Dublin San Ramon Services District
Consumer Taste Test

Technical Memorandum
on Testing Performed in July 2006

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INTRODUCTION

Over the past two years the Dublin San Ramon Services District (DSRSD) has undertaken various studies to evaluate tastes and odors in its drinking water supply. In 2005 DSRSD retained McGuire Malcolm Pirnie (MMP) and the National Food Laboratory (NFL) to conduct a consumer taste test, flavor profile analysis, consumer focus group, and water quality evaluation. Sampling, testing, and the consumer panel took place between November 29 and December 1, 2005. In a February 2006 report MMP found that:

- Consumers greatly preferred bottled water over the various public water supplies tested
- Treated water from the Del Valle Water Treatment Plant (DVWTP) was liked least
- Mocho 4 Well groundwater was preferred over the DVWTP water
- Blends of source waters showed increasing liking with increasing amount of well water or RO treated water
- Chlorine and geosmin appeared to be the constituents that have the greatest impact on consumer preferences
- No relationship appeared to exist between odor and flavor preference and hardness or total dissolved solids

In July 2006, DSRSD initiated additional testing, which included a consumer taste test and flavor profile analysis. DSRSD wanted to see if the basic results would be repeated, if seasonality had any effect, and to use East Bay Municipal Utility District water and a Hetch Hetchy sample that did not blend with local runoff. DSRSD took six samples for testing and analyses:

- East Bay Municipal Utility District (EBMUD) distribution system (mostly from the Mokelumne River watershed)
- San Francisco PUC Hetch Hetchy (Upstream of Sunol Valley WTP)
- Pump Station 20B (Blend of groundwater and surface water)
- Mocho 4 Well (local groundwater)
- Turn Out 2 (Blend of groundwater and surface water)
- Del Valle Water Treatment Plant (treating Sacramento River Delta Water from the South Bay Aqueduct of the State Water Project and local runoff)

This technical memorandum presents a review and evaluation of taste testing, water quality analyses, and flavor profile analyses that were performed between July 25 and July 27, 2006.

FLAVOR PROFILE ANALYSES

Flavor profile analysis (FPA) uses a group of four to six trained panelists to examine the sensory characteristics of water samples. Flavor attributes are determined by tasting the water sample; odor attributes (aroma) are determined by sniffing the sample. The method allows more than one flavor, odor attribute, or feeling factor (e.g., drying, chalky) to be determined per sample and each attribute's strength to be measured.

Intensities can range from 0 (non-detect) to a maximum of 12. The lowest possible detected intensity is 0.5. An odor or flavor rating of two or less is considered weak. To get a perspective, seven teaspoons of sugar dissolved into a cup of water would yield a sweet flavor intensity of 12. Sugar would be first detected (intensity of 0.5) with about 1/8 to 1/4 teaspoon dissolved in water, depending upon the individual. Our experience has been that when the intensity of an objectionable odor or flavor is 4.0 or greater, the numbers of consumers who take the trouble to telephone complaints to the water supplier generally increases precipitously. Even though considered to be weak, intensities of objectionable flavors and odors between 1.5 and 2.0 are very noticeable and can elicit negative feedback from consumers, if they are asked.

As presented in Table 1, all of the flavor or odor intensities were weak, with 2.0 being the highest. Results with intensities greater than 1.5 are highlighted in red to emphasize that they are more objectionable. Chlorine odors were detected by the panel in three of the six samples. This is not surprising in that Zone 7 Water Agency (the wholesaler of water to DSRSD) aims to maintain a total chlorine residual of about 2.0-2.5 mg/L. The Del Valle Water Treatment Plant treated water sample had a flavor and odor that were both notably earthy/musty odor. The other DSRSD/Zone 7 samples that contained a portion of DVWTP water, Pump Station 20 and Turnout 2, also had notable descriptors. The Hetchy Hetchy sample had a chlorine odor and a bitter and chlorine flavor. In contrast, the Mocho 4 Well and EBMUD samples were flavor-free.

Table 1
FPA Summary
Samples Taken on July 25 and 26, 2006

Sample Description	Odor Characteristics and Intensities (Odor Free to 12)	Flavor Characteristics and Intensities (Flavor Free to 12)	Chlorine Residual (mg/L) Total, except as noted
Turn Out 2	Chlorine 0.5	Musty 1.0 Notes: Chlorine, Slick Mouthfeel	0.6
Pump Station 20B	Pencil Shavings 1.5	Pencil Shavings 1.0 Notes: Chalky, Drying	0.4
Mocho 4 Well	Chlorine 0.5 Note: Musty	Flavor Free Notes: Musty, Bitter, Sour, Chlorine, Salty, Sweet, Soft Mouthfeel	1.4
Del Valle Water Treatment Plant	Earthy Musty 1.5	Earthy Musty 2.0 Note: Bitter	2.2
EBMUD	Sweet 1.0 Notes: Musty, Wet Cracker	Flavor Free Notes: Sweet Cracker, Wet Paper, Sweet, Musty, Bitter	1.9
Hetch Hetchy	Chlorine 1.0 Notes: Metallic, Musty	Chlorine 0.5 Bitter 1.0 Notes: Metallic, Musty, Plastic	0.3 (free)

The surface water samples (EBMUD, Hetch Hetchy, and DVWTP) have relatively low levels of dissolved solids, hardness, alkalinity, and chlorides compared to the groundwater (Mocho 4) and groundwater blends (Pump Station 20B and Turnout 2. The DVWTP sample had detectable low levels of the earthy/musty odor-causing compounds geosmin and MIB. Geosmin was also detected in the Turnout 2 sample at a level just above the detection limit of 2.0 ng/L.

Table 2
Water Quality Results
(Analyses performed by Zone 7 Water Agency, MWH Laboratories, and DSRSD staff)
Samples taken on 7/25 and 7/25/2006

		pH	Turbidity	Alkalinity	Total Dissolved Solids	Total Hardness	Chloride	Geosmin	MIB	Chlorine Residual (Total unless indicated)
	DESCRIPTION		NTU	mg/L	mg/L	mg/L	mg/L	ng/L	ng/L	mg/L
1	EBMUD	9.0	0.08	23	<5	17	3.4	<2.0	<2.0	2.1
2	Hetch Hetchy (Upstream of Sunol Valley WTP)	9.2	0.48	11	<5	10	0.2	<2.0	<2.0	0.9 (Free)
3	Pump Station 20B	8.9	0.26	88	176	94	44	<2.0	<2.0	0.9
4	Mocho 4 Well	7.6	0.15	290	488	336	78	<2.0	<2.0	1.7
5	Turn Out 2	7.9	0.14	210	374	264	72	2.6	<2.0	1.2
6	Del Valle Water Treatment Plant	8.8	0.11	60	100	54	29	5.0	6.6	2.4

QUANTITATIVE TASTE TEST

The National Food Laboratory administered a Quantitative Taste Test to 111 residents of the DSRSD service area. The participants evaluated the six samples in a monadic-sequential manner (i.e., one at a time, one after the other). Panelists were instructed to drink as much of the samples as they needed to form their opinions, then complete a self-administered questionnaire. This procedure was repeated for each sample. Samples were served in clear plastic glasses and each sample was coded with a different, randomly selected 3-digit number. The serving order was balanced such that each sample was evaluated in each serving position approximately an equal number of times. The waters were served at room temperature (20°C).

A self-administered questionnaire was given to the panelists. It contained approximately four closed-ended questions, including hedonic ratings (like/dislike) of appearance, aroma, flavor, and an overall rating. In addition, open-ended questions asked consumers to describe what they disliked about the sample, if anything. The NFL was responsible for all coding, copying and collating functions of the questionnaires.

The hedonic scale consisted of nine ratings (scores of 1-9) for each of four categories (Overall, Appearance, Aroma, and Flavor) as follows:

9	Like extremely
8	Like very much
7	Like moderately
6	Like slightly
5	Neither like nor dislike
4	Dislike slightly
3	Dislike moderately
2	Dislike very much
1	Dislike extremely

For this memorandum only the Flavor ratings were considered, as the Overall and Appearance ratings are not related directly to the water quality parameters of interest in this study. The Aroma, or Odor, category was not evaluated because the samples were not capped prior to evaluation, enabling certain odor causing compounds to escape. NFL presented the results in a separate document.

Analysis of Results

The average flavor ratings for each of the samples evaluated by the participants in the Quantitative Taste Test are presented in Table 3. The results are shown in decreasing order.

Table 3
Quantitative Taste Test Flavor Results

	Sample Description	Flavor Rating
1	**EBMUD**	**6.49**
2	**Hetch Hetchy (Upstream of Sunol Valley WTP where blending with local runoff occurs)**	**6.11**
3	**Pump Station 20B**	**5.52**
4	**Mocho 4 Well**	**5.30**
5	**Turn Out 2**	**5.13**
6	**Del Valle Water Treatment Plant**	**3.79**

The EBMUD water was clearly the favorite with a rating of 6.5, indicating that it was *liked slightly/moderately*. The Hetch Hetchy water was second and *liked slightly*. Pump Station 20B, Mocho 4 Well, and Turn-Out 2 ranged between 5.1 and 5.5 and were neither liked nor disliked. The Del Valle WTP treated water was clearly ranked lowest and was *disliked slightly/moderately*. It ranked lowest as it did during the November 2005 sampling event. During that event sample blends with proportionately more Del Valle WTP water tended to rank worse. We do not know the composition of the Pump Station 20B and Turn-Out 2 samples, so we cannot make the same finding. The EBMUD water and

water from this particular Hetch Hetchy sample site were not tested during November 2005.

Correlation with Water Quality Data

The results from Table 3 above were correlated with relevant water quality parameters to see if there are any trends that could explain the flavor ratings. Figures 1 through 6 present the average flavor ratings versus, chlorine residual, chloride, geosmin, total dissolved solids, and alkalinity measured for each of the samples.

Figure 1
Effect of Chlorine on Flavor Rating

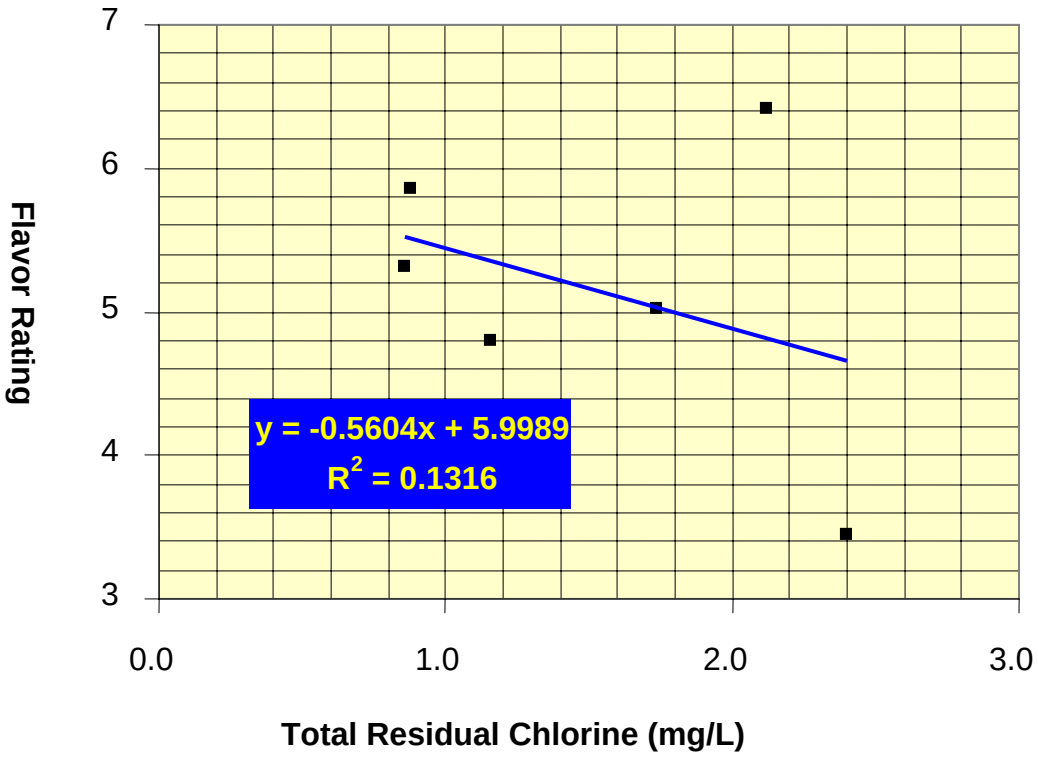


Figure 2
Effect of Geosmin on Flavor Rating

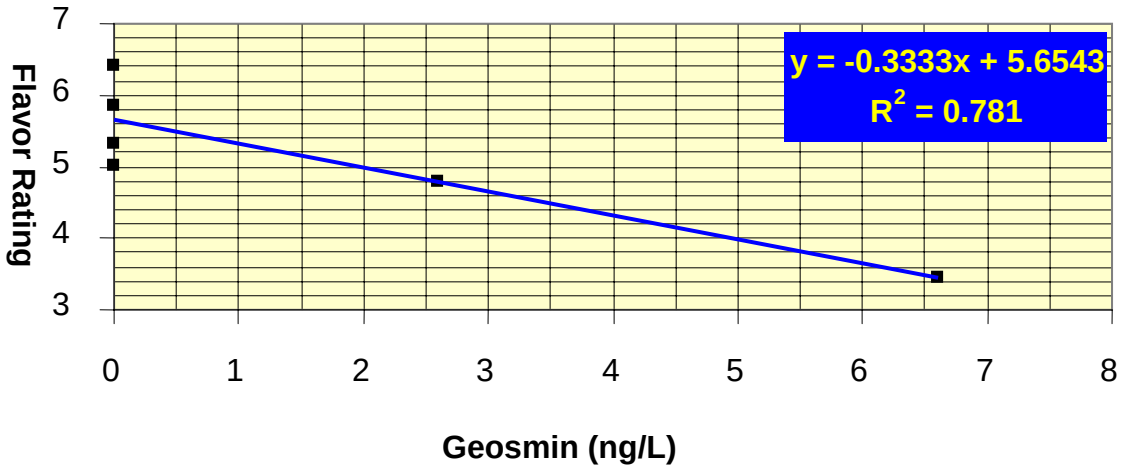


Figure 3
Effect of Chloride on Flavor Rating

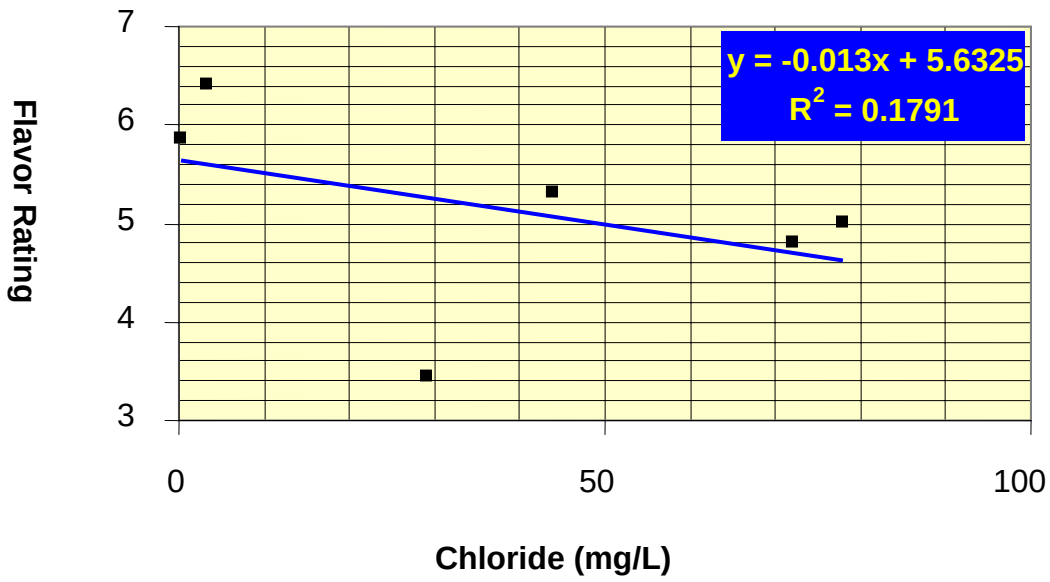


Figure 4
Effect of Total Dissolved Solids on Flavor Rating

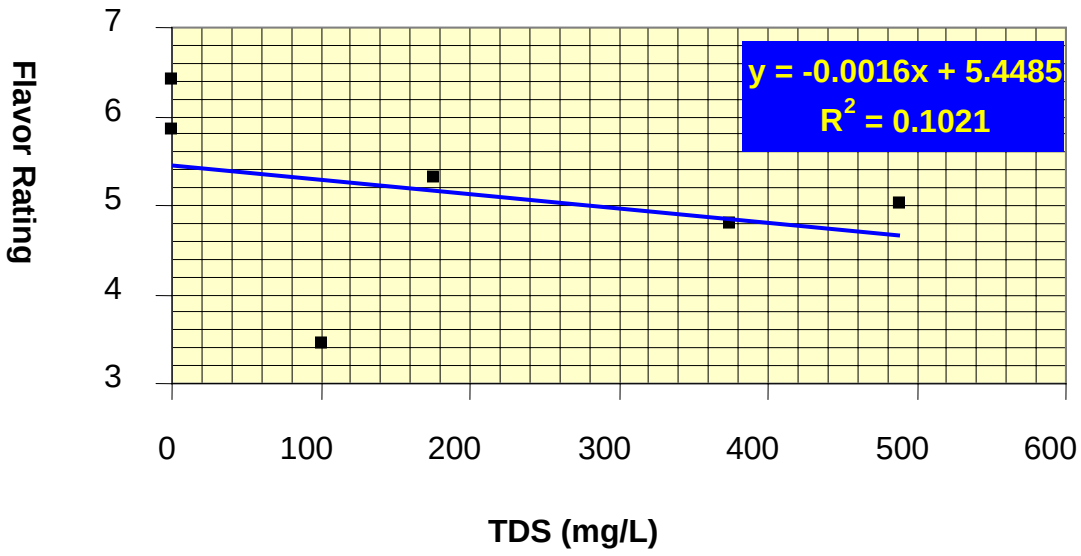


Figure 5
Effect of Hardness on Flavor Rating

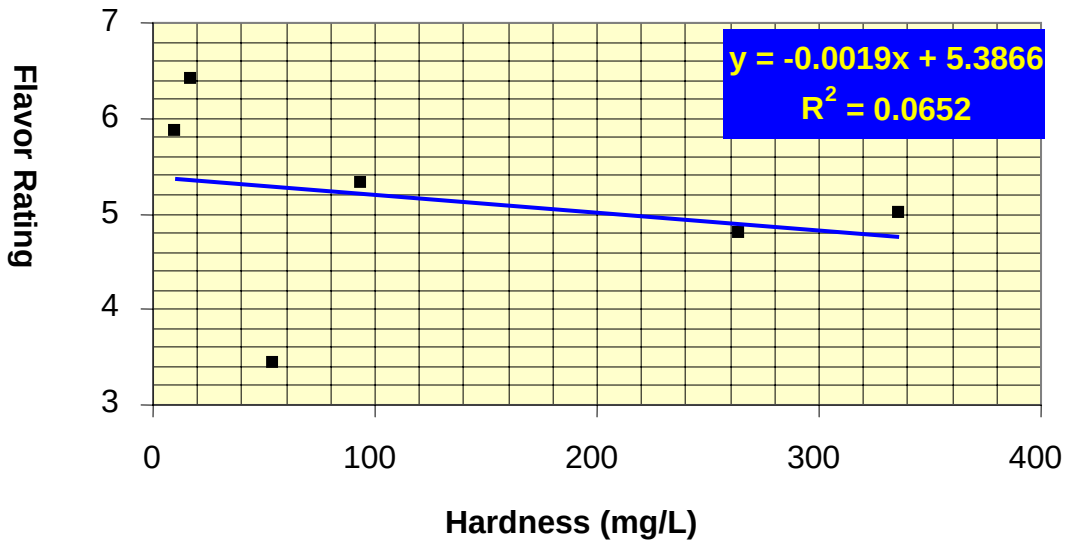
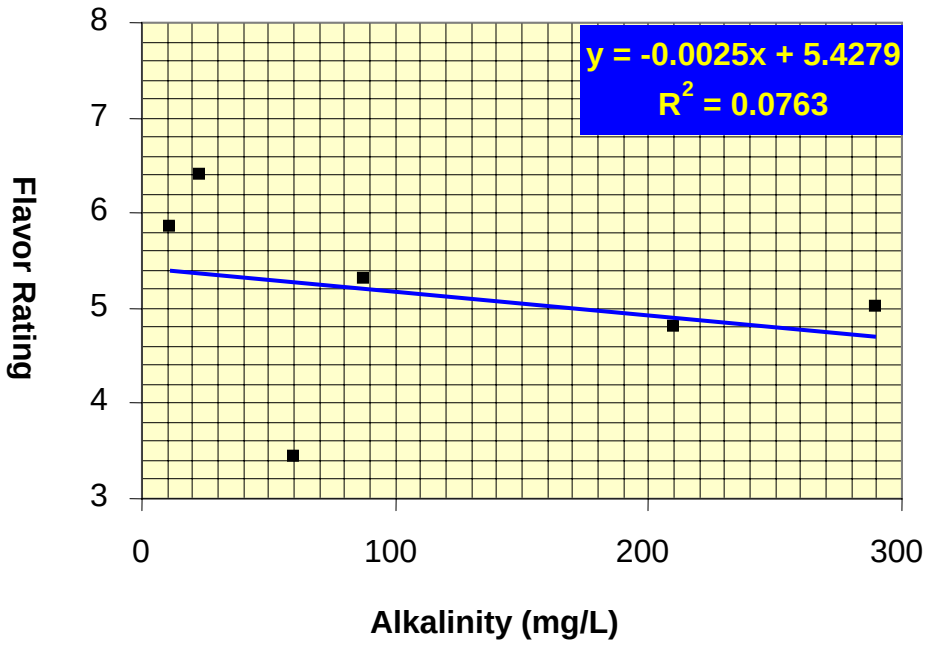


Figure 6

Effect of Alkalinity on Flavor Rating



All of the water quality parameters showed a negative correlation with the flavor rating. In other words, as the concentration of the water quality constituent increases, the flavor rating decreases. A positive correlation would mean that the flavor rating increases with an increase in the constituent concentration. Table 4 presents the correlation coefficients. The correlation coefficient is a statistic that gives a measure of how closely two variables are related. A correlation coefficient of +1 or -1 would indicate perfect correlation. As was the case with the 2005 samples, geosmin had the best correlation, indicating that the earthy and musty flavors had the most impact on consumers' perception. Chlorine did not have the same effect this time, as evidenced by a lower correlation coefficient and the fact that the most preferred water—the EBMUD sample—had the second highest chlorine residual. Chloride had a higher impact, although the correlation of -0.18 is still relatively low. Total dissolved solids, hardness, and alkalinity again appeared to have little or no effect on consumer flavor preferences.

Table 4
Correlation of Flavor Rating
With Water Quality Parameters*

Water Quality Parameter	Correlation Coefficients (r2 values)	
	November 2005 (Bottled Water Excluded)	July 2006
Total Chlorine Residual	-0.37	-0.13
Chloride	-0.08	-0.18
Geosmin	-0.61	-0.78
Total Dissolved Solids	+0.03	-0.10
Hardness	+0.09	-0.07
Alkalinity	+0.08	-0.08

*Shaded cells had positive correlations.
Unshaded cells had negative correlations

FINDINGS AND RECOMMENDATIONS

Findings

The findings from the Flavor Profile Analysis and the Consumer Taste Test largely corroborate those from the earlier tests. The findings from each are described below.

Flavor Profile Analyses

- The DVWTP sample had a distinct earth/musty odor and flavor, consistent with geosmin and MIB present in surface water, especially during the summer.
- The Mocho well sample had a barely detectable chlorine odor and was flavor free
- The Turnout 2 sample had a barely detectable chlorine odor and a slightly musty flavor resembling a combination of groundwater and DVWTP water
- Pump Station 20B water had an odor and flavor resembling pencil shavings.
- The EBMUD sample had a slightly sweet odor and was flavor free
- The Hetchy Hetchy water had a slight chlorine odor and flavor and was slightly bitter.

NFL Consumer Taste Test

- EBMUD water rated the highest
- Hetch Hetchy water appeared to be better perceived than the earlier test, suggesting that the local water portion of the blend contributed to the lower than expected rating in 2005
- DVWTP water was rated significantly lower than other waters tested
- Mocho well water was rated similar to the distribution system samples (Pump Station 20B and Turnout 2)
- NFL Flavor ratings appeared to have a:
    - Distinct inverse relationship with increasing geosmin level
    - An inverse relationship with Increasing chlorine residual
    - An inverse relationships with Increasing chloride concentration
    - No relationship appeared to exist between NFL Flavor Rating and hardness, total dissolved solids, and alkalinity

Additional Comments

Once again the results suggest that the constituents causing the off-flavors in surface water are geosmin, and possibly MIB. Chlorine did not seem to have the same impact that it did in 2005. For groundwater, chlorine and chlorides seem to have some effect on the rating.

The geosmin levels in the Del Valle WTP samples (5.0 ng/L) and MIB (6.6 ng/L) very likely caused this water to be rated the worst by the NFL panel. Surprisingly, the concentration is below 10 ng/L, which is often listed as the threshold odor concentration for geosmin.

Recommendations

Our recommendations are unchanged:

1. DSRSD should continue discussions with Zone 7 Water Agency to consider the implementation of treatment techniques to improve the aesthetic quality of water delivered to DRSD including:
    - Granular activated carbon or ozone/hydrogen peroxide for geosmin and MIB control
    - with differing mineral contents (best measured as hardness) and alkalinities.
2. Although a reduction in the total chlorine residual would reduce the intensity of chlorinous odors and flavors, the Zone 7 total chlorine residual target of 2.0-2.5 mg/L is appropriate to provide disinfectant protection and should not be changed. A reduction in the total chlorine residual would make the water system more susceptible to nitrification. A decrease or elimination of other off-flavors may reduce the negative effects of chlorine.