indicating significance when the process is completely random. It is necessary, then, to apply some additional filter to assure that the tests indicated as significant are truly outliers, and do not merely represent the tails of a Student-t distribution. I see no indication that such a filter has been applied.

The above comment appears to refer to statistical procedures such as the Bonferroni correction, which adjust the significance level to compensate for the increased probability of error when multiple comparisons are made. While many statistical comparisons were made in the draft report, the comparisons were individual rather than multiple. We hypothesized (H_o) that following storm events with diversion of treated stormwater runoff to South Lake Merced, there is no difference between bacteriological concentrations at each of the lake sampling stations near the treated stormwater discharge location (LM-1 through LM-6) and a "background" sampling station farther from the stormwater discharge area (LM-PR). H_o was tested as follows: for each diversion event, data from each of the lake sampling stations near the treated stormwater discharge location (LM-1 through LM-6) were individually compared to data from the background station (LM-PR). We also hypothesized (H_1) that following storm events, there is no difference between bacteriological concentrations at each South Lake Merced sampling station when treated stormwater runoff is diverted to the lake and when treated stormwater runoff is not diverted to the lake. To test H_1, individual comparisons were made using data from each lake sample station. For each station, data collected following storm events with diversion were compared to data collected following background storm events without diversion. Because only individual comparisons were made, a multiple-comparison correction was not needed. As an example, if we had instead hypothesized that there were no differences among any of the lake sampling stations (i.e., LM-1 compared to LM-2, LM-3, LM-4, etc.; LM-2 compared to LM-3, LM-4, etc., etc.), a multiple-comparison correction would have been required.

10) Perhaps the question should be asked, Is this difference important?, not Is this difference statistically significant? For example, in Figure 3; Probability Plot of E. Coli Concentrations n Lake Merced During Storm Events, the difference between storm events and background events may or may not be statistically significant, but it seems large enough to be important. Further, the claim made that "Probability plots of total coliform, E. coli and enterococcus concentrations (Figures 2 through 4) illustrate that bacteria concentrations were well under single sample maximum concentration criteria for full body contact recreation" is not the case. In fact, in the test group E-Coli counts get dangerously close to this limit. This suggests that if testing is to go forward, especially with even larger diversions of stormwater into the lake, far better monitoring will be required. It may be necessary to post the lake when tests are conducted to assure that boaters and fishermen do not use the lake during these periods.

As explained earlier for E. coli and Figure 3, stating that Figures 2 – 4 indicate that bacteria counts are dangerously close to acceptable limits is a misinterpretation of these probability plots (please see the above response to point No. 7). However, we will edit the above-referenced sentence as follows: "all total coliform, E. coli and enterococci concentrations were less than

single sample maximum concentration criteria."

Geometric mean E. coli concentrations at most lake sample stations were higher following diversion events than background storm events. We will edit the report to more clearly point this out, but the above statement that the difference "seems large enough to be important" is not meaningful. We applied a weight-of-evidence approach to analyzing the data. The two bacterial indicators monitored during this study most closely associated with human health risk were E. coli and enterococci. Although the diversions increased geometric mean E. coli concentrations, the differences were not statistically significant. Enterococci were not detected in most lake samples and concentrations generally were not increased by the stormwater diversions. In addition, E. coli and enterococci concentrations generally did not exceed water quality criteria for full body contact recreation. Overall, these study results suggest that the pilot diversions probably did not increase human health risk associated with fecal contamination during recreation in South Lake Merced.

Furthermore, introduction of Vista Grande stormwater runoff to South Lake Merced is a balancing act between the potential benefits of adding additional water to the lake and the potential risks such as human health impacts. Balancing these potentially conflicting priorities is a challenge, since reducing associated risk to a zero level would likely make the project prohibitively expensive. Thus a risk management perspective is needed if the community desires a feasible and successful project.

In any case, as stated earlier, we agree that any future increases in diversion volume would require vigilant monitoring. Before any additional diversions to the lake occur, we will carefully design and document additional monitoring activities.

As I'm sure you recall, I expressed serious reservations regarding the test design when this program was proposed two years ago. It now seems that those reservations were often well founded. Again, before additional testing goes forward I hope that the issues raised here will be adequately considered, and that a much more detailed project plan will be prepared that improves both the analyses and the protection of public health and safety.
Sincerely,
John Plummer

References cited in responses:

NSMCSD and SFPUC 2004a. *Preliminary Water Quality Screening Plan, 2003/04 Wet Season, Lake Merced Restoration – Phase 2 Pilot Stormwater Enhancement Project.* Prepared by the North San Mateo County Sanitation District and the San Francisco Public Utilities Commission with assistance from EOA, Inc. January 26.

NSMCSD and SFPUC 2004b. *Status Report for Preliminary Water Quality Screening Plan, 2003/04 Wet Season, Lake Merced Restoration – Phase 2 Pilot Stormwater Enhancement Project.* Prepared by the North San Mateo County Sanitation District and the San Francisco Public Utilities Commission with assistance from EOA, Inc. September.

Attachment

The issues of bacterial die-off and dilution are rightfully acknoweldged, but these arguments are appropriate only if properly framed. Also not mentioned in any of the discussions thus far include other potential factors, such as the asssociation of stormwater-borne microbes with particulate matter.

Dilution may partially explain the differences between levels of indicator bacteria in Vista Grande Canal (VGC) stormwater, and in lake water mixed with stormwater. However, is the diverted VGC stormwater, especially after it is dispersed through the perforated pipe (and after it has been slowed and filtered through the vegetation before reaching the shoreline of Lake Merced) likely to have the momentum required to result in appreciable mixing? Researchers[4] have reported that in many of the stormwater runoff outfalls found along the south shore of Lake Pontchartrain in Louisiana, the velocities of the runoff were insufficient to foster the momentum required to move contaminants in the effluent away from the near-shore region and to provide adequate momentum mixing. One frequently sees the word "plume" (see for example, ref. 2) used in relation to stormwater runoff and other contamination of fresh, ground, and marine water, in which the concentration of contaminants is highest at the point of input and decreases with distance from the point of entry. This gradient effect has been reported to occur with stormwater-borne fecal indicator bacteria discharged to both lake and marine water (i.e., highest levels of bacteria present in water at point of input, followed by decreasing concentrations as one proceeds offshore[4,15]. Hence, while dilution certainly is an issue, other factors may be involved that deserve mention.

Raising the issue of bacterial die-off without further explanation may also be misleading, and it should be noted there is no data from this project to support or refute this issue. In the study reported by Jin and colleagues[15], stormwater was pumped directly into Lake Pontchartrain, and a large fraction of indicator organisms (*Escherichia coli*; enterococci; fecal coliforms) that were attached to suspended particlulate matter were found within a short distance from the point of discharge as the velocity of the effluent plume decreased. The occurrence of particle-associated microbes in stormwater is well documented (see for example ref. 5), and the relevance here, besides for altering characteristics of microbial transport in the environment, is that particle-associated microbes tend to survive longer in natural waters[3,9,11, 18]. In addition, there are widely varying reports of the inactivation or "die-off" of microbes in the environment. Such data is usually reported as the "t_{90} " which is the time it takes for 90% (or 1 $\log_{10}$) reduction of bacteria to occur. T_{90} values for total coliforms and *E. coli* in surface waters have been reported to be as high as 115 and 720 hours, respectively (Feachem, 1983). For example, if the initial concentration of *E. coli* in surface water was 3.5 $\log_{10}$ MPN/100 mL, some investigators have estimated that it would take as long as 30 days (720 hours) for the concentration to reach 2.5 $\log_{10}$ MPN/100 mL. Other estimates of t_{90} for *E. coli* are far less; for instance, Edberg et al.[6] conservatively estimated *E. coli*'s half-life (note: not t_{90}) to be 8 days in groundwater. Differences in survival between fecal microbes such as *E. coli* and environmental bacteria such as the total coliforms may be partially explained to the fact that fecal microbes such as *E. coli* may be protected from degradation because many bacterial cells may be embedded within fecal material[19,20]. Published t_{90} values also vary widely with geographic region, temperature or other environmental condition (e.g., exposure to sunlight), composition of water, and sample location in relation to contaminant input. In a recent study, Jeng et al.[13] reported t_{90} values for *E. coli* and enterococci in surface water following a storm runoff event (2.92 cm precipitation) to be 100 hours and 115 hours, respectively. Ackerman and Weisberg[1] report that the concentrations of *E. coli* in Los Angeles County beach water following storms (>2.5 cm) remained elevated for up to 5 days following a storm; the $\log_{10}$ difference between days 1 and 3 were about 0.3 $\log_{10}$. The

point is, there is a great deal of variation in previous reports on die-off rates of *E. coli* and other microbes, and some bacteria may be more long-lived than in water than some would have the reader believe.

To my knowledge, there are no other data or analyses generated during the project to support the arguments of complete dilution and bacterial die-off. The momentum of the VGC stormwater to produce a sizeable plume in Lake Merced is questionable, and it is arguable that there was not appreciable die-off of *E. coli* and enterococci in lake samples collected within the 24 or 48 hours following cessation of diversion. Hence, these issues remain speculative at best, and when used as arguments without context, are misleading. In contrast, the proposed ability of the riparian buffer to remove microbes is consistent with what is generally known about wetlands, riparian buffers and other similar BMPs – that these processes remove fecal indicator bacteria from waste- and stormwater. The estimated bacterial removals by the riparian buffer in this study are similar to other studies; reported[12] removal efficiences for coliforms generally exceed 90% with significantly higher removal in extensively vegetated systems compared with unvegetated systems[8,10]. Finally, it should be noted that the bacteria measured here are indicators of fecal contamination – however, such bacteria are no longer considered to be indicative of more long-lived fecal microbes and pathogens in the environment, such as protozoan parasites and enteric viruses, both of which have been detected in stormwater[14,16].

Prepared by Michael J. Casteel, Ph.D., SFPUC Research Microbiologist

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