FINAL REPORT
UNIQUE CHALLENGES POSED BY SMALL STREAMS
IN DETERMINING DISSOLVED OXYGEN AND BACTERIA
WATER QUALITY CRITERIA COMPLIANCE

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UNIQUE CHALLENGES POSED BY SMALL STREAMS IN DETERMINING DISSOLVED OXYGEN AND BACTERIA WATER QUALITY CRITERIA COMPLIANCE

Prepared in Cooperation with the

Guadalupe-Blanco River Authority
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EXECUTIVE SUMMARY

Screening of water quality data to determine compliance with standards has been conducted for several years. The current list of water bodies in the Guadalupe River basin that do not meet standards for dissolved oxygen (DO) and indicator bacteria has a disproportionate share that are small creeks, many of which are not classified stream segments. While the possibility exists that there are actual manmade waste discharges that are the cause of these listings, it is also possible that the listings are a result of the unique physical conditions associated with small stream systems. Stated very simply, it appears that we are dealing with size discrimination issue.

This study reviews and analyzes the empirical monitoring data that are the basis for the listings, and the physical conditions for each of the stations. It was found that smaller streams in general tend to have the lowest DO and the highest indicator bacteria levels. Physical reasons for these results are discussed and suggestions made on the types of more detailed study that would be needed to document and ultimately correct for these physical aspects.

A closely related dimension of the situation is the standards themselves, which currently make no allowances for physical scale or size. A review of procedures for setting DO criteria is presented. A recommendation made is to consider basing DO criteria on the actual biological needs of the indigenous biological community. Presumably the biological community in a smaller stream is better adapted to the stresses of highly variable conditions than the community in larger waterways, and could thus tolerate lower natural DO levels. Another recommendation made is to implement the recommendation of the Statewide Bacterial Indicator Study for dealing with smaller highly variable streams. Briefly, that recommendation is perform monitoring in the routine manner, but only screen data that were collected when conditions were actually suitable for contact recreation.

If the recommendations of the study are followed, it is reasonable to expect that procedures for screening of data against standards can be updated to address what now appears to be a problem of size discrimination.

TABLE OF CONTENTS

ATTACHMENTS:

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

Criteria for Dissolved Oxygen (DO) and indicator bacteria both fecal coliform (FC), and *Escherichia coli* (EC), have evolved over the last several decades for a wide range of waters including rivers, lakes, and estuaries. In general, criteria are assigned to water bodies of most significance in the state, and these are designated as segments.

Over most of the decades that the standards have evolved there has been no rigid testing or compliance requirements. DO criteria were instrumental in setting waste treatment permit requirements for discharges to streams, but until fairly recently there was no significant consequence if routine monitoring data indicated a stream failed to meet the established criterion. A similar situation existed for indicator bacteria, where monitoring data were normally not collected at a high enough frequency to even allow comparison with criteria. That situation changed with implementation of the 303(d) listing program. With that program, waters of the state are periodically tested to determine whether they meet standards and support designated uses. Failure to meet standards mandates studies to determine reasons for failure and corrective actions, potentially at significant expense.

The process of determining compliance with standards is complex. In general, most waters of the state currently meet standards. All waters of the state exhibit variations in water quality parameters with season and with rain, and smaller streams tend to show more variation with rainfall related flows than do larger water bodies. For the most part, the designated segments are large enough to have reasonably uniform characteristics spatially and temporally. For example, with most segments DO readings or bacteria measurements will be essentially the same if a measurement is taken 100 feet up or downstream of the historical sampling station. Variations over the course of a year are averaged in present testing procedures. As long as there are sufficient cool weather observations, the DO averages tend to meet criteria; and as long as there are sufficient low flow observations, the bacteria averages generally do the same.

The situation tends to get more complex as smaller streams are considered. First, a substantial portion of smaller streams that have been assessed recently do not have designated criteria of their own. In these undesignated waters, assessment is done relative to the criteria that exist for the next downstream segment, that may be very different in characteristics from the stream in question. In other cases, small stream segments have had criteria assigned without detailed study. The net effect has been that in the last round of testing standards attainment, a substantial number of smaller segments were listed as not supporting designated uses.

With only a limited amount of information available, a cause for non-attainment cannot be categorically determined. However, many locations are largely natural with little upstream development. A key point may be that the physical conditions associated with smaller streams are substantially different from larger and more stable waters, and there are as yet no procedures available to address or compensate for these differences. Understanding and quantifying these differences is crucial because we are now testing compliance with criteria and basing potentially expensive actions on the outcome of the tests.

A simple way to express the problem is that small streams now fail to meet criteria more than other waters. This situation appears undesirable, as smaller streams should not be penalized simply based on size.

This document analyzes the regulatory situation with smaller streams for DO and bacteria. Section 2.0 documents the nature of the differences for small and larger streams in the Guadalupe River basin. The next section discusses physical reasons that can affect DO and bacteria results in smaller streams that need to be analyzed in more detail. Section 4.0 addresses another component of the problem, the criteria for dissolved oxygen and indicator bacteria. It reviews the process of criteria development and suggests modifications for each. The final section discusses and summarizes the issues and suggests some pathways for additional studies that might be useful to resolve the situation in a timely fashion.

2.0 DOCUMENTATION OF EXISTING CONDITIONS

Historical data in the Guadalupe River Basin were analyzed to study the relationship between physical characteristics of the water body and DO and bacteria levels. This section describes the methods and results for each group.

The analysis employs all the routine water quality monitoring data collected in the Guadalupe River basin from 1990 to 2000. Table 2-1 is a listing of monitoring stations presented by county, their locations and descriptions, and the total number of water quality measurements. Also shown on the table are the stations from water bodies listed on the current 303(d) list for both DO and indicator bacteria. Figure 2-1 shows these monitoring locations employed. Note that current monitoring activities include some newer stations that did not have enough data to be analyzed, and some of the stations listed on the table and figure are no longer being monitored.

2.1 DISSOLVED OXYGEN

Dissolved oxygen and water temperature data from 2/90 to 2/01 were retrieved from the TNRCC Surface Water Quality Monitoring database. Only data collected near the surface were used in this analysis. Stations with less than 10 samples were excluded. The percent saturation DO concentrations were calculated from water temperatures. Mean and standard deviation of the DO concentration as well as percent saturations for each monitoring station were calculated and are shown in Table 2-2. For analytical convenience, the stations are ranked based on average percent DO saturation. Percent saturation is employed because it eliminates one major source of variation (temperature) due to the amount of samples collected in cool or warm conditions. Dissolved solids also affect percent saturation which can be a factor in tidal waters.

The types of water bodies at which the monitoring stations are located were classified as main stem, lake, classified tributary, or unclassified tributary. Based on site-specific information provided by GBRA and UGRA monitoring personnel, four measures were used to characterize the stream during normal or good weather conditions:

1. Type: Riffle (water flowing over and around rocks)
   Run (water flowing smoothly with little surface turbulence)
   Pool (water impounded with little apparent velocity)
   Tidal (water subject to tidal elevation changes)
2. Depth (typical depth in feet)
3. Velocity (typical velocity in feet per second)
4. Shade (full, partly shaded, or no shading)

These characterizations are also presented in Table 2-2.

TABLE 2-1
STUDY STATIONS BY COUNTY

Station ID	Segment no.	Location	Number of data [1]			County	Segment on 2000 303(d) list due to DO or FC level
			DO	FC	EC		
12560	1813	LITTLE BLANCO RIVER AT CHICK RANCH ROAD, 2 MI. WEST OF RR 32 AND FM 473 INTERSECTION 3.6 MILES NE OF TWIN SISTERS	6	6		BLANCO	
12668	1813	BLANCO RIVER AT FM 165 1/2 MILE EAST OF BLANCO	49	48	48	BLANCO	
12669	1813	BLANCO RIVER AT BLANCO STATE PARK, PR 23	11	11		BLANCO	
12626	1808	LOWER SAN MARCOS RIVER AT SH 80 SOUTH OF LULING	153	128	49	CALDWELL	
12640	1810	PLUM CREEK AT OLD WOODEN BRIDGE ON CALDWELL CR 135, SE OF LULING	50	50	35	CALDWELL	
12642	1810	PLUM CREEK AT CR 131 NE OF LULING	1	1		CALDWELL	
12645	1810	PLUM CREEK AT CR 197, SE OF LOCKHART	15	15	15	CALDWELL	
12647	1810	PLUM CREEK AT CR 202, SE OF LOCKHART	2	2		CALDWELL	
14945	1810	CLEAR FORK OF PLUM CREEK AT CALDWELL CR 213, 0.27 MI. DOWNSTREAM OF US 183	3	3		CALDWELL	
12577	1801	GUADALUPE RIVER TIDAL BRIDGE AT SH 35 NE OF TIVOLI	35	32		CALHOUN	DO
12578	1803	GUADALUPE RIVER AT LOWER GUADALUPE DIVERSION DAM AND SALT WATER BARRIER	178	127	50	CALHOUN	
12598	1805	CANYON LAKE SOUTH OF JACOBS CREEK PARK 500 YARDS EAST OF PENINSULA	129	124	46	COMAL	
12600	1805	CANYON LAKE MID-LAKE SOUTH OF POTTERS CREEK PARK AT WEST END OF PARK	4	4		COMAL	
12601	1805	CANYON LAKE HEADWATERS ABOVE CRANES MILL PARK	4	4		COMAL	
13836	1805	CANYON LAKE USGS SITE AC	3			COMAL	
13838	1805	CANYON LAKE USGS SITE AR	3			COMAL	
13839	1805	CANYON LAKE USGS SITE BC	3			COMAL	
13840	1805	CANYON LAKE USGS SITE CC	3			COMAL	
13841	1805	CANYON LAKE USGS SITE DC	3	1		COMAL	
13842	1805	CANYON LAKE USGS SITE EC	3			COMAL	
13843	1805	CANYON LAKE USGS SITE FC	3			COMAL	
13700	1806	GUADALUPE RIVER AT RR 311, 1.9 MI. SE OF SPRING BRANCH, 7.5 MI. DOWNSTREAM FROM CURRY CREEK	93	37	36	COMAL	
14255	1806	GUADALUPE RIVER AT US 281 NORTH OF SAN ANTONIO	16	16		COMAL	
12570	1811	DRY COMAL CREEK AT MISSOURI-KANSAS-TEXAS RAILROAD CROSSING IN NEW BRAUNFELS--SEGUIN STREET STATION	50	50	50	COMAL	FC
12653	1811	COMAL RIVER BELOW CLEMONS DAM IN NEW BRAUNFELS--AT HINMON ISLAND ABOVE DAM	98	100	50	COMAL	
12656	1812	GUADALUPE RIVER AT THE BEGINNING OF CYPRESS BEND PARK IN NEW BRAUNFELS	24	25		COMAL	
12658	1812	GUADALUPE RIVER AT RIVER RD 2ND CROSSING, UPSTREAM OF NEW BRAUNFELS	128	128	49	COMAL	
13511	1812	GUADALUPE RIVER AT GRUENE ROAD CROSSING APPROX. 0.8 KM SW OF RR 306 IN GRUENE	1	1		COMAL	

TABLE 2-1 (CONTINUED)
STUDY STATIONS BY COUNTY

Station ID	Segment no.	Location	Number of data [1]			County	Segment on 2000 303(d) list due to DO or FC level
			DO	FC	EC		
13656	1812	GUADALUPE RIVER 200 FT. UPSTREAM FROM HORSESHOE FALLS, 0.8 MI. NORTH OF SATTLER, 1.8 MI. DOWNSTREAM FROM CANYON DAM	23	6		COMAL	
16703	1812	GUADALUPE RIVER 200YDS UPSTREAM OF BRIDGE ON FM306, 0.5MI DOWNSTREAM OF HORSESHOE FALLS	1	1		COMAL	
12591	1803	GUADALUPE RIVER AT FM 236 SOUTH OF CUERO	9	9		DEWITT	
12592	1803	GUADALUPE RIVER AT OLD SAN ANTONIO ROAD WEST OF CUERO	126	126	51	DEWITT	
13657	1803	SANDIES CREEK 100 FT. DOWNSTREAM OF COUNTY HIGHWAY, 1.9 MI. UPSTREAM FROM BIRDS CREEK, 2.0 MI. NE OF WESTHOFF	30	12	12	DEWITT	DO
14935	1803	SANDIES CREEK AT CR 953 OM DEWITT COUNTY	13	13	13	DEWITT	DO
14937	1804	PEACH CREEK AT CR 353 IN GONZALES COUNTY	52	52	52	GONZALES	FC
15996	1803	ELM CREEK AT GONZALES CR108, APPROX. 1.7KM SOUTH OF SMILEY	9	9		GONZALES	DO, FC
15997	1803	ELM CREEK AT GONZALES CR534, APPROX. 6.7KM ESE OF NIXON	9	9		GONZALES	DO, FC
15998	1803	SANDIES CREEK AT FM1116, 7.4KM EAST OF SMILEY AND APPROX. 3KM UPSTREAM OF CONFL. WITH ELM CREEK	26	26	18	GONZALES	DO
15110	1804	GUADALUPE RIVER IMMEDIATELY DOWNSTREAM OF H-5 DAM AT WOOD LAKE, SW OF GONZALES, TX	51	51	51	GONZALES	
12624	1808	LOWER SAN MARCOS RIVER AT LOW WATER CROSSING, PR 11 IN PALMETTO BEND STATE PARK	18	17		GONZALES	
16578	1808	SAN MARCOS RIVER AT US90A, 3.3KM WEST OF INTERSECTION OF US90A AND US183 IN GONZALES, 7KM UPSTREAM OF CONFL. WITH GUADALUPE RIVER	6	6	6	GONZALES	
12575	1804	GERONIMO CREEK AT FM 20 NORTH OF SEGUIN	4	3		GUADALUPE	
12576	1804	GERONIMO CREEK AT HABERLE ROAD 3 MILES SOUTH OF GERONIMO	3	2		GUADALUPE	
12594	1804	GUADALUPE RIVER SE OF SEGUIN ABOVE MEADOW LAKE	8	8		GUADALUPE	
12595	1804	GUADALUPE RIVER AT IH 10 WEST OF SEGUIN	1	1		GUADALUPE	
12596	1804	LAKE DUNLAP-GUADALUPE RIVER NORTH BANK AT AC'S PLACE AT MIDPOINT OF LONE STAR DRIVE	170	131	51	GUADALUPE	
14932	1804	GERONIMO CREEK AT SH 123 NEAR GERONIMO, TX	51	51	50	GUADALUPE	
14940	1804	WALNUT CREEK IN SEGUIN CITY PARK, 100 YDS. UPSTREAM OF GUADALUPE RIVER CONFLUENCE	4	3		GUADALUPE	
15149	1804	LAKE MCQUEENEY, 0.5 MI. UPSTREAM OF MCQUEENEY DAM ON SOUTHEAST BANK	38	43	38	GUADALUPE	
12628	1808	LOWER SAN MARCOS RIVER AT COUNTY ROAD IMMEDIATELY BELOW CONFLUENCE OF SAN MARCOS AND BLANCO RIVERS	21	19		HAYS	
12631	1809	BLANCO RIVER AT HAYS CR 295 EAST OF SAN MARCOS	9	9		HAYS	

TABLE 2-1 (CONTINUED)
STUDY STATIONS BY COUNTY

Station ID	Segment no.	Location	Number of data [1]			County	Segment on 2000 303(d) list due to DO or FC level
			DO	FC	EC		
12637	1809	BLANCO RIVER UPSTREAM 6.3 MI FROM BRIDGE ON US 81/IH 35	4	4		HAYS	
12538	1810	ANDREWS BRANCH OF PORTER CREEK AT HAYS CR 131 AND 3.4 MI. SE OF BUDA	1	1		HAYS	
12660	1813	BLANCO RIVER AT LOW WATER CROSSING AT CR 174	3	3		HAYS	
12661	1813	BLANCO RIVER AT BRIDGE ON SH 12 AT WIMBERLEY	28	24		HAYS	
12629	1814	UPPER SAN MARCOS RIVER DOWNSTREAM FROM STP IN SAN MARCOS	2	2		HAYS	
12671	1814	UPPER SAN MARCOS RIVER 0.7 MILE DOWNSTREAM FROM IH 35	21	27		HAYS	
12672	1814	UPPER SAN MARCOS RIVER IMMEDIATELY UPSTREAM OF IH 35 BRIDGE AT SAN MARCOS	14	22	11	HAYS	
14153	1814	SAN MARCOS (A.E. WOODS) TPWD FISH HATCHERY DISCHARGE POINT TO SAN MARCOS RIVER	1	1		HAYS	
12674	1815	CYPRESS CREEK AT FM 12 AT WIMBERLEY	29	28	11	HAYS	DO
12551	1806	CYPRESS CREEK, 1.4 KM ABOVE CONFLUENCE WITH GUADALUPE RIVER IN COMFORT	50	51	37	KENDALL	
12552	1806	CYPRESS CREEK AT SH 27 NEAR COMFORT	12	13	12	KENDALL	
12602	1806	GUADALUPE RIVER AT COUNTY RD IN WARING	1	1		KENDALL	
12603	1806	GUADALUPE RIVER AT IH 10 IN COMFORT	4	17	13	KENDALL	
12605	1806	GUADALUPE RIVER AT COUNTY RD ADJACENT TO HERMANN SONS' HOME, WEST OF COMFORT	57	69	56	KENDALL	
12541	1806	QUINLAN CREEK AT TRAVIS STREET IN KERRVILLE	47	47	32	KERR	
12542	1806	QUINLAN CREEK IN NORTH KERRVILLE AT IH 10	2	2	2	KERR	
12543	1806	VERDE CREEK, 0.2 KM UPSTREAM OF CONFLUENCE WITH GUADAUPE R. NEAR CENTER POINT	54	52	39	KERR	
12544	1806	TURTLE CREEK, AT COUNTY RD, 0.1 MI ABOVE CONFLUENCE OF GUADALUPE R., WEST OF CENTER POINT	46	47	33	KERR	
12546	1806	CAMP MEETING CREEK, 0.1 KM ABOVE CONFLUENCE WITH GUADALUPE IN KERRVILLE	54	53	38	KERR	DO
12547	1806	GOAT CREEK AT ACADIA LOOP IN KERRVILLE	38	39	25	KERR	
12549	1806	TOWN CREEK AT HAMILTON STREET IN KERRVILLE	45	47	33	KERR	
12550	1806	TOWN CREEK IN NORTH KERRVILLE ON TOWN CREEK ROAD	3	3	3	KERR	
12564	1806	THIRD CREEK, 0.5 KM ABOVE CONFLUENCE WITH GUADALUPE RIVER	13	14	1	KERR	
12566	1806	THIRD CREEK, 0.7 KM UPSTREAM OF THE CITY OF KERRVILLE WWTP	6	2	1	KERR	
12607	1806	GUADALUPE RIVER AT ROANE-HOMILIUS RD, 3 MI DOWNSTREAM OF CENTER POINT	7	6		KERR	
12608	1806	GUADALUPE RIVER CENTER POINT LAKE	57	69	54	KERR	
12610	1806	GUADALUPE RIVER AT COUNTY RD, 0.1 MI ABOVE CONFLUENCE OF TURTLE CREEK AT SEGMENT KM 166.2	32	45	32	KERR	

TABLE 2-1 (CONCLUDED)
STUDY STATIONS BY COUNTY

Station ID	Segment no.	Location	Number of data [1]			County	Segment on 2000 303(d) list due to DO or FC level
			DO	FC	EC		
12611	1806	GUADALUPE RIVER COUNTY RD BELOW FLAT ROCK DAM, AT SEGMENT KM 172.5	42	42	31	KERR	
12612	1806	GUADALUPE RIVER ABOVE FLAT ROCK DAM, AT SEGMENT KM 172.6	9	14	1	KERR	
12615	1806	GUADALUPE RIVER AT KERRVILLE STATE PARK, SEGMENT KM 174.4	50	64	53	KERR	
12616	1806	GUADALUPE RIVER AT G STREET (FORMERLY OLD MEDINA RD) IN KERRVILLE, SEGMENT KM 177.9	55	55	39	KERR	
12618	1806	GUADALUPE RIVER AT UGRA LAKE DAM	40	63	46	KERR	
12619	1806	GUADALUPE RIVER AT BEAR CREEK ROAD, 1 MI. WEST OF KERRVILLE	51	64	50	KERR	
12620	1806	GUADALUPE RIVER AT INGRAM DAM IN INGRAM	56	68	44	KERR	
12621	1806	GUADALUPE RIVER AT SH 39 NEAR HUNT, 0.1 KM BELOW THE NORTH/SOUTH FORK CONFL.	50	60	44	KERR	
15111	1806	GUADALUPE RIVER AT RIVERVIEW RD IN INGRAM, TX	4	3	3	KERR	
15113	1806	GUADALUPE RIVER AT SPLIT ROCK RD OFF SH 27, 2.6 KM DOWNSTREAM OF FLATROCK DAM	6	5	5	KERR	
12678	1816	JOHNSON CREEK AT SH 39 IN INGRAM	73	83	51	KERR	
12679	1816	JOHNSON CREEK AT TECABOCA CAMP	6	7	6	KERR	
12681	1817	NORTH FORK GUADALUPE RIVER AT FM 1340	68	79	51	KERR	
12682	1817	NORTH FORK GUADALUPE AT RIVER GAGING STATION NEAR CAMP WALDEMAR	17	27	28	KERR	
12683	1817	NORTH FORK GUADALUPE RIVER AT EASTERN BOUNDARY OF KERR WILDLIFE MANAGEMENT AREA	22	22	15	KERR	
12684	1818	SOUTH FORK GUADALUPE ADJACENT TO HUNT LIONS PARK	55	53	38	KERR	
12685	1818	SOUTH FORK GUADALUPE ADJACENT TO CAMP ARROWHEAD	16	28	13	KERR	
12686	1818	SOUTH FORK GUADALUPE ADJACENT TO CAMP MYSTIC	26	37	37	KERR	
12688	1818	SOUTH FORK GUADALUPE ADJACENT TO LYNXHAVEN LODGE AT SH 39	25	35	36	KERR	
12581	1803	GUADALUPE RIVER SH 175 SOUTH OF VICTORIA	14	9		VICTORIA	
12585	1803	GUADALUPE RIVER AT US 59 IN VICTORIA	19	9		VICTORIA	
12590	1803	GUADALUPE RIVER AT FM 447, WEST OF NURSERY AND UPSTREAM OF SOUTH TEXAS ELECTRIC	5	5	5	VICTORIA	
16579	1803	GUADALUPE RIVER AT DUPONT, 3.0KM DOWNSTREAM OF CONFL WITH BLUE BAYOU AND 17KM SOUTH OF INTERESECTION OF US59 AND US87 IN VICTORIA	4	4	5	VICTORIA	
12622	1807	COLETO CREEK AT US 77 SOUTH OF VICTORIA	25	24		VICTORIA	
12623	1807	COLETO CREEK AT US 59 ON VICTORIA-GOLIAD COUNTY LINE--IN RESERVOIR AT LAUNCH RAMP	127	128	51	VICTORIA	

[1] Surface data only.

TABLE 2-2
BASIN 18 1990 TO 2000 DISSOLVED OXYGEN DATA SUMMARY

STATION ID	Type of water body [1]	Location	Num of data	Mean (mg/L)	Standard deviation (mg/L)	Mean % saturation	Stdev of % saturation	Station characteristics [2]				Remarks	Start date	End date
								Type	Depth (ft)	Velocity (ft/s)	Shade			
15998	UN	SANDIES CREEK AT FM1116, 7.4KM EAST OF SMILEY AND APPROX. 3KM UPSTREAM OF CONFL. WITH ELM CREEK	26	5.71	1.82	62.5%	15.4%	riffle	1	0.2	full	used width and depth from measured flow by GBRA.	11/20/97	08/29/00
13657	UN	SANDIES CREEK 100 FT. DOWNSTREAM OF COUNTY HIGHWAY, 1.9 MI. UPSTREAM FROM BIRDS CREEK, 2.0 MI. NE OF WESTHOFF	30	5.82	2.47	65.5%	22.8%	riffle	2	0.05	partly		10/25/95	12/11/00
12546	UN	CAMP MEETING CREEK, 0.1 KM ABOVE CONFLUENCE WITH GUADALUPE IN KERRVILLE	54	6.29	2.96	66.6%	29.0%	riffle	1	0.5	full		05/15/90	05/16/00
14935	UN	SANDIES CREEK AT CR 953 OM DEWITT COUNTY	13	6.31	1.67	68.7%	12.9%	run	3	0.2	partly	used width and depth from measured flow by GBRA.	10/21/96	10/27/97
14937	UN	PEACH CREEK AT CR 353 IN GONZALES COUNTY	52	7.09	1.85	76.9%	13.1%	run	3	0.2	full	used width and depth from measured flow by GBRA.	10/21/96	12/18/00
12645	TR	PLUM CREEK AT CR 197, SE OF LOCKHART	15	7.30	1.40	77.1%	8.9%	riffle	1	0.1	full		10/15/96	12/09/97
12640	TR	PLUM CREEK AT OLD WOODEN BRIDGE ON CALDWELL CR 135, SE OF LULING	50	7.10	2.27	77.3%	17.0%	run	2	0.1	full	used width and depth from measured flow by GBRA.	08/09/90	12/18/00
12549	UN	TOWN CREEK AT HAMILTON STREET IN KERRVILLE	45	7.57	2.22	79.7%	17.0%				partly		05/15/90	08/08/95
12564	UN	THIRD CREEK, 0.5 KM ABOVE CONFLUENCE WITH GUADALUPE RIVER	13	7.58	1.50	80.9%	11.5%				partly		05/15/90	05/22/91
12577	MS	GUADALUPE RIVER TIDAL BRIDGE AT SH 35 NE OF TIVOLI	35	6.98	1.59	81.0%	12.2%	tidal	11	0.7	none	Velocity estimated at median flow. Tidal component in vel.	02/27/90	11/28/00
13656	MS	GUADALUPE RIVER 200 FT. UPSTREAM FROM HORSESHOE FALLS, 0.8 MI. NORTH OF SATTLER, 1.8 MI. DOWNSTREAM FROM CANYON DAM	23	8.33	1.81	82.9%	14.7%				partly		02/05/90	07/29/98
12543	UN	VERDE CREEK, 0.2 KM UPSTREAM OF CONFLUENCE WITH GUADAUPE R. NEAR CENTER POINT	54	7.94	1.85	83.4%	14.6%	run	2	0.3	partly		05/15/90	05/16/00
12578	MS	GUADALUPE RIVER AT LOWER GUADALUPE DIVERSION DAM AND SALT WATER BARRIER	178	7.30	1.49	84.2%	12.2%	run	5	3.2	none	Site is at the diversion canal after gates.	03/05/90	12/11/00
12615	MS	GUADALUPE RIVER AT KERRVILLE STATE PARK, SEGMENT KM 174.4	50	7.86	1.66	85.0%	10.1%	pool	5	0.2	partly		06/06/90	03/24/97
12541	UN	QUINLAN CREEK AT TRAVIS STREET IN KERRVILLE	47	8.40	2.18	87.1%	14.9%				partly		05/15/90	07/12/95
12621	MS	GUADALUPE RIVER AT SH 39 NEAR HUNT, 0.1 KM BELOW THE NORTH/SOUTH FORK CONFL.	50	8.15	1.17	87.6%	6.9%	run	1	1.0	partly		05/15/90	03/24/97
12682	TR	NORTH FORK GUADALUPE AT RIVER GAGING STATION NEAR CAMP WALDEMAR	17	7.82	1.21	87.7%	7.4%	riffle	2	1.0	full		07/12/94	05/16/00
12674	TR	CYPRESS CREEK AT FM 12 AT WIMBERLEY	29	7.89	1.33	87.7%	12.3%	riffle	1	0.2	full	used width and depth from measured flow by GBRA.	11/13/91	10/31/00
12685	TR	SOUTH FORK GUADALUPE ADJACENT TO CAMP ARROWHEAD	16	7.67	1.17	87.8%	7.2%	run	1	0.5	full		08/29/90	08/05/97
12610	MS	GUADALUPE RIVER AT COUNTY RD, 0.1 MI ABOVE CONFLUENCE OF TURTLE CREEK AT SEGMENT KM 166.2	32	8.25	1.90	87.8%	11.1%				partly		05/15/90	12/14/93
12544	UN	TURTLE CREEK, AT COUNTY RD, 0.1 MI ABOVE CONFLUENCE OF GUADALUPE R., WEST OF CENTER POINT	46	8.15	1.79	87.9%	11.0%				partly		05/15/90	08/08/95
12605	MS	GUADALUPE RIVER AT COUNTY RD ADJACENT TO HERMANN SONS' HOME, WEST OF COMFORT	57	8.16	1.55	87.9%	8.2%	run	3	0.5	partly		05/15/90	05/16/00
12681	TR	NORTH FORK GUADALUPE RIVER AT FM 1340	68	8.03	1.30	88.2%	11.8%	run	3	0.3	partly		05/15/90	08/05/97
12620	MS	GUADALUPE RIVER AT INGRAM DAM IN INGRAM	56	8.12	1.44	88.4%	8.9%	pool	14	0.5	none		05/15/90	03/24/97
12684	TR	SOUTH FORK GUADALUPE ADJACENT TO HUNT LIONS PARK	55	8.06	1.28	88.6%	7.8%	riffle	1	1.0	none		05/15/90	05/16/00

TABLE 2-2 (CONTINUED)
BASIN 18 1990 TO 2000 DISSOLVED OXYGEN DATA SUMMARY

STATION ID	Type of water body [1]	Location	Num of data	Mean (mg/L)	Standard deviation (mg/L)	Mean % saturation	Stdev of % saturation	Station characteristics [2]				Remarks	Start date	End date
								Type	Depth (ft)	Velocity (ft/s)	Shade			
12683	TR	NORTH FORK GUADALUPE RIVER AT EASTERN BOUNDARY OF KERR WILDLIFE MANAGEMENT AREA	22	8.00	0.71	88.9%	7.9%	run	2	0.5	none		05/12/92	10/07/96
12551	TR	CYPRESS CREEK, 1.4 KM ABOVE CONFLUENCE WITH GUADALUPE RIVER IN COMFORT	50	8.43	1.18	89.2%	8.3%				partly		05/15/90	08/08/95
12581	MS	GUADALUPE RIVER SH 175 SOUTH OF VICTORIA	14	7.92	1.47	89.5%	10.3%				none		04/16/90	04/13/94
12678	TR	JOHNSON CREEK AT SH 39 IN INGRAM	73	8.10	1.20	89.7%	8.6%	run	2	1.0	none		05/15/90	05/16/00
12552	TR	CYPRESS CREEK AT SH 27 NEAR COMFORT	12	8.57	1.40	89.7%	7.0%				partly		04/14/92	12/06/94
12686	TR	SOUTH FORK GUADALUPE ADJACENT TO CAMP MYSTIC	26	8.28	1.11	90.7%	6.5%	riffle	2	1.0	partly		04/14/92	03/24/97
12547	UN	GOAT CREEK AT ACADIA LOOP IN KERRVILLE	38	8.33	1.46	90.7%	9.9%				partly		05/15/90	03/21/95
12618	MS	GUADALUPE RIVER AT UGRA LAKE DAM	40	8.51	1.49	90.8%	10.5%	pool	18	0.01	none		09/12/90	10/07/96
12570	UN	DRY COMAL CREEK AT MISSOURI-KANSAS TEXAS RAILROAD CROSSING IN NEW BRAUNFELS--SEGUIN STREET STATION	50	8.18	2.92	91.9%	35.5%	riffle	1	0.2	partly	used width and depth measured at flow GBRA.	10/14/96	12/14/00
12626	MS	LOWER SAN MARCOS RIVER AT SH 80 SOUTH OF LULING	153	8.14	1.63	91.9%	11.2%	pool	3	0.5	partly		05/30/90	12/18/00
12608	MS	GUADALUPE RIVER CENTER POINT LAKE	57	8.56	1.58	92.9%	8.9%	riffle	1	1.0	none		05/15/90	05/16/00
12585	MS	GUADALUPE RIVER AT US 59 IN VICTORIA	19	8.06	0.84	94.4%	8.0%				none		03/06/90	08/25/94
12592	MS	GUADALUPE RIVER AT OLD SAN ANTONIO ROAD WEST OF CUERO	126	8.24	1.73	95.0%	20.2%	pool	17	0.5	none	Used datasonde to measure depth and stepped off width.	05/29/90	12/11/00
12619	MS	GUADALUPE RIVER AT BEAR CREEK ROAD, 1 MI. WEST OF KERRVILLE	51	8.59	1.25	95.4%	10.4%	run	2	1.0	none		05/15/90	10/07/96
12616	MS	GUADALUPE RIVER AT G STREET (FORMERLY OLD MEDINA RD) IN KERRVILLE, SEGMENT KM 177.9	55	8.80	1.69	95.7%	10.8%	run	2	0.5	partly		05/15/90	05/16/00
14255	MS	GUADALUPE RIVER AT US 281 NORTH OF SAN ANTONIO	16	8.81	1.45	95.9%	7.4%				none	Possibly a TNRCC site	11/09/94	07/23/98
12623	LK	COLETO CREEK AT US 59 ON VICTORIA-GOLIAD COUNTY LINE--IN RESERVOIR AT LAUNCH RAMP	127	8.14	1.44	96.0%	14.1%	pool	4	0.01	none		05/29/90	12/11/00
13700	MS	GUADALUPE RIVER AT RR 311, 1.9 MI. SE OF SPRING BRANCH, 7.5 MI. DOWNSTREAM FROM CURRY CREEK	93	8.63	1.28	96.6%	8.2%	run	4	0.5	none	Used datasonde to measure depth and stepped off width.	02/26/90	12/14/00
12622	TR	COLETO CREEK AT US 77 SOUTH OF VICTORIA	25	8.10	1.39	96.7%	17.9%				partly	Possibly a TNRCC site	04/16/90	11/30/00
14932	UN	GERONIMO CREEK AT SH 123 NEAR GERONIMO, TX	51	8.59	1.51	97.1%	16.7%	run	2	0.5	partly	used width and depth from measured flow by GBRA.	10/14/96	12/18/00
12611	MS	GUADALUPE RIVER COUNTY RD BELOW FLAT ROCK DAM, AT SEGMENT KM 172.5	42	8.76	1.90	97.2%	13.6%				none		05/15/90	08/08/95
12688	TR	SOUTH FORK GUADALUPE ADJACENT TO LYNXHAVEN LODGE AT SH 39	25	8.75	0.86	97.3%	10.6%	run	1	1.0	none		04/14/92	10/07/96
12624	MS	LOWER SAN MARCOS RIVER AT LOW WATER CROSSING, PR 11 IN PALMETTO BEND STATE PARK	18	8.29	1.40	97.7%	9.4%				partly	Possibly a Texas Watch site	05/30/90	07/15/96
12598	LK	CANYON LAKE SOUTH OF JACOBS CREEK PARK 500 YARDS EAST OF PENINSULA	129	8.70	1.15	98.4%	9.7%	pool	6	0.01	none		05/30/90	12/14/00
12671	MS	UPPER SAN MARCOS RIVER 0.7 MILE DOWNSTREAM FROM IH 35	21	8.67	0.96	100.5%	10.8%	run	5	0.5	full		05/31/90	01/21/97
12669	MS	BLANCO RIVER AT BLANCO STATE PARK, PR 23	11	8.55	1.30	100.7%	7.7%				partly	Possibly a Texas Watch site	08/05/92	07/02/96
12596	MS	LAKE DUNLAP-GUADALUPE RIVER NORTH BANK AT AC'S PLACE AT MIDPOINT OF LONE STAR DRIVE	170	8.82	1.92	100.7%	26.4%	pool	3	0.01	partly		02/26/90	12/14/00
12658	MS	GUADALUPE RIVER AT RIVER RD 2ND CROSSING, UPSTREAM OF NEW BRAUNFELS	128	9.68	1.20	101.7%	9.8%	run	5	1.0	none	Used datasonde to measure depth and stepped off width.	05/30/90	12/14/00

TABLE 2-2 (CONCLUDED)
BASIN 18 1990 TO 2000 DISSOLVED OXYGEN DATA SUMMARY

STATION ID	Type of water body [1]	Location	Num of data	Mean (mg/L)	Standard deviation (mg/L)	Mean % saturation	Stdev of % saturation	Station characteristics [2]				Remarks	Start date	End date
								Type	Depth (ft)	Velocity (ft/s)	Shade			
12628	MS	LOWER SAN MARCOS RIVER AT COUNTY ROAD IMMEDIATELY BELOW CONFLUENCE OF SAN MARCOS AND BLANCO RIVERS	21	8.77	0.60	102.3%	6.2%				none	Possibly a TNRCC site	05/31/90	01/21/97
12656	MS	GUADALUPE RIVER AT THE BEGINNING OF CYPRESS BEND PARK IN NEW BRAUNFELS	24	9.35	1.52	103.2%	10.7%				partly	Possibly a Texas Watch site	05/31/90	01/22/98
12661	MS	BLANCO RIVER AT BRIDGE ON SH 12 AT WIMBERLEY	28	9.30	0.93	104.4%	8.2%				partly	Possibly a Texas Watch site	05/17/90	07/02/96
15110	MS	GUADALUPE RIVER IMMEDIATELY DOWNSTREAM OF H-5 DAM AT WOOD LAKE, SW OF GONZALES, TX	51	9.12	1.31	104.6%	10.0%	run	4	0.8	none		10/21/96	12/18/00
12668	MS	BLANCO RIVER AT FM 165 1/2 MILE EAST OF BLANCO	49	9.63	1.40	105.8%	9.7%	pool	3	0.1	none	Velocity estimated at median flow. At low Q DO measured above dam, but below dam at higher Q.	10/28/96	12/14/00
15149	LK	LAKE MCQUEENEY, 0.5 MI. UPSTREAM OF MCQUEENEY DAM ON SOUTHEAST BANK	38	9.26	1.74	108.1%	24.3%	pool	6	0.01	partly		11/17/97	12/18/00
12653	TR	COMAL RIVER BELOW CLEMONS DAM IN NEW BRAUNFELS--AT HINMON ISLAND ABOVE DAM	98	9.37	0.83	110.1%	10.3%	pool	5	1.0	none		05/31/90	12/14/00
12672	MS	UPPER SAN MARCOS RIVER IMMEDIATELY UPSTREAM OF IH 35 BRIDGE AT SAN MARCOS	14	9.77	1.15	113.2%	14.9%	run	3	0.5	partly		07/14/92	10/31/00

[1] MS: Main stem, i.e., Guadalupe River, San Marcos River and Blanco River.
LK: Lakes.
TR: Tributaries (classified).
UN: Tributaries (unclassified).

[2] Typical low flow conditions.

Figure 2-2 shows the effect of the type of water body on the station mean percent DO saturation. Each vertical bar in the figure indicates the mean percent DO saturation at a monitoring station. Table A-1 in Attachment A shows the numbers of stations with mean percent DO saturation above the 75th percentile and below the 25th percentile for each type of water body. If there is no relationship between the type of water body and the DO level, then one would expect that 25% of the stations of each type of water body have mean percent DO saturation above the 75th percentile and 25% below the 25th percentile. Table A-2 shows that the type of water body has a significant effect on the mean percent DO saturation. For unclassified tributaries, the number of stations with mean percent DO saturation below the 25th percentile is 44% more than expected, while the number of stations with mean percent DO saturation above the 75th percentile is 25% less than expected. The unclassified tributaries which typically are smaller creeks, tend to have lower percent DO saturation. In fact, the five stations with the lowest mean percent DO saturation are all on unclassified tributaries.

Shading reduces photosynthesis and thus the production of oxygen. Figure 2-3 shows the effect of shading on the station mean DO saturation. Table A-3 in Attachment A shows the numbers of stations with mean percent DO saturation above the 75th percentile and below the 25th percentile for the three levels of shading. Table A-4 shows that low DO tends to occur in streams with higher amount of shading.

As shown in Table 2-2, besides higher amount of shading, stations with the lowest mean percent DO saturations are also characterized with low flow velocities, shallow depths, and riffles. The data appears to suggest that small streams tend to have low DO naturally.

2.2 INDICATOR BACTERIA

The analysis of FC and EC indicator bacteria data follows a similar pattern to that for DO. First, bacteria data were retrieved from the TNRCC database. Those stations that had fewer than 10 analyses were dropped. The resulting list of stations for FC is basically the same as that for DO with a net reduction of only one station. The net reduction in the number of stations for EC is 12, possibly because EC analyses did not begin on a routine basis until the 1992-3 time period. Stations were then ranked based on the geometric means of their data, with the highest data stations listed first, with the results shown in Table 2-3 for FC and Table 2-4 for EC.

Figure 2-4 shows the FC and EC ranking results with type of water body shown on the bar shading. Also shown on the figures are the geometric mean criteria for each test. The highest bacteria levels are shown on the left part of the figures, and stations in this part are often either unclassified tributary or tributary stations. The lowest bacteria levels on the right side of the figure tend to be lake or main stem stations.

FIGURE 2-2
EFFECT OF TYPE OF WATER BODY ON STATION MEAN % DO SATURATION

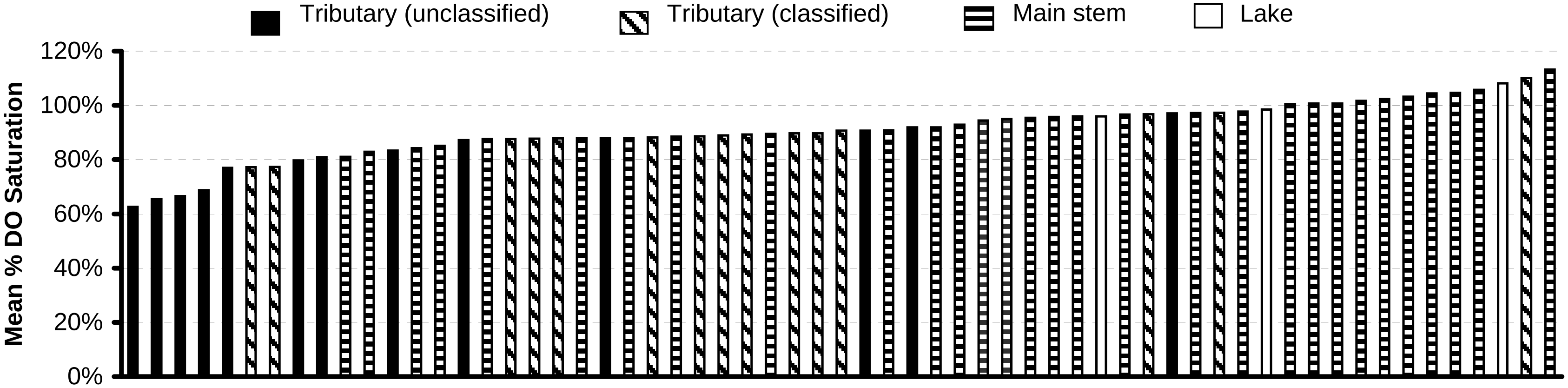


FIGURE 2-3
EFFECT OF SHADING ON STATION MEAN % DO SATURATION

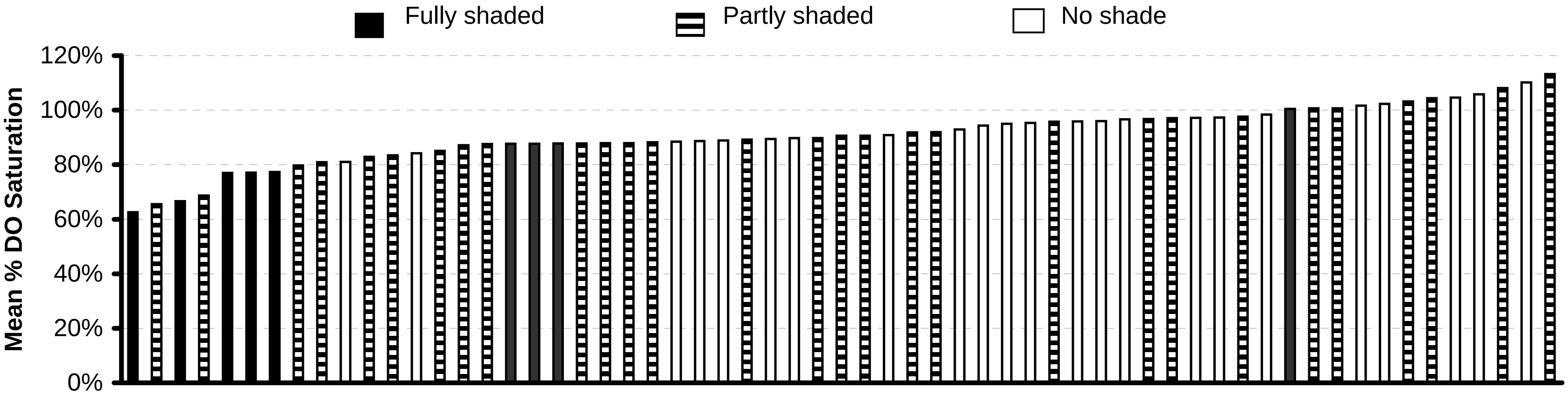


TABLE 2-3
BASIN 18 1990 TO 2000 FC DATA SUMMARY

STATION ID	Type of water body [1]	Location	Num of data	Geometric mean (cfu/dL)	Log standard deviation	Station characteristics [2]				Remarks	Start date	End date
						Type	Depth (ft)	Velocity (ft/s)	Shade			
13657	UN	SANDIES CREEK 100 FT. DOWNSTREAM OF COUNTY HIGHWAY, 1.9 MI. UPSTREAM FROM BIRDS CREEK, 2.0 MI. NE OF	12	478	0.73	riffle	2	0.05	partly		12/15/99	12/11/00
12549	UN	TOWN CREEK AT HAMILTON STREET IN KERRVILLE	47	435	0.68				partly		05/15/90	11/14/95
12546	UN	CAMP MEETING CREEK, 0.1 KM ABOVE CONFLUENCE WITH GUADALUPE IN KERRVILLE	53	406	0.58	riffle	1	0.5	full		05/15/90	05/16/00
12541	UN	QUINLAN CREEK AT TRAVIS STREET IN KERRVILLE	47	406	0.64				partly		05/15/90	11/14/95
12552	TR	CYPRESS CREEK AT SH 27 NEAR COMFORT	13	387	0.53				partly		04/14/92	12/06/94
15998	UN	SANDIES CREEK AT FM1116, 7.4KM EAST OF SMILEY AND APPROX. 3KM UPSTREAM OF CONFL. WITH ELM CREEK	26	337	0.57	riffle	1	0.2	full	used width and depth from measured flow by GBRA.	11/20/97	08/29/00
14937	UN	PEACH CREEK AT CR 353 IN GONZALES COUNTY	52	266	0.67	run	3	0.2	full	used width and depth from measured flow by GBRA.	10/21/96	12/18/00
12551	TR	CYPRESS CREEK, 1.4 KM ABOVE CONFLUENCE WITH GUADALUPE RIVER IN COMFORT	51	251	0.49				partly		05/15/90	11/14/95
14935	UN	SANDIES CREEK AT CR 953 OM DEWITT COUNTY	13	232	0.47	run	3	0.2	partly	used width and depth from measured flow by GBRA.	10/21/96	10/27/97
12543	UN	VERDE CREEK, 0.2 KM UPSTREAM OF CONFLUENCE WITH GUADAUPE R. NEAR CENTER POINT	52	224	0.55	run	2	0.3	partly		05/15/90	05/16/00
12570	UN	DRY COMAL CREEK AT MISSOURI-KANSAS-TEXAS RAILROAD CROSSING IN NEW BRAUNFELS--SEGUIN STREET STATION	50	193	0.53	riffle	1	0.2	partly	used width and depth measured at flow GBRA.	10/14/96	12/14/00
14932	UN	GERONIMO CREEK AT SH 123 NEAR GERONIMO, TX	51	193	0.34	run	2	0.5	partly	used width and depth from measured flow by GBRA.	10/14/96	12/18/00
12645	TR	PLUM CREEK AT CR 197, SE OF LOCKHART	15	190	0.31	riffle	1	0.1	full		10/15/96	12/09/97
12578	MS	GUADALUPE RIVER AT LOWER GUADALUPE DIVERSION DAM AND SALT WATER BARRIER	127	187	0.57	run	5	3.2	none	Site is at the diversion canal after gates.	05/29/90	12/11/00
12608	MS	GUADALUPE RIVER CENTER POINT LAKE	69	186	0.54	riffle	1	1.0	none		05/15/90	08/07/00
12640	TR	PLUM CREEK AT OLD WOODEN BRIDGE ON CALDWELL CR 135, SE OF LULING	50	180	0.58	run	2	0.1	full	used width and depth from measured flow by GBRA.	08/09/90	12/18/00
12615	MS	GUADALUPE RIVER AT KERRVILLE STATE PARK, SEGMENT KM 174.4	64	166	0.59	pool	5	0.2	partly		05/15/90	08/07/00
12685	TR	SOUTH FORK GUADALUPE ADJACENT TO CAMP ARROWHEAD	28	159	0.81	run	1	0.5	full		08/29/90	08/07/00
12616	MS	GUADALUPE RIVER AT G STREET (FORMERLY OLD MEDINA RD) IN KERRVILLE, SEGMENT KM 177.9	55	154	0.72	run	2	0.5	partly		05/15/90	05/16/00
12611	MS	GUADALUPE RIVER COUNTY RD BELOW FLAT ROCK DAM, AT SEGMENT KM 172.5	42	143	0.79				none		05/15/90	11/14/95
12605	MS	GUADALUPE RIVER AT COUNTY RD ADJACENT TO HERMANN SONS' HOME, WEST OF COMFORT	69	135	0.64	run	3	0.5	partly		05/15/90	08/07/00
12564	UN	THIRD CREEK, 0.5 KM ABOVE CONFLUENCE WITH GUADALUPE RIVER	14	125	0.83				partly		05/15/90	11/14/95
12544	UN	TURTLE CREEK, AT COUNTY RD, 0.1 MI ABOVE CONFLUENCE OF GUADALUPE R., WEST OF CENTER POINT	47	125	0.78				partly		05/15/90	11/14/95
12681	TR	NORTH FORK GUADALUPE RIVER AT FM 1340	79	118	0.57	run	3	0.3	partly		05/15/90	08/07/00
12596	MS	LAKE DUNLAP-GUADALUPE RIVER NORTH BANK AT AC'S PLACE AT MIDPOINT OF LONE STAR DRIVE	131	117	0.65	pool	3	0.01	partly		05/30/90	12/14/00

TABLE 2-3 (CONTINUED)
BASIN 18 1990 TO 2000 FC DATA SUMMARY

STATION ID	Type of water body [1]	Location	Num of data	Geometric mean (cfu/dL)	Log standard deviation	Station characteristics [2]				Remarks	Start date	End date
						Type	Depth (ft)	Velocity (ft/s)	Shade			
14255	MS	GUADALUPE RIVER AT US 281 NORTH OF SAN ANTONIO	16	104	0.71				none	Possibly a TNRCC site	11/09/94	07/23/98
12626	MS	LOWER SAN MARCOS RIVER AT SH 80 SOUTH OF LULING	128	100	0.69	pool	3	0.5	partly		05/30/90	12/18/00
12682	TR	NORTH FORK GUADALUPE AT RIVER GAGING STATION NEAR CAMP WALDEMAR	27	95	0.71	riffle	2	1.0	full		05/23/94	08/07/00
12656	MS	GUADALUPE RIVER AT THE BEGINNING OF CYPRESS BEND PARK IN NEW BRAUNFELS	25	90	0.63				partly	Possibly a Texas Watch site	07/11/90	06/02/98
12628	MS	LOWER SAN MARCOS RIVER AT COUNTY ROAD IMMEDIATELY BELOW CONFLUENCE OF SAN MARCOS AND BLANCO RIVERS	19	88	0.71				none	Possibly a TNRCC site	07/12/90	01/21/97
12653	TR	COMAL RIVER BELOW CLEMONS DAM IN NEW BRAUNFELS--AT HINMON ISLAND ABOVE DAM	100	84	0.47	pool	5	1.0	none		05/31/90	12/14/00
12674	TR	CYPRESS CREEK AT FM 12 AT WIMBERLEY	28	83	0.61	riffle	1	0.2	full	used width and depth from measured flow by GBRA.	11/13/91	10/31/00
12684	TR	SOUTH FORK GUADALUPE ADJACENT TO HUNT LIONS PARK	53	82	0.75	riffle	1	1.0	none		05/15/90	05/16/00
12610	MS	GUADALUPE RIVER AT COUNTY RD, 0.1 MI ABOVE CONFLUENCE OF TURTLE CREEK AT SEGMENT KM 166.2	45	80	0.58				partly		06/06/90	08/07/00
12678	TR	JOHNSON CREEK AT SH 39 IN INGRAM	83	79	0.66	run	2	1.0	none		05/15/90	08/07/00
12621	MS	GUADALUPE RIVER AT SH 39 NEAR HUNT, 0.1 KM BELOW THE NORTH/SOUTH FORK CONFL.	60	79	0.68	run	1	1.0	partly		06/06/90	08/07/00
12592	MS	GUADALUPE RIVER AT OLD SAN ANTONIO ROAD WEST OF CUERO	126	75	0.85	pool	17	0.5	none	Used datasonde to measure depth and stepped off width.	05/29/90	12/11/00
12688	TR	SOUTH FORK GUADALUPE ADJACENT TO LYNXHAVEN LODGE AT SH 39	35	73	0.72	run	1	1.0	none		04/14/92	08/07/00
12603	MS	GUADALUPE RIVER AT IH 10 IN COMFORT	17	73	0.57				none		01/23/91	08/07/00
12577	MS	GUADALUPE RIVER TIDAL BRIDGE AT SH 35 NE OF TIVOLI	32	69	0.61	tidal	11	0.7	none	Velocity estimated at median flow. Tidal component in vel.	02/27/90	11/28/00
12619	MS	GUADALUPE RIVER AT BEAR CREEK ROAD, 1 MI. WEST OF KERRVILLE	64	68	0.79	run	2	1.0	none		05/15/90	08/07/00
12612	MS	GUADALUPE RIVER ABOVE FLAT ROCK DAM, AT SEGMENT KM 172.6	14	61	0.76				none		05/15/90	10/07/96
13700	MS	GUADALUPE RIVER AT RR 311, 1.9 MI. SE OF SPRING BRANCH, 7.5 MI. DOWNSTREAM FROM CURRY CREEK	37	61	0.53	run	4	0.5	none	Used datasonde to measure depth and stepped off width.	01/12/98	12/14/00
12686	TR	SOUTH FORK GUADALUPE ADJACENT TO CAMP MYSTIC	37	56	0.74	riffle	2	1.0	partly		04/14/92	08/07/00
12658	MS	GUADALUPE RIVER AT RIVER RD 2ND CROSSING, UPSTREAM OF NEW BRAUNFELS	128	53	0.43	run	5	1.0	none	Used datasonde to measure depth and stepped off width.	05/30/90	12/14/00
12547	UN	GOAT CREEK AT ACADIA LOOP IN KERRVILLE	39	52	0.95				partly		05/15/90	12/06/94
12672	MS	UPPER SAN MARCOS RIVER IMMEDIATELY UPSTREAM OF IH 35 BRIDGE AT SAN MARCOS	22	48	0.52	run	3	0.5	partly		07/14/92	10/31/00
12620	MS	GUADALUPE RIVER AT INGRAM DAM IN INGRAM	68	42	0.85	pool	14	0.5	none		05/15/90	08/07/00
12671	MS	UPPER SAN MARCOS RIVER 0.7 MILE DOWNSTREAM FROM IH 35	27	41	0.62	run	5	0.5	full		05/31/90	03/30/99
12624	MS	LOWER SAN MARCOS RIVER AT LOW WATER CROSSING, PR 11 IN PALMETTO BEND STATE PARK	17	41	0.70				partly	Possibly a Texas Watch site	08/09/90	07/15/96
12622	TR	COLETO CREEK AT US 77 SOUTH OF VICTORIA	24	39	0.71				partly	Possibly a TNRCC site	04/16/90	11/30/00
12618	MS	GUADALUPE RIVER AT UGRA LAKE DAM	63	38	0.74	pool	18	0.01	none		05/15/90	08/07/00

TABLE 2-3 (CONCLUDED)
BASIN 18 1990 TO 2000 FC DATA SUMMARY

STATION ID	Type of water body[1]	Location	Num of data	Geometric mean (cfu/dL)	Log standard deviation	Station characteristics[2]				Remarks	Start date	End date
						Type	Depth (ft)	Velocity (ft/s)	Shade			
15110	MS	GUADALUPE RIVER IMMEDIATELY DOWNSTREAM OF H-5 DAM AT WOOD LAKE, SW OF GONZALES, TX	51	37	0.71	run	4	0.8	none		10/21/96	12/18/00
12669	MS	BLANCO RIVER AT BLANCO STATE PARK, PR 23	11	36	0.73				partly	Possibly a Texas Watch site	08/05/92	07/02/96
12661	MS	BLANCO RIVER AT BRIDGE ON SH 12 AT WIMBERLEY	24	26	0.62				partly	Possibly a Texas Watch site	05/17/90	07/02/96
12623	LK	COLETO CREEK AT US 59 ON VICTORIA-GOLIAD COUNTY LINE--IN RESERVOIR AT LAUNCH RAMP	128	25	0.72	pool	4	0.01	none		05/29/90	12/11/00
12668	MS	BLANCO RIVER AT FM 165 1/2 MILE EAST OF BLANCO	48	20	0.74	pool	3	0.1	none	Velocity estimated at median flow. At low Q DO measured above dam, but below dam at higher Q.	10/28/96	12/14/00
12683	TR	NORTH FORK GUADALUPE RIVER AT EASTERN BOUNDARY OF KERR WILDLIFE MANAGEMENT AREA	22	18	0.85	run	2	0.5	none		05/15/90	10/07/96
15149	LK	LAKE MCQUEENEY, 0.5 MI. UPSTREAM OF MCQUEENEY DAM ON SOUTHEAST BANK	43	15	0.69	pool	6	0.01	partly		11/17/97	12/18/00
12598	LK	CANYON LAKE SOUTH OF JACOBS CREEK PARK 500 YARDS EAST OF PENINSULA	124	6	0.61	pool	6	0.01	none		05/30/90	12/14/00

[1] MS: Main stem, i.e., Guadalupe River, San Marcos River and Blanco River.
LK: Lakes.
TR: Tributaries (classified).
UN: Tributaries (unclassified).

[2] Typical low flow conditions.

TABLE 2-4
BASIN 18 1990 TO 2000 EC DATA SUMMARY

STATION ID	Type of water body [1]	Location	Num of data	Geometric mean (cfu/dL)	Log standard deviation	Station characteristics [2]				Remarks	Start date	End date
						Type	Depth (ft)	Velocity (ft/s)	Shade			
12549	UN	TOWN CREEK AT HAMILTON STREET IN KERRVILLE	33	323	0.59				partly		03/01/92	11/14/95
13657	UN	SANDIES CREEK 100 FT. DOWNSTREAM OF COUNTY HIGHWAY, 1.9 MI. UPSTREAM FROM BIRDS CREEK, 2.0 MI. NE OF WESTHOFF	12	302	0.68	riffle	2	0.05	partly		12/15/99	12/11/00
12552	TR	CYPRESS CREEK AT SH 27 NEAR COMFORT	12	221	0.49				partly		04/14/92	12/06/94
12541	UN	QUINLAN CREEK AT TRAVIS STREET IN KERRVILLE	32	191	0.54				partly		03/01/92	11/14/95
12685	TR	SOUTH FORK GUADALUPE ADJACENT TO CAMP ARROWHEAD	13	168	0.56	run	1	0.5	full		05/08/00	08/07/00
12546	UN	CAMP MEETING CREEK, 0.1 KM ABOVE CONFLUENCE WITH GUADALUPE IN KERRVILLE	38	148	0.49	riffle	1	0.5	full		03/01/92	05/16/00
14937	UN	PEACH CREEK AT CR 353 IN GONZALES COUNTY	52	137	0.77	run	3	0.2	full	used width and depth from measured flow by GBRA.	10/21/96	12/18/00
15998	UN	SANDIES CREEK AT FM1116, 7.4KM EAST OF SMILEY AND APPROX. 3KM UPSTREAM OF CONFL. WITH ELM CREEK	18	131	0.42	riffle	1	0.2	full	used width and depth from measured flow by GBRA.	07/14/98	08/29/00
14935	UN	SANDIES CREEK AT CR 953 OM DEWITT COUNTY	13	123	0.44	run	3	0.2	partly	used width and depth from measured flow by GBRA.	10/21/96	10/27/97
12551	TR	CYPRESS CREEK, 1.4 KM ABOVE CONFLUENCE WITH GUADALUPE RIVER IN COMFORT	37	121	0.46				partly		03/01/92	09/13/99
12674	TR	CYPRESS CREEK AT FM 12 AT WIMBERLEY	11	116	0.47	riffle	1	0.2	full	used width and depth from measured flow by GBRA.	03/17/98	10/31/00
14932	UN	GERONIMO CREEK AT SH 123 NEAR GERONIMO, TX	50	111	0.47	run	2	0.5	partly	used width and depth from measured flow by GBRA.	10/14/96	12/18/00
12543	UN	VERDE CREEK, 0.2 KM UPSTREAM OF CONFLUENCE WITH GUADAUPE R. NEAR CENTER POINT	39	97	0.42	run	2	0.3	partly		03/01/92	05/16/00
12570	UN	DRY COMAL CREEK AT MISSOURI-KANSAS TEXAS RAILROAD CROSSING IN NEW BRAUNFELS--SEGUIN STREET STATION	50	95	0.65	riffle	1	0.2	partly	used width and depth measured at flow GBRA.	10/14/96	12/14/00
12640	TR	PLUM CREEK AT OLD WOODEN BRIDGE ON CALDWELL CR 135, SE OF LULING	35	80	0.66	run	2	0.1	full	used width and depth from measured flow by GBRA.	02/12/98	12/18/00
12615	MS	GUADALUPE RIVER AT KERRVILLE STATE PARK, SEGMENT KM 174.4	53	76	0.47	pool	5	0.2	partly		03/01/92	08/07/00
12645	TR	PLUM CREEK AT CR 197, SE OF LOCKHART	15	76	0.67	riffle	1	0.1	full		10/15/96	12/09/97
12578	MS	GUADALUPE RIVER AT LOWER GUADALUPE DIVERSION DAM AND SALT WATER BARRIER	50	71	0.59	run	5	3.2	none	Site is at the diversion canal after gates.	10/22/96	12/11/00
12681	TR	NORTH FORK GUADALUPE RIVER AT FM 1340	51	61	0.51	run	3	0.3	partly		03/01/92	08/07/00
12608	MS	GUADALUPE RIVER CENTER POINT LAKE	54	60	0.38	riffle	1	1.0	none		03/01/92	08/07/00
12616	MS	GUADALUPE RIVER AT G STREET (FORMERLY OLD MEDINA RD) IN KERRVILLE, SEGMENT KM 177.9	39	57	0.38	run	2	0.5	partly		03/01/92	05/16/00
12605	MS	GUADALUPE RIVER AT COUNTY RD ADJACENT TO HERMANN SONS' HOME, WEST OF COMFORT	56	45	0.31	run	3	0.5	partly		03/01/92	08/07/00
12682	TR	NORTH FORK GUADALUPE AT RIVER GAGING STATION NEAR CAMP WALDEMAR	28	43	0.56	riffle	2	1.0	full		05/23/94	08/07/00
12621	MS	GUADALUPE RIVER AT SH 39 NEAR HUNT, 0.1 KM BELOW THE NORTH/SOUTH FORK CONFL.	44	40	0.51	run	1	1.0	partly		07/07/92	08/07/00

TABLE 2-4 (CONTINUED)
BASIN 18 1990 TO 2000 EC DATA SUMMARY

STATION ID	Type of water body [1]	Location	Num of data	Geometric mean (cfu/dL)	Log standard deviation	Station characteristics [2]				Remarks	Start date	End date
						Type	Depth (ft)	Velocity (ft/s)	Shade			
12596	MS	LAKE DUNLAP-GUADALUPE RIVER NORTH BANK AT AC'S PLACE AT MIDPOINT OF LONE STAR DRIVE	51	40	0.64	pool	3	0.01	partly		10/14/96	12/14/00
12544	UN	TURTLE CREEK, AT COUNTY RD, 0.1 MI ABOVE CONFLUENCE OF GUADALUPE R., WEST OF CENTER POINT	33	38	0.47				partly		03/01/92	11/14/95
12678	TR	JOHNSON CREEK AT SH 39 IN INGRAM	51	36	0.39	run	2	1.0	none		03/01/92	08/07/00
12672	MS	UPPER SAN MARCOS RIVER IMMEDIATELY UPSTREAM OF IH 35 BRIDGE AT SAN MARCOS	11	34	0.51	run	3	0.5	partly		03/17/98	10/31/00
12626	MS	LOWER SAN MARCOS RIVER AT SH 80 SOUTH OF LULING	49	33	0.52	pool	3	0.5	partly		10/15/96	12/18/00
12592	MS	GUADALUPE RIVER AT OLD SAN ANTONIO ROAD WEST OF CUERO	51	32	0.85	pool	17	0.5	none	Used datasonde to measure depth and stepped off width.	10/21/96	12/11/00
12653	TR	COMAL RIVER BELOW CLEMONS DAM IN NEW BRAUNFELS--AT HINMON ISLAND ABOVE DAM	50	32	0.52	pool	5	1.0	none		10/14/96	12/14/00
13700	MS	GUADALUPE RIVER AT RR 311, 1.9 MI. SE OF SPRING BRANCH, 7.5 MI. DOWNSTREAM FROM CURRY CREEK	36	30	0.64	run	4	0.5	none	Used datasonde to measure depth and stepped off width.	01/12/98	12/14/00
12688	TR	SOUTH FORK GUADALUPE ADJACENT TO LYNXHAVEN LODGE AT SH 39	36	29	0.51	run	1	1.0	none		04/14/92	08/07/00
12603	MS	GUADALUPE RIVER AT IH 10 IN COMFORT	13	28	0.63				none		05/08/00	08/07/00
12658	MS	GUADALUPE RIVER AT RIVER RD 2ND CROSSING, UPSTREAM OF NEW BRAUNFELS	49	26	0.38	run	5	1.0	none	Used datasonde to measure depth and stepped off width.	10/14/96	12/14/00
12684	TR	SOUTH FORK GUADALUPE ADJACENT TO HUNT LIONS PARK	38	25	0.43	riffle	1	1.0	none		03/01/92	05/16/00
12610	MS	GUADALUPE RIVER AT COUNTY RD, 0.1 MI ABOVE CONFLUENCE OF TURTLE CREEK AT SEGMENT KM 166.2	32	24	0.36				partly		03/01/92	08/07/00
12611	MS	GUADALUPE RIVER COUNTY RD BELOW FLAT ROCK DAM, AT SEGMENT KM 172.5	31	24	0.51				none		03/01/92	11/14/95
12619	MS	GUADALUPE RIVER AT BEAR CREEK ROAD, 1 MI. WEST OF KERRVILLE	50	23	0.43	run	2	1.0	none		03/01/92	08/07/00
15110	MS	GUADALUPE RIVER IMMEDIATELY DOWNSTREAM OF H-5 DAM AT WOOD LAKE, SW OF GONZALES, TX	51	20	0.68	run	4	0.8	none		10/21/96	12/18/00
12686	TR	SOUTH FORK GUADALUPE ADJACENT TO CAMP MYSTIC	37	19	0.45	riffle	2	1.0	partly		04/14/92	08/07/00
12547	UN	GOAT CREEK AT ACADIA LOOP IN KERRVILLE	25	16	0.44				partly		03/01/92	12/06/94
12683	TR	NORTH FORK GUADALUPE RIVER AT EASTERN BOUNDARY OF KERR WILDLIFE MANAGEMENT AREA	15	16	0.65	run	2	0.5	none		07/07/92	10/07/96
12623	LK	COLETO CREEK AT US 59 ON VICTORIA-GOLIAD COUNTY LINE--IN RESERVOIR AT LAUNCH RAMP	51	15	0.67	pool	4	0.01	none		10/22/96	12/11/00
12620	MS	GUADALUPE RIVER AT INGRAM DAM IN INGRAM	44	14	0.38	pool	14	0.5	none		03/01/92	08/07/00
12668	MS	BLANCO RIVER AT FM 165 1/2 MILE EAST OF BLANCO	48	13	0.72	pool	3	0.1	none	Velocity estimated at median flow. At low Q DO measured above dam, but below dam at higher Q.	10/28/96	12/14/00
12618	MS	GUADALUPE RIVER AT UGRA LAKE DAM	46	12	0.45	pool	18	0.01	none		03/01/92	08/07/00
15149	LK	LAKE MCQUEENEY, 0.5 MI. UPSTREAM OF MCQUEENEY DAM ON SOUTHEAST BANK	38	8	0.71	pool	6	0.01	partly		11/17/97	12/18/00

TABLE 2-4 (CONCLUDED)
BASIN 18 1990 TO 2000 EC DATA SUMMARY

STATION ID	Type of water body [1]	Location	Num of data	Geometric mean (cfu/dL)	Log standard deviation	Station characteristics [2]				Remarks	Start date	End date
						Type	Depth (ft)	Velocity (ft/s)	Shade			
12598	LK	CANYON LAKE SOUTH OF JACOBS CREEK PARK 500 YARDS EAST OF PENINSULA	46	4	0.50	pool	6	0.01	none		10/14/96	12/14/00

[1] MS: Main stem, i.e., Guadalupe River, San Marcos River and Blanco River.
LK: Lakes.
TR: Tributaries (classified).
UN: Tributaries (unclassified).

[2] Typical low flow conditions.

FIGURE 2-4
EFFECT OF TYPE OF WATER BODY ON STATION BACTERIA LEVEL

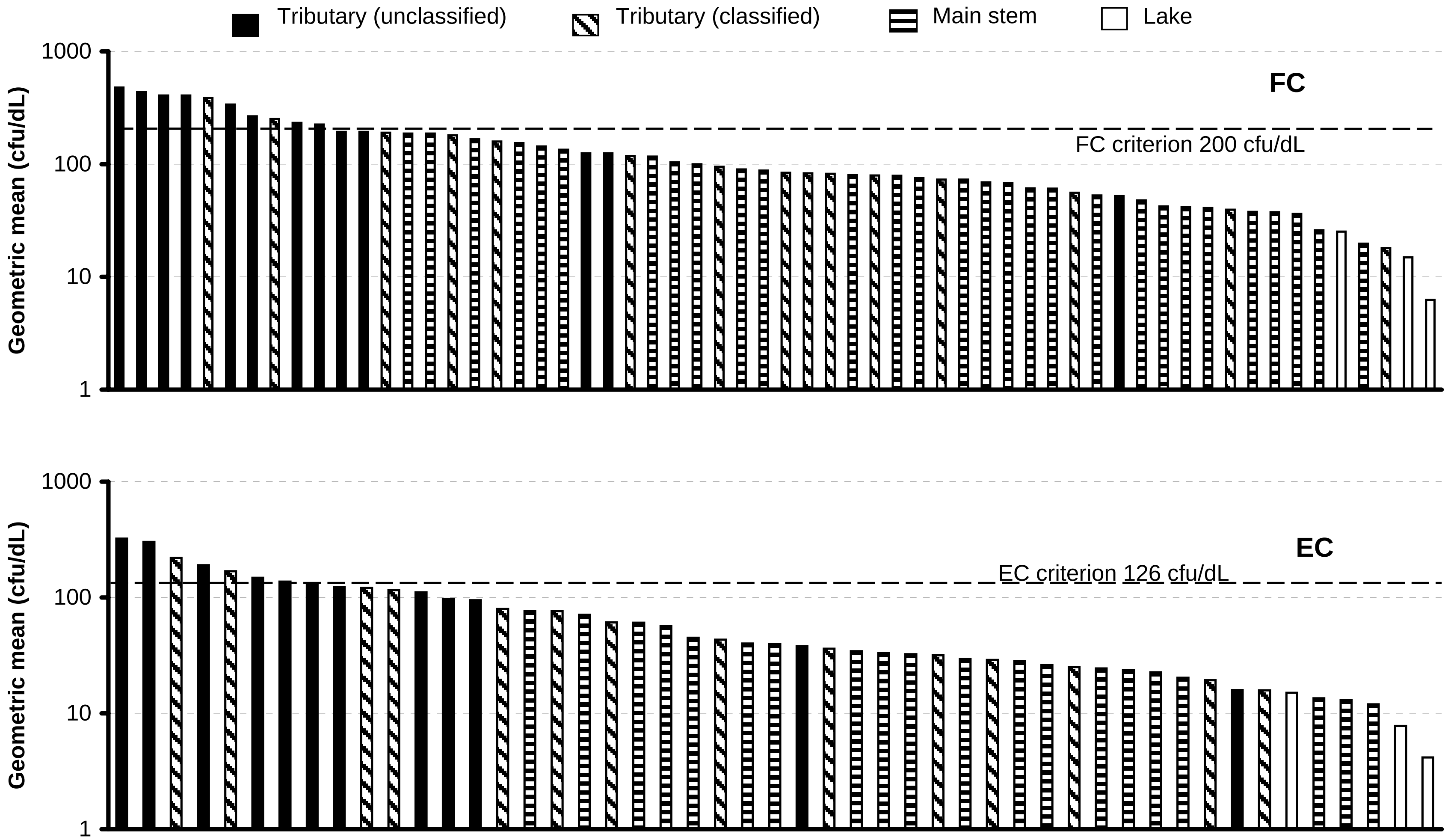


Table A-5 in Attachment A shows the numbers of stations with FC geometric mean above the 75th percentile and below the 25th percentile for each type of water body. As shown in Table A-6, for unclassified tributaries, the number of stations with FC geometric mean below the 25th percentile is 17% less than expected, while the number of stations with FC geometric mean above the 75th percentile is 52% more than expected. On the other hand, all lake stations have geometric mean below the 25th percentile. The EC data shows a similar pattern as presented in Tables A-7 and A-8. In general, small streams tend to have higher bacteria levels.

Figure 2-5 shows a similar pattern using the degree of shade for both FC and EC data. This figure and Tables A-9 to A-12 in Attachment A show that more shading appear to be associated with higher bacteria level. While the relation between shade and bacteria levels is certainly more tenuous than between shade and DO, the relation may be simply because smaller tributaries which also tend to have the greatest variation, also have the greatest shade.

Figure 2-6 shows the same data sets with the bars grouped by water depth. Again, the general pattern of shallower water depth showing more predominantly on the left or higher concentration side of the figure, seems to be the case. Tables A-13 to A-16 also show that shallower water depth tends to associate with higher bacteria level.

Another view of the bacteria data is to rank stations based on the standard error, defined as the ratio of the log standard deviation to the log of the geometric mean. There does not seem to be any particular pattern with this ranking and no figure is shown.

2.3 DISCUSSION

The general pattern from a decade of monitoring data appears to be that both lower average DO and higher average bacteria levels are found in smaller streams. Exceptions exist and there is certainly no physical requirement that smaller must yield lower DO and higher bacteria, but that appears to be the case.

FIGURE 2-5
EFFECT OF SHADING ON STATION BACTERIA LEVEL

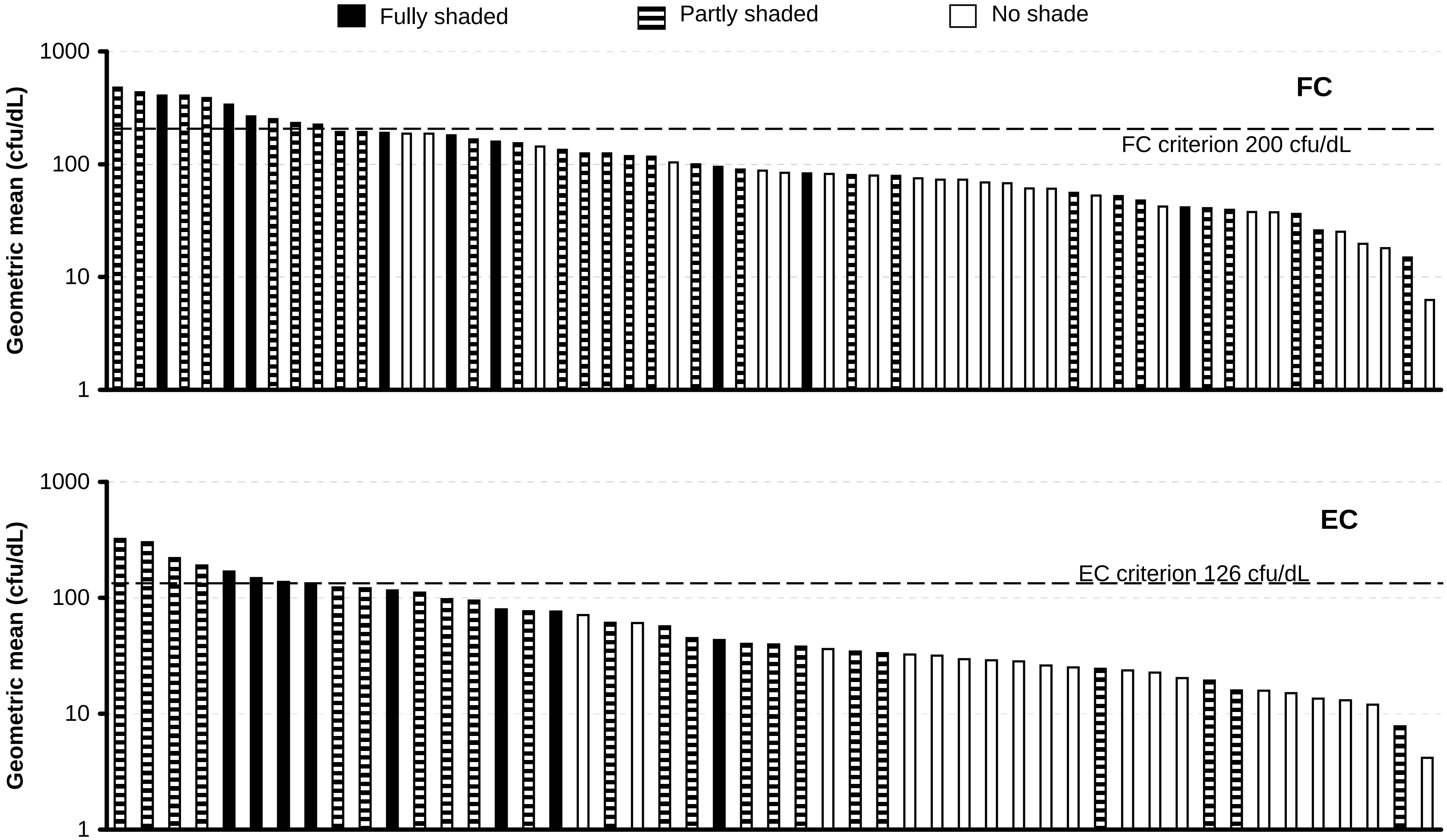
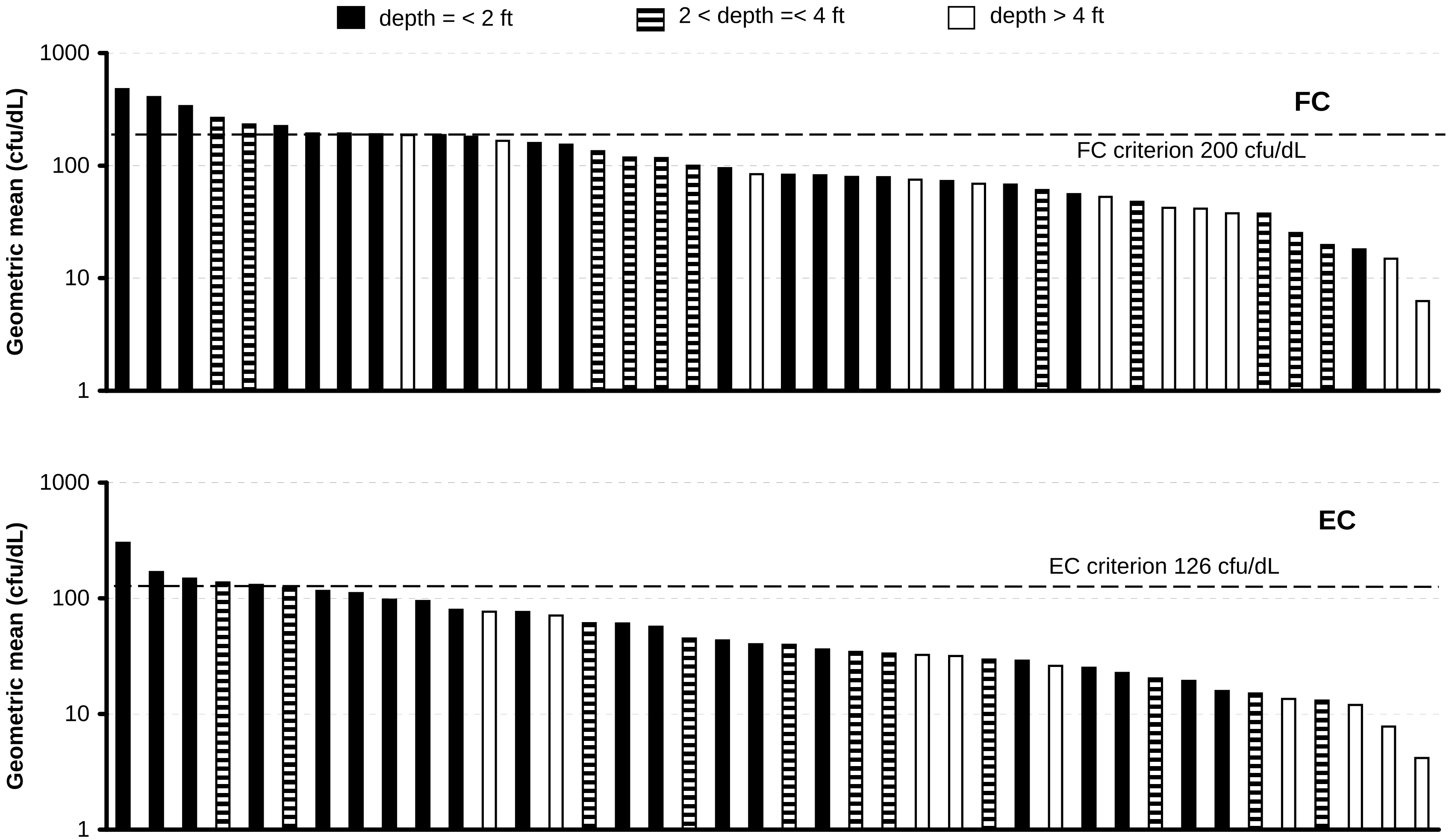


FIGURE 2-6

EFFECT OF WATER DEPTH ON STATION BACTERIA LEVEL



3.0 FACTORS THAT INFLUENCE DATA

As discussed in the previous section, smaller waters appear to show lower average DO and higher bacteria levels than their larger counterparts. This section briefly discusses some of the factors that may be responsible, and describes possible studies that might be done to better define the effects.

3.1 FACTORS THAT AFFECT DO AND BACTERIA

Shading

Locations that have a high percentage of overhanging trees receive less direct sunlight. This tends to reduce the amount of photosynthesis from attached and planktonic plants, and that will tend to yield lower stream DO values. The bacteriacidal action of sunlight is well documented, and reduced sunlight from shading should result in less rapid bacterial die-off. This should in turn produce higher average bacterial levels.

Time of Day

While shading can play a role in overall light level, the time of day that measurements are actually made can also be significant. It is well recognized that diurnal cycles exist with photosynthesis-respiration, and that DO measurements taken in the early morning can be substantially lower than those taken in the afternoon. The actual magnitude of diurnal DO swings depends on many factors including degree of shading, cloud cover on the day of sampling, plankton and periphyton levels, nutrient limitations, etc. While 24-hr measurements are now becoming more common, it is likely to be some time before such measurements are the routine method for determining criteria compliance. At this point the time of day that measurements are made must be considered as a random noise element in the data. It is not known whether this is a bigger factor in small streams or larger ones.

Temperature

Temperature plays a major role in the actual DO level that is recorded in any measurement. The saturation DO ranges from 7.5 mg/L at a summer temperature of 30°C to over 11 mg/L at a winter temperature of 10°C. Because the temperature effect is so large, it can make a substantial difference if there is a predominance of data either in the summer or winter. Because smaller streams have less mass of water, they tend to react to weather conditions with larger temperature fluctuations than do larger water bodies. Because of this characteristic, it is especially important that this source of variation be controlled. One way to accomplish this is to present the standards in terms of percent saturation rather than an absolute concentration value. If this were done, a major source of variation would be removed from the equation.

For example, in the Standards the DO criteria associated with high quality aquatic life use is an average of 5 mg/L, with a night value of no less than 4 mg/L. If this were expressed as an average of 60% of DO saturation, with night value of no less than 50% saturation, then winter and summer observations could be placed on an even basis. Another important dimension of this discussion is the cause of the DO level. The standards are designed to address DO depression from human activities like wastewater discharges, and specifically exempt natural processes. However, it is frequently impossible to distinguish a cause for a given DO observation, so screening for 303(d) purposes generally does not take cause into account.

Depth

Shallow water can have several potential effects on DO and bacteria levels. Ultimately, carefully designed and controlled experiments may need to be conducted to document the effects and determine which aspects are most significant. This discussion is intended to set the stage for such experiments.

The major effect of shallow depth is to increase exposure to both the air and sediment. More exposure to the air will tend to increase aeration and minimize differences from DO saturation. Reduced depth will also increase the amount of light available in the water that would act to increase photosynthesis and reduce bacteria levels.

The effect of sediment can be exactly opposite. If the sediment is in a depositional area and exerts a sediment oxygen demand, shallow depth can act to reduce significantly the DO levels. The more shallow the water, the sediment effect is proportionately larger. Similarly, sediment tends to contain significant levels of indicator bacteria that can transfer to the water. The more shallow the water, the greater the potential effect on bacteria levels.

Closely associated with depth is the methods used to sample and the ability to avoid disturbing the sediment during sampling. Clearly, if sediments are disturbed because of the sampling process, shallow depth can have a major effect on both DO and bacteria results from smaller streams. The thinner the water, the less likely it is that a sample can be obtained without disturbing the sediment.

Velocity

In general, higher velocity tends to support greater aeration and DO levels closer to saturation. However, if velocity acts to keep particulate matter in suspension, and that material exerts an oxygen demand or reduces light transmission, velocity may not be a net DO positive. In the case of bacteria, higher particulate levels are often associated with higher bacteria levels. Because of the relation between velocity and particulate matter, the type of stream bottom is a critical factor. Streambeds that are rocky can support higher velocities without scouring particulate matter. Areas that have soft unconsolidated sediments are easily scoured by higher velocities. In effect, a closely related dimension of velocity is flow variability. Streams that accumulate sediment during low flow periods can easily resuspend sediment when velocity increases.

Flow Variability

In general, smaller streams will exhibit a more frequent and immediate response to rainfall runoff than will larger streams or lakes. DO levels in runoff tend to be near saturation, simply because the water has been in close contact with the air. However, bacteria levels in runoff have been documented to be very high. The higher proportion of runoff effects in smaller streams will tend to make bacteria levels higher in small streams than in larger streams.

3.2 SUGGESTED ADDITIONAL DATA COLLECTION

The foregoing general discussion of mechanisms potentially affecting DO and bacteria levels in small streams is intended to introduce the topic and foster work that can lead to a more quantitative treatment of the processes. The following are suggestions of the types of experiments and efforts that might be useful to define the specific aspects of standards for smaller streams and lead… Towards More Definitive Levels.

Variations Along Streams

The first group of experiments that might be performed would be those to better define the type of variations that exist along a smaller stream with varying physical conditions. This would be an attempt to document the type of variation that is expected to exist in smaller streams to a greater degree than larger streams. Sampling could take place at set distance intervals and times over the course of a day. Such an “intensive survey” of representative small streams could provide data to characterize the actual differences between pool, riffle and run stations in close proximity, and also document the effects of shading, and time of day variations.

Variations With Depth

The next class of experiments envisioned is one of detailed DO and bacteria depth profiling in shallow (e.g., less than 2 ft depth), slow moving systems that may exhibit vertical differences. This would not be needed in streams that are flowing and well mixed. Here a suitable sampling system might be a peristaltic pump to collect samples at carefully monitored depths above the sediment. Water would be collected at small (say 1-inch) intervals, starting from the surface and taking care to avoid disturbing the sediment. At each depth the pump would be run long enough to completely flush the line at least three times, and then the water would be diverted into a sterile bacteria sample jar and into beaker where DO could be measured. A series of these detailed depth profiles may provide useful data on significant variations that might affect smaller stream sampling.

Variations With Time

More data are needed to accurately characterize variations in smaller streams both during the course of seasons and over the diurnal period. That can best be addressed by a more detailed series of 24-hr data sonde measurements, perhaps at weekly intervals at some locations of interest.

Habitat Characterization

All of the small streams being studied should have a fisheries assessment so habitat quality and fish conditions can be well understood in relation to DO and bacteria data. With that information, and DO data, it will be possible to characterize conditions and make an appropriate judgment on criteria.

4.0 STREAM STANDARDS

Part of the problem with smaller streams may be with the standards. The existing Texas DO standards have evolved over many years to represent conditions desirable for various levels of aquatic life. The criteria do not represent a level below which significant adverse effects occur. For example, the criterion established for exceptional quality aquatic life use is 6 mg/L as a daily average, with individual levels not being less than 4. A level of 3.5 mg/L measured on a summer morning is below the criterion, but it does not necessarily translate into harm to the aquatic community. A more extreme and common example occurs in many eastern Texas streams where DO levels are commonly in the 1-2 mg/L range during the summer dry periods, yet support a high or exceptional quality aquatic life use based on biological surveys.

A very different approach to setting DO standards has been taken by the U.S. Environmental Protection Agency (EPA) for Atlantic coastal waters (EPA, 2000). Here there is an attempt to determine a concentration below which there is a basis to believe that harm will occur. The method and supporting data are presented in Attachment A.

A key point is that the method is based on toxicological data for the species expected in an area. It might be useful to employ this method in small streams to establish standards for different aquatic life communities. Presumably, larger more stable systems will have a greater diversity of sensitive species that might require a higher DO level to avoid harm. Smaller streams that exhibit greater diversity in flow, and more limited and extreme flow conditions, may well have a more limited aquatic community that is better able to withstand the greater level of stress. This more hardy community may not require as high a DO level to avoid harm.

This approach appears to offer the potential to establish a technical basis for lower DO criteria in smaller, more variable systems where DO levels tend to be lower naturally. However, it would require a significant amount of technical work to develop criteria for each system.

Another improvement to the standards would be to express the DO criteria in terms of percent saturation rather than as a simple concentration. Making that change would effectively eliminate the temperature-related variations in routine monitoring data (temperature and dissolved solids in coastal waters) and allow more targeted assessments. It would also tend to reduce the number of errors of hypothesis testing in data screening, producing better answers.

Bacteria levels in smaller stream can be expected to be higher for the range of reasons related to runoff discussed in earlier sections. The way to address this in the standards appears to be that recommended in the Statewide Bacterial Indicator Study (PBS&J, 2000) for smaller, highly variable waters. That recommendation, presented in full in Attachment B, was to sample normally, but for smaller streams determine when sampling conditions were suitable for contact recreation. A proposed working definition for suitable is that only samples collected when conditions were suitable for recreation would be used for screening against the contact recreation bacteria criteria.

The determination of “suitable” will always require some judgment to deal with special cases, but a working quantitative definition proposed is:

- Water velocity less than 2 feet per second,
- Water depth 18 inches or more,
- Water visibility to a depth of 18 inches, unless the bottom is known such as an ocean beach, and
- Water temperature at least 59 degrees F.

These criteria are based on national and international safety guidelines, but judgment will always be needed to assess suitability for contact recreation.

This recommendation was made in Bacterial Indicator study, and the TNRCC has indicated its intention to consider implementation in the next triennial standards revision process.

5.0 DISCUSSION AND RECOMMENDATIONS

The empirical data in the Guadalupe River Basin appear to confirm that smaller streams have the highest proportion of locations not meeting the water quality criteria currently established. Physical reasons that appear to explain this situation were analyzed. Addressing these conditions in a quantitative manner will require a structured effort to both document the effect of the physical conditions associated with small streams on monitoring data and to suggest quantitative methods to correct the problem. A sampling program to accomplish this is suggested.

Physical conditions unique to smaller streams are only part of the problem. A related aspect is that the water quality standards do not currently have provisions to accommodate the unique conditions in smaller streams.

Major study recommendations are:

1. Perform follow-up studies on sampling procedures possibly as part of a TMDL program, to better understand and document the small stream effects on sampling data.
2. Consider switching to percent DO saturation in the standards to reduce data noise.
3. Evaluate adapting an approach to setting DO standards based on the actual needs of the species present.
4. Adopt recommendations made in the Statewide Bacteria Indicator Study (PBS&J, 2000) for monitoring normally but only screening data collected when conditions were suitable for contact recreation.

If these recommendations are followed it is reasonable to expect that stream size can be eliminated as a factor in water quality data and assessments.

6.0 REFERENCES

PBS&J. 2000. Bacteria Indicator Study Final Report. PBS&J document no. 000195.

U.S. Environmental Protection Agency (EPA). 2000. Ambient aquatic life water quality criteria for dissolved oxygen (saltwater): Cape Cod to Cape Hatteras. 49 pp.

ATTACHMENT A

SUPPLEMENTARY ANALYSES OF DISSOLVED OXYGEN AND INDICATOR BACTERIA DATA

TABLE A-1

Type of water body	Number of stations	Stations with mean % DO saturation below 25th percentile		Stations with mean % DO saturation above 75th percentile	
		Number of sites	% of sites	Number of sites	% of sites
Unclassified tributary	13	9	69.2%	0	0.0%
Classified tributary	15	2	13.3%	2	13.3%
Main stem	30	4	13.3%	11	36.7%
Lake	3	0	0.0%	2	66.7%

TABLE A-2

Type of water body	Difference from expected number of stations with mean % DO saturation above 75th percentile	Difference from expected number of stations with mean % DO saturation below 25th percentile
Unclassified tributary	44% more than expected	25% less than expected
Classified tributary	12% less than expected	12% less than expected
Main stem	12% less than expected	12% more than expected
Lake	25% less than expected	42% more than expected

TABLE A-3

Shading	Number of stations	Stations with mean % DO saturation below 25th percentile		Stations with mean % DO saturation above 75th percentile	
		Number of sites	% of sites	Number of sites	% of sites
Fully shaded	9	5	55.6%	1	11.1%
Partly shaded	29	8	27.6%	7	24.1%
No shade	23	2	8.7%	7	30.4%

TABLE A-4

Shading	Difference from expected number of stations with mean % DO saturation above 75th percentile	Difference from expected number of stations with mean % DO saturation below 25th percentile
Fully shaded	31% more than expected	14% less than expected
Partly shaded	3% more than expected	1% less than expected
No shade	16% less than expected	5% more than expected

TABLE A-5

Type of water body	Number of stations	Stations with FC geometric mean above criterion		Stations with FC geometric mean above 75th percentile		Stations with FC geometric mean below 25th percentile	
		Number of sites	% of sites	Number of sites	% of sites	Number of sites	% of sites
Unclassified tributary	13	8	61.5%	10	76.9%	1	7.7%
Classified tributary	15	2	13.3%	3	20.0%	2	13.3%
Main stem	29	0	0.0%	2	6.9%	9	31.0%
Lake	3	0	0.0%	0	0.0%	3	100.0%

TABLE A-6

Type of water body	Difference from expected number of stations with FC geometric mean above 75th percentile	Difference from expected number of stations with FC geometric mean below 25th percentile
Unclassified tributary	52% more than expected	17% less than expected
Classified tributary	5% less than expected	12% less than expected
Main stem	18% less than expected	6% more than expected
Lake	25% less than expected	75% more than expected

TABLE A-7

Type of water body	Number of stations	Stations with EC geometric mean above criterion		Stations with EC geometric mean above 75th percentile		Stations with EC geometric mean below 25th percentile	
		Number of sites	% of sites	Number of sites	% of sites	Number of sites	% of sites
Unclassified tributary	12	6	50.0%	8	66.7%	1	8.3%
Classified tributary	14	2	14.3%	4	28.6%	2	14.3%
Main stem	20	0	0.0%	0	0.0%	6	30.0%
Lake	3	0	0.0%	0	0.0%	3	100.0%

TABLE A-8

Type of water body	Difference from expected number of stations with EC geometric mean above 75th percentile	Difference from expected number of stations with EC geometric mean below 25th percentile
Unclassified tributary	42% more than expected	17% less than expected
Classified tributary	4% more than expected	11% less than expected
Main stem	25% less than expected	5% more than expected
Lake	25% less than expected	75% more than expected

TABLE A-9

Shading	Number of stations	Stations with FC geometric mean above criterion		Stations with FC geometric mean above 75th percentile		Stations with FC geometric mean below 25th percentile	
		Number of sites	% of sites	Number of sites	% of sites	Number of sites	% of sites
Fully shaded	9	3	33.3%	4	44.4%	1	11.1%
Partly shaded	28	7	25.0%	9	32.1%	7	25.0%
No shade	23	0	0.0%	2	8.7%	7	30.4%

TABLE A-10

Shading	Difference from expected number of stations with FC geometric mean above 75th percentile	Difference from expected number of stations with FC geometric mean below 25th percentile
Fully shaded	19% more than expected	14% less than expected
Partly shaded	7% more than expected	same as expected
No shade	16% less than expected	5% more than expected

TABLE A-11

Shading	Number of stations	Stations with EC geometric mean above criterion		Stations with EC geometric mean above 75th percentile		Stations with EC geometric mean below 25th percentile	
		Number of sites	% of sites	Number of sites	% of sites	Number of sites	% of sites
Fully shaded	8	4	50.0%	5	62.5%	0	0.0%
Partly shaded	22	4	18.2%	7	31.8%	3	13.6%
No shade	19	0	0.0%	0	0.0%	9	47.4%

TABLE A-12

Shading	Difference from expected number of stations with EC geometric mean above 75th percentile	Difference from expected number of stations with EC geometric mean below 25th percentile
Fully shaded	38% more than expected	25% less than expected
Partly shaded	7% more than expected	11% less than expected
No shade	25% less than expected	22% more than expected

TABLE A-13

Water depth	Number of stations	Stations with FC geometric mean above criterion		Stations with FC geometric mean above 75th percentile		Stations with FC geometric mean below 25th percentile	
		Number of sites	% of sites	Number of sites	% of sites	Number of sites	% of sites
depth =< 2 ft	20	4	20.0%	7	35.0%	1	5.0%
2 < depth =< 4 ft	11	2	18.2%	2	18.2%	4	36.4%
depth > 4 ft	11	0	0.0%	1	9.1%	5	45.5%

TABLE A-14

Water depth	Difference from expected number of stations with FC geometric mean above 75th percentile	Difference from expected number of stations with FC geometric mean below 25th percentile
depth =< 2 ft	10% more than expected	20% less than expected
2 < depth =< 4 ft	7% less than expected	11% more than expected
depth > 4 ft	16% less than expected	20% more than expected

TABLE A-15

Water depth	Number of stations	Stations with EC geometric mean above criterion		Stations with EC geometric mean above 75th percentile		Stations with EC geometric mean below 25th percentile	
		Number of sites	% of sites	Number of sites	% of sites	Number of sites	% of sites
depth =< 2 ft	20	4	20.0%	8	40.0%	3	15.0%
2 < depth =< 4 ft	11	1	9.1%	2	18.2%	3	27.3%
depth > 4 ft	9	0	0.0%	0	0.0%	4	44.4%

TABLE A-16

Water depth	Difference from expected number of stations with EC geometric mean above 75th percentile	Difference from expected number of stations with EC geometric mean below 25th percentile
depth =< 2 ft	15% more than expected	10% less than expected
2 < depth =< 4 ft	7% less than expected	2% more than expected
depth > 4 ft	25% less than expected	19% more than expected

ATTACHMENT B

EPA APPROACH FOR SALTWATER DISSOLVED OXYGEN LIMITS

An approach is presented in EPA (2000) to derive the lower limits of DO necessary to protect coastal and estuarine animals in mid-Atlantic coastal waters. A main reason for the effort was addressing the hypoxia conditions that sometimes exist in East and Gulf Coast bottom waters during the summer. The approach combines features of traditional water quality criteria with a somewhat different biological framework. It considers how to protect three aspects of biological health: survival of juveniles and adults, growth, and larval recruitment, and considers both continuous (persistent) and cyclic (diel, tidal, or episodic) exposures to low DO. The continuous situation deals with exposures longer than 24 hrs whereas the cyclic situation deals with exposures of less than 24 hrs but that may be repeated for days. The limits derived are based entirely on laboratory findings but are supported in part by field observations. The document has a brief discussion on implementation but there are no guidelines on monitoring requirements. The following is a brief summary of the procedures used to derive the limits.

A lower limit was calculated for continuous exposures by using the procedures outlined in Stephan et al. (1985), but with mortality data for only juvenile or adult stages. This limit is analogous to the Criterion Maximum Concentration (CMC) for a toxicant, except that a protective DO concentration limit is expressed as a minimum as opposed to a maximum. The CMC was determined to be 2.3 mg/L. Based on time-to-death data, a curve was derived that gives limits for cyclic exposures for various exposure times with the same protective level as the CMC for juveniles under continuous exposure.

Separately, a threshold above which long-term, continuous exposures should not cause unacceptable effects was derived from growth data (mostly from bioassays using larvae). This limit was derived following the procedures in Stephan et al. (1985) and is analogous to the Criterion Chronic Concentration (CCC) for a toxicant. The CCC was determined to be 4.8 mg/L. The limit for cyclic exposures was derived from the dose-response relationship for DO vs. growth reduction for the American lobster, and comparisons of the effects of cyclic exposure vs. continuous exposure on growth for a variety of species. It provides a degree of protection equivalent to the CCC, but for exposure durations shorter than a day.

If the DO exceeds the CCC (4.8 mg/L), the site meets objectives for protection. If the DO is below the CMC (2.3 mg/L), the site does not meet objectives for protection. When the DO is between these values, the site requires evaluation of duration and intensity of adverse exposures to determine suitability of habitat for the larval recruitment objective.

A larval recruitment model was developed based on early life history information and exposure-response relationships. The limit from the model represents allowable DO conditions below the CCC, provided that the duration of exposure does not exceed a corresponding allowable number of days that ensure adequate recruitment during the larval recruitment season. The severity of cyclic exposure was evaluated with a time-to-death model. The limit is obtained from the modeled relationships between daily cohort mortality and the allowable number of days at a given maximum daily larval cohort mortality that protects against greater than 5% cumulative impairment of recruitment over a recruitment season.

A possible pathway to address differences in stream systems is to perform similar analyses on the species common to each aquatic system. Presumably the species that exist in more stable environments such as lakes and perennial rivers will include some that are more sensitive to DO stress. Small streams with wide variation in conditions from place to place and over time will be populated by hardier species that can tolerate lower DO levels. Developing such criteria would be a major literature and possibly laboratory undertaking, but it would provide a firm technical basis for site-specific criteria.

Appendix B in the EPA document is included in this attachment. The appendix tabulated the data used to derive the lower DO limit.

REFERENCES

Stephan, C.E., et al. 1985. Guidelines for deriving numerical national water quality criteria for the protection of aquatic organisms and their uses. NTIS Publication No.: PB85-227049.

U.S. Environmental Protection Agency (EPA). 2000. Ambient aquatic life water quality criteria for dissolved oxygen (Saltwater): Cape Cod to Cape Hatteras. 49 pp.

Appendix B. Acute Sensitivity of Juvenile and Adult Saltwater Animals to Low Dissolved Oxygen. Exposure Durations Ranged from 1 to 4 Days.

Species	Common name	Life Stage	Method[a]	Duration (days)	Salinity (g/kg)	Temp. (/C)	LC50 (mg/L)	LC5 (mg/L)	LC5/ LC50	Reference
Americamysis bahia	mysid shrimp	juvenile, <24 hr	FM	4	31-32	25-27	1.29	1.5	1.16	Poucher and Coiro, 1997
Americamysis bahia	mysid shrimp	juvenile, <24 hr	FM	4	31-32	25-27	1.25			Poucher and Coiro, 1997
Ampelisca abdita	amphipod	juvenile	FM	4	31-32	20-21	< 0.9			Poucher and Coiro, 1997
Apeltes quadracus	four spine stickleback	juvenile/adult	FM	4	31.0	19.4	0.91	1.2	1.32	Poucher and Coiro, 1997
Brevoortia tyrannus	Atlantic menhaden	juvenile	FM	4	29-31	19-20	1.21	1.9	1.57	Poucher and Coiro, 1997
Brevoortia tyrannus	Atlantic menhaden	juvenile (131.9 mm TL)	FM	4	6.9	28	1.04	1.6	1.49	Burton et al., 1980
Callinectes sapidus	blue crab	adults	SM	1	30.0	-	< 1.0			Carpenter and Cargo, 1957
Carcinus maenus	green crab	juvenile/young adult	FM	4	30-31	20	< 0.54			Poucher and Coiro, 1997
Carcinus maenus	green crab	adult	SM	2	15	10	< 0.21			Theede et al., 1969
Crangon septemspinosa	sand shrimp	juvenile/young adult	FM	4	31.0	19.9	0.97	1.6	1.65	Poucher and Coiro, 1997
Crassostrea virginica	eastern oyster	juvenile	SM	4	21	25	< 1.5			Baker and Mann 1992
Crassostrea virginica	eastern oyster	juvenile	SM	4	30	30	0.88			Stickle, 1988; Stickle et al., 1989
Eurypanopeus depressus	flat mud crab	juvenile	SM	4	28	-	0.57			Stickle, 1988; Stickle et al., 1989
Homarus americanus	American lobster	juvenile	SM	2	20	15	0.9			McLeese, 1956
Homarus americanus	American lobster	juvenile	SM	2	25	15	1.0			McLeese, 1956
Homarus americanus	American lobster	juvenile	SM	2	30	15	0.8			McLeese, 1956
Homarus americanus	American lobster	juvenile, stage 5-6	FM	1	30-32	19-21	0.94	1.6	1.70	Poucher and Coiro, 1997
Leiostomus xanthurus	spot	juvenile (87.6 mm TL)	FM	4	6.9	28	0.70	0.81	1.16	Burton et al., 1980
Morone saxatilis	striped bass	juvenile	FM	4	30-30.5	21-22	1.53	2.0	1.31	Poucher and Coiro, 1997
Morone saxatilis	striped bass	juvenile	FM	4	32.0	18-20	1.63	1.9	1.17	Poucher and Coiro, 1997
Palaemonetes pugio	daggerblade grass shrimp	juvenile	FM	4	30-31	19-21	0.72	1.1	1.53	Poucher and Coiro, 1997
Palaemonetes vulgaris	marsh grass shrimp	juvenile	FM	4	30-32	24-25	1.02	1.4	1.37	Poucher and Coiro, 1997
Paralichthys dentatus	summer flounder	metamorphosed juveniles	FM	4	31-32	20.5	1.10	1.3	1.18	Poucher and Coiro, 1997
Paralichthys dentatus	summer flounder	metamorphosed juvenlies	FM	1	29-30	24-25	1.59	1.9	1.19	Poucher and Coiro, 1997

Species	**Common name**	**Life Stage**	**Method[a]**	**Duration (days)**	**Salinity (g/kg)**	**Temp. (/C)**	**LC50 (mg/L)**	**LC5 (mg/L)**	**LC5/ LC50**	**Reference**
Pleuronectes americanus	winter flounder	metamorphosed juveniles	FM	4	31-32	20-21	1.46	1.7	1.16	Poucher and Coiro, 1997
Pleuronectes americanus	winter flounder	metamorphosed juveniles	FM	4	29-30	19-20	1.30	1.6	1.23	Poucher and Coiro, 1997
Prionotus carolinus	northern sea robin	juvenile	FM	4	31-32	19-20	0.55	0.8	1.45	Poucher and Coiro, 1997
Rithropanopeus harrisii	Harris mud crab	juvenile	SM	4	30.0	10.0	0.51			Stickle, 1988; Stickle et al., 1989
Scopthalmus aquosus	windowpane flounder	juvenile	FM	2	30.0	19-20	0.81	1.2	1.48	Poucher and Coiro, 1997
Spisula solidissima	Atlantic surfclam	juvenile	FM	4	30-32	22-24	0.43	0.7	1.63	Poucher and Coiro, 1997
Stenotomus chrysops	scup	juvenile	FM	1	30-31	20-21	1.29			Poucher and Coiro, 1997
Stenotomus chrysops	scup	juvenile	FM	1	31-32	20-21	1.22			Poucher and Coiro, 1997
Syngnathus fuscus	pipe fish	juvenile	FM	1	31	18-20	1.63	1.9	1.17	Poucher and Coiro, 1997
Tautoga onitis	tautog	juvenile	FM	4	31-32	24-25	0.82	1.1	1.34	Poucher and Coiro, 1997
Tautoga onitis	tautog	juvenile	FM	4	31.5	24.2	0.82	1.2	1.46	Poucher and Coiro, 1997

[a] FM=flowthrough measured, SM=static measured

ATTACHMENT C

RECOMMENDATIONS IN STATEWIDE BACTERIA INDICATOR STUDY

A goal of water quality monitoring for contact recreation is to assess the potential pathogenicity of surface waters to contact recreators. Ideally, we would like to measure the concentration of pathogenic organisms in surface waters and compare that to a risk threshold level. Technology exists for monitoring all known waterborne viral, bacterial, and protozoan pathogens and parasites, but cost prohibits its application. Because we cannot currently test directly for pathogenicity in water samples, we must continue to rely on indicators of fecal-related pathogens. Currently, we use measurement of FC indicator bacteria to judge health risks for swimmers. However, the relationship between FC bacteria and waterborne illness is tenuous, as discussed previously.

The U.S. EPA (1986) recommended the use of two bacterial indicators (EC in fresh waters and EN in fresh or marine waters) as superior to FC as an indicator of fecal contamination and the implied threat of the presence of enteric pathogens. While the 1986 EPA criteria document is based on studies that were conducted approximately two decades ago, the recommendation to cease using the FC test and change to EC and EN testing, with new numerical criteria, still appears to be valid. The primary reason for switching is that the EC and EN tests are somewhat more specific to feces than the thermotolerant coliform test commonly called fecal coliform (Niemi et al., 1997). Being more specific to feces reduces the false positive readings from various soil and plant sources and thus increases the probability that a positive reading will be from a human or animal waste source. This is critical because Texas standards (307.7(a)) note that site-specific uses and criteria apply specifically to waste discharges and the activities of man and not where criteria are exceeded by natural phenomena.

The technology to identify human waste through DNA tracing has substantial potential. However, the techniques have largely been developed in medical situations, and applications to contact recreation regulation are yet to be realized in a practical sense. A variety of other bacteria and viruses have been suggested in the scientific literature as alternate indicators of fecal contamination, but currently there is not sufficient evidence that they are superior to EC and EN, especially when monitoring costs are considered.

While switching to EC and EN, with new geometric mean criteria and elimination of the 5 samples in 30 days requirement, is a step forward, it does not completely resolve the original issue driving the need for the study. This was the requirement that screening for compliance with the standards under the 303(d) listing process had revealed that many essentially rural or undeveloped waterbodies were failing without having a “source” whose load could be allocated in a TMDL study. It was widely accepted that the problem stemmed from having standards developed for public swimming areas in good weather, but applying them to small streams in all weather where a portion of the data showed levels much higher than the standards. The challenge was translating this understanding into standards that would work quantitatively and still be accepted by diverse interest groups involved in the setting of water quality standards. This can be viewed as another step in the process envisioned in the acronym TMDL—Towards More Definitive Levels.

Following EPA's lead on considering different levels of usage, and consistent with the practice followed by a number of other states, we proposed classifying the waters of Texas into four groups. These groups are defined and discussed below.

A. **Designated Public Swimming Areas**. These are areas where contact recreation (primarily full-body contact swimming) is encouraged and managed to some degree by a public agency or a property owner. These high-use swimming areas are precisely the type of sites employed by federal agencies in previous epidemiological studies used to set the existing and recommended criteria, except that the Texas sites almost never have wastewater inputs and generally have excellent water quality. However, they can be expected to have higher bacteria levels following local rains, and may need to either be closed to swimming by the managing entity during those periods or public notice provided of a potential health risk. Considering both dry and wet weather data, they must meet recommended geometric mean criteria. The single-sample not-to-exceed values in the EPA criteria document, or other site-specific values could be used for short-term closure decisions.

B. **Stable Water Areas**. These are areas where the water level is reasonably constant and high velocities or other dangerous conditions are rare. Swimming and wading is common and not discouraged by public agencies, but in these areas, there is no direct public management or support such as lifeguards. Examples include most Gulf beaches, bays and estuaries, as well as reservoirs with public access points. These areas can be expected to have higher bacteria levels during and immediately after major rains, but in the absence of a pollution source have long-term average levels that are well within contact recreation criteria. Because these areas are not managed for swimming use, there would be no short-term swimming closures in response to runoff-induced bacteria levels. Accordingly, the appropriate vehicle for public safety regulation would be the long-term geometric mean of routine monitoring data. These data would be suitable for identifying locations with high bacteria levels from either anthropogenic or natural sources. Single sample not-to-exceed values would not be employed because there is no active management of contact recreation.

C. **Waters with Substantial Variance in Levels and Velocities**. These are areas where wading and limited swimming can occur when flow and weather conditions are suitable, but always without public support. These include most rivers and creeks that are naturally subject to wide variations in flow and quality conditions. Bacteria testing should be performed on a routine basis over all conditions for a variety of reasons, but only observations made under conditions suitable for contact recreation would be used for assessing compliance with bacterial criteria for contact recreation. Conditions suitable for contact recreation would generally be low to moderate flow without local recent rain and reasonably warm weather. Because the conditions that may be suitable for contact recreation can be highly variable and site-specific, the agency performing the monitoring should be responsible for identifying those samples to be used for assessing bacterial suitability for contact recreation. The determination of site suitability for contact recreation would be based on pre-defined objective criteria specific to the site such as water velocity, water clarity, depth, and temperature. Recommendations for such criteria are presented below.

D. **Non-Contact Recreation Areas**. These are areas that are determined to be inappropriate for contact recreation due to factors such as heavy commercial vessel traffic or untreated wastewater discharges. There are a small number of such locations that is not likely to change in the short term.

In 1997 Region 6 of EPA produced draft guidance for dealing with water quality standards for recreation. The document recommends a presumptive contact recreation use except where a use cannot be attained. Federal regulations allow demonstration of non-attainment based on “human caused conditions that…prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place.” This is the case for Group D waters. There is no practical way for Texas to correct untreated wastewater discharges from across an international border and the environmental effect of removing commercial vessel traffic and associated employment and people would appear to be substantially larger than any recreational benefits that might result from such action.

It is important to recognize that while some water uses such as providing habitat for aquatic life apply and must be supported at all times, that is not true for contact recreation. The contact recreation use cannot be safely supported in all waters at all times. With some waters, the use can be supported most of the time. For example, ocean beaches can support the use all the time except during major storms where government officials enforce evacuation orders. With small streams, similar safety concerns following large rains are much more common, but it is rare for government to evacuate or mandate staying out of the water. While the particulars differ between waters, the basic point is common: the swimming use cannot be supported under all conditions because public safety must be considered.

Small watersheds without wastewater discharges frequently have only runoff flows. These runoff flows are generally not suitable for swimming and also tend to have high bacterial levels.

Setting a minimum watershed size for contact recreation use has been done in some states and would appear to be a valid approach. However, it may be more complex in Texas because of the slightly greater degree of geographic diversity. Most importantly, a waterbody might be suitable for some measure of swimming use in some conditions but not in others. Because of this temporal variability a different approach is proposed.

Group C waters that typically exhibit a substantial amount of temporal variability would be presumed to be able to support contact recreation, and the same EC and EN criteria would apply as in Group A and B waters when conditions were suitable. The difference would be that the agency collecting the data would also judge the water's suitability for swimming at the time of data collection using predefined criteria. For example, the water must have a velocity that is low enough to be manageable by the public. For swimming safety the water should either be deep like a lake, or if shallow then either clear enough to see the bottom or the bottom should be regular enough to walk with confidence (e.g. a Gulf beach). The depth should also be great enough that full body contact recreation is possible, and it should be warm enough so that recreational swimming is practical.

The criteria proposed for determining suitability in Class C waters are:

- Water velocity less than 2 feet per second,
- Water depth 18 inches or more,
- Water visibility, at least a half meter or 18 inches, unless the bottom is known such as an ocean beach, and
- Temperature, at least 59°F.

The proposed criteria are grounded in national and international swimming safety guidelines, but judgement would still need to be employed in determining suitability such that bacteria results should be compared with contact recreation criteria because special cases will exist. The underlying philosophy for such a judgment should be:

Independent of bacteria levels, would I let my kids swim there?

If the agency cannot collectively answer in the affirmative based on objective and quantifiable criteria, then the water should not be considered suitable for swimming at that time. Data obtained at that time should not be used for determining compliance with bacterial contact recreation criteria in the 303(d) listing process. When conditions are determined to be suitable for swimming, the data would be used for 303(d)-list screening.

MONITORING CONSISTENT WITH SITE CONTACT RECREATION USAGE

Bacterial monitoring is performed for a number of reasons. One is to insure that waters are of acceptable quality when swimming use or shellfish harvesting is probable. Another is to help locate inappropriate sewage discharges. A third and relatively new use for monitoring data is to allow screening for compliance with water quality standards. This last use has focused the need to make the standards more consistent with actual data and contact recreation uses.

The historical situation that existed when many of the important epidemiological studies were performed was one of swimming beaches impacted by partially treated wastewater discharges. That is true both for the standards in place to today and for those recommended by EPA (1986). Today the water quality conditions are substantially different, with high bacteria levels primarily associated with rain runoff, with a possible contribution of sewage leaks and other sources in some urban areas. Another major change from the time when the criteria were developed is that monitoring is not limited to swimming beaches during warm dry weather, but now includes a wide variety of waters and conditions. Specific monitoring recommendations to address the changed conditions include:

1. As recommended by EPA (1986), monitoring frequency should track the level of recreational use. The five samples in 30 days sampling frequency (essentially weekly) recommended in EPA criteria documents may be desirable for some high use designated public swimming beaches (Group A waters) but not others. For example, Barton Springs Pool in Austin, with a very high level of use per area of water, is monitored daily while other public swimming beaches with a lower level of use may be monitored monthly. The actual rate of sampling should be determined locally, considering site-specific and seasonal variability.

2. Bacterial testing typically requires at least 24 hours for incubation. Consistent with EPA's BEACH initiative, entities responsible for managing designated public swimming areas (Group A waters) should adopt a more rapid method for responding to short-term high bacteria levels. For example, turbidity that had previously been correlated with bacterial levels, and that could be read in a near real-time basis rather than waiting for a bacterial incubation period, could be used for short term closure decisions. Other possible predictors could be local rainfall or flow.

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