EXHIBIT A

EDCC's
Aquatic Life Supplemental Report
(Report)

Aquatic Life Supplemental Report
Dissolved Minerals Rulemaking

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September 30, 2009

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Background

In the Record of Decision (ROD) dated April 14, 2009 (Attachment A), EPA informed ADEQ that they were unable to approve the site specific criteria revisions for dissolved minerals (sulfate, chloride and total dissolved solids) previously approved by Arkansas Pollution Control & Ecology (APC&E) Commission in response to the 3rd party rulemaking initiated by El Dorado Chemical Company (EDCC). In the justification for the ROD, EPA stated that:

> "….EPA has determined that supporting documentation remains insufficient to demonstrate that the site-specific minerals criteria for the waterbodies…..are appropriately protective of aquatic life."

EPA indicated that lingering concerns regarding the potential for in-stream aquatic toxicity from the adopted criteria was the basis for its decision as stipulated in the ROD. The ROD specifically stated that "EPA disapproves all proposed site specific criteria revisions for chloride, sulfate and TDS in all submissions on the grounds that current documentation provided by ADEQ **does not clearly demonstrate** adequate protection of aquatic life uses for the receiving streams and associated waterbodies [emphasis added]." The ROD does offer that ADEQ could pursue the site specific revisions for minerals in these waterbodies by providing adequate scientific documentation to show that the Gulf Coastal seasonal and perennial fishery aquatic life uses will be protected.

Subsequent to receiving the ROD, EPA, ADEQ and representatives for the 3rd party petitioners participated in a conference call on April 29, 2009. The purpose of the call was to clarify EPA concerns that resulted in the decision and to determine what information EPA might require to address those perceived information deficiencies. During the conference call, approaches to address EPA concerns were discussed. EPA indicated that the following tasks could provide the additional information allowing further evaluation of the potential for in stream toxicity and the support of aquatic life in the receiving streams.

1. Task 1. A literature review of current research related to dissolved mineral toxicity;

2. Task 2. Additional chronic WET testing on a simulated effluent and other water samples developed to mimic the receiving stream segments downstream of the discharge from EDCC which were the subject of the 3rd party rulemaking and approved by ADEQ and the Commission.

3. Task 3. Modeling using GRI salinity model to predict the potential for toxicity at the concentrations adopted by the ADEQ rulemaking.

In addition, EPA requested that a study plan be developed to set forth the process by which the additional information would be presented and to establish a decision process that would document maintenance of the aquatic life uses. This study plan was developed and submitted to ADEQ for their review and comment and for subsequent submittal to EPA for their review. The Study Plan is provided in Attachment B.

Based on the information presented in the ROD and the additional discussion during the conference call, it was determined that the following tasks would be completed to address the EPA concerns related to the protection of the aquatic life uses of the receiving streams.

Objective

The objective of the supplemental report was to develop and provide additional documentation addressing issues identified by EPA as deficiencies stipulated in the Dissolved Mineral ROD related to the potential for instream toxicity.

Tasks

The proposed tasks include:

1. develop additional information through an updated literature review on dissolved mineral toxicity;

2. conduct additional WET testing utilizing spiked samples to simulate the concentrations proposed in the rulemakings; and

3. complete modeling using GRI model.

Task1. Develop additional information through an updated literature review of dissolved mineral toxicity information

The current scientific literature related to the toxicity of dissolved minerals will be reviewed with a focus on Cl, SO_4 and TDS. The research will indicate a range of concentrations at which the target dissolved minerals present a toxicity potential. The research data will be compared to the criteria approved by ADEQ and the Commission.

The goal of this task is to supplement the information presented during the rulemaking process and clarify the existing scientific data related to dissolved mineral toxicity.

The potential for toxicity associated with the concentrations adopted in the recent rulemaking were evaluated in light of the current scientific literature.

Results

The current science behind dissolved mineral toxicity has evolved to more clearly identify the relationship between the various ionic compounds and the relative toxicities of the individual anions, specifically sulfate and chloride. This information supports that the criteria approved in the EDCC 3rd party rulemaking are supportive of the receiving stream aquatic communities.

Arkansas Dissolved Mineral implementation Strategy

The Arkansas Department of Environmental Quality (ADEQ), Regulation No. 2 contains the established water quality standards for chloride, sulfate, and Total Dissolved Solids (TDS) for the State of Arkansas (ADEQ, 2007). Regulation No 2 provided stream specific dissolved mineral criterion for numerous listed named streams and stream segments.

In addition, for those streams not specifically listed, the default dissolved mineral criteria is established on an ecoregion basis. These default criteria were first established in the 1987 revision of Reg. 2, (ADPCE, 1987) as "guidelines" based on the data developed as part of the Ecoregion Reference Streams documentation (ADPCE, 1987-Volumes I and II). The guidelines were based on the characterization of "least disturbed" streams in each of the aquatic ecoregions identified in Arkansas. The streams selected for this ecoregion study were selected to represent a "least disturbed" condition. Therefore, the oil gas and mineral production areas of the Gulf Coastal Plan Ecoregion in southern Arkansas were specifically excluded from the ecoregion reference study. The dissolved mineral "guidelines" were adopted as default criteria during the 1993 standards revision.

Unless specifically listed in Regulation No. 2, the ecoregion default dissolved mineral criteria were applied to all unnamed streams regardless of the historical condition and long term water quality.

This "blanket application" of ecoregion dissolved mineral criteria created numerous streams that exceeded the ecoregion criteria. The Dissolved Mineral Implementation Strategy was developed by ADEQ to address the apparent over application of the least disturbed dissolved mineral criterion. The strategy was to allow modification of individual streams and stream segments through site specific development of dissolved mineral criteria through the 3rd party rulemaking process. This 3rd party rulemaking process (an approved policy in the ADEQ Continuous Planning Process (CPP) for the implementation of Regulation No. 2.) is provided in Reg. 2 under Section 2.306.

The CPP dissolved mineral implementation strategy has been utilized and approved by both ADEQ and EPA. This criteria development process has resulted in 90+ stream segments having site specific dissolved mineral criteria as identified in the current Regulation No. 2 (ADEQ, 2007). Many of these approved 3rd party rulemakings have approved chloride, sulfate and TDS criteria above those concentrations proposed in the EDCC rulemaking demonstrating that the concentrations approved in the EDCC rulemaking do not represent concentrations that present an issue related to the preservation of the stream segments designated uses.

According to the most recent version of Regulation No. 2, the maximum dissolved mineral criteria approved in previous 3rd party rulemakings are:

- Chloride: 631 mg/L (Reach of Boggy Creek - Clean Harbors rulemaking),
- Sulfate: 860 mg/L (Holly Creek – ALCOA rulemaking),
- TDS: 1600 mg/L (Holly Creek – ALCOA rulemaking).

In comparison, the dissolved mineral criteria approved by ADEQ in the EDCC 3rd party rulemaking are a fraction of these maximums and represent the mid-range concentrations of those previously approved. The ranges of dissolved mineral criteria approved in the EDCC rulemaking are:

- Chloride: 23 to 360 mg/L,
- Sulfate: 67-125 mg/L,
- TDS: 315-855mg/L,

Many of these 3rd party rulemakings are located within the Ouachita River basin where the default criteria are 15 mg/L for chloride, 20 mg/L for sulfate, and 142 mg/L for TDS. However many stream segments within the Ouachita River basin have site specific criteria which are considerably higher and would not have been approved if the criteria were not protective of the aquatic life uses assigned to the stream segment.

As recently as May 23, 2008, ADEQ, APC&E Commission and U.S. EPA approved a 3rd party rulemaking for 43 stream segments increasing the chloride criteria above that approved by ADEQ (but EPA has yet to approve) in 2 of the 4 reaches in the

EDCC rulemaking. The Bayou Meto Water Management district (BMWMD) rulemaking was approved without actual field documentation of existing conditions, without modeling to project expected concentrations, no evaluation of aquatic life community, minimal stream habitat documentation and no evaluation of toxicity other than 2 references (APAH, 1992 and Kennedy, 2003). These references provided toxicity values for chloride as 230 mg/L and sulfate at > 300 mg/L and larval fish toxicity at 860 mg/L chloride and >1000mg/L for sulfate. These larval fish toxicity values are above the EDCC 3rd party ADEQ approved values.

Toxicity of Dissolved Minerals

There is ample documentation in the scientific literature demonstrating the potential toxicity of dissolved minerals varies widely depending on several factors. The dissolved minerals (anions; sulfate and chloride and the sum of the dissolved minerals; TDS) do not exist in the environment as elements but are bound with cations to form compounds. In addition to the concentration of the individual minerals, one of the most important variables in determining the toxicity of a dissolved mineral complex is the combination of compounds.

EPA requested a more through review of the literature related to dissolved mineral toxicity. The following section provides additional information related to the existing literature. This review is not meant to provide an exhaustive literature review but to generally provide additional information related to dissolved mineral toxicity as it impacts this approved rulemaking.

EPA has not developed a TDS or sulfate national criterion for the protection of freshwater aquatic organisms but has developed State site-specific guidelines (IDNR 2009). However, EPA's current national criterion for the protection of aquatic life from chloride is at acute levels of 860 mg/L and chronic levels of 230 mg/L, based on the testing of 12 different genera (APHA, 2009). This criterion is driven by concentrations to protect the agricultural use and not exclusively the aquatic life use.

More recent literature has focused on the relationships of toxicity between sulfate, chloride and other cations in the environment (IDNR, 2009). Research has shown that chloride and hardness concentrations affect sulfate's toxicity to aquatic invertebrates by causing changes in the organism's osmoregulation (IDNR, 2009). Due to the well studied relationship of sulfate toxicity and chloride and hardness concentrations, the IDNR has developed and proposed to the EPA a new approach the criteria development using a new sulfate formula which can be applied to Iowa's new water quality standard criteria for protection of aquatic organisms (IDNR, 2009).

After an extensive scientific literature review, and based on the scientific data, IDNR found chloride toxicity to be dependent on sulfate and even more so on hardness levels. This condition led to the development of the final proposed formulas for calculating chloride criteria:

- Chloride Acute Value in (mg/L) = 287.8 $(\text{Hardness})^{0.205797}(\text{Sulfate})^{-0.07452}$, and
- Chloride Chronic Value (mg/L) = 177.87$(\text{Hardness})^{0.205797}(\text{Sulfate})^{-0.07452}$

Applying this equation and using the Gulf Coastal Plain ecoregion background criteria of 18.7 (chloride) and 41.3mg/L (sulfate), the chronic criteria would be 426 mg/L and the acute criteria would be 688 mg/L, both of which exceed the concentrations approved by ADEQ in the EDCC 3rd party rulemaking.

In addition, IDNR is proposing that the sulfate criterion be modified to account for the effects of hardness and chloride concentrations. Based on the look-up table produced by IDNR, and assuming a water hardness of 100mg/L, the sulfate criteria would vary between 1,043 mg/L (assuming the ecoregion background concentration of 20 mg/L) and 840 mg/L (assuming the maximum of 360 mg/L chloride). In the Gulf Coastal Plain where the water hardness is typically less than 100 mg/L, the INDR formula would result in a sulfate criterion of 500 mg/L regardless of the chloride concentration. The 500 mg/L criteria is four times the maximum value (125 mg/L) approved by ADEQ in the EDCC 3rd party rulemaking.

Additional Toxicity Data

Studies conducted by D.R. Mount, et al. (1997) and W.L. Goodfellow, et al. (2000), find that TDS toxicity is dependent on other ionic compositions, including chloride and sulfate, and effects on ion imbalances during testing of aquatic species. The Virginia DEQ has suggested that TDS standards should consider component-ion effects (Schoenholtz, et al. 2008).

The effects of alkalinity and hardness on the toxicity of dissolved solids in textile effluent were also shown to affect the relative toxicity to the water flea (*Ceriodaphnia bubia*). The results of the research by Lasier et al., indicated that effluents with lower carbonate alkalinity had increased reproduction when compared to those with higher carbonate alkalinity. In addition, they reported that sodium chloride salinity produced greater reproduction in water flea WET tests than did sodium sulfate salinity (http://www.pwrc.usgs.gov/resshow/wingr1rs/wingr1rs.htm).

IDNR conclude that total dissolved solids toxicity is caused mainly by the relationship found between chloride and sulfate (described above). Therefore, they propose replacement of TDS standards with the proposed chloride and sulfate criteria formula developed above (IDNR, 2009).

The IDNR states that the current EPA guidelines for sulfate toxicity are far too low and that the protection of aquatic life is better achieved through IDNR's developed formulas (IDNR, 2009). IDNR believes that the protection of aquatic life can be achieved with TDS concentrations above 3000 mg/L as long as sodium sulfate comprise the majority of the TDS complex.(IDNR, 2009).

Task 2. Conduct additional WET testing utilizing spiked samples to simulate the concentration of dissolved minerals approved by ADEQ in the in the EDCC 3rd party rulemaking

Since the purpose of the additional WET testing is to demonstrate the ability of the approved criteria to support the aquatic life, the chronic WET tests were completed on a series of synthetic waters developed to mimic the dissolved mineral complex of the EDCC discharge and that of the three downstream segments as identified in the 3rd party rulemaking. The synthetic waters were developed to represent the maximum dissolved mineral concentrations of the EDCC outfall and of the downstream receiving segments based on the concentrations approved by ADEQ and the Commission in the EDCC 3rd party rulemaking. The synthetic waters were developed to target the sulfate, chloride and TDS concentrations approved by the ADEQ Commission. Once the grab samples were characterized, the synthetic waters were developed with the intent of maintaining the relative chemical balance characterized from the receiving stream segments.

The analytical suite completed on grab samples from the EDCC Outfall 001 and each stream segment included:

- Chloride,
- Fluoride,
- Sulfate,
- Total dissolved solids,
- Nitrite-N,
- Bicarbonate alkalinity,
- Total alkalinity,
- Carbonate alkalinity,
- Specific conductance,
- Total organic carbon,
- Total inorganic carbon,
- Boron,
- Calcium,
- Iron,
- Magnesium,
- Manganese,
- Potassium,
- Silicon,
- Sodium,
- Aluminum,
- Barium,
- Heavy metals (As, Cu, Ni, Cd, Cr, Pb, & Zn),
- Total Suspended Solids, and
- Hardness

EPA methods were used for the analyses and NPDES detection levels were reported. In addition, analyses of the synthetic waters were completed before and after the WET tests to verify that the analytical targets for the dissolved minerals were attained in the 100% exposures. These analytical results are provided in Attachment C.

The synthetic matrices were developed based on the results of analyses of water samples collected July 15, 2009 from each stream segment. The analytical results of the ambient waters, the composition of the synthetic waters and the compounds used to develop the synthetic waters are provided in Attachment D.

In addition to the analytical suite completed in the lab, in-situ physicochemical parameters were recorded at the time of sample collection and flows were recorded. This data is summarized the Table 1 below.

Results

The results of the toxicity testing on the synthetic waters developed to mimic the approved dissolved mineral criteria demonstrated that approved criteria are protective of the aquatic life communities.

Water Quality of the Subject Reaches

Water samples were collected from four locations within the Haynes Creek watershed on July 15, 2009 (Figure 1). Table 1 summarizes the in-situ physicochemical parameters measures at the time of sample collection.

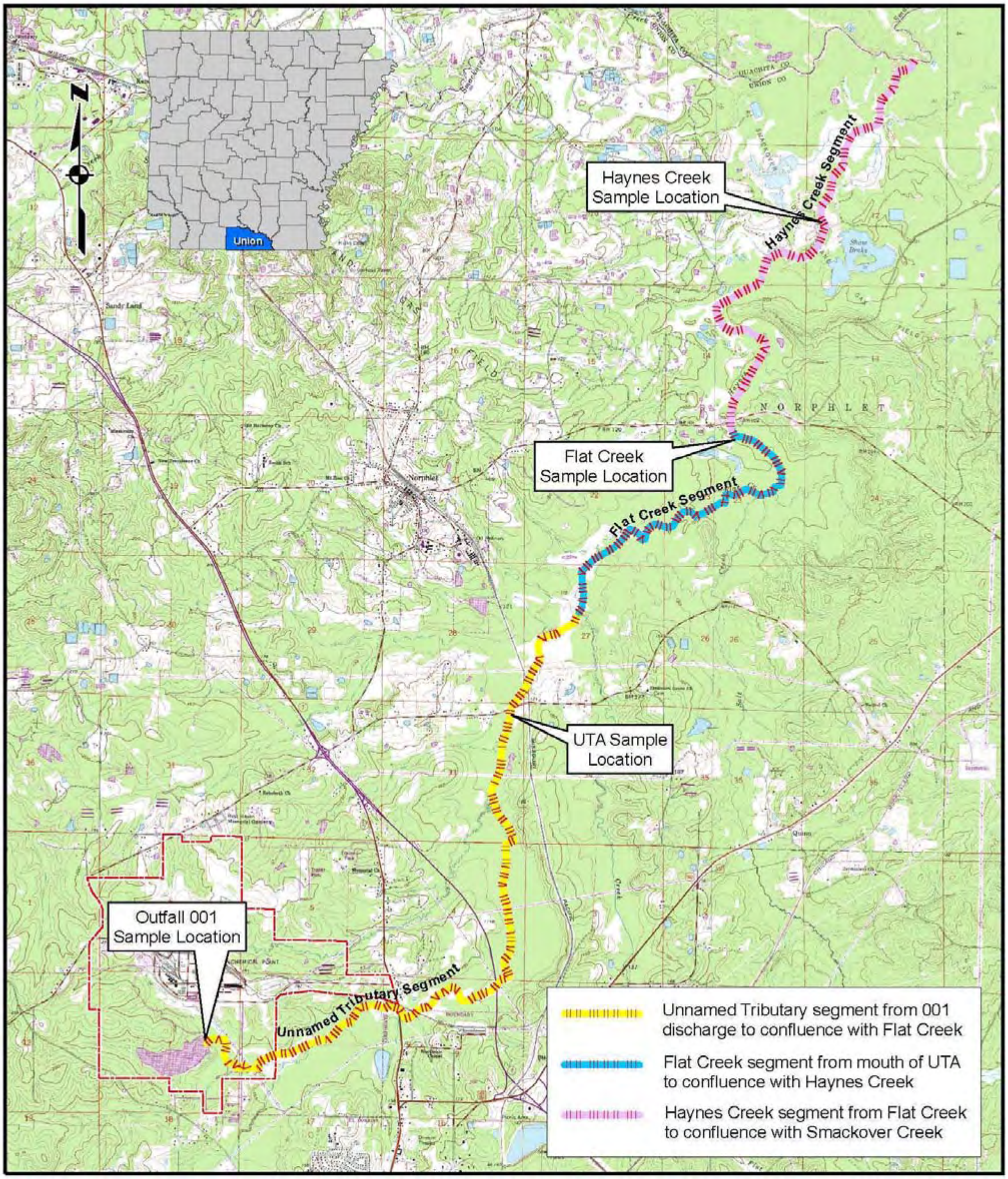

Figure 1. Stream reaches and sample locations evaluated for development of synthetic dissolved mineral matrix representing stream segments included in 3rd party rulemaking for EDCC and Haynes Creek Watershed.

Table 1. Summary of in situ physicochemical parameters as measured during sample collection. 7/15/2009.

7/15/2009	Study Reach			
Measurement	**001**	**UTA**	**Flat**	**Haynes**
Time	820	900	945	1030
Temperature, C^{o}	28.8	26.7	27.5	28.2
Dissolved Oxygen, mg/L	4.8	4	4.5	4
Specific Conductance, uS	368	342	595	1606
pH, su	8.72	7.59	7.51	7.42
Turbidity, ntu	14.1	10.4	9.92	5.27

The analytical composition of the ambient waters and the targeted sulfate, chloride and TDS concentrations are summarized in Table 2. Attachment E provides the analytical results and includes figures illustrating the downstream contributions to the dissolved mineral complex. The upper reaches (Reaches just downstream of EDCC Outfall 001 and the unnamed tributary contribute small percentages of the dissolved mineral constituents compared to the two downstream reaches. This illustrates that the majority of the TDS complex in the Haynes Creek watershed are attributed to the downstream watersheds and are predominately sodium chloride. The downstream reaches receive contributions from watersheds which have historical and current oil and gas production fields.

Table 2. Water quality of ambient waters of the Haynes Creek Watershed as sampled on 7/15/2009.

	Analyses of samples collected				Targeted dissolved mineral concentrations*			
Measurement	**001**	**UTA**	**Flat**	**Haynes**	**001**	**UTA**	**Flat**	**Haynes**
Chloride	28	25.2	100	485	23	16	165	360
Fluoride	<0.500	<0.500	<0.500	<0.500				
Sulfate	28.8	28.4	43.3	39	125	80	67	55
Nitrate- N	0.637	4.14	1.85	1.85				
Nitrite- N	1.18	<0.500	<0.500	<0.500				
Hardness	38	34	60	164				
Aluminum	0.264	0.403	0.382	0.202				
Arsenic	<0.050	<0.050	<0.050	<0.050				
Barium	0.057	0.066	0.126	0.287				
Boron	<0.100	<0.100	0.124	0.319				
Cadmium	<0.008	<0.008	<0.008	<0.008				
Calcium	10.9	10.5	18.2	47.2				
Chromium	<0.020	<0.020	<0.020	<0.020				
Copper	<0.005	<0.005	<0.005	<0.005				
Iron	0.181	0.396	0.817	0.57				
Lead	0.054	0.03	<0.022	<0.022				
Magnesium	2.75	2.96	5.05	12.4				
Manganese	0.138	0.073	0.089	0.09				
Nickel	<0.010	<0.010	<0.010	<0.010				
Potassium	7	6.93	9.14	13.3				
Selenium	<0.081	<0.081	<0.081	<0.081				
Silicon	4.45	4.65	2.16	1.47				
Sodium	57	60.5	102	239				
Zinc	<0.005	<0.005	<0.005	<0.005				
Ammonia- N	2.93	<0.50	<0.50	<0.50				
Specific conductance	397	364	634	1710				
Total dissolved solids	230	240	370	960	475	315	560	855
Total organic carbon	8.63	7.8	8.14	8.63				
Total Alkalinity	95	90	72	68				
Total Suspended Solids	11	8	6	6				
Bicarbonate alkalinity	89	90	72	68				
Carbonate Alkalinity	6	<5.0	<5.0	<5.0				
Total inorganic carbon	27.6	22.6	18.8	16.6				

* Targeted dissolved minerals as approved by ADEQ in the EDCC 3rd party rulemaking.

A TMDL for Flat Creek watershed (and the adjacent Salt Creek watershed) was completed in 2003 (FTN, 2003). The TMDL supports that the unnamed tributary does not contribute significantly to the chloride, sulfate and TDS downstream in Flat and Haynes Creek. The TMDL identified the Oil-Wasteland – Fluvaquent soil complex as dominating the watersheds comprising sixty percent of the mapped areas within the watersheds. Although oil/gas extraction was not identified as a major land use of the watersheds, a large portion of the forest/wetlands areas were considered to have been impacted by this activity. That portion of the watershed was identified as 67 to 89% of the watersheds. In addition, the TMDL indicated that were no point sources contributing to the loads in the TMDL watersheds. The TMDL identified non-point sources as past and present oil field exploration activities and urban runoff from the City of El Dorado.

The Texas Commission on Environmental Quality (TCEQ) developed a total daily maximum load (TMDL) for dissolved solids in Petronila Creek and found that saline pore water in shallow aquifers (along with historical contributions from historical oil production areas over 50+ years in the watershed) likely contributed to the high salinity (dissolved solids) of the receiving stream. The water quality standards for Petronila Creek expressed as annual average concentrations of dissolved minerals are 1500mg/L, 500mg/L and 4,000 mg/L of chloride, sulfate, and TDS respectively (http://www.tceq.state.tx.us/assets/public/implementation/water/tmdl/32petronila/32-petronilatmdlapproved.pdf).

WET Tests Results

The WET tests demonstrated that the approved dissolved mineral criteria are protective of the typical in stream aquatic life communities of the receiving streams for which the criteria were approved. Table 3 provides a summary of the WET test results and the details of each test are provided in Attachment F. The WET tests were the routine 7-day chronic tests using both the fathead minnow (*Pimephales promelas)* and the water flea (*Ceriodaphnia dubia).*

Table 3. Results of the 7-day chronic WET tests completed on synthetic waters.

ORGANISM	Water Flea				Fathead Minnow			
REACH	**001**	**UTA**	**Flat**	**Haynes**	**001**	**UTA**	**Flat**	**Haynes**
ENDPOINT								
Survival NOEC	100	100	100	100	100	100	100	100
Sub-lethal NOEC	100	100	50	25	100	100	100	100
Percent survival in 100%	90	90	100	100	94	94	94	96
Sub-lethal 100% Cnt.	12.2 16.6	17.76 18.2	14 15	9 15	0.536 0.378	0.399 0.378	0.451 0.378	0.564 0.378
Dissolved mineral concentration	Target Vs. Actual	Target Vs. Actual	Target Vs. Actual	Target Vs. Actual	Target Vs. Actual	Target Vs. Actual	Target Vs. Actual	Target Vs. Actual
Chloride mg/L	23/28	16/18	165/157	360/378	23/28	16/18	165/157	360
Sulfate mg/L	125/109	80/80	67/61	55/51	125/109	80/80	67/61	55/51
TDS mg/L	475/410	315/300	560/510	855/810	475/410	315/300	560/510	855/810

The fathead minnow WET tests **PASSED ALL tests endpoints in ALL reaches represented**, including the sub-lethal growth endpoint. The minimum survival in the 100% exposures was 94 percent. **The growth endpoint of the 100% exposure surpassed the control growth in all tests.**

The water flea **PASSED the survival endpoint in ALL reaches represented.** The minimum survival in any single 100% exposure was 90%. The sub-lethal NOEC passed in 2 of the 4 tests. The two which passed were the outfall and the UTA synthetic exposures.

The failures occurred in the Flat Creek and the Haynes Creek synthetic exposures. The statistical differences in the control and the synthetic waters for these two reaches may or may not be directly related to the dissolved minerals. The control criteria for a valid test requires that the average neonate production in the control be 15 per female. The control reproduction minimally attained that criterion with only 15 per female. The two synthetic waters that passed produced 17 and 18 per female. The reduced neonate production in the Flat and Haynes synthetic waters impacted the determination of significance. The impact of the variability in the control neonate production is additionally demonstrated in that although the neonate per female production in the 100% exposure of the Outfall 001 synthetic waters was less that that produced in the Flat synthetic exposure (12.2 and 14 respectively), it was not significantly different that the control in that test which produced 16.6 neonates per female.

Additionally, the organisms exposed in the WET test were not allowed to acclimate to the changes in the dissolved minerals between their culture medium and the test exposures. The literature referenced above in the discussion of the existing state of the science, supports that organisms demonstrate a level of acclimation to dissolved mineral conditions. The exposure of organisms cultured in soft waters with low dissolved mineral concentrations are impacted differently than those invertebrate assemblages that reside (and often thrive) in that environment.

The performance of the WET tests demonstrate that the approved dissolved mineral criteria are supportive of the aquatic life in the stream reaches subject of the rulemaking.

Task 3. Complete Modeling Using GRI Salinity Model

The toxicity potential of the adopted dissolved mineral criteria as presented in the 3^{rd} party rulemaking was determined using the salinity model developed by the Gas Research Institute. The model (A salinity/toxicity relationship to predict acute toxicity of Saline waters to freshwater organisms, D. Gulley and D.R. Mount, 1996) was developed to predict acute toxicity (24, 48 and 96 hour toxicity LC 50 and predicted percent survival) based on mineral concentration and mineral imbalances of seven major ions including Na, K, Ca, Mg, Cl, SO_4 and HCO_3. The model is a simplistic acute toxicity predictor. In addition to modeling the EDCC effluent, the model was used to predict the potential for toxicity for the three additional stream segments included in the 3^{rd} party rulemaking. Mineral concentrations representing the 95^{th} percentile of the historical discharge were utilized as the baseline modeling to demonstrate the toxicity potential at the maximum possible effluent concentrations. Additional modeling for each subsequent downstream segment was completed based on the ADEQ approved criteria.

The concentrations of the seven major ions as characterized by the sample collected on July 15, 2009 from each stream segment were used in the predictive modeling using the GRI model. Baseline model runs were completed utilizing known concentrations of the seven target ions (as measured on July 15, 2009) and the concentrations of sulfate, chloride, and TDS as approved in the EDCC 3rd party rulemaking (the concentrations approved in the rulemaking represents the 95th percentile of the long term data record for the target parameters in accordance with the ADEQ CPP policies to address the dissolved mineral criterion).

The GRI modeling projected the toxicity potential of the approved criteria for each stream segment.

Results

The results of the GRI modeling demonstrates that there is NO predicted toxicity related to dissolved mineral concentrations at the concentrations approved by the EDCC 3rd party rulemaking. Table 4 presents the model input data and Table 5 summarizes the results of the GRI salinity model predicting percent survival of three target species in waters representing both ambient conditions as characterized by samples collected on July 15, 2009 and using the dissolved mineral concentrations approved by ADEQ Commission in the EDCC 3rd party rulemaking. The print-outs of the individual model runs are provided in Attachment G.

The GRI model failed to predict lethality to any of the three species at any of the dissolved mineral combinations for any of the study reaches. The predicted minimum survival was projected in the Haynes Creek exposure and was 97.3 % survival, only a 2.7 percent lethality in 100% exposure. None of the model runs predicted significant lethality in any of the projected dissolved mineral combinations.

Table 4. Dissolved mineral water quality of ambient waters in the Haynes Creek Watershed and the target sulfate , chloride and TDS utilized in the GRI modeling 7/15/2009

Parameter	Dissolved minerals as measured in July 2009				Targeted dissolved mineral concentrations			
	001	**UTA**	**Flat**	**Haynes**	**001**	**UTA**	**Flat**	**Haynes**
Chloride	28	25.2	100	485	23	16	165	360
Sulfate	28.8	28.4	43.3	39	125	80	67	55
Hardness	38	34	60	164	--	--	--	--
Calcium	10.9	10.5	18.2	47.2	--	--	--	--
Magnesium	2.75	2.96	5.05	12.4	--	--	--	--
Manganese	0.138	0.073	0.089	0.09	--	--	--	--
Potassium	7	6.93	9.14	13.3	--	--	--	--
Sodium	57	60.5	102	239	--	--	--	--
Total dissolved solids	230	240	370	960	475	315	560	855

Table 5. EDCC 3rd Party Rulemaking STR Model Results using the GRI Salinity model.[A]

	% Survival at each Site[B]							
Test	**001**	**001 b**	**UTA**	**UTA b**	**Flat**	**Flat b**	**Haynes**	**Haynes b**
***Ceriodaphnia* 24-h**	100	99.9	100	100	100	99.9	99.7	99.8
***Ceriodaphnia* 48-h**	99.9	99.9	99.9	99.9	99.9	99.8	99	99.5
***Daphnia* 24-h**	99.5	99.4	99.5	99.5	99.3	99.1	98.2	98.6
***Daphnia* 48-h**	99.4	99.3	99.4	99.4	99	98.8	97.3	97.9
Fathead Minnow 24-h	99.5	99.5	99.5	99.5	99.5	99.4	99.2	99.3
Fathead Minnow 48-h	99.4	99.4	99.4	99.4	99.4	99.3	98.9	99
Fathead Minnow 96-h	98.5	98.4	98.5	98.4	98.4	98.2	97.4	97.7

A=Results and raw data from the STR model are available upon request in the form of a 3.5 inch diskette. In order to access the data and retrieve model run results a 3.5 inch diskette drive is required. The STR model runs in MS-DOS format and must be run from the diskette drive on newer windows based computers. To run the model type "a:\STR" into the "Run" program window available from the "start" menu. The program will initialize and provide a user friendly menu system that will walk you through use of the model.

B= Sites that end in "b" reflect targeted chloride and sulfate levels represented by the ADEQ approves criteria

These results support the findings of the aquatic life field assessment presented during the 3rd party rulemaking. The criteria approved by ADEQ in the EDCC 3rd party rulemaking are supportive of the aquatic life of the receiving streams as demonstrated by:

- lack of toxicity as represented by the WET testing history and as provided by the results of the chronic WET testing completed as part of this effort,
- the existing literature provides that the effect of dissolved minerals in ambient waters is widely variable depending on the chemical composition of the dissolved mineral complex and that concentrations approved in the EDCC 3rd party rulemaking are well below concentrations which are typically considered as causing adverse effects,
- the lack of toxicity (even at increased concentrations) as predicted using the GRI modeling,
- the criteria approved for the stream segments are less than the criteria that have been approved for numerous other stream segments and,
- the criteria are supportive of the typical aquatic life of the target stream reaches.

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Attachment A

EPA ROD

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 6
1445 ROSS AVENUE, SUITE 1200
DALLAS, TX 75202-2733

APR 14 2009

Ms. Teresa Marks
Director
Arkansas Department of Environmental Quality
5301 Northshore Drive
North Little Rock, AR 72118-5317

Dear Ms. Marks:

I would like to provide you with the Environmental Protection Agency's (EPA) findings concerning the review of additional supporting information related to several site-specific water quality standards revisions to Regulation No. 2, *Regulation Establishing Water Quality Standards for Surface Waters of the State of Arkansas* originally submitted by your letters, dated September 17, 2007. These site-specific revisions were for three separate submissions: El Dorado Chemical Company, Great Lakes Chemical Corporation, and Lion Oil Company.

Your original September 17, 2007, letters included a request for EPA's approval of the removal of the domestic water supply designated uses, along with revised site-specific aquatic life criteria for chloride, sulfate, and total dissolved solids (TDS). EPA previously approved the removal of the domestic water supply uses from the waters associated with the El Dorado Chemical Company (EDCC) and four of five requested waterbodies for Great Lakes Chemical Corporation (GLCC), but was not able to approve the use removals associated with the fifth GLCC waterbody segment or the three waterbody segments associated with Lion Oil. In today's action, EPA approves the removal of the domestic water supply use for these four waters, given that they are not currently used as a source of supply for a public water system, nor are they being considered for such use and are intermittent in nature.

As you know, EPA was not able to approve the site-specific criteria revisions for the three separate submissions from EDCC, GLCC and Lion Oil as detailed in our January 3, 2008, letters to you. EPA was not able to take action on these submissions because they lacked specific supporting information necessary for EPA approval. EPA requested specific additional information for these provisions in the January 3, 2008 letter. Your August 14, 2008, response included some, but not all of the requested information. EPA staff requested the remaining supporting information via e-mail on November 11, 2008. Additional data were forwarded to EPA via email on November 19, 2008.

EPA again reviewed the submissions from EDCC, GLCC and Lion Oil taking into consideration the additional supporting information that was made available. Based on that subsequent review, EPA has determined that supporting documentation remains insufficient to demonstrate that the site-specific minerals criteria for the waterbodies associated with EDCC, GLCC, and Lion Oil are appropriately protective of aquatic life. Therefore, EPA disapproves the site-specific chloride, sulfate, and TDS criteria for the EDCC, GLCC, and Lion Oil submissions. A detailed basis for EPA's determination and a description of the specific issues regarding the adequacy of these studies and supporting documentation are identified in the enclosed Record of Decision. As described in 40 CFR §131.21(c), new and revised standards do not go into effect for CWA purposes until approved by EPA. Therefore, the previously approved numeric criteria under Regulation No. 2 (April 23, 2004) remain in effect for CWA purposes for all waters identified in the EDCC, GLCC and Lion Oil submissions.

I would like to acknowledge the efforts of the Pollution Control and Ecology Commission, and particularly Arkansas Department of Environmental Quality (ADEQ). We encourage the Commission and ADEQ to work with the third parties, EDCC, GLCC, and Lion Oil, in responding to the issues identified here and detailed in the enclosed Record of Decision.

We look forward to the continuation of our work with you on these water quality standards revisions and encourage early coordination on any future proposed water quality standards revisions to facilitate EPA's review of State-adopted water quality standards submitted for approval. If you have any questions or concerns, please contact me at (214) 665-7101, or have your staff contact Russell Nelson at (214) 665-6646 or Matt Hubner at (214) 665-9736.

Sincerely yours,

Miguel I. Flores
Director
Water Quality Protection Division

Enclosure

cc: Steve Drown, Chief, Water Division, ADEQ
Sarah Clem, Technical Assistance Manager, ADEQ

Enclosure

RECORD OF DECISION: EPA APPROVAL AND DISAPPROVAL OF SITE-SPECIFIC REVISIONS TO THE ARKANSAS WATER QUALITY STANDARDS

Site Specific Domestic Water Supply Use Removal and Minerals Criteria Revisions for Great Lakes Chemical Company (GLCC), El Dorado Chemical Company (EDCC), and Lion Oil
Union County, Arkansas

U.S. Environmental Protection Agency – Region 6

March 2009

Enclosure

RECORD OF DECISION: EPA APPROVAL AND DISAPPROVAL OF SITE-SPECIFIC REVISIONS TO THE ARKANSAS WATER QUALITY STANDARDS

Site Specific Domestic Water Supply Use Removal and Minerals Criteria Revisions for Great Lakes Chemical Company (GLCC), El Dorado Chemical Company (EDCC), and Lion Oil
Union County, Arkansas

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EPA APPROVAL AND DISAPPROVAL OF SITE-SPECIFIC REVISIONS TO THE ARKANSAS WATER QUALITY STANDARDS

Site Specific Domestic Water Supply Use Removal and Minerals Criteria Revisions for Great Lakes Chemical Company (GLCC), El Dorado Chemical Company (EDCC), and Lion Oil
Union County, Arkansas

I. INTRODUCTION

Purpose

As described in §303(c) of the Clean Water Act (CWA) and in the standards regulation (40 CFR §131.20), States and authorized Tribes have primary responsibility to develop and adopt water quality standards to protect their waters. Authority to approve or disapprove new and/or revised standards submitted to EPA for review has been delegated to the Water Quality Protection Division Director, in Region 6. Tribal or State water quality standards are not considered effective under the CWA until approved by EPA.[1]

The purpose of this record of decision is to provide the basis for the Environmental Protection Agency's (EPA) approval of domestic drinking water use removals and disapproval of site-specific water quality criteria revisions to Regulation No. 2: *Regulation Establishing Water Quality Standards for Surface Waters of the State of Arkansas* adopted by the Arkansas Pollution Control and Ecology Commission (APC&EC) in Minute Order 07-18. The drinking water use removals and site-specific revisions for chloride, sulfate, and total dissolved solids (TDS) are associated with three separate submissions: El Dorado Chemical Company (EDCC), Great Lakes Chemical Corporation (GLCC) and Lion Oil Company.

Chronology of Events

August 31, 2006	Three individual third parties, EDCC, GLCC, and Lion Oil, filed a petition with the APC&EC to amend Regulation No. 2.

[1] "Alaska rule" [*Federal Register*: April 27, 2000 (Volume 65, Number 82)]

September 22, 2006	The APC&EC's Regulations Committee met to review the petition and recommended that the Commission institute a rule-making proceeding to consider adopting the proposed revisions to Regulation No. 2.
September 22, 2006	The APC&EC accepted the Regulations Committee recommendation and initiated the rulemaking proceeding via Minute Order 06-37.
September 27-28, 2006	Public notice of the proposed rule-making was published.
November 13, 2006	Public hearing on the proposed rule-making was held in El Dorado, Arkansas.
November 29, 2006	Public comment period ended on the proposed changes to Regulation No. 2.
January 19, 2007	Responsiveness summary was filed with the APC&EC.
June 22, 2007	Teresa Marks, Director, Arkansas Department of Environmental Quality (ADEQ), signed Minute Order 07-18 adopting changes to Regulation No. 2.
September 17, 2007	Miguel I. Flores, Director, Water Quality Protection Division, EPA Region 6, received letter from Teresa Marks, Director, ADEQ, requesting EPA approval of the adopted revisions and transmitting the water quality standards submission package.
November 9, 2007	EPA approves removal of domestic drinking water uses for EDCC and the majority for GLCC. No action is taken on all segments for Lion Oil and 1 for GLCC.
January 3, 2008	EPA issues no action letter to Teresa Marks (ADEQ) concerning site specific criteria and drinking water use removals.
August 14, 2008	Miguel I. Flores receives letter from Teresa Marks responding to the issues raised by EPA in the January 3, 2008 no action letter.
November 11, 2008	EPA requests additional material not included in previous letter from Teresa Marks.
November 19, 2008	ADEQ forwards additional materials to EPA staff.

Background

In separate letters dated August 17, 2007, from Teresa Marks, ADEQ, to Miguel Flores, EPA Region 6, ADEQ requested EPA approval of several site-specific water quality standards revisions to Regulation No. 2 for twelve streams and multiple segments in the Gulf Coastal ecoregion of Arkansas. These streams are the receiving waterbodies for discharges from EDCC, GLCC and Lion Oil, in Union County, Arkansas.

The letter included a request for EPA approval of the removal of the domestic water supply designated uses for eleven of the twelve waterbodies associated with the facilities identified above, along with site-specific criteria for chloride, sulfate, and total dissolved solids (TDS) for all twelve waterbodies and segments. EPA took no action in relation to the site-specific minerals criteria for all waterbodies and for four waterbodies concerning drinking water use removal. This record of decision applies to the site-specific criteria revisions and remaining domestic water supply designated use removals for the waterbodies for which such action was requested. The general details of each request are addressed individually in the following text.

Summary of Revised Provisions

A. El Dorado Chemical Company

Table 1 below provides a detailed description of the four streams to which the site-specific minerals revisions apply for EDCC. EPA previously approved the removal of the domestic water supply use from UTB, UTA, Flat Creek, and Haynes Creek. Table 2 depicts the proposed site-specific criteria for chloride, sulfate, and TDS, for the four waterbodies.

Table 1. Description of stream segments for which the proposed site-specific criteria revisions apply.

Stream Segment Descriptions
Unnamed tributary to the unnamed tributary to Flat Creek (UTB) from the El Dorado Chemical Company outfall 001 discharge to the confluence with unnamed tributary of Flat Creek (UTA)
Unnamed tributary to Flat Creek (UTA) from the confluence of UTB to the confluence with Flat Creek
Flat Creek from the mouth of UTA tributary to the mouth of Haynes Creek
Haynes Creek from the confluence of Flat and Salt Creeks downstream to the confluence with Smackover Creek

Table 2. Proposed site-specific water quality criteria revisions for chloride, sulfate, and TDS, for four waterbodies submitted by ADEQ to EPA for review and approval.

Stream Segment Name	Chloride (mg/L)		Sulfate (mg/L)		TDS (mg/L)	
	Previous	Revised	Previous	Revised	Previous	Revised
UTB	14	23	31	125	123	475
UTA	14	16	31	80	123	315

Stream Segment Name	Chloride (mg/L)		Sulfate (mg/L)		TDS (mg/L)	
	Previous	Revised	Previous	Revised	Previous	Revised
Flat Creek	14	165	31	67	123	560
Haynes Creek	14	360	31	55	123	855

B. Great Lakes Chemical Corporation

Table 3 below provides a detailed description of the six streams for which the proposed site-specific minerals revisions and drinking water use removal apply for GLCC. EPA previously approved the removal of domestic water supply use from UT002, UT004, UT003, and UTLCB-2. Bayou de Loutre was not approved for drinking water use removal and is addressed later in the document. Table 4 depicts the proposed site-specific criteria for chloride, sulfate, and TDS, for the six waterbodies.

Table 3. Description of stream segments for which the proposed site-specific criteria revisions and one drinking water use removal apply.

Stream Segment Descriptions
Unnamed tributary into which Great Lakes Chemical Corporation outfall 002 discharges (UT002) to the confluence with Bayou de Loutre
Unnamed tributary into which Great Lakes Chemical Corporation outfall 004 discharges (UT004) to the confluence with Bayou de Loutre
Bayou de Loutre from the mouth of Outfall 004 tributary downstream to the mouth of Gum Creek[2]
Unnamed tributary to an unnamed tributary of Little Cornie Bayou (UT003)
Unnamed tributary of Little Cornie Bayou (UTLCB-2) to Little Cornie Bayou
Little Cornie Bayou from the confluence of UTLCB-2 to the Arkansas/Louisiana State line[3]

Table 4. Proposed site-specific water quality criteria revisions for chloride, sulfate, and TDS, for six waterbodies submitted by ADEQ to EPA for review and approval.

Stream Segment Name	Chloride (mg/L)		Sulfate (mg/L)		TDS (mg/L)	
	Previous	Revised	Previous	Revised	Previous	Revised
UT002	14	65	31	35	123	141
UT004	14	239	--	--	123	324
Bayou de Loutre	250	278	--	--	--	--
UT003	14	538	31	35	123	519

[2] Bayou de Loutre – No action taken by EPA (January 3, 2008) on removal of domestic water use
[3] Little Cornie Bayou – Not identified for drinking water use removal

Stream Segment Name	Chloride (mg/L)		Sulfate (mg/L)		TDS (mg/L)	
	Previous	Revised	Previous	Revised	Previous	Revised
UTLCB-2	14	305	--	--	123	325
Little Cornie Bayou	200	215	20	25	--	--

C. Lion Oil

Table 5 below provides a detailed description of the three streams for which the proposed drinking water use removal apply for Lion Oil. EPA previously took no action in the removal of the domestic water supply use for Loutre Creek and two of the nine segments of Bayou de Loutre upstream of Gum Creek. Table 4 depicts the proposed site-specific criteria for chloride, sulfate, and TDS, for the six waterbodies.

Table 5. Description of stream segments for which the proposed domestic water supply designated use removals apply.

Stream Segment Descriptions
Loutre Creek from Highway 15 South to the confluence of Bayou de Loutre
Bayou de Loutre from Loutre Creek to the discharge for the City of El Dorado South facility*
Bayou de Loutre from the discharge for the City of El Dorado South downstream to the mouth of Gum Creek**

Table 6. Proposed site-specific water quality criteria revisions for chloride, sulfate, and TDS, for Loutre Creek and nine segments of Bayou de Loutre submitted by ADEQ to EPA for review and approval.

Stream Segment Name	Chloride (mg/L)		Sulfate (mg/L)		TDS (mg/L)	
	Previous	Revised	Previous	Revised	Previous	Revised
Loutre Creek	14	256	31	997	123	1756
Bayou de Loutre*	250	264	90	635	500	1236
Bayou de Loutre**	--	--	90	431	500	966
Bayou de Loutre[4]	--	--	90	345	750	780
Bayou de Loutre[5]	--	--	90	296	--	--
Bayou de Loutre[6]	--	--	90	263	--	--

[4] Bayou de Loutre – from the mouth of Gum Creek downstream to the mouth of Boggy Creek
[5] Bayou de Loutre – from the mouth of Boggy Creek downstream to the mouth of Hibank Creek
[6] Bayou de Loutre – from the mouth of Hibank Creek downstream to the mouth of Mill Creek

Stream Segment Name	Chloride (mg/L)		Sulfate (mg/L)		TDS (mg/L)	
	Previous	Revised	Previous	Revised	Previous	Revised
Bayou de Loutre[7]	--	--	90	237	--	--
Bayou de Loutre[8]	--	--	90	216	--	--
Bayou de Loutre[9]	--	--	90	198	--	--
Bayou de Loutre[10]	--	--	90	171	--	--

II. REVISED PROVISIONS EPA IS DISAPPROVING

Site-Specific Criteria for Chloride, Sulfate, and TDS

Supporting documentation remains insufficient to demonstrate that the site-specific minerals criteria for the waterbodies associated with EDCC, GLCC, and Lion Oil are appropriately protective of aquatic life. Although Section 3.6.2 – "Whole Effluent Toxicity (WET) Testing" of the August 17, 2007 submissions provided the results of outfall biomonitoring for the water flea and fathead minnow, it remains unclear what minerals concentrations (chloride, sulfate, and TDS) were associated with each of these tests and whether or not the minerals concentrations during WET testing were representative of the adopted site-specific minerals criteria under review for effluent receiving streams.

The evidence included in the reports and subsequent materials requested by EPA do not include a general evaluation or review of the site-specific criteria for associated waterbodies in light of the available scientific literature concerning the toxicity effects of chloride, sulfate, and TDS to aquatic organisms. Supporting documentation from the literature or other appropriate documentation is important for providing a clear demonstration that the proposed site-specific criteria are appropriately protective of the aquatic life uses (Gulf Coastal seasonal or perennial fishery) in these waterbodies. Such information may also be useful to supplement the biomonitoring information, especially if the minerals concentrations present during the biomonitoring testing referenced above are not available or were not representative of the adopted site-specific minerals criteria under review for receiving waterbodies (UTB - EDCC; UT002, UT003, UT004 - GLCC; and Loutre Creek - Lion Oil)

Literature (Mount and Gulley)[11] cited in ADEQ's August 14, 2008 response, proposes that the development of the salinity/toxicity relationship (STR) model supports higher

[7] Bayou de Loutre – from the mouth of Mill Creek downstream to the mouth of Buckaloo Branch
[8] Bayou de Loutre – from the mouth of Buckaloo Branch downstream to the mouth of Bear Creek
[9] Bayou de Loutre – from the mouth of Bear Creek to the final segment of Bayou de Loutre
[10] Bayou de Loutre (Final Segment) to the Arkansas/Louisiana state line
[11] Mount, D.R. and D.D. Gulley. 1992. Development of a salinity/toxicity relationship to predict acute toxicity of saline waters to freshwater organisms. GRI-92/0301. Gas research Institute, Chicago, IL, USA

acute lethality concentrations than those proposed in the criteria. EPA's review of this study indicates lower concentrations of ions in combination can adversely affect sensitive aquatic species, yet other combinations may ameliorate such effects. Thus, the necessity for documentation and identification of specific mineral concentrations is critical to supporting that protection of aquatic life uses will be met by the proposed criteria.

EPA disapproves all proposed site-specific criteria revisions for chloride, sulfate, and TDS in all submissions on the grounds that current documentation provided by ADEQ does not clearly demonstrate adequate protection of aquatic life uses for the receiving and associated waterbodies. Under 40 CFR §131.21(c), new and revised standards do not go into effect for CWA purposes without EPA approval. EPA does not intend to propose or promulgate criteria for the previously identified waters. Therefore, previous approved numeric criteria under Regulation No. 2 (April 23, 2004) remain in effect.

If the State decides to pursue site-specific revisions for minerals in these waterbodies, adequate supporting scientific documentation must be provided to show that the Gulf Coastal seasonal or perennial fishery aquatic life uses will be protected. The previously requested mineral concentration data associated with outfall WET testing are necessary to support that effluent being tested reflect proposed criteria values. If these values are not available, use of STR modeling as well as background literature searches on ecoregion species' salinity tolerances would provide a minimal level of support to the revision.

III. REVISED PROVISIONS EPA IS APPROVING

Domestic Water Supply Use Removals

EPA previously took no action concerning the removal of domestic drinking water uses for the waterbodies listed above for GLCC and Lion Oil. Documentation, in the form of a letter from Arkansas Department of Health (ADH), showing that there were no current or proposed public drinking water considerations for these waterbodies was missing or inadequate and therefore did not support the revision.

Two letters, dated July 24, 2006 and May 12, 2008, from ADH were submitted by ADEQ on EPA's request subsequent to the study report. The letters respectively state that Bayou de Loutre upstream of Gum Creek and Loutre Creek are not currently used as a source of supply for a public water system, nor are they being considered for such use.

In addition, the UAA study cites two reasons (see 40 CFR §131.10(g)(2) and (5)) for why the domestic water supply use is not an attainable use in Loutre Creek and the three segments of Bayou de Loutre. Specifically, the report cites the intermittent nature of these streams and lack of consistent base flow, along with the presence of shallow pools and run areas that would not support the intake and storage areas necessary for the development of a domestic water supply system.

EPA agrees with the conclusions of the study and approves the removal of the domestic water supply use from Bayou de Loutre from the confluence of UT004 downstream to the confluence of Loutre Creek for the GLCC submission. For Lion Oil, EPA approves the removal of the domestic water supply use from Loutre Creek and two segments of Bayou de Loutre between the confluence with Loutre Creek and confluence with Gum Creek.

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Mrs Teresa Marks
ADEQ
5301 Northshore Drive
North Little Rock, AR 72118-5317

Attachment B

Supplemental Info Study Plan

219 Brown Lane Bryant, AR 72022 (501) 847-7077 (501) 847-7943 fax

GBMc

June 9, 2009

Mr. Steve Drown, Chief
Water Division
Arkansas Department of Environmental Quality
5301 Northshore Drive
North Little Rock, AR 72118

Re: Aquatic Life Support Justification Study Plan to Address EPAs Mineral ROD Associated with El Dorado Chemical Company (EDCC), in Union County, Arkansas
NPDES AR0000752, AFIN 70-00040
GBMc No. 2042-06-070

Dear Mr. Drown:

On behalf of EDCC, please find the attached Study Plan developed to address issues that led to EPAs denial of modifications to Regulation No. 2 implementing the dissolved mineral criteria adopted by the Arkansas Department of Pollution Control and Ecology Commission (the Commission). The 3rd party rulemaking modified the sulfate, chloride and total dissolved solids criteria in the EDCC Outfall 001 receiving stream, and in unnamed and named tributaries of the Flat Creek Watershed in Union County, Arkansas.

In their ROD of April 14, 2009 and during the subsequent conference call on April 29, 2009, EPA provided guidance as to the rationale leading to their denial and suggested additional actions to provide documentation EPA perceived as lacking. EPA concerns regarding the potential for instream aquatic toxicity from the adopted criteria were the basis for its decision as stipulated in the ROD. The ROD specifically stated that:

> "EPA disapproves all proposed site specific criteria revisions for chloride, sulfate and TDS in all submissions on the grounds that current documentation provided by ADEQ does not clearly demonstrate adequate protection of aquatic life uses for the receiving streams and associated waterbodies."

The proposed Study Plan seeks to provide additional information to clearly demonstrate that the approved criteria are adequate for the protection of aquatic life uses for the receiving streams. The approach proposed in the Study Plan focuses on those efforts identified by EPA during the conference call that would reasonably provide the additional information EPA requires.

It is our understanding that this proposed Study Plan will be forwarded to EPA for their review and comment. However, EDCC wishes to proceed with the proposed activities to have the documentation available prior to the expiration of the current consent administrative order (December 2009) authorizing the current dissolved mineral discharge conditions. Therefore, EDCC intends to proceed with the implementation of the proposed study plan after consideration of any comments and/or edits provided by ADEQ.

EDCC looks forward to the resolution of the rulemaking issues and appreciates the efforts of ADEQ in their review and comments provided related to the proposed plan. If you have any questions, please do not hesitate to contact me or Vince Blubaugh at (501) 847-7077.

Respectfully submitted,
GBM[c] & ASSOCIATES

Roland McDaniel
Principal/Senior Scientist

Enclosure

CC: Sarah Clem, Water Division ADEQ
John Carver, EDCC
Greg Withrow, EDCC
Chuck Nestrud, CN&J

Aquatic Life Support Justification
Study Plan
Dissolved Minerals Rulemaking
El Dorado Chemical Company

Background

In the Record of Decision (ROD) dated April 14, 2009 (Attachment A), EPA informed ADEQ that they were unable to approve the site specific criteria revisions for dissolved minerals (sulfate, chloride and total dissolved solids) previously approved by Arkansas Department of Pollution Control & Ecology (ADPC&E) Commission in response to the 3rd party rulemaking initiated by El Dorado Chemical Company (EDCC). In the justification for the ROD, EPA stated that:

> "....EPA has determined that supporting documentation remains insufficient to demonstrate that the site-specific minerals criteria for the waterbodies.....are appropriately protective of aquatic life."

EPA implicated that lingering concerns regarding the potential for in-stream aquatic toxicity from the adopted criteria was the basis for its decision as stipulated in the ROD. The ROD specifically stated that "EPA disapproves all proposed site specific criteria revisions for chloride, sulfate and TDS in all submissions on the grounds that current documentation provided by ADEQ **does not clearly demonstrate** adequate protection of aquatic life uses for the receiving streams and associated waterbodies [emphasis added]." The ROD does offer that ADEQ could pursue the site specific revisions for minerals in these waterbodies by providing adequate scientific documentation to show that the Gulf Coastal seasonal and perennial fishery aquatic life uses will be protected.

Subsequent to receiving the ROD, EPA, ADEQ and representatives for the 3rd party petitioners participated in a conference call on April 29, 2009. The purpose of the call was to clarify EPA concerns that resulted in the decision and to determine what information EPA might require to address those perceived information deficiencies. During the conference call, approaches to address EPA concerns were discussed including:

1. an effort to more clearly identify mineral concentrations during historical WET testing as data exist;

2. a literature review of current research related to dissolved mineral toxicity;

3. speciation of the dissolved minerals at EDCC during routine WET testing over the next 12 months to characterize the current dissolved mineral complex of each effluent;

4. modeling using GRI salinity model to predict the potential for toxicity at the concentrations adopted by the ADEQ rulemaking; and

5. additional chronic WET testing on a simulated effluent and other water samples developed to mimic the receiving stream segments downstream of the discharge from EDCC which were the subject of the 3rd party rulemaking and approved by ADEQ and the Commission.

EPA indicated that items 2, 4 and 5 would be of most interest and could provide the additional information allowing further evaluation of the potential for instream toxicity and the support of aquatic life in the receiving streams.

In addition, EPA requested that a "Study Plan" be developed to set forth the process by which the additional information would be presented and to establish a decision process that would document maintenance of the aquatic life uses.

Based on the information presented in the ROD and the additional discussion during the conference call, it was determined that the following approach would be implemented to address the EPA concerns related to the protection of the aquatic life uses of the receiving streams.

Plan Objective

The objective of the Dissolved Minerals Use Support Study Plan is to develop and provide additional documentation addressing issues identified by EPA as those most likely to address the deficiencies stipulated in the Dissolved Mineral ROD related to the potential for instream toxicity.

The proposed approach includes three tasks including:

1. develop additional information through an updated literature review on dissolved mineral toxicity;

2. conduct additional WET testing utilizing spiked samples to simulate the concentrations proposed in the rulemakings; and

3. complete modeling using GRI model.

Task 1. Develop additional information through an updated literature review of dissolved mineral toxicity

This task will review and summarize the current scientific literature related to the toxicity of dissolved minerals with a focus on Cl, SO_4 and TDS. The research will implicate a range of concentrations at which the target dissolved minerals present a toxicity potential. The research data will be compared to the criteria approved by ADEQ and the Commission.

The goal of this task is to supplement the information presented during the rulemaking process and clarify the existing scientific data related to dissolved mineral toxicity.

The potential for toxicity associated with the concentrations adopted in the recent rulemaking will be evaluated in light of the current scientific literature.

Schedule

Complete 30 days after the Study Plan has been accepted by ADEQ and EPA.

Task 2. Conduct additional WET testing utilizing spiked samples to simulate the concentration of dissolved minerals proposed in the rulemakings

Chronic WET tests will be completed on a series of synthetic matrices developed to mimic the dissolved mineral complex of the EDCC discharge and that of the three downstream segments as identified in the 3rd party rulemaking. The synthetic matrix will be developed to represent the maximum dissolved mineral concentrations of the EDCC outfall and of the downstream receiving segments based on the concentrations approved by ADEQ and the Commission in the 3rd party rulemaking.

The synthetic matrices will be developed based on the results of analyses completed on water samples from each stream segment. A chemical balance of the synthetic matrix will be developed to characterize the matrix. The analytical suite will include:

- Chloride,
- Fluoride,
- Sulfate,
- Total dissolved solids,
- Nitrite-N,
- Bicarbonate alkalinity,
- Total alkalinity,
- Carbonate alkalinity,
- Specific conductance,
- Total organic carbon,
- Total inorganic carbon,
- Boron,
- Calcium,
- Iron,
- Magnesium,
- Manganese,
- Potassium,
- Silicon,
- Sodium,
- Aluminum,
- Barium,
- Heavy metals (As, Cu, Ni, Cd, Cr, Pb, & Zn),
- Total Suspended Solids, and
- Hardness

EPA methods will be used for the analyses and NPDES detection levels will be attained. The analyses will be completed before and after the WET tests to verify the analytical targets for the dissolved minerals were attained in the 100% exposures.

Schedule

Complete 90 days after the Study Plan has been accepted by ADEQ and EPA.

Task 3. Complete modeling using GRI model

The toxicity potential of the adopted dissolved mineral criteria as presented in the 3rd party rulemaking will be determined through a modeling effort using the salinity model developed by the Gas Research Institute. The model (A salinity/toxicity relationship to predict acute toxicity of Saline waters to freshwater organisms, D. Gulley and D.R. Mount, 1996) was developed to predict acute toxicity based on mineral concentration and mineral imbalances of seven major ions (Na, K, Ca, Mg, Cl, SO_4 HCO_3). The model is a simplistic acute toxicity predictor. In addition to modeling the EDCC effluent, the model will be developed for the three additional stream segments included in the 3rd party rulemaking. Mineral concentrations representing the 95th percentile of the historical discharge will be utilized as the baseline modeling to demonstrate the toxicity potential at the maximum possible effluent concentrations. Additional modeling for each subsequent downstream segment will be completed based on the proposed criteria.

The known concentrations of the seven major ions will be developed from analyses of water samples collected from each stream segment identified in the rulemaking as provided in the table below.

Summary of dissolved mineral WQS Modifications. EDCC 3rd party rule making.

Unnamed tributary to unnamed tributary to Flat Creek (UTB) – from EDCC 001 Discharge to the confluence with unnamed tributary of Flat Creek (UTA)	Unnamed tributary to Flat Creek (UTA) – from confluence of UTB to the confluence with Flat Creek
Instream Criteria	**Instream Criteria**
Amend ecoregion dissolved minerals criteria: Chloride from 14 mg/L to 23 mg/L; Sulfate from 31 mg/L to 125 mg/L, and TDS from 123 mg/L to 475 mg/L	Amend ecoregion dissolved minerals criteria: Chloride from 14 mg/L to 16 mg/L; Sulfate from 31 mg/L to 80 mg/L, and TDS from 123 mg/L to 315 mg/L
Flat Creek – from mouth of UTA tributary to the mouth of Haynes Creek	**Haynes Creek from confluence of Flat and Salt Creeks, downstream to confluence with Smackover Creek**
Instream Criteria	**Instream Criteria**
Amend ecoregion dissolved minerals criteria: Chloride from 14 mg/L to 165 mg/L; Sulfate from 31 mg/L to 67 mg/L, and TDS from 123 mg/L to 560 mg/L	Amend ecoregion dissolved minerals criteria: Chloride from 14 mg/L to 360 mg/L; Sulfate from 31 mg/L to 55 mg/L, and TDS from 123 mg/L to 855 mg/L

Baseline model runs will be completed utilizing known concentrations of the seven target ions. In addition, a matrix of modeling projections will be completed to bracket those concentrations projected to generate a potential for instream toxicity. The model projections will then be compared to the individual criterion in each segment identified during the rulemaking process.

The GRI modeling will project the concentrations at which toxicity, due to the dissolved minerals, can be expected given the complex mineral ions specific to the discharge from EDCC and the receiving streams. A decision related to the potential for instream toxicity can be made based on the modeling projections as they compare to the adopted dissolved mineral criteria for each individual segment.

Schedule

Complete 120 days after the Study Plan has been accepted by ADEQ and EPA.

Task 4. Final dissolved mineral supplemental report

A draft final report providing the results of the additional documentation will be developed and presented to ADEQ for their review and comment. Comments received from ADEQ will be addressed and a final report for submission to EPA will be submitted through ADEQ. The decision to pursue EPA approval of the proposed criteria would be determined based on the results of the additional documentation allowing EPA to make a determination related to the potential for toxicity of the proposed mineral criteria and the maintenance of the designated fishery and aquatic life uses.

Schedule

Draft final report complete 150 days after the Study Plan has been accepted by ADEQ and EPA.

Attachment A

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 6
1445 ROSS AVENUE, SUITE 1200
DALLAS, TX 75202-2733

APR 14 2009

Ms. Teresa Marks
Director
Arkansas Department of Environmental Quality
5301 Northshore Drive
North Little Rock, AR 72118-5317

Dear Ms. Marks:

I would like to provide you with the Environmental Protection Agency's (EPA) findings concerning the review of additional supporting information related to several site-specific water quality standards revisions to Regulation No. 2, *Regulation Establishing Water Quality Standards for Surface Waters of the State of Arkansas* originally submitted by your letters, dated September 17, 2007. These site-specific revisions were for three separate submissions: El Dorado Chemical Company, Great Lakes Chemical Corporation, and Lion Oil Company.

Your original September 17, 2007, letters included a request for EPA's approval of the removal of the domestic water supply designated uses, along with revised site-specific aquatic life criteria for chloride, sulfate, and total dissolved solids (TDS). EPA previously approved the removal of the domestic water supply uses from the waters associated with the El Dorado Chemical Company (EDCC) and four of five requested waterbodies for Great Lakes Chemical Corporation (GLCC), but was not able to approve the use removals associated with the fifth GLCC waterbody segment or the three waterbody segments associated with Lion Oil. In today's action, EPA approves the removal of the domestic water supply use for these four waters, given that they are not currently used as a source of supply for a public water system, nor are they being considered for such use and are intermittent in nature.

As you know, EPA was not able to approve the site-specific criteria revisions for the three separate submissions from EDCC, GLCC and Lion Oil as detailed in our January 3, 2008, letters to you. EPA was not able to take action on these submissions because they lacked specific supporting information necessary for EPA approval. EPA requested specific additional information for these provisions in the January 3, 2008 letter. Your August 14, 2008, response included some, but not all of the requested information. EPA staff requested the remaining supporting information via e-mail on November 11, 2008. Additional data were forwarded to EPA via email on November 19, 2008.

EPA again reviewed the submissions from EDCC, GLCC and Lion Oil taking into consideration the additional supporting information that was made available. Based on that subsequent review, EPA has determined that supporting documentation remains insufficient to demonstrate that the site-specific minerals criteria for the waterbodies associated with EDCC, GLCC, and Lion Oil are appropriately protective of aquatic life. Therefore, EPA disapproves the site-specific chloride, sulfate, and TDS criteria for the EDCC, GLCC, and Lion Oil submissions. A detailed basis for EPA's determination and a description of the specific issues regarding the adequacy of these studies and supporting documentation are identified in the enclosed Record of Decision. As described in 40 CFR §131.21(c), new and revised standards do not go into effect for CWA purposes until approved by EPA. Therefore, the previously approved numeric criteria under Regulation No. 2 (April 23, 2004) remain in effect for CWA purposes for all waters identified in the EDCC, GLCC and Lion Oil submissions.

I would like to acknowledge the efforts of the Pollution Control and Ecology Commission, and particularly Arkansas Department of Environmental Quality (ADEQ). We encourage the Commission and ADEQ to work with the third parties, EDCC, GLCC, and Lion Oil, in responding to the issues identified here and detailed in the enclosed Record of Decision.

We look forward to the continuation of our work with you on these water quality standards revisions and encourage early coordination on any future proposed water quality standards revisions to facilitate EPA's review of State-adopted water quality standards submitted for approval. If you have any questions or concerns, please contact me at (214) 665-7101, or have your staff contact Russell Nelson at (214) 665-6646 or Matt Hubner at (214) 665-9736.

Sincerely yours,

Miguel I. Flores
Director
Water Quality Protection Division

Enclosure

cc: Steve Drown, Chief, Water Division, ADEQ
Sarah Clem, Technical Assistance Manager, ADEQ

Enclosure

RECORD OF DECISION:
EPA APPROVAL AND DISAPPROVAL OF SITE-SPECIFIC REVISIONS TO THE ARKANSAS WATER QUALITY STANDARDS

Site Specific Domestic Water Supply Use Removal and Minerals Criteria Revisions for Great Lakes Chemical Company (GLCC), El Dorado Chemical Company (EDCC), and Lion Oil
Union County, Arkansas

U.S. Environmental Protection Agency – Region 6

March 2009

Enclosure

RECORD OF DECISION:
EPA APPROVAL AND DISAPPROVAL OF SITE-SPECIFIC REVISIONS TO THE ARKANSAS WATER QUALITY STANDARDS

Site Specific Domestic Water Supply Use Removal and Minerals Criteria Revisions for Great Lakes Chemical Company (GLCC), El Dorado Chemical Company (EDCC), and Lion Oil
Union County, Arkansas

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Enclosure

RECORD OF DECISION: EPA APPROVAL AND DISAPPROVAL OF SITE-SPECIFIC REVISIONS TO THE ARKANSAS WATER QUALITY STANDARDS

Site Specific Domestic Water Supply Use Removal and Minerals Criteria Revisions for Great Lakes Chemical Company (GLCC), El Dorado Chemical Company (EDCC), and Lion Oil
Union County, Arkansas

I. INTRODUCTION

Purpose

As described in §303(c) of the Clean Water Act (CWA) and in the standards regulation (40 CFR §131.20), States and authorized Tribes have primary responsibility to develop and adopt water quality standards to protect their waters. Authority to approve or disapprove new and/or revised standards submitted to EPA for review has been delegated to the Water Quality Protection Division Director, in Region 6. Tribal or State water quality standards are not considered effective under the CWA until approved by EPA.[1]

The purpose of this record of decision is to provide the basis for the Environmental Protection Agency's (EPA) approval of domestic drinking water use removals and disapproval of site-specific water quality criteria revisions to Regulation No. 2: *Regulation Establishing Water Quality Standards for Surface Waters of the State of Arkansas* adopted by the Arkansas Pollution Control and Ecology Commission (APC&EC) in Minute Order 07-18. The drinking water use removals and site-specific revisions for chloride, sulfate, and total dissolved solids (TDS) are associated with three separate submissions: El Dorado Chemical Company (EDCC), Great Lakes Chemical Corporation (GLCC) and Lion Oil Company.

Chronology of Events

August 31, 2006	Three individual third parties, EDCC, GLCC, and Lion Oil, filed a petition with the APC&EC to amend Regulation No. 2.

[1] "Alaska rule" [*Federal Register*: April 27, 2000 (Volume 65, Number 82)]

September 22, 2006	The APC&EC's Regulations Committee met to review the petition and recommended that the Commission institute a rule-making proceeding to consider adopting the proposed revisions to Regulation No. 2.
September 22, 2006	The APC&EC accepted the Regulations Committee recommendation and initiated the rulemaking proceeding via Minute Order 06-37.
September 27-28, 2006	Public notice of the proposed rule-making was published.
November 13, 2006	Public hearing on the proposed rule-making was held in El Dorado, Arkansas.
November 29, 2006	Public comment period ended on the proposed changes to Regulation No. 2.
January 19, 2007	Responsiveness summary was filed with the APC&EC.
June 22, 2007	Teresa Marks, Director, Arkansas Department of Environmental Quality (ADEQ), signed Minute Order 07-18 adopting changes to Regulation No. 2.
September 17, 2007	Miguel I. Flores, Director, Water Quality Protection Division, EPA Region 6, received letter from Teresa Marks, Director, ADEQ, requesting EPA approval of the adopted revisions and transmitting the water quality standards submission package.
November 9, 2007	EPA approves removal of domestic drinking water uses for EDCC and the majority for GLCC. No action is taken on all segments for Lion Oil and 1 for GLCC.
January 3, 2008	EPA issues no action letter to Teresa Marks (ADEQ) concerning site specific criteria and drinking water use removals.
August 14, 2008	Miguel I. Flores receives letter from Teresa Marks responding to the issues raised by EPA in the January 3, 2008 no action letter.
November 11, 2008	EPA requests additional material not included in previous letter from Teresa Marks.
November 19, 2008	ADEQ forwards additional materials to EPA staff.

Background

In separate letters dated August 17, 2007, from Teresa Marks, ADEQ, to Miguel Flores, EPA Region 6, ADEQ requested EPA approval of several site-specific water quality standards revisions to Regulation No. 2 for twelve streams and multiple segments in the Gulf Coastal ecoregion of Arkansas. These streams are the receiving waterbodies for discharges from EDCC, GLCC and Lion Oil, in Union County, Arkansas.

The letter included a request for EPA approval of the removal of the domestic water supply designated uses for eleven of the twelve waterbodies associated with the facilities identified above, along with site-specific criteria for chloride, sulfate, and total dissolved solids (TDS) for all twelve waterbodies and segments. EPA took no action in relation to the site-specific minerals criteria for all waterbodies and for four waterbodies concerning drinking water use removal. This record of decision applies to the site-specific criteria revisions and remaining domestic water supply designated use removals for the waterbodies for which such action was requested. The general details of each request are addressed individually in the following text.

Summary of Revised Provisions

A. El Dorado Chemical Company

Table 1 below provides a detailed description of the four streams to which the site-specific minerals revisions apply for EDCC. EPA previously approved the removal of the domestic water supply use from UTB, UTA, Flat Creek, and Haynes Creek. Table 2 depicts the proposed site-specific criteria for chloride, sulfate, and TDS, for the four waterbodies.

Table 1. Description of stream segments for which the proposed site-specific criteria revisions apply.

Stream Segment Descriptions
Unnamed tributary to the unnamed tributary to Flat Creek (UTB) from the El Dorado Chemical Company outfall 001 discharge to the confluence with unnamed tributary of Flat Creek (UTA)
Unnamed tributary to Flat Creek (UTA) from the confluence of UTB to the confluence with Flat Creek
Flat Creek from the mouth of UTA tributary to the mouth of Haynes Creek
Haynes Creek from the confluence of Flat and Salt Creeks downstream to the confluence with Smackover Creek

Table 2. Proposed site-specific water quality criteria revisions for chloride, sulfate, and TDS, for four waterbodies submitted by ADEQ to EPA for review and approval.

Stream Segment Name	Chloride (mg/L)		Sulfate (mg/L)		TDS (mg/L)	
	Previous	Revised	Previous	Revised	Previous	Revised
UTB	14	23	31	125	123	475
UTA	14	16	31	80	123	315

Stream Segment Name	Chloride (mg/L)		Sulfate (mg/L)		TDS (mg/L)	
	Previous	Revised	Previous	Revised	Previous	Revised
Flat Creek	14	165	31	67	123	560
Haynes Creek	14	360	31	55	123	855

B. Great Lakes Chemical Corporation

Table 3 below provides a detailed description of the six streams for which the proposed site-specific minerals revisions and drinking water use removal apply for GLCC. EPA previously approved the removal of domestic water supply use from UT002, UT004, UT003, and UTLCB-2. Bayou de Loutre was not approved for drinking water use removal and is addressed later in the document. Table 4 depicts the proposed site-specific criteria for chloride, sulfate, and TDS, for the six waterbodies.

Table 3. Description of stream segments for which the proposed site-specific criteria revisions and one drinking water use removal apply.

Stream Segment Descriptions
Unnamed tributary into which Great Lakes Chemical Corporation outfall 002 discharges (UT002) to the confluence with Bayou de Loutre
Unnamed tributary into which Great Lakes Chemical Corporation outfall 004 discharges (UT004) to the confluence with Bayou de Loutre
Bayou de Loutre from the mouth of Outfall 004 tributary downstream to the mouth of Gum Creek[2]
Unnamed tributary to an unnamed tributary of Little Cornie Bayou (UT003)
Unnamed tributary of Little Cornie Bayou (UTLCB-2) to Little Cornie Bayou
Little Cornie Bayou from the confluence of UTLCB-2 to the Arkansas/Louisiana State line[3]

Table 4. Proposed site-specific water quality criteria revisions for chloride, sulfate, and TDS, for six waterbodies submitted by ADEQ to EPA for review and approval.

Stream Segment Name	Chloride (mg/L)		Sulfate (mg/L)		TDS (mg/L)	
	Previous	Revised	Previous	Revised	Previous	Revised
UT002	14	65	31	35	123	141
UT004	14	239	--	--	123	324
Bayou de Loutre	250	278	--	--	--	--
UT003	14	538	31	35	123	519

[2] Bayou de Loutre – No action taken by EPA (January 3, 2008) on removal of domestic water use
[3] Little Cornie Bayou – Not identified for drinking water use removal

Stream Segment Name	Chloride (mg/L)		Sulfate (mg/L)		TDS (mg/L)	
	Previous	Revised	Previous	Revised	Previous	Revised
UTLCB-2	14	305	--	--	123	325
Little Cornie Bayou	200	215	20	25	--	--

C. Lion Oil

Table 5 below provides a detailed description of the three streams for which the proposed drinking water use removal apply for Lion Oil. EPA previously took no action in the removal of the domestic water supply use for Loutre Creek and two of the nine segments of Bayou de Loutre upstream of Gum Creek. Table 4 depicts the proposed site-specific criteria for chloride, sulfate, and TDS, for the six waterbodies.

Table 5. Description of stream segments for which the proposed domestic water supply designated use removals apply.

Stream Segment Descriptions
Loutre Creek from Highway 15 South to the confluence of Bayou de Loutre
Bayou de Loutre from Loutre Creek to the discharge for the City of El Dorado South facility*
Bayou de Loutre from the discharge for the City of El Dorado South downstream to the mouth of Gum Creek**

Table 6. Proposed site-specific water quality criteria revisions for chloride, sulfate, and TDS, for Loutre Creek and nine segments of Bayou de Loutre submitted by ADEQ to EPA for review and approval.

Stream Segment Name	Chloride (mg/L)		Sulfate (mg/L)		TDS (mg/L)	
	Previous	Revised	Previous	Revised	Previous	Revised
Loutre Creek	14	256	31	997	123	1756
Bayou de Loutre*	250	264	90	635	500	1236
Bayou de Loutre**	--	--	90	431	500	966
Bayou de Loutre[4]	--	--	90	345	750	780
Bayou de Loutre[5]	--	--	90	296	--	--
Bayou de Loutre[6]	--	--	90	263	--	--

[4] Bayou de Loutre – from the mouth of Gum Creek downstream to the mouth of Boggy Creek
[5] Bayou de Loutre – from the mouth of Boggy Creek downstream to the mouth of Hibank Creek
[6] Bayou de Loutre – from the mouth of Hibank Creek downstream to the mouth of Mill Creek

Stream Segment Name	Chloride (mg/L)		Sulfate (mg/L)		TDS (mg/L)	
	Previous	Revised	Previous	Revised	Previous	Revised
Bayou de Loutre[7]	--	--	90	237	--	--
Bayou de Loutre[8]	--	--	90	216	--	--
Bayou de Loutre[9]	--	--	90	198	--	--
Bayou de Loutre[10]	--	--	90	171	--	--

II. REVISED PROVISIONS EPA IS DISAPPROVING

Site-Specific Criteria for Chloride, Sulfate, and TDS

Supporting documentation remains insufficient to demonstrate that the site-specific minerals criteria for the waterbodies associated with EDCC, GLCC, and Lion Oil are appropriately protective of aquatic life. Although Section 3.6.2 – "Whole Effluent Toxicity (WET) Testing" of the August 17, 2007 submissions provided the results of outfall biomonitoring for the water flea and fathead minnow, it remains unclear what minerals concentrations (chloride, sulfate, and TDS) were associated with each of these tests and whether or not the minerals concentrations during WET testing were representative of the adopted site-specific minerals criteria under review for effluent receiving streams.

The evidence included in the reports and subsequent materials requested by EPA do not include a general evaluation or review of the site-specific criteria for associated waterbodies in light of the available scientific literature concerning the toxicity effects of chloride, sulfate, and TDS to aquatic organisms. Supporting documentation from the literature or other appropriate documentation is important for providing a clear demonstration that the proposed site-specific criteria are appropriately protective of the aquatic life uses (Gulf Coastal seasonal or perennial fishery) in these waterbodies. Such information may also be useful to supplement the biomonitoring information, especially if the minerals concentrations present during the biomonitoring testing referenced above are not available or were not representative of the adopted site-specific minerals criteria under review for receiving waterbodies (UTB - EDCC; UT002, UT003, UT004 - GLCC; and Loutre Creek - Lion Oil)

Literature (Mount and Gulley)[11] cited in ADEQ's August 14, 2008 response, proposes that the development of the salinity/toxicity relationship (STR) model supports higher

[7] Bayou de Loutre – from the mouth of Mill Creek downstream to the mouth of Buckaloo Branch
[8] Bayou de Loutre – from the mouth of Buckaloo Branch downstream to the mouth of Bear Creek
[9] Bayou de Loutre – from the mouth of Bear Creek to the final segment of Bayou de Loutre
[10] Bayou de Loutre (Final Segment) to the Arkansas/Louisiana state line
[11] Mount, D.R. and D.D. Gulley. 1992. Development of a salinity/toxicity relationship to predict acute toxicity of saline waters to freshwater organisms. GRI-92/0301. Gas research Institute, Chicago, IL, USA

acute lethality concentrations than those proposed in the criteria. EPA's review of this study indicates lower concentrations of ions in combination can adversely affect sensitive aquatic species, yet other combinations may ameliorate such effects. Thus, the necessity for documentation and identification of specific mineral concentrations is critical to supporting that protection of aquatic life uses will be met by the proposed criteria.

EPA disapproves all proposed site-specific criteria revisions for chloride, sulfate, and TDS in all submissions on the grounds that current documentation provided by ADEQ does not clearly demonstrate adequate protection of aquatic life uses for the receiving and associated waterbodies. Under 40 CFR §131.21(c), new and revised standards do not go into effect for CWA purposes without EPA approval. EPA does not intend to propose or promulgate criteria for the previously identified waters. Therefore, previous approved numeric criteria under Regulation No. 2 (April 23, 2004) remain in effect.

If the State decides to pursue site-specific revisions for minerals in these waterbodies, adequate supporting scientific documentation must be provided to show that the Gulf Coastal seasonal or perennial fishery aquatic life uses will be protected. The previously requested mineral concentration data associated with outfall WET testing are necessary to support that effluent being tested reflect proposed criteria values. If these values are not available, use of STR modeling as well as background literature searches on ecoregion species' salinity tolerances would provide a minimal level of support to the revision.

III. REVISED PROVISIONS EPA IS APPROVING

Domestic Water Supply Use Removals

EPA previously took no action concerning the removal of domestic drinking water uses for the waterbodies listed above for GLCC and Lion Oil. Documentation, in the form of a letter from Arkansas Department of Health (ADH), showing that there were no current or proposed public drinking water considerations for these waterbodies was missing or inadequate and therefore did not support the revision.

Two letters, dated July 24, 2006 and May 12, 2008, from ADH were submitted by ADEQ on EPA's request subsequent to the study report. The letters respectively state that Bayou de Loutre upstream of Gum Creek and Loutre Creek are not currently used as a source of supply for a public water system, nor are they being considered for such use.

In addition, the UAA study cites two reasons (see 40 CFR §131.10(g)(2) and (5)) for why the domestic water supply use is not an attainable use in Loutre Creek and the three segments of Bayou de Loutre. Specifically, the report cites the intermittent nature of these streams and lack of consistent base flow, along with the presence of shallow pools and run areas that would not support the intake and storage areas necessary for the development of a domestic water supply system.

EPA agrees with the conclusions of the study and approves the removal of the domestic water supply use from Bayou de Loutre from the confluence of UT004 downstream to the confluence of Loutre Creek for the GLCC submission. For Lion Oil, EPA approves the removal of the domestic water supply use from Loutre Creek and two segments of Bayou de Loutre between the confluence with Loutre Creek and confluence with Gum Creek.

United States
Environmental Protection Agency
Region 6
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Dallas, Tx 75202-2733

http://www.epa.gov/region6
1-800-887-6063

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Mrs Teresa Marks
ADEQ
5301 Northshore Drive
North Little Rock, AR 72118-5317

Attachment C

Analytical Data Summary and Figures

Arkansas Analytical Inc.
11701 I-30 Bldg 1, Ste 115 - Little Rock, AR 72209
501-455-3233 Fax 501-455-6118

29 July 2009

Roland McDaniel
GBMC & Associates
219 Brown Lane
Bryant, AR 72022

RE: El Dorado Chemical

SDG Number: 0907190

Enclosed are the results of analyses for samples received by the laboratory on 16-Jul-09 10:15. If you have any questions concerning this report, please feel free to contact me.

Sample Receipt Information:

Custody Seals	✔
Containers Intact	✔
COC/Labels Agree	✔
Preservation Confirmed	✔
Received On Ice	✔
Temperature on Receipt	12.0°C

Sincerely,

Norma James
President

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29 July 2009

Roland McDaniel
GBMC & Associates
219 Brown Lane
Bryant, AR 72022
Project: El Dorado Chemical

Date Received: 16-Jul-09 10:15

ANALYTICAL RESULTS

Lab Number:	**0907190-01**
Sample Name:	**001**
Date/Time Collected:	**7/15/09 8:15**
Sample Matrix:	**Water**

Anions	Units	Result	Date/Time Analyzed	Batch	Method
Chloride	mg/L	**28.0**	7/16/09 16:48	A907167	300.0/9056A
Fluoride	mg/L	< 0.500	7/16/09 20:30	A907167	300.0/9056A
Sulfate as SO4	mg/L	**28.8**	7/16/09 20:30	A907167	300.0/9056A
Nitrate as N	mg/L	**0.637**	7/16/09 20:30	A907167	300.0/9056A
Nitrite as N	mg/L	**1.18**	7/16/09 20:30	A907167	300.0/9056A

Total Metals	Units	Result	Date/Time Analyzed	Batch	Method
Aluminum	mg/L	**0.264**	7/20/09 18:22	A907186	200.7
Arsenic	mg/L	< 0.050	7/20/09 18:21	A907186	200.7
Barium	mg/L	**0.057**	7/20/09 18:23	A907186	200.7
Boron	mg/L	< 0.100	7/20/09 18:23	A907186	200.7
Cadmium	mg/L	< 0.008	7/20/09 18:26	A907186	200.7
Calcium	mg/L	**10.9**	7/20/09 18:25	A907186	200.7
Chromium	mg/L	< 0.020	7/20/09 18:24	A907186	200.7
Copper	mg/L	< 0.005	7/20/09 18:22	A907186	200.7
Iron	mg/L	**0.181**	7/20/09 18:24	A907186	200.7
Lead	mg/L	**0.054**	7/20/09 18:25	A907186	200.7
Magnesium	mg/L	**2.75**	7/20/09 18:24	A907186	200.7
Manganese	mg/L	**0.138**	7/20/09 18:24	A907186	200.7
Nickel	mg/L	< 0.010	7/20/09 18:22	A907186	200.7
Potassium	mg/L	**7.00**	7/20/09 18:26	A907186	200.7
Selenium	mg/L	< 0.081	7/20/09 18:21	A907186	200.7
Silicon	mg/L	**4.45**	7/21/09 16:42	A907186	200.7
Sodium	mg/L	**57.0**	7/20/09 18:30	A907186	200.7
Zinc	mg/L	< 0.005	7/20/09 18:25	A907186	200.7

Wet Chemistry	Units	Result	Date/Time Analyzed	Batch	Method
Ammonia as N	mg/L	**2.93**	7/23/09 8:03	A907221	4500-NH3D
Hardness	mg/L	**38.0**	7/22/09 16:40	A907207	2340 C
Specific Conductance (EC)	uS/cm	**397**	7/20/09 15:27	A907190	120.1
TDS	mg/L	**230**	7/17/09 14:51	A907178	2540C
TOC	mg/L	**8.63**	7/21/09 13:06	A907187	5310/9060A
Total Alkalinity	mg/L	**95.0**	7/21/09 15:00	A907233	2320 B
TSS	mg/L	**11**	7/16/09 15:12	A907169	2540D
Bicarbonate Alkalinity	mg/L	**89.0**	7/21/09 15:00	A907234	2320B
Carbonate Alkalinity	mg/L	**6.0**	7/21/09 15:00	A907235	2320B
Total Inorganic Carbon	mg/L	**27.6**	7/28/09 9:49	A907225	5310/9060A mod.

This report must be reproduced in its entirety.

29 July 2009

Roland McDaniel
GBMC & Associates
219 Brown Lane
Bryant, AR 72022
Project: El Dorado Chemical

Date Received: 16-Jul-09 10:15

ANALYTICAL RESULTS

Lab Number:	**0907190-02**
Sample Name:	**UTA**
Date/Time Collected:	**7/15/09 9:00**
Sample Matrix:	**Water**

Anions	Units	Result	Date/Time Analyzed	Batch	Method
Chloride	mg/L	**25.2**	7/17/09 10:18	A907167	300.0/9056A
Fluoride	mg/L	< 0.500	7/16/09 17:32	A907167	300.0/9056A
Sulfate as SO4	mg/L	**28.4**	7/17/09 10:18	A907167	300.0/9056A
Nitrate as N	mg/L	**4.14**	7/16/09 17:32	A907167	300.0/9056A
Nitrite as N	mg/L	< 0.500	7/16/09 17:32	A907167	300.0/9056A

Total Metals	Units	Result	Date/Time Analyzed	Batch	Method
Aluminum	mg/L	**0.403**	7/20/09 18:58	A907186	200.7
Arsenic	mg/L	< 0.050	7/20/09 18:58	A907186	200.7
Barium	mg/L	**0.066**	7/20/09 18:59	A907186	200.7
Boron	mg/L	< 0.100	7/20/09 19:00	A907186	200.7
Cadmium	mg/L	< 0.008	7/20/09 19:02	A907186	200.7
Calcium	mg/L	**10.5**	7/20/09 19:01	A907186	200.7
Chromium	mg/L	< 0.020	7/20/09 19:01	A907186	200.7
Copper	mg/L	< 0.005	7/21/09 8:39	A907186	200.7
Iron	mg/L	**0.396**	7/20/09 19:00	A907186	200.7
Lead	mg/L	**0.030**	7/20/09 19:02	A907186	200.7
Magnesium	mg/L	**2.96**	7/20/09 19:01	A907186	200.7
Manganese	mg/L	**0.073**	7/20/09 19:00	A907186	200.7
Nickel	mg/L	< 0.010	7/20/09 18:59	A907186	200.7
Potassium	mg/L	**6.93**	7/20/09 19:02	A907186	200.7
Selenium	mg/L	< 0.081	7/20/09 18:58	A907186	200.7
Silicon	mg/L	**4.65**	7/21/09 15:42	A907186	200.7
Sodium	mg/L	**60.5**	7/20/09 19:06	A907186	200.7
Zinc	mg/L	< 0.005	7/21/09 8:39	A907186	200.7

Wet Chemistry	Units	Result	Date/Time Analyzed	Batch	Method
Ammonia as N	mg/L	< 0.50	7/23/09 8:03	A907221	4500-NH3D
Hardness	mg/L	**34.0**	7/22/09 16:40	A907207	2340 C
Specific Conductance (EC)	uS/cm	**364**	7/20/09 15:27	A907190	120.1
TDS	mg/L	**240**	7/17/09 14:51	A907178	2540C
TOC	mg/L	**7.80**	7/21/09 13:06	A907187	5310/9060A
Total Alkalinity	mg/L	**90.0**	7/21/09 15:00	A907233	2320 B
TSS	mg/L	**8.0**	7/16/09 15:12	A907169	2540D
Bicarbonate Alkalinity	mg/L	**90.0**	7/21/09 15:00	A907234	2320B
Carbonate Alkalinity	mg/L	< 5.0	7/21/09 15:00	A907235	2320B
Total Inorganic Carbon	mg/L	**22.6**	7/28/09 9:49	A907225	5310/9060A mod.

This report must be reproduced in its entirety.

29 July 2009

Roland McDaniel
GBMC & Associates
219 Brown Lane
Bryant, AR 72022
Project: El Dorado Chemical

Date Received: 16-Jul-09 10:15

ANALYTICAL RESULTS

Lab Number:	**0907190-03**
Sample Name:	**Flat CR**
Date/Time Collected:	**7/15/09 9:45**
Sample Matrix:	**Water**

Anions	Units	Result	Date/Time Analyzed	Batch	Method
Chloride	mg/L	**100**	7/17/09 10:40	A907167	300.0/9056A
Fluoride	mg/L	< 0.500	7/16/09 18:39	A907167	300.0/9056A
Sulfate as SO4	mg/L	**43.3**	7/17/09 10:40	A907167	300.0/9056A
Nitrate as N	mg/L	**1.85**	7/16/09 18:39	A907167	300.0/9056A
Nitrite as N	mg/L	< 0.500	7/16/09 18:39	A907167	300.0/9056A

Total Metals	Units	Result	Date/Time Analyzed	Batch	Method
Aluminum	mg/L	**0.382**	7/20/09 19:10	A907186	200.7
Arsenic	mg/L	< 0.050	7/20/09 19:09	A907186	200.7
Barium	mg/L	**0.126**	7/20/09 19:10	A907186	200.7
Boron	mg/L	**0.124**	7/20/09 19:11	A907186	200.7
Cadmium	mg/L	< 0.008	7/20/09 19:13	A907186	200.7
Calcium	mg/L	**18.2**	7/20/09 19:18	A907186	200.7
Chromium	mg/L	< 0.020	7/20/09 19:12	A907186	200.7
Copper	mg/L	< 0.005	7/20/09 19:09	A907186	200.7
Iron	mg/L	**0.817**	7/20/09 19:12	A907186	200.7
Lead	mg/L	< 0.022	7/20/09 19:13	A907186	200.7
Magnesium	mg/L	**5.05**	7/20/09 19:12	A907186	200.7
Manganese	mg/L	**0.089**	7/20/09 19:11	A907186	200.7
Nickel	mg/L	< 0.010	7/20/09 19:10	A907186	200.7
Potassium	mg/L	**9.14**	7/20/09 19:14	A907186	200.7
Selenium	mg/L	< 0.081	7/20/09 19:09	A907186	200.7
Silicon	mg/L	**2.16**	7/21/09 15:45	A907186	200.7
Sodium	mg/L	**102**	7/20/09 19:17	A907186	200.7
Zinc	mg/L	< 0.005	7/20/09 19:13	A907186	200.7

Wet Chemistry	Units	Result	Date/Time Analyzed	Batch	Method
Ammonia as N	mg/L	< 0.50	7/23/09 8:03	A907221	4500-NH3D
Hardness	mg/L	**60.0**	7/22/09 16:40	A907207	2340 C
Specific Conductance (EC)	uS/cm	**634**	7/20/09 15:27	A907190	120.1
TDS	mg/L	**370**	7/17/09 14:51	A907178	2540C
TOC	mg/L	**8.14**	7/21/09 13:06	A907187	5310/9060A
Total Alkalinity	mg/L	**72.0**	7/21/09 15:00	A907233	2320 B
TSS	mg/L	**6.0**	7/16/09 15:12	A907169	2540D
Bicarbonate Alkalinity	mg/L	**72.0**	7/21/09 15:00	A907234	2320B
Carbonate Alkalinity	mg/L	< 5.0	7/21/09 15:00	A907235	2320B
Total Inorganic Carbon	mg/L	**18.8**	7/28/09 9:49	A907225	5310/9060A mod.

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29 July 2009

Roland McDaniel
GBMC & Associates
219 Brown Lane
Bryant, AR 72022
Project: El Dorado Chemical

Arkansas Analytical Inc.

Date Received: 16-Jul-09 10:15

ANALYTICAL RESULTS

Lab Number:	**0907190-04**
Sample Name:	**Haynes**
Date/Time Collected:	**7/15/09 10:30**
Sample Matrix:	**Water**

Anions	Units	Result	Date/Time Analyzed	Batch	Method
Chloride	mg/L	**485**	7/17/09 11:02	A907167	300.0/9056A
Fluoride	mg/L	< 0.500	7/16/09 19:01	A907167	300.0/9056A
Sulfate as SO4	mg/L	**39.0**	7/17/09 11:02	A907167	300.0/9056A
Nitrate as N	mg/L	**1.85**	7/16/09 19:01	A907167	300.0/9056A
Nitrite as N	mg/L	< 0.500	7/16/09 19:01	A907167	300.0/9056A

Total Metals	Units	Result	Date/Time Analyzed	Batch	Method
Aluminum	mg/L	**0.202**	7/20/09 19:22	A907186	200.7
Arsenic	mg/L	< 0.050	7/20/09 19:21	A907186	200.7
Barium	mg/L	**0.287**	7/20/09 19:23	A907186	200.7
Boron	mg/L	**0.319**	7/20/09 19:23	A907186	200.7
Cadmium	mg/L	< 0.008	7/20/09 19:26	A907186	200.7
Calcium	mg/L	**47.2**	7/20/09 19:30	A907186	200.7
Chromium	mg/L	< 0.020	7/20/09 19:24	A907186	200.7
Copper	mg/L	< 0.005	7/20/09 19:22	A907186	200.7
Iron	mg/L	**0.570**	7/20/09 19:24	A907186	200.7
Lead	mg/L	< 0.022	7/20/09 19:25	A907186	200.7
Magnesium	mg/L	**12.4**	7/20/09 19:29	A907186	200.7
Manganese	mg/L	**0.090**	7/20/09 19:24	A907186	200.7
Nickel	mg/L	< 0.010	7/20/09 19:22	A907186	200.7
Potassium	mg/L	**13.3**	7/20/09 19:26	A907186	200.7
Selenium	mg/L	< 0.081	7/20/09 19:21	A907186	200.7
Silicon	mg/L	**1.47**	7/21/09 15:47	A907186	200.7
Sodium	mg/L	**239**	7/20/09 19:20	A907186	200.7
Zinc	mg/L	< 0.005	7/20/09 19:25	A907186	200.7

Wet Chemistry	Units	Result	Date/Time Analyzed	Batch	Method
Ammonia as N	mg/L	< 0.50	7/23/09 8:03	A907221	4500-NH3D
Hardness	mg/L	**164**	7/22/09 16:40	A907207	2340 C
Specific Conductance (EC)	uS/cm	**1710**	7/20/09 15:27	A907190	120.1
TDS	mg/L	**960**	7/17/09 14:51	A907178	2540C
TOC	mg/L	**8.63**	7/21/09 13:06	A907187	5310/9060A
Total Alkalinity	mg/L	**68.0**	7/21/09 15:00	A907233	2320 B
TSS	mg/L	**6.0**	7/16/09 15:12	A907169	2540D
Bicarbonate Alkalinity	mg/L	**68.0**	7/21/09 15:00	A907234	2320B
Carbonate Alkalinity	mg/L	< 5.0	7/21/09 15:00	A907235	2320B
Total Inorganic Carbon	mg/L	**16.6**	7/28/09 9:49	A907225	5310/9060A mod.

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29 July 2009

Roland McDaniel
GBMC & Associates
219 Brown Lane
Bryant, AR 72022
Project: El Dorado Chemical

Date Received: 16-Jul-09 10:15

QUALITY CONTROL RESULTS

Anions -- Batch: A907167 (Water)
Prepared: 16-Jul-09 14:09 By: WF -- Analyzed: 17-Jul-09 01:18 By: MEL

Analyte	BLK	LCS / LCSD	MS / MSD	Dup	RPD	Qualifiers
Chloride	<0.500 mg/L	102% / NA	102% / 102%		0.0746%	
Fluoride	<0.500 mg/L	106% / NA	105% / 106%		0.685%	
Nitrate as N	<0.500 mg/L	101% / NA	102% / 102%		0.734%	
Nitrite as N	<0.500 mg/L	110% / NA	112% / 113%		0.928%	
Sulfate as SO4	<0.500 mg/L	101% / NA	103% / 103%		0.0941%	

Wet Chemistry -- Batch: A907169 (Water)
Prepared: 16-Jul-09 15:12 By: AP -- Analyzed: 16-Jul-09 15:12 By: AP

Analyte	BLK	LCS / LCSD	MS / MSD	Dup	RPD	Qualifiers
TSS	<1.0 mg/L	90.4% / 86.5%	NA / NA		4.35%	

Wet Chemistry -- Batch: A907178 (Water)
Prepared: 17-Jul-09 14:51 By: AP -- Analyzed: 17-Jul-09 14:51 By: AP

Analyte	BLK	LCS / LCSD	MS / MSD	Dup	RPD	Qualifiers
TDS	<1.0 mg/L	104% / 104%	NA / NA		0.00%	

Total Metals -- Batch: A907186 (Water)
Prepared: 20-Jul-09 09:13 By: TT -- Analyzed: 20-Jul-09 18:46 By: RH

Analyte	BLK	LCS / LCSD	MS / MSD	Dup	RPD	Qualifiers
Aluminum	<0.030 mg/L	111% / NA	119% / 120%		0.719%	
Arsenic	<0.050 mg/L	110% / NA	116% / 116%		0.487%	
Barium	<0.005 mg/L	107% / NA	106% / 109%		2.23%	
Boron	<0.100 mg/L	101% / NA	101% / 103%		1.53%	
Cadmium	<0.008 mg/L	113% / NA	110% / 112%		1.59%	
Calcium	<0.100 mg/L	105% / NA	82.5% / 86.1%		1.82%	
Chromium	<0.020 mg/L	105% / NA	105% / 107%		2.30%	
Copper	<0.005 mg/L	101% / NA	112% / 111%		0.894%	
Iron	<0.010 mg/L	101% / NA	84.3% / 88.5%		3.40%	
Lead	<0.022 mg/L	94.4% / NA	94.4% / 97.3%		2.72%	
Magnesium	<0.100 mg/L	105% / NA	111% / 116%		3.83%	
Manganese	<0.010 mg/L	108% / NA	106% / 108%		1.56%	
Nickel	<0.010 mg/L	109% / NA	107% / 110%		2.47%	
Potassium	<0.100 mg/L	91.7% / NA	92.0% / 104%		7.35%	
Selenium	<0.081 mg/L	108% / NA	101% / 109%		6.64%	
Silicon	<0.050 mg/L	108% / NA	97.0% / 116%		1.91%	
Sodium	<1.00 mg/L	90.8% / NA	MBA / MBA		2.92%	MBA
Zinc	<0.005 mg/L	98.5% / NA	113% / 115%		1.45%	

This report must be reproduced in its entirety.

29 July 2009

Roland McDaniel
GBMC & Associates
219 Brown Lane
Bryant, AR 72022
Project: El Dorado Chemical

Date Received: 16-Jul-09 10:15

QUALITY CONTROL RESULTS

Wet Chemistry -- Batch: A907187 (Water)
Prepared: 20-Jul-09 09:15 By: SB -- Analyzed: 21-Jul-09 13:06 By: SB

Analyte	BLK	LCS / LCSD	MS / MSD	Dup	RPD	Qualifiers
TOC	<1.00 mg/L	106% / NA	106% / 107%		1.14%	

Wet Chemistry -- Batch: A907190 (Water)
Prepared: 20-Jul-09 15:27 By: AT -- Analyzed: 20-Jul-09 15:27 By: AT

Analyte	BLK	LCS / LCSD	MS / MSD	Dup	RPD	Qualifiers
Specific Conductance (EC)	NA	100% / 100%	NA / NA		0.0707%	

Wet Chemistry -- Batch: A907207 (Water)
Prepared: 21-Jul-09 13:42 By: SB -- Analyzed: 22-Jul-09 16:40 By: SB

Analyte	BLK	LCS / LCSD	MS / MSD	Dup	RPD	Qualifiers
Hardness	<2.0 mg/L	96.0% / 97.5%	NA / NA		1.55%	

Wet Chemistry -- Batch: A907221 (Water)
Prepared: 23-Jul-09 08:03 By: SB -- Analyzed: 23-Jul-09 08:03 By: SB

Analyte	BLK	LCS / LCSD	MS / MSD	Dup	RPD	Qualifiers
Ammonia as N	<0.50 mg/L	107% / NA	109% / 113%		3.11%	

Wet Chemistry -- Batch: A907225 (Water)
Prepared: 22-Jul-09 15:31 By: SB -- Analyzed: 28-Jul-09 09:49 By: SB

Analyte	BLK	LCS / LCSD	MS / MSD	Dup	RPD	Qualifiers
Total Inorganic Carbon	<1.00 mg/L	102% / NA	105% / 105%		0.337%	

Wet Chemistry -- Batch: A907233 (Water)
Prepared: 21-Jul-09 15:00 By: KP -- Analyzed: 21-Jul-09 15:00 By: KP

Analyte	BLK	LCS / LCSD	MS / MSD	Dup	RPD	Qualifiers
Total Alkalinity	<5.0 mg/L	99.0% / 99.0%	NA / NA		0.00%	

Wet Chemistry -- Batch: A907234 (Water)
Prepared: 21-Jul-09 15:00 By: KP -- Analyzed: 21-Jul-09 15:00 By: KP

Analyte	BLK	LCS / LCSD	MS / MSD	Dup	RPD	Qualifiers
Bicarbonate Alkalinity	<5.0 mg/L	99.0% / 99.0%	NA / NA		0.00%	

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29 July 2009

Roland McDaniel
GBMC & Associates
219 Brown Lane
Bryant, AR 72022
Project: El Dorado Chemical

Date Received: 16-Jul-09 10:15

QUALITY CONTROL RESULTS

Wet Chemistry -- Batch: A907235 (Water)
Prepared: 21-Jul-09 15:00 By: KP -- Analyzed: 21-Jul-09 15:00 By: KP

Analyte	BLK	LCS / LCSD	MS / MSD	Dup	RPD	Qualifiers
Carbonate Alkalinity	<5.0 mg/L	NA / NA	NA / NA		0.00%	

QUALIFIER(S)

*MBA: Masked By Analyte

All Analysis performed according to EPA approved methodology when available:
SW 846, Revised December, 1996; EPA 600/4-79-020, Revised March, 1983; Standard Methods, 20th Edition.
Instrument calibration and quality control samples performed at or above frequency specified in analytical method.

Reviewed by: Norma James

Norma James
President

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29 July 2009

Roland McDaniel
GBMC & Associates
219 Brown Lane
Bryant, AR 72022
Project: El Dorado Chemical

Date Received: 16-Jul-09 10:15

CHAIN OF CUSTODY FORM(S)

Arkansas Analytical Inc.

11701 Interstate 30, Bldg. 1, Ste. 115
Little Rock, AR 72209
PHONE: 501-455-3233
FAX: 501-455-6118

CHAIN OF CUSTODY RECORD

CLIENT INFORMATION	Project Description	Turnaround Time	Preservation Codes:	
GBMc & Associates	El Dorado Chemical	24 Hour	1. Cool, 4 Degrees Centigrade	4. Thiosulfate for Dechlorination
219 Brown Lane		48 Hour	2. Sulfuric Acid (H_2SO_4), pH < 2	5. Hydrochloric Acid(HCl)
Bryant, AR 72022	Reporting Information	72 Hour	3. Nitric Acid (HNO_3), pH < 2	6. Sodium Hydroxide (NaOH), pH > 12
	Telephone: 501-847-7077	Routine (5 Day)	TEST PARAMETERS	Bottle Type Code
Attn: Roland McDaniel	Fax: 501-847-7943	Preservative Code:	1 / 1,2 / 1,5 / 1,5 / 1,3	G = Glass; P = Plastic
	Email: rmcdaniel@gbmcassoc.com	Bottle Type:	P / P / GV / GV / P	V = Septum; A = Amber

Sampler(s) Signature

Sampler(s) Printed

Field Number	SAMPLE COLLECTION Date/s	Time/s	Grab	Comp	Number of Bottles	Sample Matrix	SAMPLE IDENTIFICATION/ DESCRIPTION	Cl, F, SO4, NO3, NO2, Alkalinity, Bicarbonate Alkalinity, Carbonate Alkalinity, Conductivity, TDS, TSS	Ammonia	TOC	Total Inorganic Carbon	Hardness, Al, As, Ba, B, Ca, Cd, Cr, Cu, Fe, Pb, Mg, Mn, Ni, K, Se, Si, Na, Zn	Arkansas Analytical Work Order Number: 0907190-
001	7/15/09	0815	x		8		—	✓	✓	✓	✓	✓	01
UTA		0900	x		8		—	✓	✓	✓	✓	✓	02
Flat CR		0945	x		8		—	✓	✓	✓	✓	✓	03
HAYNES		1030	x		8		—	✓	✓	✓	✓	✓	04

1. Relinquished by: (Signature)	Date/Time	2. Received by: (Signature)

3. Relinquished by: (Signature)	Date/Time	4. Received by lab: (Signature)
Gary Tannum	7/16/09 1015	Sarah E Ronal

SAMPLE CONDITION UPON RECEIPT IN LAB

1. CUSTODY SEALS: ✓ Yes ___No
2. CONTAINERS CORRECT: | Yes ___No
3. COC/LABELS AGREE: | Yes ___No
4. PRESERVATION CONFIRMED: | Yes ___No
5. RECEIVED ON ICE: ___Yes ___No
6. TEMPERATURE ON RECEIPT: 12°C

FOR COMPLETION BY LAB ONLY

REMARKS / SAMPLE COMMENTS

P.O. Number -

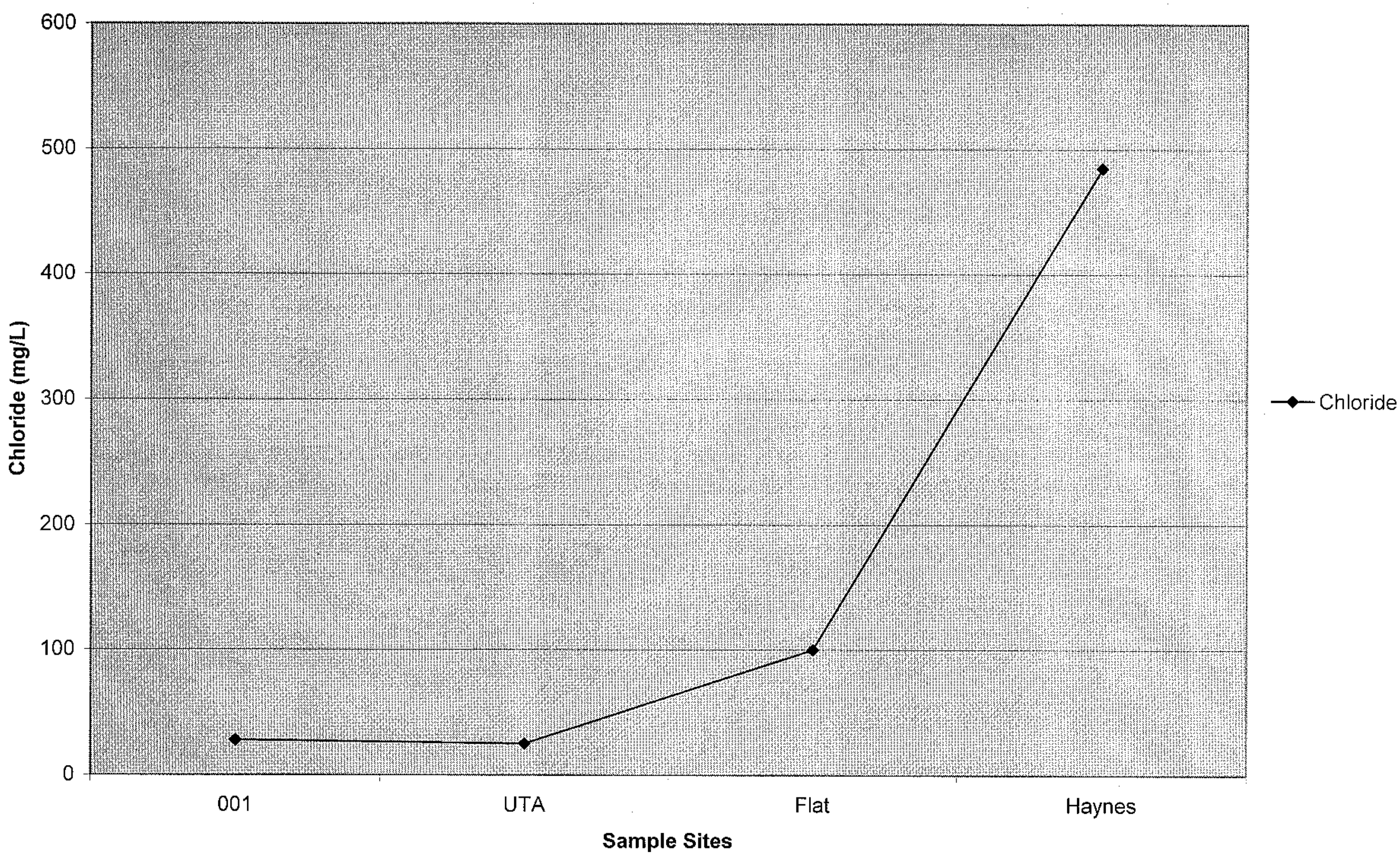
With Questions please -
Contact Roland McDaniel
501-847-7077

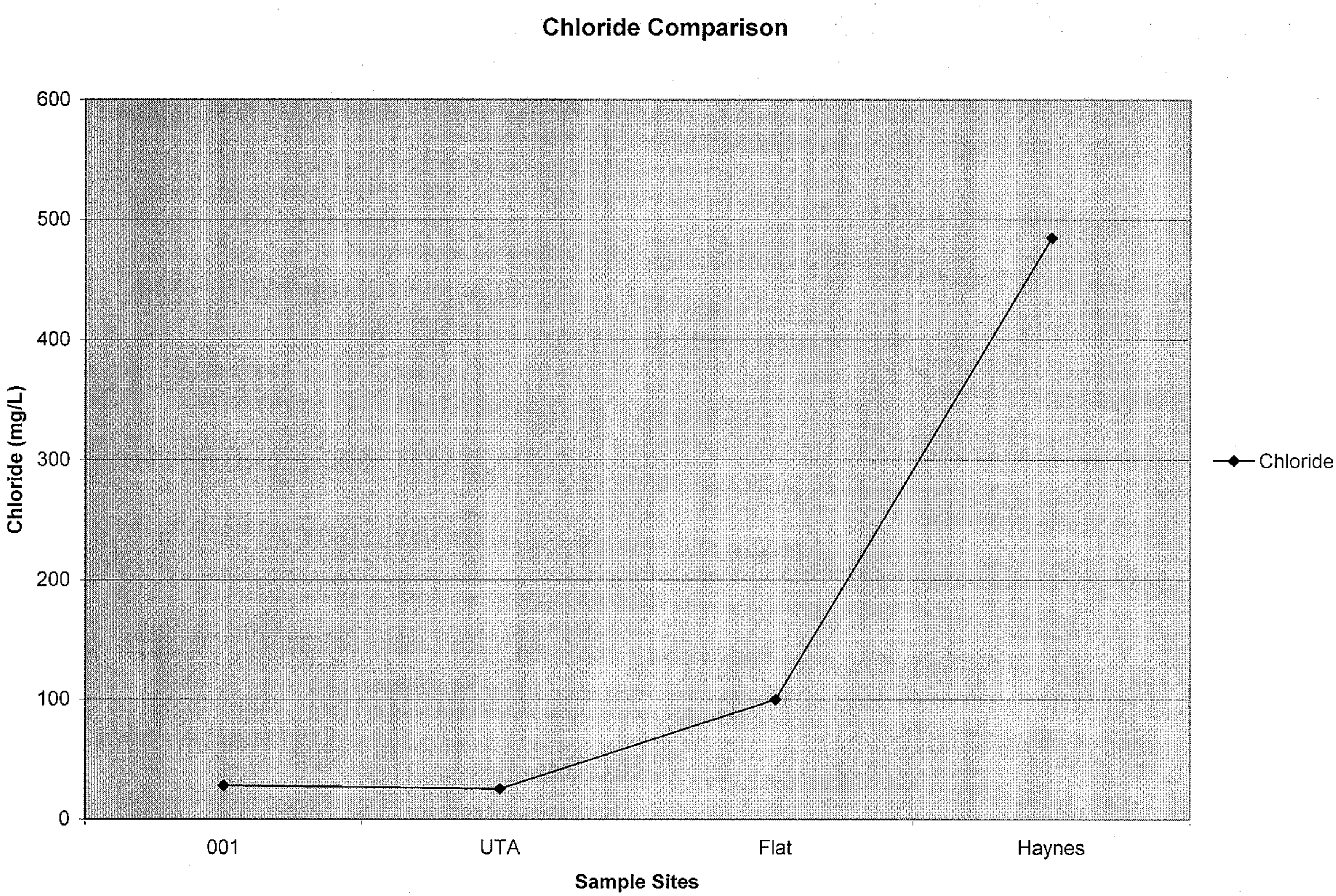
This report must be reproduced in its entirety.

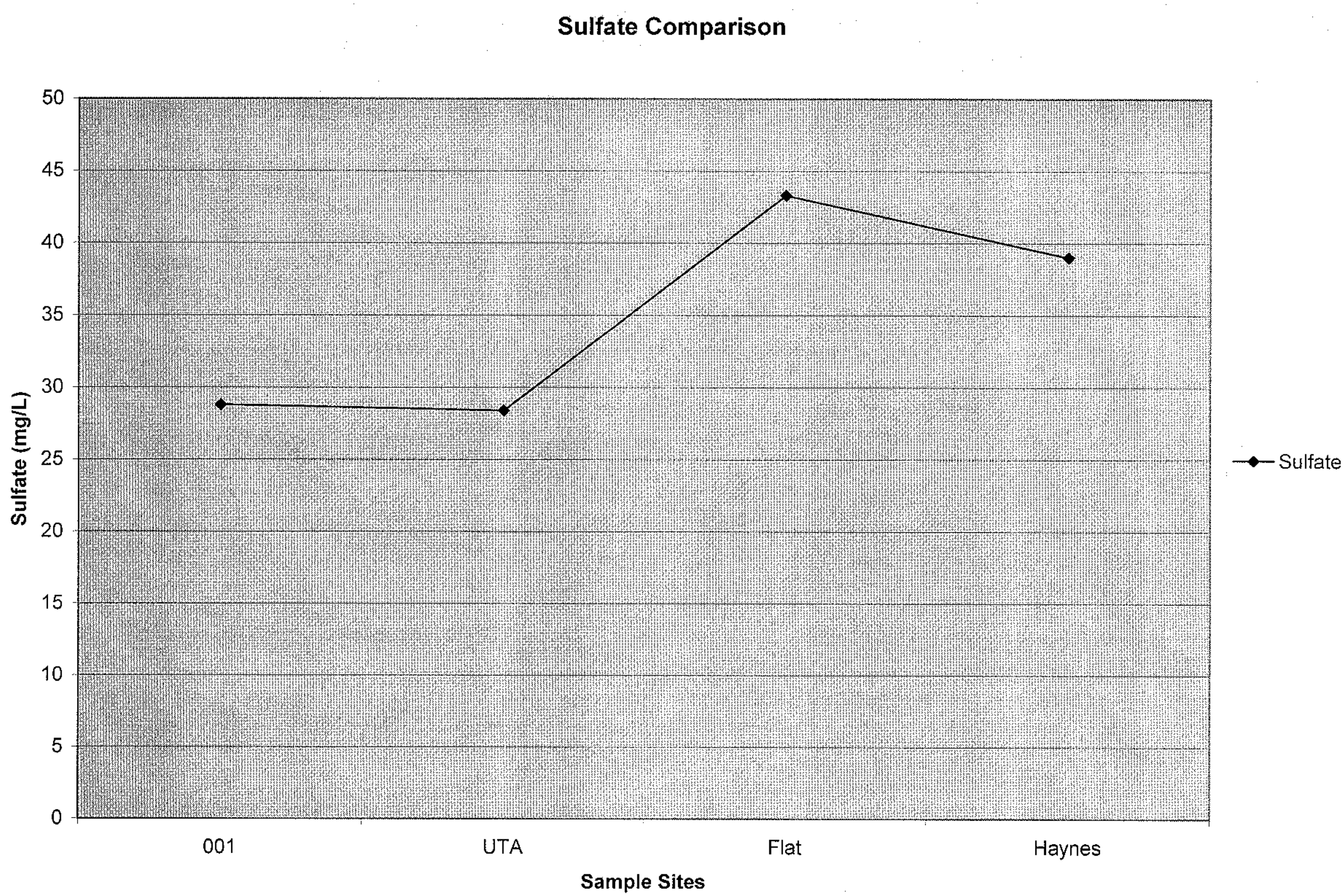
Water quality El Dorado Chemical Company 2042-99-010

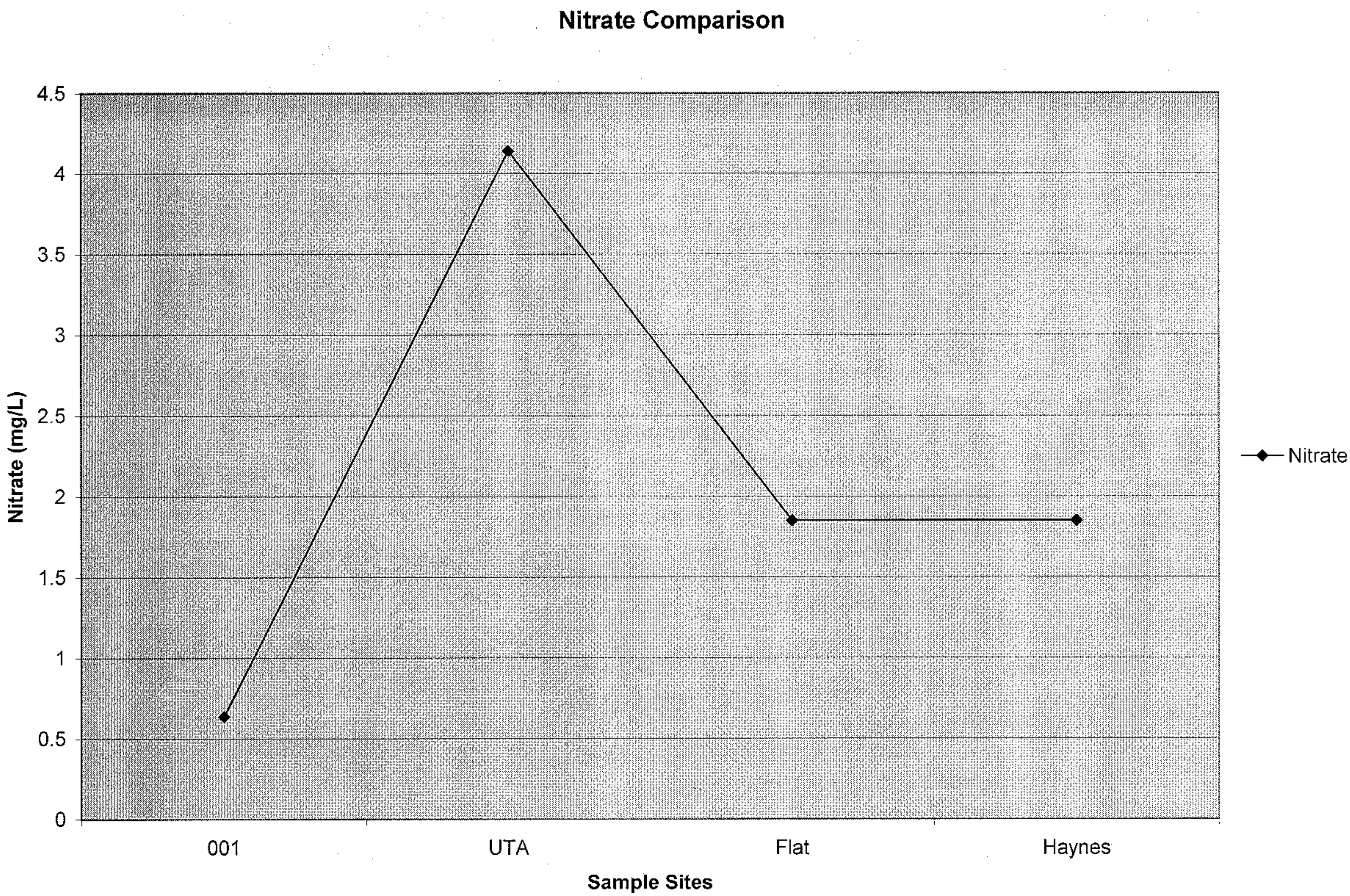
7/15/2009					Targeted dissolved mineral concentrations			
Measurement	001	UTA	Flat	Haynes	001	UTA	Flat	Haynes
Field Crew	SKH/REM							
Time	815	900	945	1030				
Chloride	28	25.2	100	485	23	16	165	360
Fluoride	<0.500	<0.500	<0.500	<0.500				
Sulfate	28.8	28.4	43.3	39	125	80	67	55
Nitrate- N	0.637	4.14	1.85	1.85				
Nitrite- N	1.18	<0.500	<0.500	<0.500				
Hardness	38	34	60	164				
Aluminum	0.264	0.403	0.382	0.202				
Arsenic	<0.050	<0.050	<0.050	<0.050				
Barium	0.057	0.066	0.126	0.287				
Boron	<0.100	<0.100	0.124	0.319				
Cadmium	<0.008	<0.008	<0.008	<0.008				
Calcium	10.9	10.5	18.2	47.2				
Chromium	<0.020	<0.020	<0.020	<0.020				
Copper	<0.005	<0.005	<0.005	<0.005				
Iron	0.181	0.396	0.817	0.57				
Lead	0.054	0.03	<0.022	<0.022				
Magnesium	2.75	2.96	5.05	12.4				
Manganese	0.138	0.073	0.089	0.09				
Nickel	<0.010	<0.010	<0.010	<0.010				
Potassium	7	6.93	9.14	13.3				
Selenium	<0.081	<0.081	<0.081	<0.081				
Silicon	4.45	4.65	2.16	1.47				
Sodium	57	60.5	102	239				
Zinc	<0.005	<0.005	<0.005	<0.005				
Ammonia- N	2.93	<0.50	<0.50	<0.50				
Specific conductance	397	364	634	1710				
Total dissolved solids	230	240	370	960	475	315	560	855
Total organic carbon	8.63	7.8	8.14	8.63				
Total Alkalinity	95	90	72	68				
Total Suspended Solids	11	8	6	6				
Bicarbonate alkalinity	89	90	72	68				
Carbonate Alkalinity	6	<5.0	<5.0	<5.0				
Total inorganic carbon	27.6	22.6	18.8	16.6				

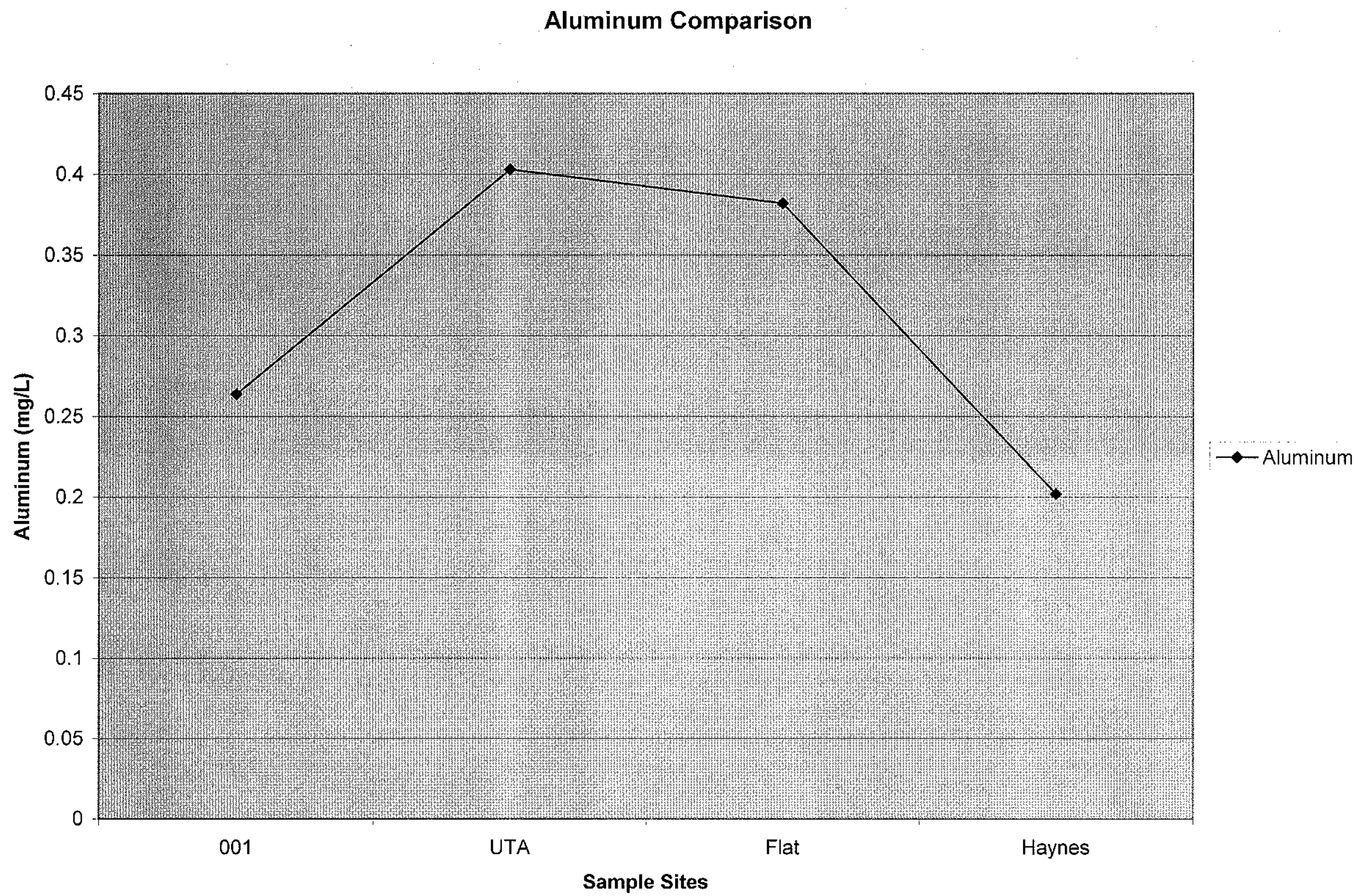
Chloride Comparison

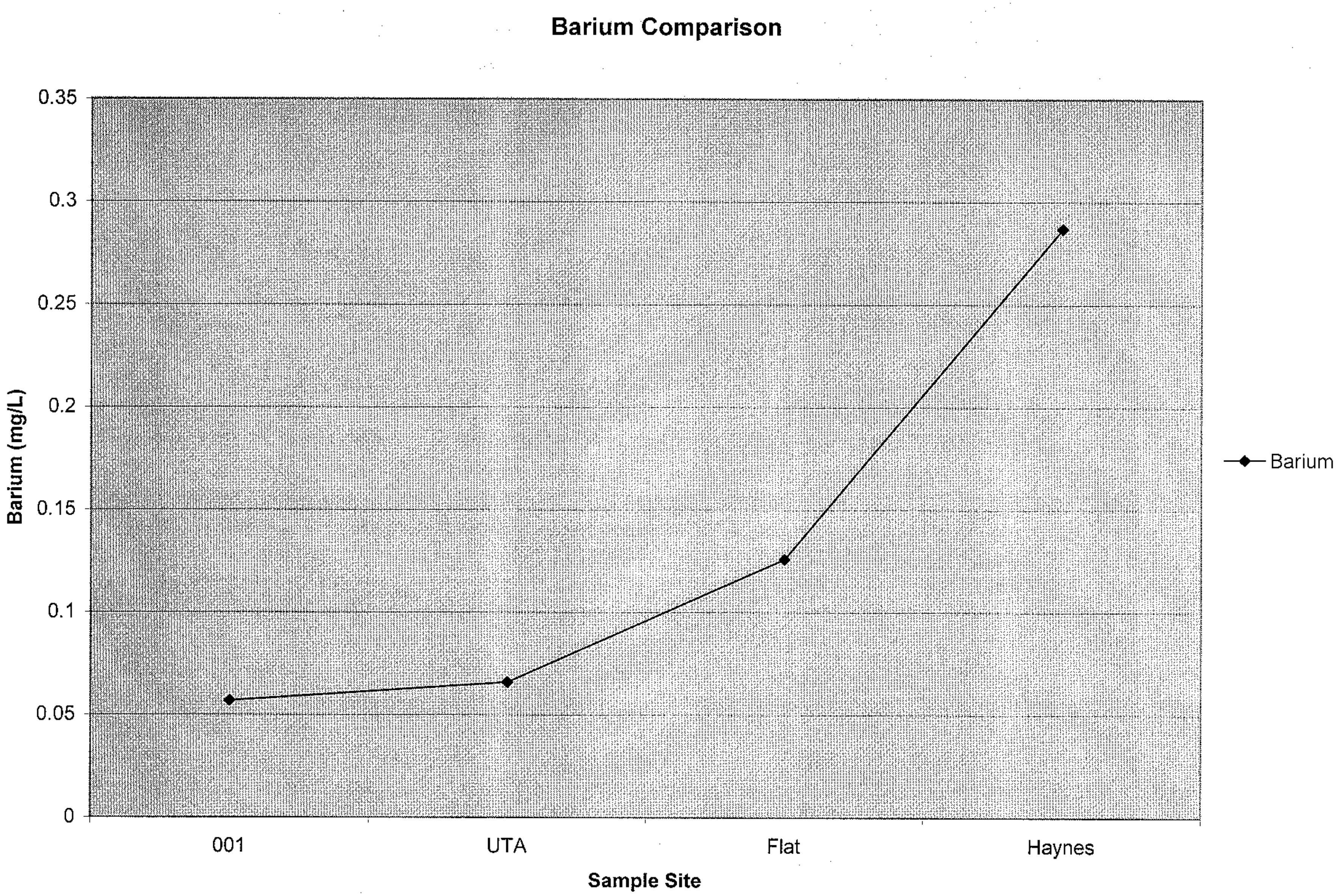



Chloride Comparison
Chloride (mg/L)
600
500
400
300
200
100
0
001
UTA
Flat
Haynes
Sample Sites
Chloride

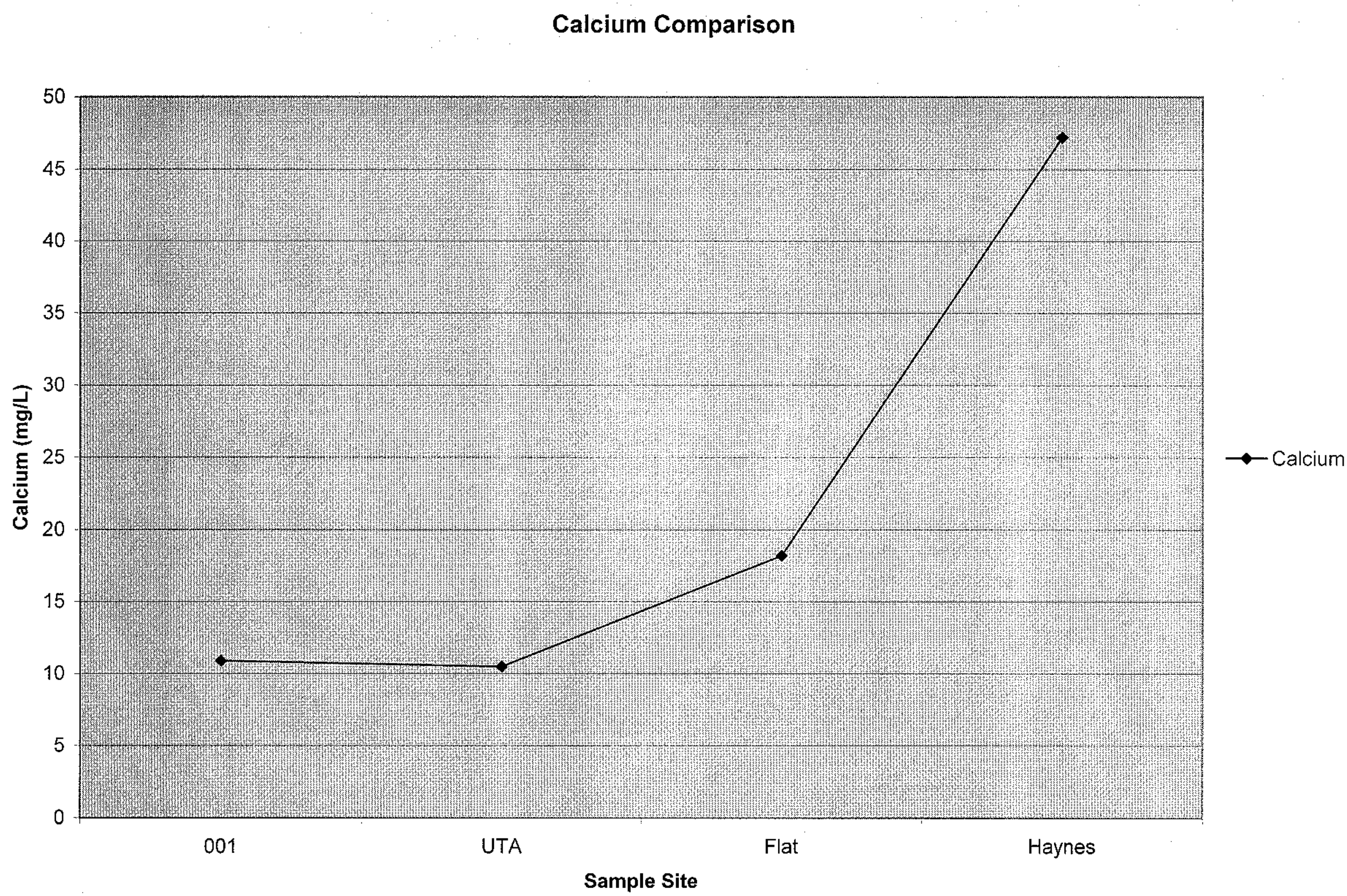

Sulfate Comparison
Sulfate (mg/L)
50
45
40
35
30
25
20
15
10
5
0
001
UTA
Flat
Haynes
Sample Sites
Sulfate


Nitrate Comparison
Nitrate (mg/L)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
001
UTA
Flat
Haynes
Sample Sites
Nitrate

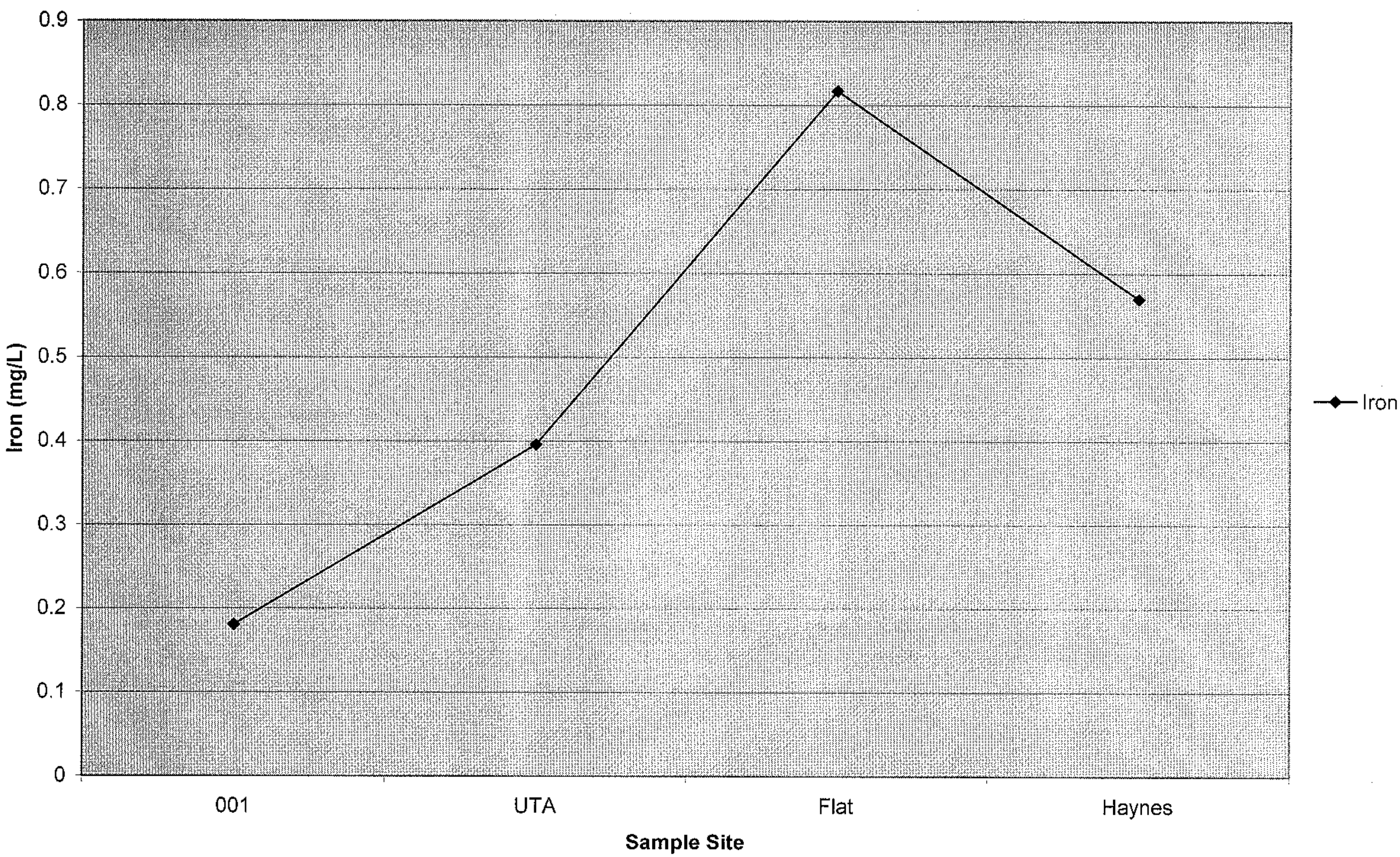

Aluminum Comparison
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Aluminum (mg/L)
001
UTA
Flat
Haynes
Sample Sites
Aluminum

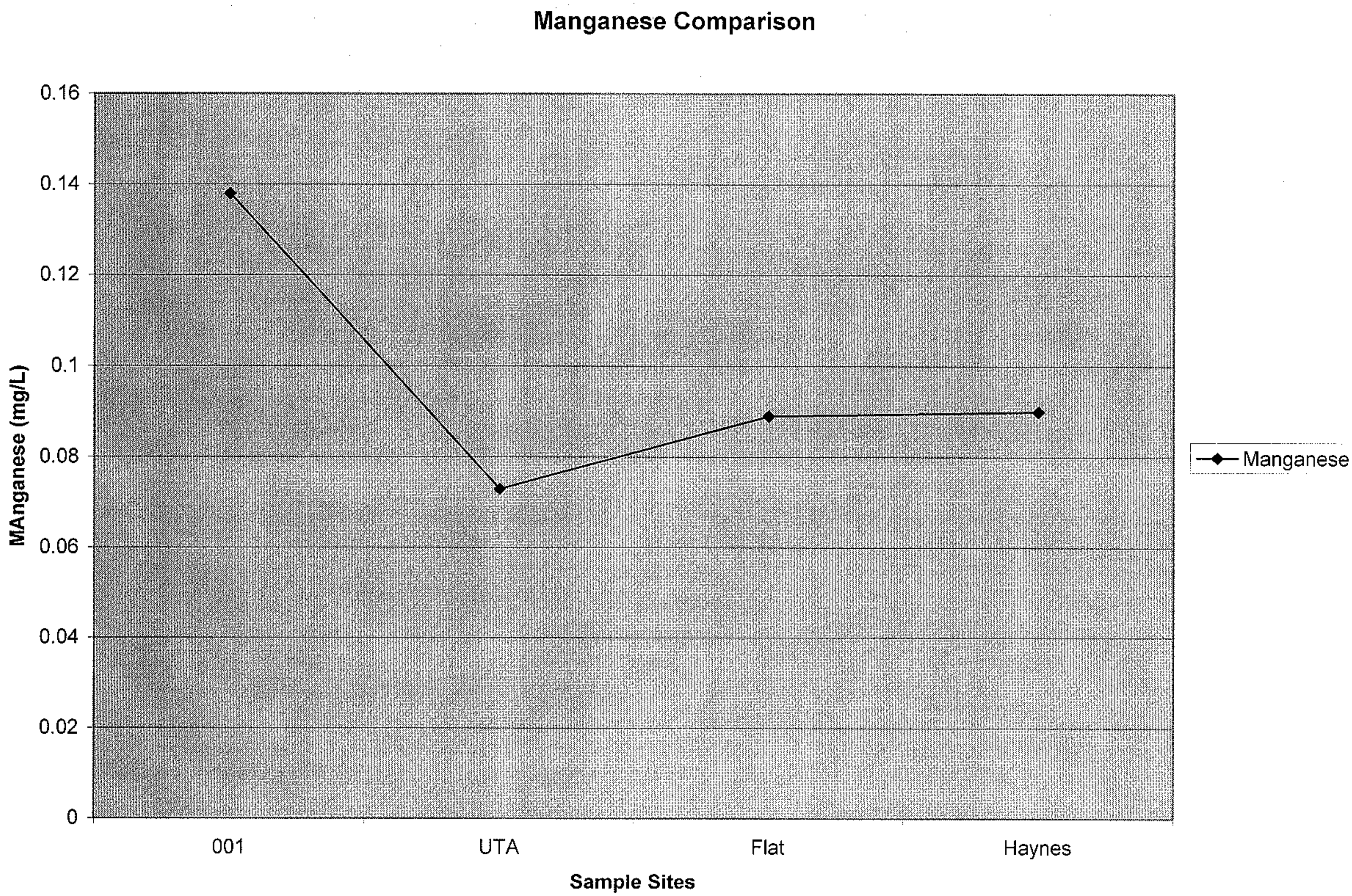


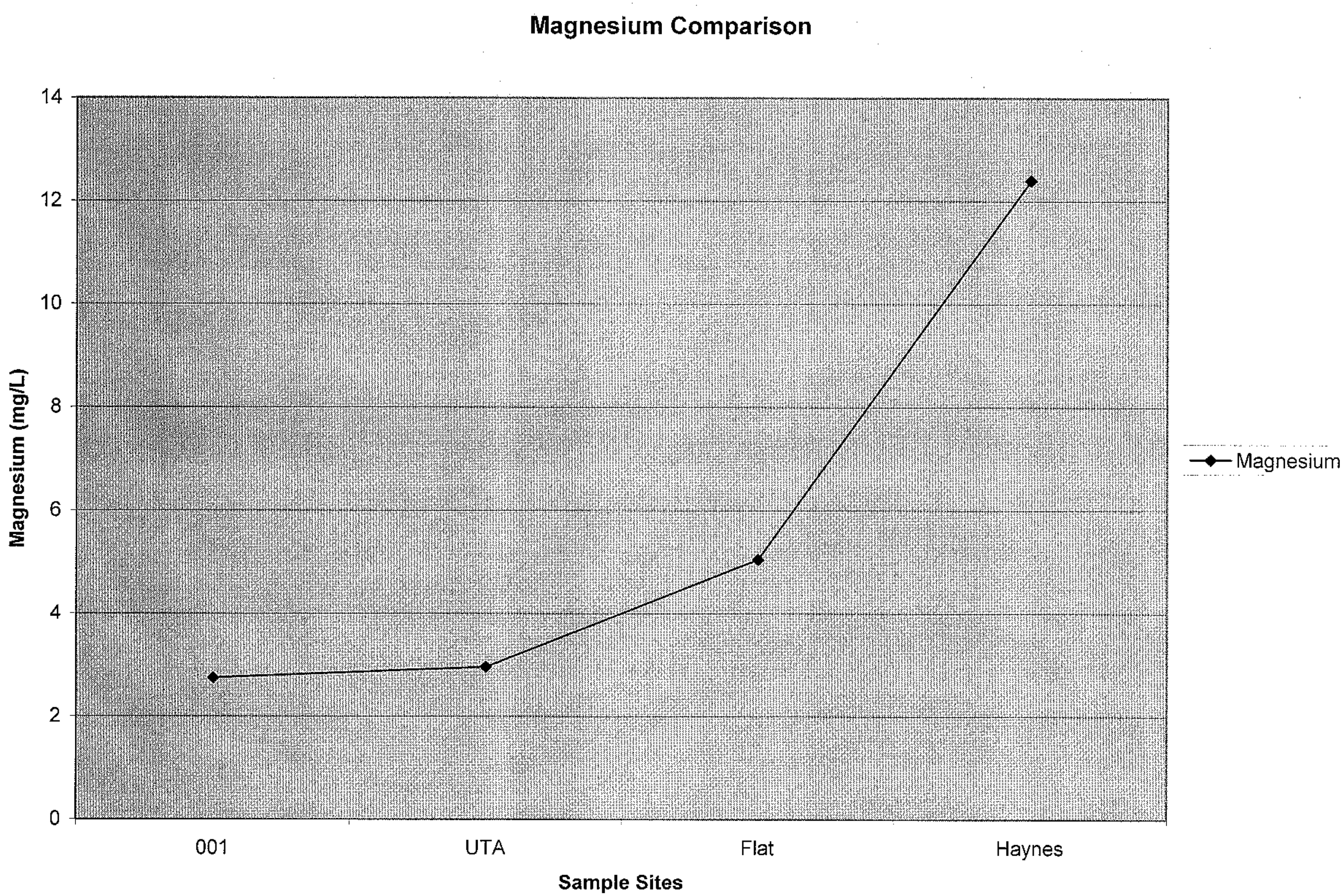
Barium Comparison
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Barium (mg/L)
001
UTA
Flat
Haynes
Sample Site
Barium


Calcium Comparison
50
45
40
35
30
25
20
15
10
5
0
Calcium (mg/L)
001
UTA
Flat
Haynes
Sample Site
Calcium

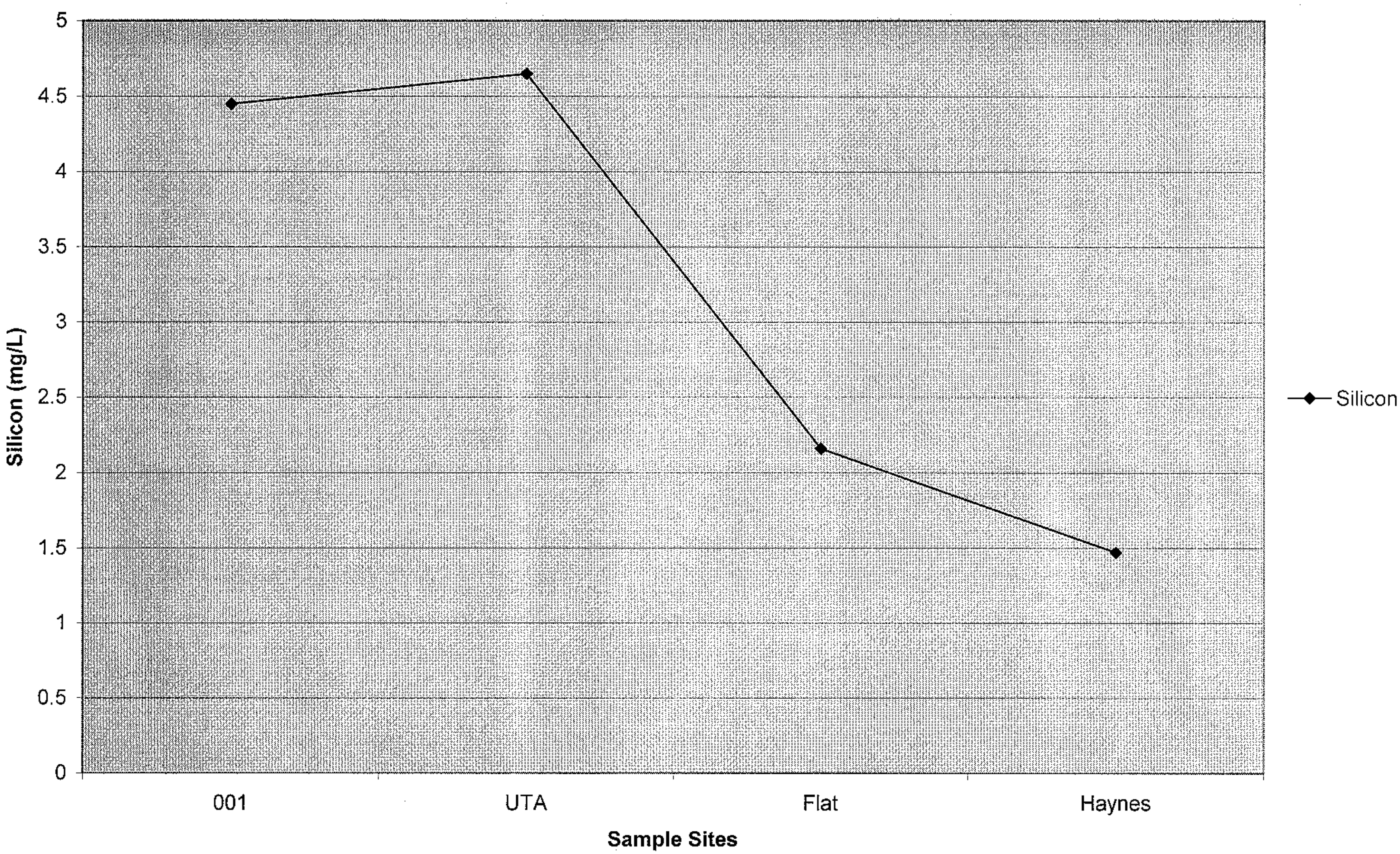
Iron Comparison



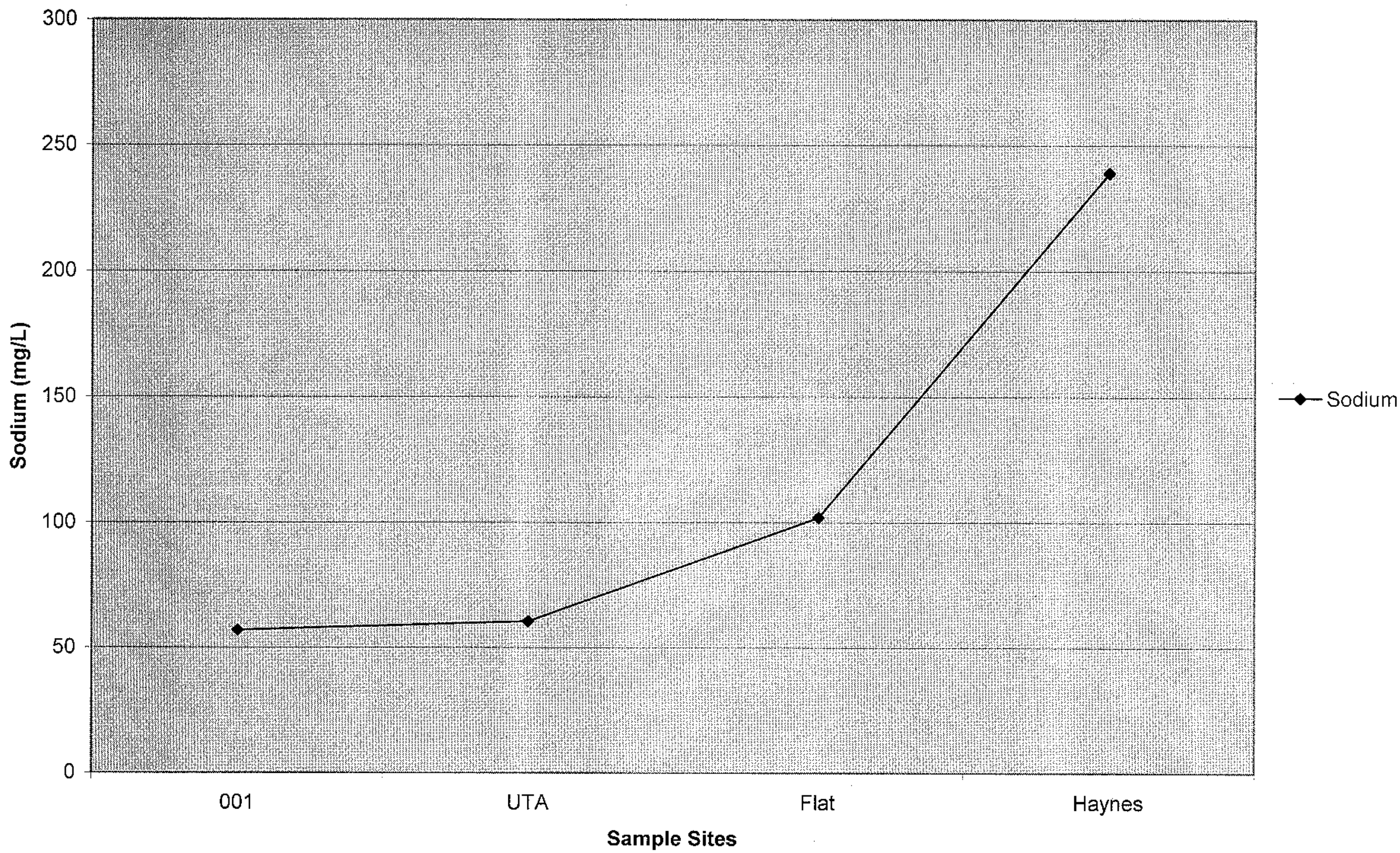

Manganese Comparison
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
MAnganese (mg/L)
001
UTA
Flat
Haynes
Sample Sites
Manganese

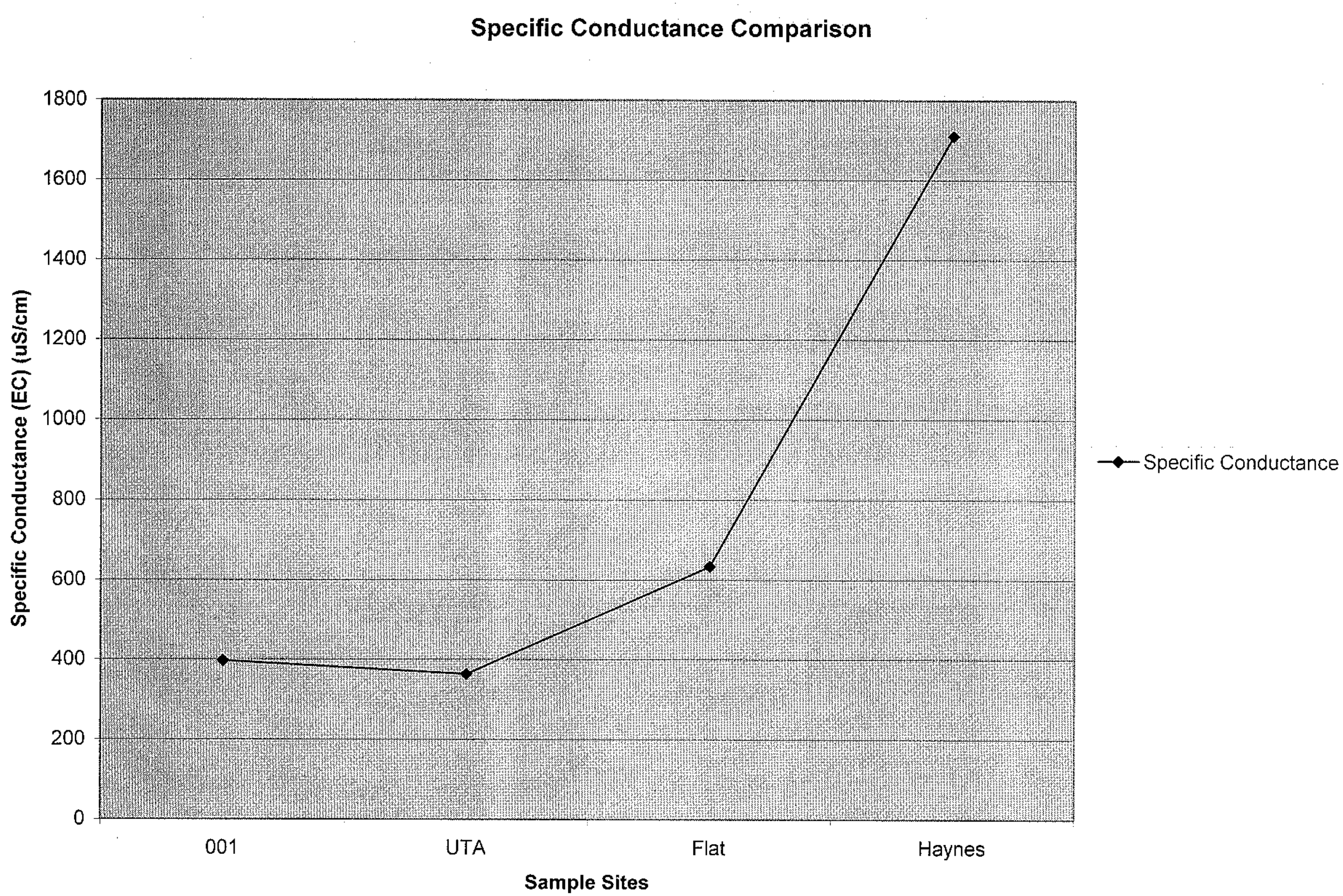

Magnesium Comparison
Magnesium (mg/L)
14
12
10
8
6
4
2
0
001
UTA
Flat
Haynes
Sample Sites
Magnesium

Silicon Comparison

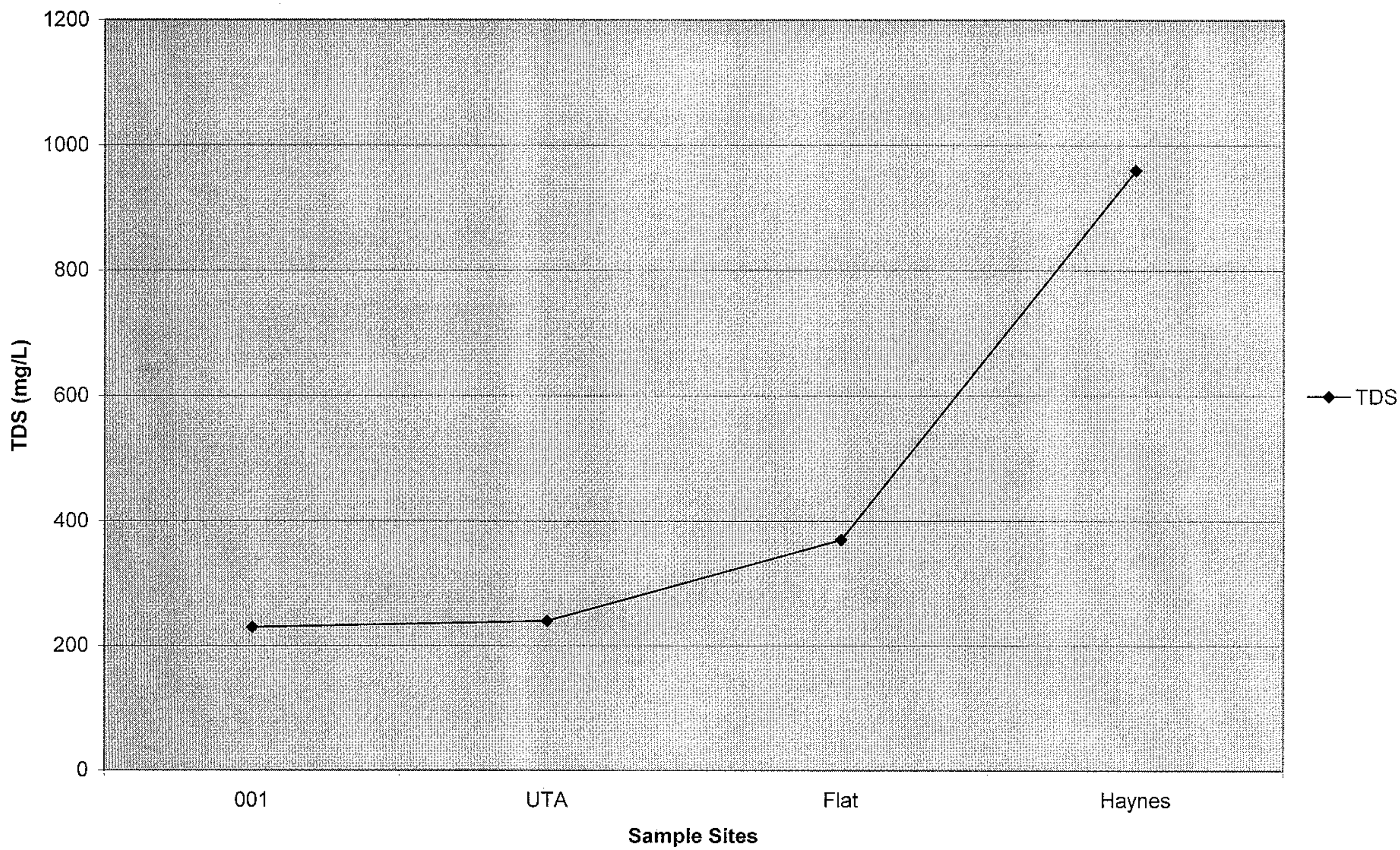


Sodium Comparison




Specific Conductance Comparison
1800
1600
1400
1200
1000
800
600
400
200
0
Specific Conductance (EC) (uS/cm)
001
UTA
Flat
Haynes
Sample Sites
Specific Conductance

Total Dissolved Solid Comparison



Attachment D

Synthetic Water Development Chemicals

EDC-001											
	0907190-01		0907190-02		0907190-03		0907190-04				
	001		UTA		Flat CR		Haynes				atomic
	mg/L	target	mg/L	target	mg/L	target	mg/L	target			weight
Chloride	28	23	25.2	16	100	165	485	360			35
Sulfate	28.8	125	28.4	80	43.3	67	39	55			96
Sodium	57		60.5		102		239				23
Potassium	7		6.93		9.14		13.3				39
Calcium	10.9		10.5		18.2		47.2				40
Magnesium	2.75		2.96		5.05		12.5				24.3
Carbonate(CO3)	3		<5		<5		<5				60
Nitrate(No3)	0.637		4.14		1.8		1.85				62
TDS	230	475	240	315	370	560	960	855			
			mg	mg	mg	mg	mg	mg	mg	mg	mg
compound	g/mole	mg/L	Na	CL	K	SO4	Ca	Mg	CO3	NO3	TDS
Sodium Chloride(NaCl)	58	30	11.896552	18.10345	0	0	0	0	0	0	30
Sodium Sulfate(Na2SO4)	142	100	32.394366	0	0	67.6056	0	0	0	0	100
Sodium Carbonate(Na2CO3)	106	175	75.943396	0	0	0	0	0	99.0566	0	175
Sodium Nitrate(NaNO3)	85	0	0	0	0	0	0	0	0	0	0
Potassium Chloride(KCl)	75	10	0	4.666667	5.2	0	0	0	0	0	9.866667
Potassium Sulfate(K2SO4)	174	10	0	0	4.4827586	5.51724	0	0	0	0	10
Potassium Carbonate(K2CO3)	138	10	0	0	5.6521739	0	0	0	4.347826	0	10
Potassium Nitrate(KNO3)	101	0	0	0	0	0	0	0	0	0	0
Calcium Chloride(CaCl2)	110	0	0	0	0	0	0	0	0	0	0
Calcium Sulfate(CaSO4)	136	60	0	0	0	42.3529	17.647059	0	0	0	60
Calcium Carbonate(CaCO3)	100	15	0	0	0	0	6	0	9	0	15
Calcium Nitrate(Ca(No3)2)	164	0	0	0	0	0	0	0	0	0	0
Magnesium Chloride(MgCl2)	94.3	0	0	0	0	0	0	0	0	0	0
Magnesium Sulfate(MgSO4)	120.3	10	0	0	0	7.98005	0	2.01995	0	0	10
Magnesium Carbonate(MgCO3)	84.3	15	0	0	0	0	0	4.323843	10.67616	0	15
Magnesium Nitrate(Mg(NO3)2)	148.3	0	0	0	0	0	0	0	0	0	0
we have these chemicals		Sum:	120.23431	22.77011	15.334933	123.456	23.647059	6.343794	123.0806	0	434.8667
		existing	57	28	7	28.8	10.9	2.75	3	0.637	230
		Target		23		125					475
ratio to sodium		existing	1		0.122807		0.1912281	0.048246			
theoretical			1		0.1275421		0.1966748	0.052762			

EDC-UTA											
	0907190-01		0907190-02		0907190-03		0907190-04				
	001		UTA		Flat CR		Haynes				atomic
	mg/L	target	mg/L	target	mg/L	target	mg/L	target			weight
Chloride	28	23	25.2	16	100	165	485	360			35
Sulfate	28.8	125	28.4	80	43.3	67	39	55			96
Sodium	57		60.5		102		239				23
Potassium	7		6.93		9.14		13.3				39
Calcium	10.9		10.5		18.2		47.2				40
Magnesium	2.75		2.96		5.05		12.5				24.3
Carbonate(CO3)	3		<5		<5		<5				60
Nitrate(No3)	0.637		4.14		1.8		1.85				62
TDS	230	475	240	315	370	560	960	855			
			mg	mg	mg	mg	mg	mg	mg	mg	mg
compound	g/mole	mg/L	Na	CL	K	SO4	Ca	Mg	CO3	NO3	TDS
Sodium Chloride(NaCl)	58	12	4.758621	7.241379	0	0	0	0	0	0	12
Sodium Sulfate(Na2SO4)	142.04	67	21.70423	0	0	45.29577	0	0	0	0	67
Sodium Carbonate(Na2CO3)	106	150	65.09434	0	0	0	0	0	84.90566	0	150
Sodium Nitrate(NaNO3)	75	0	0	0	0	0	0	0	0	0	0
Potassium Chloride(KCl)	74.551	9	0	4.2	4.68	0	0	0	0	0	8.88
Potassium Sulfate(K2SO4)	174.259	4	0	0	1.793103	2.206897	0	0	0	0	4
Potassium Carbonate(K2CO3)	138	7	0	0	3.956522	0	0	0	3.043478	0	7
Potassium Nitrate(KNO3)	101	0	0	0	0	0	0	0	0	0	0
Calcium Chloride(CaCl2)	110	5	0	1.818182	0	0	3.181818	0	0	0	5
Calcium Sulfate(CaSO4)	136.4	24	0	0	0	16.94118	7.058824	0	0	0	24
Calcium Carbonate(CaCO3)	100	14	0	0	0	0	5.6	0	8.4	0	14
Calcium Nitrate(Ca(No3)2)	164	0	0	0	0	0	0	0	0	0	0
Magnesium Chloride(MgCl2)	95.2	3	0	2.226935	0	0	0	0.773065	0	0	3
Magnesium Sulfate(MgSO4)	120.4	15	0	0	0	11.97007	0	3.029925	0	0	15
Magnesium Carbonate(MgCO3)	84.3	3	0	0	0	0	0	0.864769	2.135231	0	3
Magnesium Nitrate(Mg(NO3)2)	148.3	0	0	0	0	0	0	0	0	0	0
		Sum:	91.55719	15.4865	10.42963	76.41392	15.84064	4.667759	98.48437	0	312.88
		existing	60.5	25.2	6.93	28.4	10.5	2.96	<5	4.14	240
		Target		16		80					315
ratio to sodium		existing	1		0.114545		0.173554	0.048926			
theoretical			1		0.113914		0.173014	0.050982			
				yes	yes	yes	yes	yes			yes

EDC- Flat CR										atomic
	0907190-01		0907190-02		0907190-03		0907190-04			
	001		UTA		Flat CR		Haynes			atomic
	mg/L	target	mg/L	target	mg/L	target	mg/L	target		weight
Chloride	28	23	25.2	16	100	165	485	360		35
Sulfate	28.8	125	28.4	80	43.3	67	39	55		96
Sodium	57		60.5		102		239			23
Potassium	7		6.93		9.14		13.3			39
Calcium	10.9		10.5		18.2		47.2			40
Magnesium	2.75		2.96		5.05		12.5			24.3
Carbonate(CO3)	3		<5		<5		<5			60
Nitrate(No3)	0.637		4.14		1.8		1.85			62
TDS	230	475	240	315	370	560	960	855		

compound	g/mole	mg/L	mg Na	mg CL	mg K	mg SO4	mg Ca	mg Mg	mg CO3	mg NO3	mg TDS
Sodium Chloride(NaCl)	58	240	95.17241	144.8276	0	0	0	0	0	0	240
Sodium Sulfate(Na2SO4)	142	45	14.57746	0	0	30.42254	0	0	0	0	45
Sodium Carbonate(Na2CO3)	106	160	69.43396	0	0	0	0	0	90.56604	0	160
Sodium Nitrate(NaNO3)	85	0	0	0	0	0	0	0	0	0	0
Potassium Chloride(KCl)	75	10	0	4.666667	5.2	0	0	0	0	0	9.866667
Potassium Sulfate(K2SO4)	174	13	0	0	5.827586	7.172414	0	0	0	0	13
Potassium Carbonate(K2CO3)	138	10	0	0	5.652174	0	0	0	4.347826	0	10
Potassium Nitrate(KNO3)	101	0	0	0	0	0	0	0	0	0	0
Calcium Chloride(CaCl2)	110	20	0	7.272727	0	0	12.72727	0	0	0	20
Calcium Sulfate(CaSO4)	136	40	0	0	0	28.23529	11.76471	0	0	0	40
Calcium Carbonate(CaCO3)	100	15	0	0	0	0	6	0	9	0	15
Calcium Nitrate(Ca(No3)2)	164	0	0	0	0	0	0	0	0	0	0
Magnesium Chloride(MgCl2)	94.3	15	0	11.13468	0	0	0	3.865323	0	0	15
Magnesium Sulfate(MgSO4)	120.3	4	0	0	0	3.19202	0	0.80798	0	0	4
Magnesium Carbonate(MgCO3)	84.3	15	0	0	0	0	0	4.323843	10.67616	0	15
Magnesium Nitrate(Mg(NO3)2)	148.3	0	0	0	0	0	0	0	0	0	0
we have these chemicals		Sum:	179.1838	167.9017	16.67976	69.02226	30.49198	8.997147	114.59	0	586.8667
		existing	102	100	9.14	43.3	18.2	5.05	<5	1.8	370
		Target		165		67					560
ratio to sodium		existing	1		0.089608		0.178431	0.04951			
theoretical			1		0.093087		0.170171	0.050212			

EDC- Haynes											
	0907190-01		0907190-02		0907190-03		0907190-04				
	001		UTA		Flat CR		Haynes				atomic
	mg/L	target	mg/L	target	mg/L	target	mg/L	target			weight
Chloride	28	23	25.2	16	100	165	485	360			35
Sulfate	28.8	125	28.4	80	43.3	67	39	55			96
Sodium	57		60.5		102		239				23
Potassium	7		6.93		9.14		13.3				39
Calcium	10.9		10.5		18.2		47.2				40
Magnesium	2.75		2.96		5.05		12.5				24.3
Carbonate(CO3)	3		<5		<5		<5				60
Nitrate(No3)	0.637		4.14		1.8		1.85				62
TDS	230	475	240	315	370	560	960	855			
			mg	mg	mg	mg	mg	mg	mg	mg	mg
compound	g/mole	mg/L	Na	CL	K	SO4	Ca	Mg	CO3	NO3	TDS
Sodium Chloride(NaCl)	58	510	202.2414	307.7586	0	0	0	0	0	0	510
Sodium Sulfate(Na2SO4)	142.04	10	3.239437	0	0	6.760563	0	0	0	0	10
Sodium Carbonate(Na2CO3)	106	120	52.07547	0	0	0	0	0	67.92453	0	120
Sodium Nitrate(NaNO3)	85	0	0	0	0	0	0	0	0	0	0
Potassium Chloride(KCl)	74.551	18	0	8.4	9.36	0	0	0	0	0	17.76
Potassium Sulfate(K2SO4)	174.259	18	0	0	8.068966	9.931034	0	0	0	0	18
Potassium Carbonate(K2CO3)	138	11	0	0	6.217391	0	0	0	4.782609	0	11
Potassium Nitrate(KNO3)	101	0	0	0	0	0	0	0	0	0	0
Calcium Chloride(CaCl2)	110	55	0	20	0	0	35	0	0	0	55
Calcium Sulfate(CaSO4)	136.4	26	0	0	0	18.35294	7.647059	0	0	0	26
Calcium Carbonate(CaCO3)	100	9	0	0	0	0	3.6	0	5.4	0	9
Calcium Nitrate(Ca(No3)2)	164	0	0	0	0	0	0	0	0	0	0
Magnesium Chloride(MgCl2)	95.2	22	0	16.33086	0	0	0	5.669141	0	0	22
Magnesium Sulfate(MgSO4)	120.4	26	0	0	0	20.74813	0	5.25187	0	0	26
Magnesium Carbonate(MgCO3)	84.3	9	0	0	0	0	0	2.594306	6.405694	0	9
Magnesium Nitrate(Mg(NO3)2)	148	0	0	0	0	0	0	0	0	0	0
we have these chemicals		Sum:	257.5563	352.4895	23.64636	55.79267	46.24706	13.51532	84.51283	0	833.76
		existing	239	485	13.3	39	47.2	12.5	<5	1.85	960
		Target		360		55					855
ratio to sodium		existing	1		0.055649		0.19749	0.052301			
theoretical			1		0.09181		0.179561	0.052475			

Attachment E

Synthetic WET Test Results

September 12, 2009

Chronic WET Testing

Synthetic Matrices

Prepared for:

Mr. Roland McDaniel

Principal/ Senior Scientist

GBMC and Associates

RE: El Dorado Chemical

Prepared by:

Arkansas Analytical, Inc.

11701 I-30, Bldg 1, Suite 115

Little Rock, AR 72209

Overview

The purpose of this report is to provide results of chronic biomonitoring (WET) tests. The tests were performed utilizing synthetic mixtures of salts diluted with moderately hard water in a dilution series. The species tested were *ceriodaphnia dubia* and *pimephales promelas.* The tests were performed utilizing standard testing protocol as defined in Test 1000.0 (Fathead minnow, Pimephales promelas, Larval Survival and Growth Test and, in Test 1002.0 (Ceriodaphnia dubia, Survival and Reproduction Test). A standard dilution series of 0%, 6.25%, 12.5%, 25%, 50%, and 100% were analyzed.

Tabulated below find a summary of the Test Matrices, the target and actual concentrations of the analytes of interest, and the test results.

Sample ID	Target /Actual Concentrations			*Ceriodaphnia dubia*		*Pimephales Promelas*	
	Chloride (mg/L)	Sulfate (mg/L)	TDS(mg/L)	NOEC/LOEC Survival	NOEC/ LOEC Reproduction	NOEC/ LOEC Survival	NOEC/ LOEC Growth
EDC 001	23/28.1	125/ 109	475/410	100%	100%	100%	100%
EDC UTA	16/17.7	80/80.	315/300	100%	100%	100%	100%
EDC Flat Creek	165/157	67/61.3	560/510	100%	50%	100%	100%
EDC Haynes	360/378	55/50.6	855/810	100%	25%	100%	100%

Synthetic Mixture Preparation

A variety of salts were selected to prepare solutions containing the desired analytes at target concentrations. The target analytes were chloride, sulfate, and TDS. Additionally, it was desirable to match the cation ratio to that of the original tested "native" samples. All salts were dried to remove the moisture content before weighing, except in the case of hydrated salts. Concentrates were prepared which were diluted to a working volume each day of the test. The same concentrate was utilized for the entire test. Salts of sodium, calcium, potassium, and magnesium were used. EDC 001 and EDC UTA were also dosed with an amount of lead standard to match the concentration in the "native" samples.

On the following pages are detailed bench sheets from each sample tested. Included are the data sheets followed by the statistical analysis. Also included are the water chemistry analyses from each day of testing. Copies of the raw bench sheets are provided as well in the Appendix.

Also find a detail of the salts used to prepare the synthetic mixtures and the lab analysis of the solutions as used for the test.

EDC- 001 Synthetic

Bench Sheets

Statistical Analysis

Chemistry Bench Sheets

SURVIVAL DATA FOR FATHEAD MINNOW LARVAL SURVIVAL AND GROWTH TEST

LAB # / SAMPLE ID				TEST START	DATE 9/01/09			TIME 1415				
CLIENT	EDC-001 SYNTHETIC			TEST END	DATE 9/8/2009			TIME		1150		
				AGE AND SOURCE OF MINNOWS								
				D A Y (NUMBER SURVIVING)					SURVIVAL			
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	10	10	10	10	10	10	10	100		
	B	10	10	10	10	10	10	10	10	100		
	C	10	10	10	10	10	10	10	10	100		
	D	10	10	10	10	10	10	10	10	100		
0	E	10	10	10	10	10	10	10	10	100	100	0
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	10	10	10	10	10	10	10	100		
	B	10	10	10	10	10	10	10	10	100		
	C	10	10	10	10	10	10	10	10	100		
	D	10	10	10	10	10	10	10	10	100		
6.25%	E	10	10	10	10	10	10	10	10	100	100	
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	10	10	10	10	10	10	10	100		
	B	10	9	9	9	9	9	9	9	90		
	C	10	10	10	10	10	10	10	10	100		
	D	10	10	10	10	10	10	10	10	100		
12.50%	E	10	10	10	10	10	10	10	10	100	98	
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	10	10	9	9	9	9	9	90		
	B	10	10	10	10	10	10	10	10	100		
	C	10	10	10	10	10	10	10	10	100		
	D	10	10	10	10	10	10	10	10	100		
25%	E	10	9	9	9	9	9	9	9	90	96	
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	10	10	10	10	10	10	10	100		
	B	10	10	10	10	10	10	10	10	100		
	C	10	10	10	10	10	10	10	10	100		
	D	10	10	10	10	10	10	10	10	100		
50%	E	10	10	10	10	10	10	10	10	100	100	
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	9	9	9	9	9	9	9	90		
	B	10	10	10	10	10	10	10	10	100		
	C	10	10	10	10	10	10	10	10	100		
	D	10	10	10	10	10	10	10	9	90		
100%	E	10	9	9	9	9	9	9	9	90	94	5.83
ANALYST		KP	KP	KP	KP	MG	MG	CT	KP			
DATE:		9/1/2009	9/2/2009	9/3/2009	9/4/2009	9/5/2009	9/6/2009	9/7/2009	9/8/2009			
TIME:		1415	1545	1705	1325	935	1040	1100	1150			

CV = PERCENT COEFFICIENT OF VARIATION: STANDARD DEVIATION/MEAN * 100

AA# EDC-001, FATHEAD MINNOW SURVIVAL, CHRONIC
File: H:\TOXSTAT\MONTE\CKSMPLEF.   Transform: ARC SINE(SQUARE ROOT(Y))

Shapiro - Wilk's test for normality

D =   0.085

W =   0.893

Critical W (P = 0.05) (n = 30) = 0.927
Critical W (P = 0.01) (n = 30) = 0.900

Data FAIL normality test. Try another transformation.

Warning - The first three homogeneity tests are sensitive to non-normal data and should not be performed.

AA# EDC-001, FATHEAD MINNOW SURVIVAL, CHRONIC
File: H:\TOXSTAT\MONTE\CKSMPLEF.   Transform: ARC SINE(SQUARE ROOT(Y))

Hartley's test for homogeneity of variance
Bartlett's test for homogeneity of variance

These two tests can not be performed because at least one group has zero variance.

Data FAIL to meet homogeneity of variance assumption.
Additional transformations are useless.

TITLE: AA# EDC-001, FATHEAD MINNOW SURVIVAL, CHRONIC
FILE: H:\TOXSTAT\MONTE\CKSMPLEF.
TRANSFORM: ARC SINE(SQUARE ROOT(Y))   NUMBER OF GROUPS: 6

GRP	IDENTIFICATION	REP	VALUE	TRANS VALUE
1	CONTROL	1	1.0000	1.4120
1	CONTROL	2	1.0000	1.4120
1	CONTROL	3	1.0000	1.4120
1	CONTROL	4	1.0000	1.4120
1	CONTROL	5	1.0000	1.4120
2	6.25 % EFFLUENT	1	1.0000	1.4120
2	6.25 % EFFLUENT	2	1.0000	1.4120
2	6.25 % EFFLUENT	3	1.0000	1.4120
2	6.25 % EFFLUENT	4	1.0000	1.4120
2	6.25 % EFFLUENT	5	1.0000	1.4120

3	12.5 % EFFLUENT	1	1.0000	1.4120
3	12.5 % EFFLUENT	2	0.9000	1.2490
3	12.5 % EFFLUENT	3	1.0000	1.4120
3	12.5 % EFFLUENT	4	1.0000	1.4120
3	12.5 % EFFLUENT	5	1.0000	1.4120
4	25.0 % EFFLUENT	1	0.9000	1.2490
4	25.0 % EFFLUENT	2	1.0000	1.4120
4	25.0 % EFFLUENT	3	1.0000	1.4120
4	25.0 % EFFLUENT	4	1.0000	1.4120
4	25.0 % EFFLUENT	5	0.9000	1.2490
5	50 % EFFLUENT	1	1.0000	1.4120
5	50 % EFFLUENT	2	1.0000	1.4120
5	50 % EFFLUENT	3	1.0000	1.4120
5	50 % EFFLUENT	4	1.0000	1.4120
5	50 % EFFLUENT	5	1.0000	1.4120
6	100 % EFFLUENT	1	0.9000	1.2490
6	100 % EFFLUENT	2	1.0000	1.4120
6	100 % EFFLUENT	3	1.0000	1.4120
6	100 % EFFLUENT	4	0.9000	1.2490
6	100 % EFFLUENT	5	0.9000	1.2490

AA# EDC-001, FATHEAD MINNOW SURVIVAL, CHRONIC
File: H:\TOXSTAT\MONTE\CKSMPLEF. Transform: ARC SINE(SQUARE ROOT(Y))

STEEL'S MANY-ONE RANK TEST - Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	RANK SUM	CRIT. VALUE	df	SIG
1	CONTROL	1.412				
2	6.25 % EFFLUENT	1.412	27.50	16.00	5.00	
3	12.5 % EFFLUENT	1.379	25.00	16.00	5.00	
4	25.0 % EFFLUENT	1.347	22.50	16.00	5.00	
5	50 % EFFLUENT	1.412	27.50	16.00	5.00	
6	100 % EFFLUENT	1.314	20.00	16.00	5.00	

Critical values use k = 5, are 1 tailed, and alpha = 0.05

Pimephales promelas **FATHEAD MINNOW** TEST 1000.0

WEIGHT DATA FOR LARVAL SURVIVAL AND GROWTH TEST

LAB # / #s:	NA			TEST DATES (BEGIN / END):	9/01-08/09
CLIENT:	EDC			WEIGHING DATE / TIME:	9/09/09, 1130
ANALYSTS:	KP			DRYING TEMP (DEGREES C):	60
SAMPLE ID:	EDC 001 SYNTHETIC			DRYING TIME (HOURS):	24

	REP#	FINAL DRY WEIGHT TIN+LARVAE (g)	INTIAL WEIGHT TIN (g)	TOTAL DRY WEIGHT OF LARVAE (g)	NUMBER OF LARVAE	DRY WEIGHT OF LARVAE (mg)	
CONTROL	A	0.98654	0.98248	0.00406	10	0.406	AVG DRY
	B	0.99623	0.99247	0.00376	10	0.376	WEIGHT (mg)
	C	1.00374	0.99986	0.00388	10	0.388	0.378
	D	1.00286	0.99980	0.00306	10	0.306	CV
0	E	0.98262	0.97848	0.00414	10	0.414	11.4
CONC:	A	0.98935	0.98517	0.00418	10	0.418	AVG DRY
	B	0.98835	0.98392	0.00443	10	0.443	WEIGHT (mg)
	C	0.96200	0.95775	0.00425	10	0.425	0.432
	D	0.96836	0.96391	0.00445	10	0.445	CV
6.25%	E	0.99183	0.98756	0.00427	10	0.427	2.7
CONC:	A	1.01071	1.00629	0.00442	10	0.442	AVG DRY
	B	0.96670	0.96258	0.00412	10	0.412	WEIGHT (mg)
	C	0.97363	0.96860	0.00503	10	0.503	0.461
	D	0.98075	0.97625	0.00450	10	0.450	CV
12.50%	E	0.97897	0.97397	0.00500	10	0.500	8.5
CONC:	A	0.97104	0.96656	0.00448	10	0.448	AVG DRY
	B	0.97829	0.97347	0.00482	10	0.482	WEIGHT (mg)
	C	0.97141	0.96700	0.00441	10	0.441	0.456
	D	0.96965	0.96528	0.00437	10	0.437	CV
25%	E	0.96572	0.96101	0.00471	10	0.471	4.3
CONC:	A	0.97858	0.97391	0.00467	10	0.467	AVG DRY
	B	0.97912	0.97440	0.00472	10	0.472	WEIGHT (mg)
	C	0.96689	0.96266	0.00423	10	0.423	0.446
	D	0.97360	0.96917	0.00443	10	0.443	CV
50%	E	0.97064	0.96641	0.00423	10	0.423	5.2
CONC:	A	0.99229	0.98787	0.00442	10	0.442	AVG DRY
	B	0.96819	0.96324	0.00495	10	0.495	WEIGHT (mg)
	C	0.97467	0.96792	0.00675	10	0.675	0.536
	D	1.01443	1.00919	0.00524	10	0.524	CV
100%	E	0.97707	0.97164	0.00543	10	0.543	16.2

CV = (STANDARD DEVIATION/MEAN)*100

REMARKS:

AA# EDC-001, FATHEAD MINNOW GROWTH, CHRONIC, 9-1-09
File: H:\TOXSTAT\MONTE\CKSMPLGR.   Transform: ARC SINE(SQUARE ROOT(Y))

Shapiro - Wilk's test for normality

D = 0.050

W = 0.907

Critical W (P = 0.05) (n = 30) = 0.927
Critical W (P = 0.01) (n = 30) = 0.900

Data PASS normality test at P=0.01 level. Continue analysis.

AA# EDC-001, FATHEAD MINNOW GROWTH, CHRONIC, 9-1-09
File: H:\TOXSTAT\MONTE\CKSMPLGR.   Transform: ARC SINE(SQUARE ROOT(Y))

Bartlett's test for homogeneity of variance
Calculated B1 statistic = 17.00

Table Chi-square value = 15.09 (alpha = 0.01, df = 5)
Table Chi-square value = 11.07 (alpha = 0.05, df = 5)

Data FAIL B1 homogeneity test at 0.01 level. Try another transformation.

TITLE: AA# EDC-001, FATHEAD MINNOW GROWTH, CHRONIC, 9-1-09
FILE: H:\TOXSTAT\MONTE\CKSMPLGR.
TRANSFORM: ARC SINE(SQUARE ROOT(Y))   NUMBER OF GROUPS: 6

GRP	IDENTIFICATION	REP	VALUE	TRANS VALUE
1	CONTROL	1	0.4060	0.6908
1	CONTROL	2	0.3760	0.6601
1	CONTROL	3	0.3880	0.6724
1	CONTROL	4	0.3060	0.5862
1	CONTROL	5	0.4130	0.6980
2	6.25 % EFFLUENT	1	0.4180	0.7030
2	6.25 % EFFLUENT	2	0.4430	0.7283
2	6.25 % EFFLUENT	3	0.4250	0.7101
2	6.25 % EFFLUENT	4	0.4450	0.7303
2	6.25 % EFFLUENT	5	0.4270	0.7121
3	12.5 % EFFLUENT	1	0.4420	0.7273
3	12.5 % EFFLUENT	2	0.4120	0.6969
3	12.5 % EFFLUENT	3	0.5030	0.7884
3	12.5 % EFFLUENT	4	0.4500	0.7353
3	12.5 % EFFLUENT	5	0.5000	0.7854
4	25 % EFFLUENT	1	0.4480	0.7333

4	25 % EFFLUENT	2	0.4820	0.7674
4	25 % EFFLUENT	3	0.4410	0.7263
4	25 % EFFLUENT	4	0.4370	0.7222
4	25 % EFFLUENT	5	0.4710	0.7564
5	50 % EFFLUENT	1	0.4670	0.7524
5	50 % EFFLUENT	2	0.4720	0.7574
5	50 % EFFLUENT	3	0.4230	0.7081
5	50 % EFFLUENT	4	0.4430	0.7283
5	50 % EFFLUENT	5	0.4230	0.7081
6	100 % EFFLUENT	1	0.4420	0.7273
6	100 % EFFLUENT	2	0.4950	0.7804
6	100 % EFFLUENT	3	0.6750	0.9642
6	100 % EFFLUENT	4	0.5240	0.8094
6	100 % EFFLUENT	5	0.5430	0.8285

AA# EDC-001, FATHEAD MINNOW GROWTH, CHRONIC, 9-1-09
File: H:\TOXSTAT\MONTE\CKSMPLGR.   Transform: ARC SINE(SQUARE ROOT(Y))

ANOVA TABLE

SOURCE	DF	SS	MS	F
Between	5	0.067	0.013	6.509
Within (Error)	24	0.050	0.002	
Total	29	0.117		

Critical F value =   2.62 (0.05,5,24)
Since F > Critical F REJECT Ho: All equal

AA# EDC-001, FATHEAD MINNOW GROWTH, CHRONIC, 9-1-09
File: H:\TOXSTAT\MONTE\CKSMPLGR.   Transform: ARC SINE(SQUARE ROOT(Y))

DUNNETT'S TEST   -   TABLE 1 OF 2   Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	MEAN CALCULATED IN ORIGINAL UNITS	T STAT	SIG
1	CONTROL	0.661	0.378		
2	6.25 % EFFLUENT	0.717	0.432	-1.921	
3	12.5 % EFFLUENT	0.747	0.461	-2.960	
4	25 % EFFLUENT	0.741	0.456	-2.767	
5	50 % EFFLUENT	0.731	0.446	-2.410	
6	100 % EFFLUENT	0.822	0.536	-5.576	

Dunnett table value = 2.36   (1 Tailed Value, P=0.05, df=24,5)

AA# EDC-001, FATHEAD MINNOW GROWTH, CHRONIC, 9-1-09
File: H:\TOXSTAT\MONTE\CKSMPLGR.   Transform: ARC SINE(SQUARE ROOT(Y))

DUNNETT'S TEST   -   TABLE 2 OF 2   Ho:Control<Treatment

GROUP	IDENTIFICATION	NUM OF REPS	Minimum Sig Diff (IN ORIG. UNITS)	% of CONTROL	DIFFERENCE FROM CONTROL
1	CONTROL	5			
2	6.25 % EFFLUENT	5	0.064	17.1	-0.054
3	12.5 % EFFLUENT	5	0.064	17.1	-0.084
4	25 % EFFLUENT	5	0.064	17.1	-0.078
5	50 % EFFLUENT	5	0.064	17.1	-0.068
6	100 % EFFLUENT	5	0.064	17.1	-0.158

SURVIVAL AND REPRODUCTION TEST

Ceriodaphnia dubia

Discharger: EDC
Location: 001 synthetic matrix
prepared 9/1/09
Lab Number/s: na

Analyst: KP
Test Start - Date/ Time: 9/1/2009 1430
Test Stop - Date/Time: 9/8/2009 0930

Conc 1 — 0 %

Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
1	0	0	0	0	0	0	0	0	0	0	0			KP
2	0	0	0	0	0	0	0	0	0	0	0			KP
3	0	0	5	0	3	3	0	0	0	2	13			
4	2	3	0	2	0	0	0	5	3	8	23			
5	3	5	3	4	3	0	0	7	8	10	43			KP
6	8	11	7	10	7	8	X0	10	7	2	70	9		KP
7														
8													16.6	
Total	13	19	15	16	13	11	X0	22	18	22	149			

Conc 2 — 6.25 %

Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
1	0	0	0	0	0	0	0	0	0	0	0			
2	0	0	0	0	0	0	0	0	0	0	0			
3	0	2	0	2	0	2	0	0	0	3	9			
4	0	0	3	1	4	0	4	5	6	0	23			
5	5	6	2	4	4	6	5	7	7	7	53			
6	5	9	8	11	10	3	8	0	12	12	78	10		
7														
8														
Total	10	17	13	18	18	11	17	12	25	22	163			

Conc 3 — 12.5 %

Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
1	0	0	0	0	0	0	0	0	0	0	0			
2	0	0	0	0	0	0	0	0	0	0	0			
3	0	2	0	2	2	0	0	X0	0	0	6			
4	2	0	4	0	0	1	0	-	2	0	9			
5	5	4	5	4	6	0	7	-	3	6	40			
6	7	6	11	5	7	10	12	-	7	9	74	9		
7														
8														
Total	14	12	20	11	15	11	19	X0	12	15	129			

Conc 4 — 25 %

Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
1	0	0	0	0	0	0	0	0	0	0	0			
2	0	0	0	0	0	0	0	0	0	0	0			
3	4	0	0	0	0	0	0	0	0	0	4			
4	0	0	5	0	2	0	3	3	0	0	13			
5	7	4	6	5	8	3	7	4	6	5	55			
6	6	9	2	14	3	7	11	6	9	7	74	10		
7														
8														
Total	17	13	13	19	13	10	21	13	15	12	146			

Conc 5 — 50 %

Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
1	0	0	0	0	0	0	0	0	0	0	0			
2	0	0	0	0	0	0	0	0	0	0	0			
3	0	0	2	0	0	2	0	0	0	0	4			
4	5	0	0	0	0	6	3	4	4	3	25			
5	4	5	7	0	6	5	8	3	2	4	44			
6	4	6	6	7	7	8	12	12	10	10	82	10		
7														
8														
Total	13	11	15	7	13	21	23	19	16	17	155			

Conc 6 — 100 %

Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
1	0	0	0	0	0	X0	0	0	0	0	0			
2	0	0	0	0	0	0	0	0	0	0	0			
3	0	0	0	0	2	-	0	0	0	0	2			
4	4	5	0	5	4	-	2	4	0	0	24			
5	3	5	7	3	4	-	2	4	0	2	30			
6	4	4	7	12	6	-	6	8	0	7	54	9	12.2	
7														
8														
Total	11	14	14	20	16	X0	10	16	0	9	110			

X= DEAD; Y= MALE

AA # EDC-001, CERIODAPHNIA DUBIA CHRONIC, REPRODUCTION
File: H:\TOXSTAT\MONTE\CKSMPLEC.   Transform: NO TRANSFORMATION

Shapiro - Wilk's test for normality

******** Shapiro - Wilk's Test is aborted ********

This test can not be performed because total number of replicates is greater than 50.

Total number of replicates = 60

AA # EDC-001, CERIODAPHNIA DUBIA CHRONIC, REPRODUCTION
File: H:\TOXSTAT\MONTE\CKSMPLEC.   Transform: NO TRANSFORMATION

Bartlett's test for homogeneity of variance
Calculated B1 statistic = 4.62

Table Chi-square value = 15.09 (alpha = 0.01, df = 5)
Table Chi-square value = 11.07 (alpha = 0.05, df = 5)

Data PASS B1 homogeneity test at 0.01 level. Continue analysis.

FISHER'S EXACT TEST

IDENTIFICATION	NUMBER OF DEAD	NUMBER OF ALIVE	TOTAL ANIMALS
CONTROL	1	9	10
6.25	0	10	10
TOTAL	1	19	20

CRITICAL FISHER'S VALUE (10,10,1) (p=0.05) IS LESS THAN 0. b VALUE IS 0.
NO SIGNIFICANT DIFFERENCE

FISHER'S EXACT TEST

IDENTIFICATION	NUMBER OF ALIVE	NUMBER OF DEAD	TOTAL ANIMALS
CONTROL	9	1	10
12.5	9	1	10
TOTAL	18	2	20

CRITICAL FISHER'S VALUE (10,10,9) (p=0.05) IS 4. b VALUE IS 9.
Since b is greater than 4 there is no significant difference between CONTROL and TREATMENT at the 0.05 level.

FISHER'S EXACT TEST

IDENTIFICATION	NUMBER OF DEAD	NUMBER OF ALIVE	TOTAL ANIMALS
CONTROL	1	9	10
25	0	10	10

TOTAL	1	19	20

CRITICAL FISHER'S VALUE (10,10,1) (p=0.05) IS LESS THAN 0. b VALUE IS 0.
NO SIGNIFICANT DIFFERENCE

FISHER'S EXACT TEST

IDENTIFICATION	NUMBER OF DEAD	NUMBER OF ALIVE	NUMBER OF TOTAL ANIMALS
CONTROL	1	9	10
50	0	10	10
TOTAL	1	19	20

CRITICAL FISHER'S VALUE (10,10,1) (p=0.05) IS LESS THAN 0. b VALUE IS 0.
NO SIGNIFICANT DIFFERENCE

FISHER'S EXACT TEST

IDENTIFICATION	NUMBER OF ALIVE	NUMBER OF DEAD	NUMBER OF TOTAL ANIMALS
CONTROL	9	1	10
100	9	1	10
TOTAL	18	2	20

CRITICAL FISHER'S VALUE (10,10,9) (p=0.05) IS 4. b VALUE IS 9.
Since b is greater than 4 there is no significant difference between CONTROL and TREATMENT at the 0.05 level.

SUMMARY OF FISHER'S EXACT TESTS

GROUP	IDENTIFICATION	NUMBER EXPOSED	NUMBER DEAD	SIG (P=.05)
	CONTROL	10	1	

1	6.25	10	0
2	12.5	10	1
3	25	10	0
4	50	10	0
5	100	10	1

TITLE: AA # EDC-001, CERIODAPHNIA DUBIA CHRONIC, REPRODUCTION
FILE: H:\TOXSTAT\MONTE\CKSMPLEC.
TRANSFORM: NO TRANSFORMATION NUMBER OF GROUPS: 6

GRP	IDENTIFICATION	REP	VALUE	TRANS VALUE
1	CONTROL	1	13.0000	13.0000
1	CONTROL	2	19.0000	19.0000
1	CONTROL	3	15.0000	15.0000
1	CONTROL	4	16.0000	16.0000
1	CONTROL	5	13.0000	13.0000
1	CONTROL	6	11.0000	11.0000
1	CONTROL	7	0.0000	0.0000
1	CONTROL	8	22.0000	22.0000
1	CONTROL	9	18.0000	18.0000
1	CONTROL	10	22.0000	22.0000
2	6.25 % EFFLUENT	1	10.0000	10.0000
2	6.25 % EFFLUENT	2	17.0000	17.0000
2	6.25 % EFFLUENT	3	13.0000	13.0000
2	6.25 % EFFLUENT	4	18.0000	18.0000
2	6.25 % EFFLUENT	5	18.0000	18.0000
2	6.25 % EFFLUENT	6	11.0000	11.0000
2	6.25 % EFFLUENT	7	17.0000	17.0000
2	6.25 % EFFLUENT	8	12.0000	12.0000
2	6.25 % EFFLUENT	9	25.0000	25.0000
2	6.25 % EFFLUENT	10	22.0000	22.0000
3	12.5 % EFFLUENT	1	14.0000	14.0000
3	12.5 % EFFLUENT	2	12.0000	12.0000
3	12.5 % EFFLUENT	3	20.0000	20.0000
3	12.5 % EFFLUENT	4	11.0000	11.0000
3	12.5 % EFFLUENT	5	15.0000	15.0000
3	12.5 % EFFLUENT	6	11.0000	11.0000
3	12.5 % EFFLUENT	7	19.0000	19.0000
3	12.5 % EFFLUENT	8	0.0000	0.0000
3	12.5 % EFFLUENT	9	12.0000	12.0000
3	12.5 % EFFLUENT	10	15.0000	15.0000
4	25.0 % EFFLUENT	1	17.0000	17.0000
4	25.0 % EFFLUENT	2	13.0000	13.0000
4	25.0 % EFFLUENT	3	13.0000	13.0000
4	25.0 % EFFLUENT	4	19.0000	19.0000
4	25.0 % EFFLUENT	5	13.0000	13.0000
4	25.0 % EFFLUENT	6	10.0000	10.0000
4	25.0 % EFFLUENT	7	21.0000	21.0000
4	25.0 % EFFLUENT	8	13.0000	13.0000
4	25.0 % EFFLUENT	9	15.0000	15.0000
4	25.0 % EFFLUENT	10	12.0000	12.0000
5	50.0 % EFFLUENT	1	13.0000	13.0000

5	50.0 % EFFLUENT	2	11.0000	11.0000
5	50.0 % EFFLUENT	3	15.0000	15.0000
5	50.0 % EFFLUENT	4	7.0000	7.0000
5	50.0 % EFFLUENT	5	13.0000	13.0000
5	50.0 % EFFLUENT	6	21.0000	21.0000
5	50.0 % EFFLUENT	7	23.0000	23.0000
5	50.0 % EFFLUENT	8	19.0000	19.0000
5	50.0 % EFFLUENT	9	16.0000	16.0000
5	50.0 % EFFLUENT	10	17.0000	17.0000
6	100 % EFFLUENT	1	11.0000	11.0000
6	100 % EFFLUENT	2	14.0000	14.0000
6	100 % EFFLUENT	3	14.0000	14.0000
6	100 % EFFLUENT	4	20.0000	20.0000
6	100 % EFFLUENT	5	16.0000	16.0000
6	100 % EFFLUENT	6	0.0000	0.0000
6	100 % EFFLUENT	7	10.0000	10.0000
6	100 % EFFLUENT	8	16.0000	16.0000
6	100 % EFFLUENT	9	0.0000	0.0000
6	100 % EFFLUENT	10	9.0000	9.0000

AA # EDC-001, CERIODAPHNIA DUBIA CHRONIC, REPRODUCTION
File: H:\TOXSTAT\MONTE\CKSMPLEC. Transform: NO TRANSFORMATION

ANOVA TABLE

SOURCE	DF	SS	MS	F
Between	5	186.800	37.360	1.289
Within (Error)	54	1564.800	28.978	
Total	59	1751.600		

Critical F value = 2.45 (0.05,5,40)
Since F < Critical F FAIL TO REJECT Ho: All equal

AA # EDC-001, CERIODAPHNIA DUBIA CHRONIC, REPRODUCTION
File: H:\TOXSTAT\MONTE\CKSMPLEC. Transform: NO TRANSFORMATION

DUNNETT'S TEST - TABLE 1 OF 2 Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	MEAN CALCULATED IN ORIGINAL UNITS	T STAT	SIG
1	CONTROL	14.900	14.900		
2	6.25 % EFFLUENT	16.300	16.300	-0.582	
3	12.5 % EFFLUENT	12.900	12.900	0.831	
4	25.0 % EFFLUENT	14.600	14.600	0.125	
5	50.0 % EFFLUENT	15.500	15.500	-0.249	
6	100 % EFFLUENT	11.000	11.000	1.620	

Dunnett table value = 2.31 (1 Tailed Value, P=0.05, df=40,5)

AA # EDC-001, CERIODAPHNIA DUBIA CHRONIC, REPRODUCTION
File: H:\TOXSTAT\MONTE\CKSMPLEC.   Transform: NO TRANSFORMATION

DUNNETT'S TEST - TABLE 2 OF 2   Ho:Control<Treatment

GROUP	IDENTIFICATION	NUM OF REPS	Minimum Sig Diff (IN ORIG. UNITS)	% of CONTROL	DIFFERENCE FROM CONTROL
1	CONTROL	10			
2	6.25 % EFFLUENT	10	5.561	37.3	-1.400
3	12.5 % EFFLUENT	10	5.561	37.3	2.000
4	25.0 % EFFLUENT	10	5.561	37.3	0.300
5	50.0 % EFFLUENT	10	5.561	37.3	-0.600
6	100 % EFFLUENT	10	5.561	37.3	3.900

AA # EDC-001, CERIODAPHNIA DUBIA CHRONIC, REPRODUCTION
File: H:\TOXSTAT\MONTE\CKSMPLEC.   Transform: NO TRANSFORMATION

STEEL'S MANY-ONE RANK TEST - Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	RANK SUM	CRIT. VALUE	df	SIG
1	CONTROL	14.900				
2	6.25 % EFFLUENT	16.300	106.50	75.00	10.00	
3	12.5 % EFFLUENT	12.900	91.00	75.00	10.00	
4	25.0 % EFFLUENT	14.600	96.00	75.00	10.00	
5	50.0 % EFFLUENT	15.500	105.00	75.00	10.00	
6	100 % EFFLUENT	11.000	86.50	75.00	10.00	

Critical values use k = 5, are 1 tailed, and alpha = 0.05

CHEMICAL DATA SHEET FOR CHRONIC TOXICITY TESTING						*Pimephales promelas*			
Lab #/ Sample ID		EDC 001 Synthetic				Test Start: 9/1/09			
Client:	EDC					Test End: 9/8/09			
		Day of Test							
		1	2	3	4	5	6	7	**notes/remarks**
Control	0%	1-Sep	2-Sep	3-Sep	4-Sep	5-Sep	6-Sep	7-Sep	
D.O. (mg/L)	INITIAL	8.8	8.7	8.7	8.5	8.5	8.5	8.4	
	FINAL	8.2	8	8	8.3	8.4	8.4	8.1	
pH (s.u.)	INITIAL	7.7	7.9	7.7	7.8	7.9	7.5	7.9	
	FINAL	8	8.2	8	7.4	7.6	7.7	7.7	
temp (C)	INITIAL	20	21.3	21.8	22.1	22 .4	22.3	22.9	
	FINAL	25	25	25	25	25	25	25	
ALKALINITY (mg/L)		52	52	52	52	52	52	52	
HARDNESS (mg/L)		88	88	88	88	88	88	88	
CONDUCTIVITY (umhos/cm)		291	291	291	291	291	291	291	
CHLORINE (mg/L)		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
CONC:	**6.25%**								
D.O. (mg/L)	INITIAL	8.9	8.6	8.5	8.4	8.5	8.6	8.4	
	FINAL	8.2	8.1	8.2	8.3	8.2	8.2	8	
pH (s.u)	INITIAL	8.6	8.8	8.5	8.6	8.1	7.8	7.9	
	FINAL	8	8	8.2	7.4	7.6	7.3	7.8	
temp (C)	INITIAL	19.7	22	22	22.8	22.5	22.1	24.7	
	FINAL	25	25	25	25	25	25	25	
CONC:	**12.50%**								
D.O. (mg/L)	INITIAL	8.9	8.6	8.5	8.4	8.5	8.5	8.4	
	FINAL	8	8	8.1	7.6	8.1	8.1	7.7	
pH (mg/L)	INITIAL	8.8	9.4	8.5	8.6	8.2	7.9	8	
	FINAL	8.1	7.9	8.2	7.5	7.6	7.5	8	
temp (C)	INITIAL	19.8	22	22	22.5	22.4	22.1	24.6	
	FINAL	25	25	25	25	25	25	25	
CONC:	**25%**								
D.O. (mg/L)	INITIAL	8.8	8.5	8.5	8.5	8.5	8.5	8.5	
	FINAL	8	7.9	8.1	7.6	8.1	8.1	7.6	
pH (s.u.)	INITIAL	9.1	9.8	8.6	8.6	8.1	8	8.1	
	FINAL	8.2	8	8.2	7.6	7.8	7.8	8	
temp (C)	INITIAL	19.9	22	22	22.5	22.4	22	24.6	
	FINAL	25	25	25	25	25	25	25	
CONC:	**50%**								
D.O. (mg/L)	INITIAL	8.9	8.2	8.4	8.3	8.4	8.5	8.6	
	FINAL	7.8	7.9	8.1	7.6	7.9	8	7.7	
pH (s.u.)	INITIAL	9	10.4	8.6	8.6	8.3	8.3	8.2	
	FINAL	8.2	8.2	8.2	7.6	7.8	7.7	8.1	
temp (C)	INITIAL	20	22.1	21.9	22.7	22.4	22	24.4	
	FINAL	25	25	25	25	25	25	25	
CONC:	**100%**								
D.O. (mg/L)	INITIAL	8.9	8	8.6	7.7	8.4	8.4	8.6	
	FINAL	7.6	7.9	8	7.5	7.9	7.7	7.7	
pH (s.u.)	INITIAL	9.9	10.9	8.8	8.7	8.4	8.7	8.6	
	FINAL	8.9	9.1	8.2	7.8	7.9	7.9	8.2	
temp (C)	INITIAL	20.3	22.1	21.9	23	22.4	22	24.2	
	FINAL	25	25	25	25	25	25	25	
CONC:	**100%**								
ALKALINITY (mg/L)		162	162	162	162	162	162	162	
HARDNESS (mg/L)		42	42	42	42	42	42	42	
CONDUCTIVITY (umhos/cm)		778	778	778	778	778	778	778	
CHLORINE (mg/L)		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	

CHEMICAL DATA SHEET FOR CHRONIC TOXICITY TESTING					*Ceriodaphnia Dubia*			
Lab #/ Sample ID		EDC 001 Synthetic			Test Start: 9/1/09			
Client:	EDC				Test End: 9/8/09			
		Day of Test						
		1	2	3	4	5	6	7	**notes/remarks**
Control	0%	1-Sep	2-Sep	3-Sep	4-Sep	5-Sep	6-Sep	7-Sep	
D.O. (mg/L)	INITIAL	8.8	8.7	8.7	8.5	8.5	8.5	8.4	began pH
	FINAL	8.1	8.1	8.6	9	8.7	7.7		adjustment
pH (s.u.)	INITIAL	7.7	7.9	7.7	7.8	7.9	7.5	7.8	9/3/2009
	FINAL	7.8	8.2	7	7.9	7.7	8.1		
temp (C)	INITIAL	20	21.3	21.8	22.1	22 .4	22.3	22.9	
	FINAL	25	25	25	25	25	25	25	
ALKALINITY (mg/L)		52	52	52	52	52	52	52	
HARDNESS (mg/L)		88	88	88	88	88	88	88	
CONDUCTIVITY (umhos/cm)		291	291	291	291	291	291	291	
CHLORINE (mg/L)		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
CONC:	**6.25%**								
D.O. (mg/L)	INITIAL	8.9	8.6	8.5	8.4	8.5	8.6	8.4	
	FINAL	8.1	7.9	8.8	8.9	8.7	7.8		
pH (s.u)	INITIAL	8.6	8.8	8.5	8.6	8.7	7.8	7.9	
	FINAL	8	8.3	7.4	8	7.8	8.1		
temp (C)	INITIAL	19.7	22	22	22.8	22.5	22.1	24.7	
	FINAL	25	25	25	25	25	25	25	
CONC:	**12.50%**								
D.O. (mg/L)	INITIAL	8.9	8.6	8.5	8.4	8.5	8.5	8.4	
	FINAL	8	7.9	8.8	8.9	8.4	7.6		
pH (mg/L)	INITIAL	8.8	9.4	8.5	8.6	8.2	7.9	8	
	FINAL	8	8.3	7.6	8	7.9	8.1		
temp (C)	INITIAL	19.8	22	22	22.5	22.4	22.1	24.6	
	FINAL	25	25	25	25	25	25	25	
CONC:	**25%**								
D.O. (mg/L)	INITIAL	8.8	8.5	8.5	8.5	8.5	8.5	8.5	
	FINAL	7.8	7.9	8.8	8.8	8.5	7.6		
pH (s.u.)	INITIAL	9.1	9.8	8.6	8.6	8.1	8	8.1	
	FINAL	8.2	8.3	7.8	8	7.9	8.1		
temp (C)	INITIAL	19.9	22	22	22.5	22.4	22	24.6	
	FINAL	25	25	25	25	25	25	25	
CONC:	**50%**								
D.O. (mg/L)	INITIAL	8.9	8.2	8.4	8.3	8.4	8.5	8.6	
	FINAL	7.8	7.9	8.8	8.8	8.5	7.7		
pH (s.u.)	INITIAL	9	10.4	8.6	8.6	8.3	8.3	8.2	
	FINAL	8.4	8.4	8	8.1	7.9	8.1		
temp (C)	INITIAL	20	22.1	21.9	22.7	22.4	22	24.4	
	FINAL	25	25	25	25	25	25		
CONC:	**100%**								
D.O. (mg/L)	INITIAL	8.9	8	8.6	7.7	8.4	8.4	8.6	
	FINAL	7.7	7.9	8.7	8.9	8.5	7.7		
pH (s.u.)	INITIAL	9.9	10.9	8.8	8.7	8.4	8.7	8.6	
	FINAL	8.8	8.7	8.1	8.2	8	8.2		
temp (C)	INITIAL	20.3	22.1	21.9	23	22.4	22	24.2	
	FINAL	25	25	25	25	25	25		
CONC:	**100%**								
ALKALINITY (mg/L)		162	162	162	162	162	162	162	
HARDNESS (mg/L)		42	42	42	42	42	42	42	
CONDUCTIVITY (umhos/cm)		778	778	778	778	778	778	778	
CHLORINE (mg/L)		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	

EDC UTA Synthetic

Bench Sheets

Statistical Analysis

Chemistry Bench Sheets

SURVIVAL DATA FOR FATHEAD MINNOW LARVAL SURVIVAL AND GROWTH TEST

LAB # / SAMPLE ID		TEST START	DATE 9/01/09	TII TIME	1515
CLIENT	EDC-UTA SYNTHETIC	TEST END	DATE 9/8/2009	TIME	1130
AGE AND SOURCE OF MINNOWS					

		D A Y (NUMBER SURVIVING)								SURVIVAL		
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	10	10	10	10	10	10	10	100		
	B	10	10	10	10	10	10	10	10	100		
	C	10	10	10	10	10	10	10	10	100		
	D	10	10	10	10	10	10	10	10	100		
0	E	10	10	10	10	10	10	10	10	100	100	0
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	10	10	10	10	10	10	10	100		
	B	10	10	10	10	10	10	10	10	100		
	C	10	10	10	10	10	10	10	10	100		
	D	10	10	10	10	10	10	10	10	100		
6.25%	E	10	10	10	10	10	10	10	10	100	100	
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	10	10	10	10	10	10	10	100		
	B	10	10	10	10	10	10	10	10	100		
	C	10	10	10	10	10	10	10	9	90		
	D	10	10	10	10	10	10	10	10	100		
12.50%	E	10	10	10	10	10	10	10	10	100	98	
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	10	10	10	10	10	10	10	100		
	B	10	10	10	10	10	10	10	10	100		
	C	10	10	10	10	10	10	10	10	100		
	D	10	10	10	10	10	10	10	10	100		
25%	E	10	10	10	10	10	10	10	10	100	100	
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	10	10	10	10	10	10	10	100		
	B	10	10	10	10	10	10	10	10	100		
	C	10	10	10	10	10	10	10	10	100		
	D	10	10	10	10	10	10	10	10	100		
50%	E	10	10	10	10	10	10	10	9	90	97.5	
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	10	10	10	10	10	10	10	100		
	B	10	10	10	10	10	10	10	10	100		
	C	10	10	10	10	10	10	10	10	100		
	D	10	10	10	10	10	10	10	10	100		
100%	E	10	8	8	8	8	8	8	7	70	94	14.27
ANALYST		KP	KP	KP	KP	KP	KP	SB	KP			
DATE:		9/1/2009	9/2/2009	9/3/2009	9/4/2009	9/5/2009	9/6/2009	9/7/2009	9/8/2009			
TIME:		1515	1445	1025	1005	1000	1115	1235	1130			

CV = PERCENT COEFFICIENT OF VARIATION: STANDARD DEVIATION/MEAN * 100

AA# EDC-UTA, FATHEAD MINNOW SURVIVAL, CHRONIC
File: H:\TOXSTAT\MONTE\CKSMPLEF.   Transform: ARC SINE(SQUARE ROOT(Y))

Shapiro - Wilk's test for normality

D = 0.184

W = 0.642

Critical W (P = 0.05) (n = 30) = 0.927
Critical W (P = 0.01) (n = 30) = 0.900

Data FAIL normality test. Try another transformation.

Warning - The first three homogeneity tests are sensitive to non-normal data and should not be performed.

AA# EDC-UTA, FATHEAD MINNOW SURVIVAL, CHRONIC
File: H:\TOXSTAT\MONTE\CKSMPLEF.   Transform: ARC SINE(SQUARE ROOT(Y))

Hartley's test for homogeneity of variance
Bartlett's test for homogeneity of variance

These two tests can not be performed because at least one group has zero variance.

Data FAIL to meet homogeneity of variance assumption.
Additional transformations are useless.

TITLE: AA# EDC-UTA, FATHEAD MINNOW SURVIVAL, CHRONIC
FILE: H:\TOXSTAT\MONTE\CKSMPLEF.
TRANSFORM: ARC SINE(SQUARE ROOT(Y))   NUMBER OF GROUPS: 6

GRP	IDENTIFICATION	REP	VALUE	TRANS VALUE
1	CONTROL	1	1.0000	1.4120
1	CONTROL	2	1.0000	1.4120
1	CONTROL	3	1.0000	1.4120
1	CONTROL	4	1.0000	1.4120
1	CONTROL	5	1.0000	1.4120
2	6.25 % EFFLUENT	1	1.0000	1.4120
2	6.25 % EFFLUENT	2	1.0000	1.4120
2	6.25 % EFFLUENT	3	1.0000	1.4120
2	6.25 % EFFLUENT	4	1.0000	1.4120
2	6.25 % EFFLUENT	5	1.0000	1.4120

3	12.5	% EFFLUENT	1	1.0000	1.4120
3	12.5	% EFFLUENT	2	1.0000	1.4120
3	12.5	% EFFLUENT	3	0.9000	1.2490
3	12.5	% EFFLUENT	4	1.0000	1.4120
3	12.5	% EFFLUENT	5	1.0000	1.4120
4	25.0	% EFFLUENT	1	1.0000	1.4120
4	25.0	% EFFLUENT	2	1.0000	1.4120
4	25.0	% EFFLUENT	3	1.0000	1.4120
4	25.0	% EFFLUENT	4	1.0000	1.4120
4	25.0	% EFFLUENT	5	1.0000	1.4120
5	50	% EFFLUENT	1	1.0000	1.4120
5	50	% EFFLUENT	2	1.0000	1.4120
5	50	% EFFLUENT	3	1.0000	1.4120
5	50	% EFFLUENT	4	1.0000	1.4120
5	50	% EFFLUENT	5	0.9000	1.2490
6	100	% EFFLUENT	1	1.0000	1.4120
6	100	% EFFLUENT	2	1.0000	1.4120
6	100	% EFFLUENT	3	1.0000	1.4120
6	100	% EFFLUENT	4	1.0000	1.4120
6	100	% EFFLUENT	5	0.7000	0.9912

AA# EDC-UTA, FATHEAD MINNOW SURVIVAL, CHRONIC
File: H:\TOXSTAT\MONTE\CKSMPLEF. Transform: ARC SINE(SQUARE ROOT(Y))

STEEL'S MANY-ONE RANK TEST - Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	RANK SUM	CRIT. VALUE	df	SIG
1	CONTROL	1.412				
2	6.25 % EFFLUENT	1.412	27.50	16.00	5.00	
3	12.5 % EFFLUENT	1.379	25.00	16.00	5.00	
4	25.0 % EFFLUENT	1.412	27.50	16.00	5.00	
5	50 % EFFLUENT	1.379	25.0C	16.00	5.00	
6	100 % EFFLUENT	1.328	25.00	16.00	5.00	

Critical values use k = 5, are 1 tailed, and alpha = 0.05

Pimephales promelas **FATHEAD MINNOW** TEST 1000.0

WEIGHT DATA FOR LARVAL SURVIVAL AND GROWTH TEST

LAB # / #s:	NA	TEST DATES (BEGIN / END):	9/01-08/09
CLIENT:	EDC	WEIGHING DATE / TIME:	9/09/09, 1130
ANALYSTS:	KP	DRYING TEMP (DEGREES C):	60
SAMPLE ID:	EDC UTA SYNTHETIC	DRYING TIME (HOURS):	24

	REP#	FINAL DRY WEIGHT TIN+LARVAE (g)	INTIAL WEIGHT TIN (g)	TOTAL DRY WEIGHT OF LARVAE (g)	NUMBER OF LARVAE	DRY WEIGHT OF LARVAE (mg)	
CONTROL	A	0.98654	0.98248	0.00406	10	0.406	AVG DRY
	B	0.99623	0.99247	0.00376	10	0.376	WEIGHT (mg)
	C	1.00374	0.99986	0.00388	10	0.388	0.378
	D	1.00286	0.99980	0.00306	10	0.306	CV
0	E	0.98262	0.97849	0.00413	10	0.413	11.3
CONC:	A	1.00476	1.00088	0.00388	10	0.388	AVG DRY
	B	0.99007	0.98691	0.00316	10	0.316	WEIGHT (mg)
	C	1.00911	1.00518	0.00393	10	0.393	0.388
	D	1.00250	0.99831	0.00419	10	0.419	CV
6.25%	E	0.97503	0.97078	0.00425	10	0.425	11.2
CONC:	A	1.01143	1.00777	0.00366	10	0.366	AVG DRY
	B	0.98569	0.98254	0.00315	10	0.315	WEIGHT (mg)
	C	0.98765	0.98411	0.00354	10	0.354	0.342
	D	0.97774	0.97469	0.00305	10	0.305	CV
12.50%	E	1.00228	0.99858	0.00370	10	0.370	8.8
CONC:	A	0.98259	0.97900	0.00359	10	0.359	AVG DRY
	B	0.97564	0.97122	0.00442	10	0.442	WEIGHT (mg)
	C	1.01316	1.00887	0.00429	10	0.429	0.413
	D	1.00283	0.99870	0.00413	10	0.413	CV
25%	E	0.99551	0.99129	0.00422	10	0.422	7.7
CONC:	A	0.99983	0.99534	0.00449	10	0.449	AVG DRY
	B	1.00060	0.99653	0.00407	10	0.407	WEIGHT (mg)
	C	0.98915	0.98489	0.00426	10	0.426	0.438
	D	0.99922	0.99545	0.00377	10	0.377	CV
50%	E	1.01027	1.00498	0.00529	10	0.529	13.1
CONC:	A	1.00054	0.99624	0.00430	10	0.430	AVG DRY
	B	1.00091	0.99688	0.00403	10	0.403	WEIGHT (mg)
	C	0.99733	0.99321	0.00412	10	0.412	0.399
	D	0.99075	0.98730	0.00345	10	0.345	CV
100%	E	1.00555	1.00150	0.00405	10	0.405	8.0

CV = (STANDARD DEVIATION/MEAN)*100

REMARKS:

AA# EDC-UTA, FATHEAD MINNOW GROWTH, CHRONIC, 9-1-09
File: H:\TOXSTAT\MONTE\CKSMPLGR. Transform: ARC SINE(SQUARE ROOT(Y))

Shapiro - Wilk's test for normality

D = 0.042

W = 0.929

Critical W (P = 0.05) (n = 30) = 0.927
Critical W (P = 0.01) (n = 30) = 0.900

Data PASS normality test at P=0.01 level. Continue analysis.

AA# EDC-UTA, FATHEAD MINNOW GROWTH, CHRONIC, 9-1-09
File: H:\TOXSTAT\MONTE\CKSMPLGR. Transform: ARC SINE(SQUARE ROOT(Y))

Bartlett's test for homogeneity of variance
Calculated B1 statistic = 2.24

Table Chi-square value = 15.09 (alpha = 0.01, df = 5)
Table Chi-square value = 11.07 (alpha = 0.05, df = 5)

Data PASS B1 homogeneity test at 0.01 level. Continue analysis.

TITLE: AA# EDC-UTA, FATHEAD MINNOW GROWTH, CHRONIC, 9-1-09
FILE: H:\TOXSTAT\MONTE\CKSMPLGR.
TRANSFORM: ARC SINE(SQUARE ROOT(Y)) NUMBER OF GROUPS: 6

GRP	IDENTIFICATION	REP	VALUE	TRANS VALUE
1	CONTROL	1	0.4060	0.6908
1	CONTROL	2	0.3760	0.6601
1	CONTROL	3	0.3880	0.6724
1	CONTROL	4	0.3060	0.5862
1	CONTROL	5	0.4130	0.6980
2	6.25 % EFFLUENT	1	0.3880	0.6724
2	6.25 % EFFLUENT	2	0.3160	0.5970
2	6.25 % EFFLUENT	3	0.3930	0.6776
2	6.25 % EFFLUENT	4	0.4190	0.7040
2	6.25 % EFFLUENT	5	0.4250	0.7101
3	12.5 % EFFLUENT	1	0.3660	0.6497
3	12.5 % EFFLUENT	2	0.3150	0.5959
3	12.5 % EFFLUENT	3	0.3540	0.6372
3	12.5 % EFFLUENT	4	0.3050	0.5851
3	12.5 % EFFLUENT	5	0.3700	0.6539
4	25 % EFFLUENT	1	0.3590	0.6425

4	25 % EFFLUENT	2	0.4420	0.7273
4	25 % EFFLUENT	3	0.4290	0.7142
4	25 % EFFLUENT	4	0.4130	0.6980
4	25 % EFFLUENT	5	0.4220	0.7071
5	50 % EFFLUENT	1	0.4490	0.7343
5	50 % EFFLUENT	2	0.4070	0.6919
5	50 % EFFLUENT	3	0.4260	0.7111
5	50 % EFFLUENT	4	0.3770	0.6611
5	50 % EFFLUENT	5	0.5290	0.8144
6	100 % EFFLUENT	1	0.4300	0.7152
6	100 % EFFLUENT	2	0.4030	0.6878
6	100 % EFFLUENT	3	0.4120	0.6969
6	100 % EFFLUENT	4	0.3450	0.6278
6	100 % EFFLUENT	5	0.4050	0.6898

AA# EDC-UTA, FATHEAD MINNOW GROWTH, CHRONIC, 9-1-09
File: H:\TOXSTAT\MONTE\CKSMPLGR. Transform: ARC SINE(SQUARE ROOT(Y))

ANOVA TABLE

SOURCE	DF	SS	MS	F
Between	5	0.028	0.006	3.175
Within (Error)	24	0.042	0.002	
Total	29	0.070		

Critical F value = 2.62 (0.05,5,24)
Since F > Critical F REJECT Ho: All equal

AA# EDC-UTA, FATHEAD MINNOW GROWTH, CHRONIC, 9-1-09
File: H:\TOXSTAT\MONTE\CKSMPLGR. Transform: ARC SINE(SQUARE ROOT(Y))

DUNNETT'S TEST - TABLE 1 OF 2 Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	MEAN CALCULATED IN ORIGINAL UNITS	T STAT	SIG
1	CONTROL	0.661	0.378		
2	6.25 % EFFLUENT	0.672	0.388	-0.404	
3	12.5 % EFFLUENT	0.624	0.342	1.400	
4	25 % EFFLUENT	0.698	0.413	-1.368	
5	50 % EFFLUENT	0.723	0.438	-2.302	
6	100 % EFFLUENT	0.684	0.399	-0.830	

Dunnett table value = 2.36 (1 Tailed Value, P=0.05, df=24,5)

AA# EDC-UTA, FATHEAD MINNOW GROWTH, CHRONIC, 9-1-09
File: H:\TOXSTAT\MONTE\CKSMPLGR. Transform: ARC SINE(SQUARE ROOT(Y))

DUNNETT'S TEST - TABLE 2 OF 2 Ho:Control<Treatment

GROUP	IDENTIFICATION	NUM OF REPS	Minimum Sig Diff (IN ORIG. UNITS)	% of CONTROL	DIFFERENCE FROM CONTROL
1	CONTROL	5			
2	6.25 % EFFLUENT	5	0.060	15.8	-0.010
3	12.5 % EFFLUENT	5	0.060	15.8	0.036
4	25 % EFFLUENT	5	0.060	15.8	-0.035
5	50 % EFFLUENT	5	0.060	15.8	-0.060
6	100 % EFFLUENT	5	0.060	15.8	-0.021

Ceriodaphnia dubia

SURVIVAL AND REPRODUCTION TEST

Discharger:	EDC	Lab Number/s	
Location:	UTA SYNTHETIC MATRIX	na	
	prepared 9/1/09		

Analyst: KP
Test Start - Date/ Time: 9/1/2009 1520
Test Stop - Date/Time: 9/8/2009 0850

Conc 1 %	Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
0	1	0	0	0	0	0	0	0	0	0	0	0			KP
	2	0	0	0	0	0	0	0	0	0	0	0			KP
	3	0	0	0	4	5	0	3	2	0	0	14			
	4	3	5	5	0	0	1	4	4	3	3	28			
	5	5	7	9	5	8	3	7	6	3	7	60			KP
	6	7	9	5	8	8	7	9	10	9	8	80			KP
	7												10		
	8													18.2	
	Total	15	21	19	17	21	11	23	22	15	18	182		CV	20.68868

Conc 2 %	Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
6.25	1	0	0	0	0	0	0	0	0	0	0	0			
	2	0	0	0	0	0	0	0	0	0	0	0			
	3	0	1	0	0	4	0	2	1	3	0	11			
	4	3	1	0	4	6	5	4	2	1	0	26			
	5	8	5	1	4	0	7	7	6	8	6	52			
	6	7	8	6	10	7	11	10	4	7	5	75			
	7												10		
	8													16.4	
	Total	18	15	7	18	17	23	23	13	19	11	164		CV	30.85149

Conc 3 %	Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
12.5	1	0	0	0	0	0	0	0	0	0	0	0			
	2	0	0	0	0	0	0	0	0	0	0	0			
	3	0	1	0	1	0	0	0	1	2	0	5			
	4	4	4	3	0	3	5	7	3	4	4	37			
	5	7	8	5	9	0	5	7	9	8	6	64			
	6	6	9	12	8	6	9	9	7	10	9	85			
	7												10		
	8													19.1	
	Total	17	22	20	18	9	19	23	20	24	19	191		CV	21.86034

X= DEAD; Y= MALE

Conc 4 %	Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
25	1	0	0	0	0	0	0	0	0	0	0	0			
	2	0	0	0	0	0	0	0	0	0	0	0			
	3	0	0	0	0	0	0	1	2	0	0	3			
	4	4	5	2	4	4	2	4	0	2	1	28			
	5	6	7	5	5	2	7	7	8	10	9	66			
	6	7	11	6	8	12	7	6	9	7	4	77			
	7												10		
	8													17.4	
	Total	17	23	13	17	18	16	18	19	19	14	174		CV	16.074

Conc 5 %	Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
50	1	0	0	0	0	0	0	0	0	0	0	0			
	2	0	0	0	0	0	0	0	0	0	0	0			
	3	0	1	0	0	0	0	1	1	0	2	5			
	4	4	2	3	2	2	3	0	0	3	4	23			
	5	6	6	4	8	6	5	5	3	5	2	50			
	6	3	11	7	7	9	9	8	7	8	6	75			
	7												10		
	8													15.3	
	Total	13	20	14	17	17	17	14	11	16	14	153		CV	16.89

Conc 6 %	Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
100	1	0	0	0	0	X0	0	0	0	0	0	0			
	2	0	0	0	0	-	0	0	0	0	0	0			
	3	0	4	2	0	-	0	3	0	2	1	12			
	4	6	0	2	4	-	5	3	5	0	3	28			
	5	5	8	6	9	-	5	4	2	6	3	48			
	6	6	12	9	9	-	5	7	10	9	5	72			
	7												9		
	8													17.78	
	Total	17	24	19	22	X0	15	17	17	17	12	160		CV	20.041

AA # EDC-UTA, CERIODAPHNIA DUBIA CHRONIC, REPRODUCTION
File: H:\TOXSTAT\MONTE\CKSMPLEC.   Transform: NO TRANSFORMATION

Shapiro - Wilk's test for normality

******** Shapiro - Wilk's Test is aborted ********

This test can not be performed because total number of replicates is greater than 50.

Total number of replicates = 60

AA # EDC-UTA, CERIODAPHNIA DUBIA CHRONIC, REPRODUCTION
File: H:\TOXSTAT\MONTE\CKSMPLEC.   Transform: NO TRANSFORMATION

Bartlett's test for homogeneity of variance
Calculated B1 statistic = 10.62

Table Chi-square value = 15.09 (alpha = 0.01, df = 5)
Table Chi-square value = 11.07 (alpha = 0.05, df = 5)

Data PASS B1 homogeneity test at 0.01 level. Continue analysis.

TITLE: AA # EDC-UTA, CERIODAPHNIA DUBIA CHRONIC, REPRODUCTION
FILE: H:\TOXSTAT\MONTE\CKSMPLEC.
TRANSFORM: NO TRANSFORMATION   NUMBER OF GROUPS: 6

GRP	IDENTIFICATION	REP	VALUE	TRANS VALUE
1	CONTROL	1	15.0000	15.0000
1	CONTROL	2	21.0000	21.0000
1	CONTROL	3	19.0000	19.0000
1	CONTROL	4	17.0000	17.0000
1	CONTROL	5	21.0000	21.0000
1	CONTROL	6	11.0000	11.0000
1	CONTROL	7	23.0000	23.0000
1	CONTROL	8	22.0000	22.0000
1	CONTROL	9	15.0000	15.0000
1	CONTROL	10	18.0000	18.0000
2	6.25 % EFFLUENT	1	18.0000	18.0000
2	6.25 % EFFLUENT	2	15.0000	15.0000
2	6.25 % EFFLUENT	3	7.0000	7.0000
2	6.25 % EFFLUENT	4	18.0000	18.0000
2	6.25 % EFFLUENT	5	17.0000	17.0000
2	6.25 % EFFLUENT	6	23.0000	23.0000

FISHER'S EXACT TEST

IDENTIFICATION	ALIVE	DEAD	TOTAL ANIMALS
CONTROL	10	0	10
6.25	10	0	10
TOTAL	20	0	20

(ALIVE, DEAD and TOTAL ANIMALS are grouped under the heading NUMBER OF.)

CRITICAL FISHER'S VALUE (10,10,10) (p=0.05) IS 6. b VALUE IS 10.
Since b is greater than 6 there is no significant difference between CONTROL and TREATMENT at the 0.05 level.

FISHER'S EXACT TEST

IDENTIFICATION	ALIVE	DEAD	TOTAL ANIMALS
CONTROL	10	0	10
12.5	10	0	10
TOTAL	20	0	20

(ALIVE, DEAD and TOTAL ANIMALS are grouped under the heading NUMBER OF.)

CRITICAL FISHER'S VALUE (10,10,10) (p=0.05) IS 6. b VALUE IS 10.
Since b is greater than 6 there is no significant difference between CONTROL and TREATMENT at the 0.05 level.

FISHER'S EXACT TEST

IDENTIFICATION	ALIVE	DEAD	TOTAL ANIMALS
CONTROL	10	0	10

(ALIVE, DEAD and TOTAL ANIMALS are grouped under the heading NUMBER OF.)

25	10	0	10
TOTAL	20	0	20

CRITICAL FISHER'S VALUE (10,10,10) (p=0.05) IS 6. b VALUE IS 10.
Since b is greater than 6 there is no significant difference between CONTROL and TREATMENT at the 0.05 level.

FISHER'S EXACT TEST

	NUMBER OF		
IDENTIFICATION	ALIVE	DEAD	TOTAL ANIMALS
CONTROL	10	0	10
50	10	0	10
TOTAL	20	0	20

CRITICAL FISHER'S VALUE (10,10,10) (p=0.05) IS 6. b VALUE IS 10.
Since b is greater than 6 there is no significant difference between CONTROL and TREATMENT at the 0.05 level.

FISHER'S EXACT TEST

	NUMBER OF		
IDENTIFICATION	ALIVE	DEAD	TOTAL ANIMALS
CONTROL	10	0	10
100	9	1	10
TOTAL	19	1	20

CRITICAL FISHER'S VALUE (10,10,10) (p=0.05) IS 6. b VALUE IS 9.
Since b is greater than 6 there is no significant difference between CONTROL and TREATMENT at the 0.05 level.

SUMMARY OF FISHER'S EXACT TESTS

GROUP	IDENTIFICATION	NUMBER EXPOSED	NUMBER DEAD	SIG (P=.05)
	CONTROL	10	0	
1	6.25	10	0	
2	12.5	10	0	
3	25	10	0	
4	50	10	0	
5	100	10	1	

TITLE: AA # EDC-UTA, CERIODAPHNIA DUBIA CHRONIC, REPRODUCTION
FILE: H:\TOXSTAT\MONTE\CKSMPLEC.
TRANSFORM: NO TRANSFORMATION NUMBER OF GROUPS: 6

GRP	IDENTIFICATION	REP	VALUE	TRANS VALUE
1	CONTROL	1	15.0000	15.0000
1	CONTROL	2	21.0000	21.0000
1	CONTROL	3	19.0000	19.0000
1	CONTROL	4	17.0000	17.0000
1	CONTROL	5	21.0000	21.0000
1	CONTROL	6	11.0000	11.0000
1	CONTROL	7	23.0000	23.0000
1	CONTROL	8	22.0000	22.0000
1	CONTROL	9	15.0000	15.0000
1	CONTROL	10	18.0000	18.0000
2	6.25 % EFFLUENT	1	18.0000	18.0000
2	6.25 % EFFLUENT	2	15.0000	15.0000
2	6.25 % EFFLUENT	3	7.0000	7.0000
2	6.25 % EFFLUENT	4	18.0000	18.0000
2	6.25 % EFFLUENT	5	17.0000	17.0000
2	6.25 % EFFLUENT	6	23.0000	23.0000
2	6.25 % EFFLUENT	7	23.0000	23.0000
2	6.25 % EFFLUENT	8	13.0000	13.0000
2	6.25 % EFFLUENT	9	19.0000	19.0000
2	6.25 % EFFLUENT	10	11.0000	11.0000
3	12.5 % EFFLUENT	1	17.0000	17.0000
3	12.5 % EFFLUENT	2	22.0000	22.0000
3	12.5 % EFFLUENT	3	20.0000	20.0000
3	12.5 % EFFLUENT	4	18.0000	18.0000
3	12.5 % EFFLUENT	5	9.0000	9.0000
3	12.5 % EFFLUENT	6	19.0000	19.0000
3	12.5 % EFFLUENT	7	23.0000	23.0000
3	12.5 % EFFLUENT	8	20.0000	20.0000
3	12.5 % EFFLUENT	9	24.0000	24.0000
3	12.5 % EFFLUENT	10	19.0000	19.0000
4	25.0 % EFFLUENT	1	17.0000	17.0000
4	25.0 % EFFLUENT	2	23.0000	23.0000
4	25.0 % EFFLUENT	3	13.0000	13.0000
4	25.0 % EFFLUENT	4	17.0000	17.0000
4	25.0 % EFFLUENT	5	18.0000	18.0000

4	25.0 % EFFLUENT	6	16.0000	16.0000
4	25.0 % EFFLUENT	7	18.0000	18.0000
4	25.0 % EFFLUENT	8	19.0000	19.0000
4	25.0 % EFFLUENT	9	19.0000	19.0000
4	25.0 % EFFLUENT	10	14.0000	14.0000
5	50.0 % EFFLUENT	1	13.0000	13.0000
5	50.0 % EFFLUENT	2	20.0000	20.0000
5	50.0 % EFFLUENT	3	14.0000	14.0000
5	50.0 % EFFLUENT	4	17.0000	17.0000
5	50.0 % EFFLUENT	5	17.0000	17.0000
5	50.0 % EFFLUENT	6	17.0000	17.0000
5	50.0 % EFFLUENT	7	14.0000	14.0000
5	50.0 % EFFLUENT	8	11.0000	11.0000
5	50.0 % EFFLUENT	9	16.0000	16.0000
5	50.0 % EFFLUENT	10	14.0000	14.0000
6	100 % EFFLUENT	1	17.0000	17.0000
6	100 % EFFLUENT	2	24.0000	24.0000
6	100 % EFFLUENT	3	19.0000	19.0000
6	100 % EFFLUENT	4	22.0000	22.0000
6	100 % EFFLUENT	5	0.0000	0.0000
6	100 % EFFLUENT	6	15.0000	15.0000
6	100 % EFFLUENT	7	17.0000	17.0000
6	100 % EFFLUENT	8	17.0000	17.0000
6	100 % EFFLUENT	9	17.0000	17.0000
6	100 % EFFLUENT	10	12.0000	12.0000

AA # EDC-UTA, CERIODAPHNIA DUBIA CHRONIC, REPRODUCTION
File: H:\TOXSTAT\MONTE\CKSMPLEC.   Transform: NO TRANSFORMATION

ANOVA TABLE

SOURCE	DF	SS	MS	F
Between	5	102.333	20.467	1.072
Within (Error)	54	1031.400	19.100	
Total	59	1133.733		

Critical F value = 2.45 (0.05,5,40)
Since F < Critical F FAIL TO REJECT Ho: All equal

AA # EDC-UTA, CERIODAPHNIA DUBIA CHRONIC, REPRODUCTION
File: H:\TOXSTAT\MONTE\CKSMPLEC.   Transform: NO TRANSFORMATION

DUNNETT'S TEST - TABLE 1 OF 2   Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	MEAN CALCULATED IN ORIGINAL UNITS	T STAT	SIG
1	CONTROL	18.200	18.200		
2	6.25 % EFFLUENT	16.400	16.400	0.921	
3	12.5 % EFFLUENT	19.100	19.100	-0.460	
4	25.0 % EFFLUENT	17.400	17.400	0.409	

5	50.0 % EFFLUENT	15.300	15.300	1.484
6	100 % EFFLUENT	16.000	16.000	1.126

Dunnett table value = 2.31 (1 Tailed Value, P=0.05, df=40,5)

AA # EDC-UTA, CERIODAPHNIA DUBIA CHRONIC, REPRODUCTION
File: H:\TOXSTAT\MONTE\CKSMPLEC. Transform: NO TRANSFORMATION

DUNNETT'S TEST - TABLE 2 OF 2 Ho:Control<Treatment

GROUP	IDENTIFICATION	NUM OF REPS	Minimum Sig Diff (IN ORIG. UNITS)	% of CONTROL	DIFFERENCE FROM CONTROL
1	CONTROL	10			
2	6.25 % EFFLUENT	10	4.515	24.8	1.800
3	12.5 % EFFLUENT	10	4.515	24.8	-0.900
4	25.0 % EFFLUENT	10	4.515	24.8	0.800
5	50.0 % EFFLUENT	10	4.515	24.8	2.900
6	100 % EFFLUENT	10	4.515	24.8	2.200

AA # EDC-UTA, CERIODAPHNIA DUBIA CHRONIC, REPRODUCTION
File: H:\TOXSTAT\MONTE\CKSMPLEC. Transform: NO TRANSFORMATION

STEEL'S MANY-ONE RANK TEST - Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	RANK SUM	CRIT. VALUE	df	SIG
1	CONTROL	18.200				
2	6.25 % EFFLUENT	16.400	95.50	75.00	10.00	
3	12.5 % EFFLUENT	19.100	114.00	75.00	10.00	
4	25.0 % EFFLUENT	17.400	96.50	75.00	10.00	
5	50.0 % EFFLUENT	15.300	79.00	75.00	10.00	
6	100 % EFFLUENT	16.000	96.00	75.00	10.00	

Critical values use k = 5, are 1 tailed, and alpha = 0.05

CHEMICAL DATA SHEET FOR CHRONIC TOXICITY TESTING						*Pimephales promelas*			
Lab #/ Sample ID		EDC UTA SYNTHETIC				Test Start: 9/1/09			
Client:	EDC					Test End: 9/8/09			
		Day of Test							
		1	2	3	4	5	6	7	**notes/remarks**
Control	0%	1-Sep	2-Sep	3-Sep	4-Sep	5-Sep	6-Sep	7-Sep	
D.O. (mg/L)	INITIAL	8.8	8.7	8.7	8.5	8.5	8.5	8.4	pH
	FINAL	8.2	8	8	8	8.4	8.4	8.1	adjusted
pH (s.u.)	INITIAL	7.7	7.9	7.7	7.8	7.9	7.5	7.9	9/3/2009
	FINAL	8	8.2	8	7.8	7.6	7.7	7.7	
temp (C)	INITIAL	20	21.3	21.8	22.1	22.4	22.3	22.9	
	FINAL	25	25	25	25	25	25	25	
ALKALINITY (mg/L)		52	52	52	52	52	52	52	
HARDNESS (mg/L)		88	88	88	88	88	88	88	
CONDUCTIVITY (umhos/cm)		291	291	291	291	291	291	291	
CHLORINE (mg/L)		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
CONC:	**6.25%**								
D.O. (mg/L)	INITIAL	8.8	8.6	8.7	8.6	8.7	9.1	8.5	
	FINAL	8.1	8	8	7.8	8.3	8.4	8	
pH (s.u)	INITIAL	7.7	8.8	8.4	7.9	7.7	7.9	7.9	
	FINAL	7.9	8.3	8	7.8	7.8	7.8	7.5	
temp (C)	INITIAL	19.9	22	21.8	22.2	22.6	22	22.9	
	FINAL	25	25	25	25	25	25	25	
CONC:	**12.50%**								
D.O. (mg/L)	INITIAL	8.8	8.6	8.6	8.6	8.6	8.8	8.6	
	FINAL	8	7.9	8	7.8	8.2	8	8	
pH (mg/L)	INITIAL	7.9	9.4	8.6	8	8	8	7.9	
	FINAL	7.9	8.3	8.1	7.9	7.7	7.8	7.4	
temp (C)	INITIAL	19.7	22	21.7	22.3	22.5	21.9	23.2	
	FINAL	25	25	25	25	25	25	25	
CONC:	**25%**								
D.O. (mg/L)	INITIAL	8.8	8.5	8.5	8.5	8.5	8.7	8.6	
	FINAL	7.8	7.9	7.9	7.9	8.2	8.3	7.6	
pH (s.u.)	INITIAL	8.3	9.8	8.6	8.2	8	8	8	
	FINAL	7.9	8.3	8.1	7.9	7.8	7.9	7.4	
temp (C)	INITIAL	19.9	22	21.8	22.4	22.5	21.9	23.4	
	FINAL	25	25	25	25	25	25	25	
CONC:	**50%**								
D.O. (mg/L)	INITIAL	8.8	8.2	8.3	8.4	8.4	8.6	8.6	
	FINAL	7.7	7.9	7.7	7.6	8.1	8.5	7.6	
pH (s.u.)	INITIAL	9.1	10.4	8.8	8.7	8.2	8.1	8	
	FINAL	8.1	8.4	8.2	7.9	7.9	8	7.4	
temp (C)	INITIAL	20.1	22.1	21.9	22.6	22.4	21.9	23.4	
	FINAL	25	25	25	25	25	25	25	
CONC:	**100%**								
D.O. (mg/L)	INITIAL	8.9	8	7.9	8	8	8.6	8.6	
	FINAL	7.7	7.8	7.6	7.7	8.1	8.4	7.5	
pH (s.u.)	INITIAL	9.7	10.9	8.4	8.5	8.4	8.2	8.1	
	FINAL	8.6	9.2	8.2	8	8	8	7.6	
temp (C)	INITIAL	20.4	22.1	22.1	22.7	22.5	22.1	23.7	
	FINAL	25	25	25	25	25	25	25	
CONC:	**100%**								
ALKALINITY (mg/L)		90	90	90	90	90	90	90	
HARDNESS (mg/L)		32	32	32	32	32	32	32	
CONDUCTIVITY (umhos/cm)		551	551	551	551	551	551	551	
CHLORINE (mg/L)		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	

CHEMICAL DATA SHEET FOR CHRONIC TOXICITY TESTING						*Ceriodaphnia Dubia*			
Lab #/ Sample ID		EDC UTA SYNTHETIC				Test Start: 9/1/09			
Client:	EDC					Test End: 9/8/09			
		Day of Test							
		1	**2**	**3**	**4**	**5**	**6**	**7**	**notes/remarks**
Control	0%	1-Sep	2-Sep	3-Sep	4-Sep	5-Sep	6-Sep	7-Sep	
D.O. (mg/L)	INITIAL	8.8	8.7	8.7	8.5	8.5	8.5	8.4	
	FINAL	8.7	8.2	8.6	8	8.3	7.6		
pH (s.u.)	INITIAL	7.7	7.9	7.7	7.8	7.9	7.5	0.8	
	FINAL	7.9	8.4	7.7	7.8	7.8	7.9		
temp (C)	INITIAL	20	21.3	21.8	22.1	22.4	22.3	22.8	
	FINAL	25	25	25	25	25	25		
ALKALINITY (mg/L)		52	52	52	52	52	52	52	
HARDNESS (mg/L)		88	88	88	88	88	88	88	
CONDUCTIVITY (umhos/cm)		291	291	291	291	291	291	291	
CHLORINE (mg/L)		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
CONC:	**6.25%**								
D.O. (mg/L)	INITIAL	8.8	8.6	8.7	8.6	8.7	9.1	8.5	
	FINAL	8.1	8.2	8.6	7.8	8.3	7.5		
pH (s.u)	INITIAL	7.7	8.8	8.4	7.9	7.7	7.9	7.9	
	FINAL	7.8	8.4	7.8	7.8	7.8	7.9		
temp (C)	INITIAL	19.9	22	21.8	22.2	22.6	22	22.9	
	FINAL	25	25	25	25	25	25		
CONC:	**12.50%**								
D.O. (mg/L)	INITIAL	8.8	8.6	8.6	8.6	8.6	8.8	8.6	
	FINAL	8	8	8.7	7.8	8.3	7.6		
pH (mg/L)	INITIAL	7.9	9.4	9.2	8	8	8	7.9	
	FINAL	7.9	8.4	7.9	7.9	8	7.9		
temp (C)	INITIAL	19.7	22	21.7	22.3	22.5	21.9	23.2	
	FINAL	25	25	25	25	25	25		
CONC:	**25%**								
D.O. (mg/L)	INITIAL	8.8	8.5	8.5	8.5	8.5	8.7	8.6	
	FINAL	7.7	7.8	8.7	7.9	8.7	7.6		
pH (s.u.)	INITIAL	8.3	9.8	9.6	8.2	8	8	8	
	FINAL	7.9	8.4	8	7.9	8	8	8	
temp (C)	INITIAL	19.9	22	21.8	22.4	22.5	21.9	23.4	
	FINAL	25	25	25	25	25	25		
CONC:	**50%**								
D.O. (mg/L)	INITIAL	8.8	8.2	8.3	8.4	8.4	8.6	8.6	
	FINAL	7.7	7.8	8.7	7.6	8.4	7.7		
pH (s.u.)	INITIAL	9.1	10.4	8.8	8.7	8.2	8.1	8	
	FINAL	8.1	8.5	8	7.9	8.1	8		
temp (C)	INITIAL	20.1	22.1	21.9	22.6	22.4	21.9	23.4	
	FINAL	25	25	25	25	25	25		
CONC:	**100%**								
D.O. (mg/L)	INITIAL	8.9	8	7.9	8	8	8.6	8.6	
	FINAL	7.6	7.7	8.7	7.7	8.4	7.7		
pH (s.u.)	INITIAL	9.7	10.9	10.7	8.5	8.4	8.2	8.1	
	FINAL	8.5	8.8	8.2	8	8.1	8.1		
temp (C)	INITIAL	20.4	22.1	22.1	22.7	22.5	22.1	23.7	
	FINAL	25	25	25	25	25	25		
CONC:	**100%**								
ALKALINITY (mg/L)		90	90	90	90	90	90	90	
HARDNESS (mg/L)		32	32	32	32	32	32	32	
CONDUCTIVITY (umhos/cm)		551	551	551	551	551	551	551	
CHLORINE (mg/L)		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	

EDC Flat Creek

Bench Sheets

Statistical Analysis

Chemistry Bench Sheets

SURVIVAL DATA FOR FATHEAD MINNOW LARVAL SURVIVAL AND GROWTH TEST

LAB # / SAMPLE ID				TEST START		DATE 9/01/09		TII TIME		1545		
CLIENT	EDC FLAT CREEK SYN			TEST END		DATE 9/8/2009		TIME		1430		
AGE AND SOURCE OF MINNOWS												
		D A Y (NUMBER SURVIVING)								SURVIVAL		
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	10	10	10	10	10	10	10	100		
	B	10	10	10	10	10	10	10	10	100		
	C	10	10	10	10	10	10	10	10	100		
	D	10	10	10	10	10	10	10	10	100		
0	E	10	10	10	10	10	10	10	10	100	100	0
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	10	10	10	10	10	10	10	100		
	B	10	10	10	10	10	10	10	10	100		
	C	10	10	10	10	10	10	10	10	100		
	D	10	9	9	9	9	9	9	9	90		
6.25%	E	10	10	10	10	10	10	10	10	100	98	
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	10	10	10	10	10	10	10	100		
	B	10	10	10	10	10	10	10	9	90		
	C	10	10	9	9	9	9	9	8	80		
	D	10	10	10	10	10	10	10	10	100		
12.50%	E	10	10	10	10	10	10	10	10	100	94	
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	9	9	9	9	9	9	9	90		
	B	10	10	10	10	10	10	10	10	100		
	C	10	10	10	10	10	10	10	10	100		
	D	10	10	10	10	10	10	10	10	100		
25%	E	10	10	10	10	10	10	10	10	100	98	
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	10	10	10	10	10	10	10	100		
	B	10	10	10	10	10	10	10	9	90		
	C	10	10	10	10	10	10	10	9	90		
	D	10	10	10	10	10	10	10	10	100		
50%	E	10	10	10	10	10	10	10	9	90	92.5	
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	10	10	10	10	10	10	10	100		
	B	10	10	10	10	10	10	10	10	100		
	C	10	9	9	9	9	9	9	9	90		
	D	10	10	10	10	10	10	10	10	100		
100%	E	10	8	8	8	8	8	8	8	80	94	9.52
ANALYST		KP	KP	KP	KP	KP	KP	SB	KP			
DATE:		9/1/2009	9/2/2009	9/3/2009	9/4/2009	9/5/2009	9/6/2009	9/7/2009	9/8/2009			
TIME:		1545	1355	1140	1045	950	1100	1105	1430			

CV = PERCENT COEFFICIENT OF VARIATION: STANDARD DEVIATION/MEAN * 100

AA# EDC-Flat Creek, FATHEAD MINNOW SURVIVAL, CHRONIC
File: H:\TOXSTAT\MONTE\CKSMPLEF.   Transform: ARC SINE(SQUARE ROOT(Y))

Shapiro - Wilk's test for normality

D = 0.226

W = 0.873

Critical W (P = 0.05) (n = 30) = 0.927
Critical W (P = 0.01) (n = 30) = 0.900

Data FAIL normality test. Try another transformation.

Warning - The first three homogeneity tests are sensitive to non-normal data and should not be performed.

AA# EDC-Flat Creek, FATHEAD MINNOW SURVIVAL, CHRONIC
File: H:\TOXSTAT\MONTE\CKSMPLEF.   Transform: ARC SINE(SQUARE ROOT(Y))

Hartley's test for homogeneity of variance
Bartlett's test for homogeneity of variance

These two tests can not be performed because at least one group has zero variance.

Data FAIL to meet homogeneity of variance assumption.
Additional transformations are useless.

TITLE: AA# EDC-Flat Creek, FATHEAD MINNOW SURVIVAL, CHRONIC
FILE: H:\TOXSTAT\MONTE\CKSMPLEF.
TRANSFORM: ARC SINE(SQUARE ROOT(Y))   NUMBER OF GROUPS: 6

GRP	IDENTIFICATION	REP	VALUE	TRANS VALUE
1	CONTROL	1	1.0000	1.4120
1	CONTROL	2	1.0000	1.4120
1	CONTROL	3	1.0000	1.4120
1	CONTROL	4	1.0000	1.4120
1	CONTROL	5	1.0000	1.4120
2	6.25 % EFFLUENT	1	1.0000	1.4120
2	6.25 % EFFLUENT	2	1.0000	1.4120
2	6.25 % EFFLUENT	3	1.0000	1.4120
2	6.25 % EFFLUENT	4	0.9000	1.2490
2	6.25 % EFFLUENT	5	1.0000	1.4120

3	12.5 % EFFLUENT	1	1.0000	1.4120
3	12.5 % EFFLUENT	2	0.9000	1.2490
3	12.5 % EFFLUENT	3	0.8000	1.1071
3	12.5 % EFFLUENT	4	1.0000	1.4120
3	12.5 % EFFLUENT	5	1.0000	1.4120
4	25.0 % EFFLUENT	1	0.9000	1.2490
4	25.0 % EFFLUENT	2	1.0000	1.4120
4	25.0 % EFFLUENT	3	1.0000	1.4120
4	25.0 % EFFLUENT	4	1.0000	1.4120
4	25.0 % EFFLUENT	5	1.0000	1.4120
5	50 % EFFLUENT	1	1.0000	1.4120
5	50 % EFFLUENT	2	0.9000	1.2490
5	50 % EFFLUENT	3	0.9000	1.2490
5	50 % EFFLUENT	4	1.0000	1.4120
5	50 % EFFLUENT	5	0.9000	1.2490
6	100 % EFFLUENT	1	1.0000	1.4120
6	100 % EFFLUENT	2	1.0000	1.4120
6	100 % EFFLUENT	3	0.9000	1.2490
6	100 % EFFLUENT	4	1.0000	1.4120
6	100 % EFFLUENT	5	0.8000	1.1071

AA# EDC-Flat Creek, FATHEAD MINNOW SURVIVAL, CHRONIC
File: H:\TOXSTAT\MONTE\CKSMPLEF.   Transform: ARC SINE(SQUARE ROOT(Y))

STEEL'S MANY-ONE RANK TEST - Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	RANK SUM	CRIT. VALUE	df	SIG
1	CONTROL	1.412				
2	6.25 % EFFLUENT	1.379	25.00	16.00	5.00	
3	12.5 % EFFLUENT	1.318	22.50	16.00	5.00	
4	25.0 % EFFLUENT	1.379	25.00	16.00	5.00	
5	50 % EFFLUENT	1.314	20.00	16.00	5.00	
6	100 % EFFLUENT	1.318	22.50	16.00	5.00	

Critical values use k = 5, are 1 tailed, and alpha = 0.05

Ceriodaphnia dubia

SURVIVAL AND REPRODUCTION TEST

Discharger: EDC
Location: FLAT CREEK SYNTHETIC
prepared 9/1/09
Lab Number/s: na

Analyst: KP
Test Start - Date/ Time: 9/1/2009 1520
Test Stop - Date/Time: 9/8/2009 0850

Conc 1 — 0 %

Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
1	0	0	0	0	0	0	0	0	0	0	0			KP
2	0	0	0	0	0	0	0	0	0	0	0			KP
3	3	4	0	0	2	0	0	3	0	4	16			
4	0	2	2	2	2	5	3	8	2	0	26			
5	5	3	6	6	2	0	1	0	4	3	30			KP
6	0	10	7	6	11	8	10	11	10	5	78			KP
7												10		
8													15	
Total	8	19	15	14	17	13	14	22	16	12	150		CV	25.72408

Conc 2 — 6.25 %

Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
1	0	0	0	0	0	0	0	0	0	0	0			
2	0	0	0	0	0	0	0	0	0	0	0			
3	3	0	0	0	3	0	4	3	4	5	22			
4	0	3	1	3	6	3	0	7	0	0	23			
5	1	7	4	3	0	6	1	7	7	6	42			
6	3	1	9	0	10	9	2	5	10	7	50			
7												10		
8													13.7	
Total	7	11	14	6	19	18	7	17	21	12	137		CV	39.80166

Conc 3 — 12.5 %

Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
1	0	0	0	0	0	0	0	0	0	0	0			
2	0	0	0	0	0	0	0	0	0	0	0			
3	0	0	0	0	2	0	0	4	0	2	8			
4	0	3	2	2	4	1	2	3	3	2	22			
5	2	3	1	2	2	1	1	1	5	1	19			
6	0	4	10	0	7	6	9	9	10	8	63			
7												10		
8													11.2	
Total	2	10	13	4	15	8	12	17	18	13	112		CV	47.02004

Conc 4 — 25 %

Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
1	0	0	0	0	0	0	0	0	0	0	0			
2	0	0	0	0	0	0	0	0	0	0	0			
3	3	0	0	0	4	4	1	4	0	4	20			
4	0	4	2	3	5	4	3	3	2	0	26			
5	2	5	2	6	0	1	3	1	4	2	26			
6	6	7	7	0	8	7	6	12	7	6	66			
7												10		
8													13.8	
Total	11	16	11	9	17	16	13	20	13	12	138		CV	24.347

Conc 5 — 50 %

Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
1	0	0	0	0	0	0	0	0	0	0	0			
2	0	0	0	0	0	0	0	0	0	0	0			
3	0	4	3	0	2	2	0	3	0	0	14			
4	3	0	0	3	1	6	2	0	2	2	19			
5	5	4	3	3	5	1	1	5	2	6	35			
6	8	9	5	2	0	5	0	4	6	7	46			
7												10		
8													11.4	
Total	16	17	11	8	8	14	3	12	10	15	114		CV	37.944

Conc 6 — 100 %

Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
1	0	0	0	0	0	0	0	0	0	0	0			
2	0	0	0	0	0	0	0	0	0	0	0			
3	0	0	0	0	1	0	0	3	3	0	7			
4	3	0	3	1	0	0	1	0	0	0	8			
5	4	0	0	2	1	0	0	5	7	4	23			
6	1	4	0	7	9	5	4	2	4	6	42			
7												10		
8													8	
Total	8	4	3	10	11	5	5	10	14	10	80		CV	44.876

X= DEAD; Y= MALE

```
AA # EDC-Flat Creek, CERIODAPHNIA DUBIA CHRONIC, REPROD
File: H:\TOXSTAT\MONTE\CKSMPLEC.        Transform: NO TRANSFORMATION

Shapiro - Wilk's test for normality
------------------------------------------------------------------------------

        ******** Shapiro - Wilk's Test is aborted ********

This test can not be performed because total number of replicates
is greater than 50.

Total number of replicates =   60

------------------------------------------------------------------------------



AA # EDC-Flat Creek, CERIODAPHNIA DUBIA CHRONIC, REPROD
File: H:\TOXSTAT\MONTE\CKSMPLEC.        Transform: NO TRANSFORMATION

------------------------------------------------------------------------------
Bartlett's test for homogeneity of variance
Calculated B1 statistic =    3.51

------------------------------------------------------------------------------
Table Chi-square value =   15.09  (alpha = 0.01, df =   5)
Table Chi-square value =   11.07  (alpha = 0.05, df =   5)

Data PASS B1 homogeneity test at 0.01 level. Continue analysis.
```

FISHER'S EXACT TEST

IDENTIFICATION	NUMBER OF ALIVE	NUMBER OF DEAD	NUMBER OF TOTAL ANIMALS
CONTROL	10	0	10
6.25	10	0	10
TOTAL	20	0	20

CRITICAL FISHER'S VALUE (10,10,10) (p=0.05) IS 6. b VALUE IS 10.
Since b is greater than 6 there is no significant difference between CONTROL and TREATMENT at the 0.05 level.

FISHER'S EXACT TEST

IDENTIFICATION	NUMBER OF ALIVE	NUMBER OF DEAD	NUMBER OF TOTAL ANIMALS
CONTROL	10	0	10
12.5	10	0	10
TOTAL	20	0	20

CRITICAL FISHER'S VALUE (10,10,10) (p=0.05) IS 6. b VALUE IS 10.
Since b is greater than 6 there is no significant difference between CONTROL and TREATMENT at the 0.05 level.

FISHER'S EXACT TEST

IDENTIFICATION	NUMBER OF ALIVE	NUMBER OF DEAD	NUMBER OF TOTAL ANIMALS
CONTROL	10	0	10
25	10	0	10

TOTAL	20	0	20

CRITICAL FISHER'S VALUE (10,10,10) (p=0.05) IS 6. b VALUE IS 10.
Since b is greater than 6 there is no significant difference between CONTROL and TREATMENT at the 0.05 level.

FISHER'S EXACT TEST

IDENTIFICATION	NUMBER OF ALIVE	DEAD	TOTAL ANIMALS
CONTROL	10	0	10
50	10	0	10
TOTAL	20	0	20

CRITICAL FISHER'S VALUE (10,10,10) (p=0.05) IS 6. b VALUE IS 10.
Since b is greater than 6 there is no significant difference between CONTROL and TREATMENT at the 0.05 level.

FISHER'S EXACT TEST

IDENTIFICATION	NUMBER OF ALIVE	DEAD	TOTAL ANIMALS
CONTROL	10	0	10
100	10	0	10
TOTAL	20	0	20

CRITICAL FISHER'S VALUE (10,10,10) (p=0.05) IS 6. b VALUE IS 10.
Since b is greater than 6 there is no significant difference between CONTROL and TREATMENT at the 0.05 level.

SUMMARY OF FISHER'S EXACT TESTS

NUMBER	NUMBER	SIG

GROUP	IDENTIFICATION	EXPOSED	DEAD	(P=.05)
	CONTROL	10	0	
1	6.25	10	0	
2	12.5	10	0	
3	25	10	0	
4	50	10	0	
5	100	10	0	

TITLE: AA # EDC-Flat Creek, CERIODAPHNIA DUBIA CHRONIC, REPROD
FILE: H:\TOXSTAT\MONTE\CKSMPLEC.
TRANSFORM: NO TRANSFORMATION NUMBER OF GROUPS: 6

GRP	IDENTIFICATION	REP	VALUE	TRANS VALUE
1	CONTROL	1	8.0000	8.0000
1	CONTROL	2	19.0000	19.0000
1	CONTROL	3	15.0000	15.0000
1	CONTROL	4	14.0000	14.0000
1	CONTROL	5	17.0000	17.0000
1	CONTROL	6	13.0000	13.0000
1	CONTROL	7	14.0000	14.0000
1	CONTROL	8	22.0000	22.0000
1	CONTROL	9	16.0000	16.0000
1	CONTROL	10	12.0000	12.0000
2	6.25 % EFFLUENT	1	7.0000	7.0000
2	6.25 % EFFLUENT	2	11.0000	11.0000
2	6.25 % EFFLUENT	3	14.0000	14.0000
2	6.25 % EFFLUENT	4	6.0000	6.0000
2	6.25 % EFFLUENT	5	19.0000	19.0000
2	6.25 % EFFLUENT	6	18.0000	18.0000
2	6.25 % EFFLUENT	7	7.0000	7.0000
2	6.25 % EFFLUENT	8	17.0000	17.0000
2	6.25 % EFFLUENT	9	21.0000	21.0000
2	6.25 % EFFLUENT	10	12.0000	12.0000
3	12.5 % EFFLUENT	1	2.0000	2.0000
3	12.5 % EFFLUENT	2	10.0000	10.0000
3	12.5 % EFFLUENT	3	13.0000	13.0000
3	12.5 % EFFLUENT	4	4.0000	4.0000
3	12.5 % EFFLUENT	5	15.0000	15.0000
3	12.5 % EFFLUENT	6	8.0000	8.0000
3	12.5 % EFFLUENT	7	12.0000	12.0000
3	12.5 % EFFLUENT	8	17.0000	17.0000
3	12.5 % EFFLUENT	9	18.0000	18.0000
3	12.5 % EFFLUENT	10	13.0000	13.0000
4	25.0 % EFFLUENT	1	11.0000	11.0000
4	25.0 % EFFLUENT	2	16.0000	16.0000
4	25.0 % EFFLUENT	3	11.0000	11.0000
4	25.0 % EFFLUENT	4	9.0000	9.0000
4	25.0 % EFFLUENT	5	17.0000	17.0000
4	25.0 % EFFLUENT	6	16.0000	16.0000
4	25.0 % EFFLUENT	7	13.0000	13.0000
4	25.0 % EFFLUENT	8	20.0000	20.0000

4	25.0 % EFFLUENT	9	13.0000	13.0000
4	25.0 % EFFLUENT	10	12.0000	12.0000
5	50.0 % EFFLUENT	1	16.0000	16.0000
5	50.0 % EFFLUENT	2	17.0000	17.0000
5	50.0 % EFFLUENT	3	11.0000	11.0000
5	50.0 % EFFLUENT	4	8.0000	8.0000
5	50.0 % EFFLUENT	5	8.0000	8.0000
5	50.0 % EFFLUENT	6	14.0000	14.0000
5	50.0 % EFFLUENT	7	3.0000	3.0000
5	50.0 % EFFLUENT	8	12.0000	12.0000
5	50.0 % EFFLUENT	9	10.0000	10.0000
5	50.0 % EFFLUENT	10	15.0000	15.0000
6	100 % EFFLUENT	1	8.0000	8.0000
6	100 % EFFLUENT	2	4.0000	4.0000
6	100 % EFFLUENT	3	3.0000	3.0000
6	100 % EFFLUENT	4	10.0000	10.0000
6	100 % EFFLUENT	5	11.0000	11.0000
6	100 % EFFLUENT	6	5.0000	5.0000
6	100 % EFFLUENT	7	5.0000	5.0000
6	100 % EFFLUENT	8	10.0000	10.0000
6	100 % EFFLUENT	9	14.0000	14.0000
6	100 % EFFLUENT	10	10.0000	10.0000

AA # EDC-Flat Creek, CERIODAPHNIA DUBIA CHRONIC, REPROD
File: H:\TOXSTAT\MONTE\CKSMPLEC.   Transform: NO TRANSFORMATION

ANOVA TABLE

SOURCE	DF	SS	MS	F
Between	5	306.200	61.240	3.188
Within (Error)	54	1037.200	19.207	
Total	59	1343.400		

Critical F value = 2.45 (0.05,5,40)
Since F > Critical F REJECT Ho: All equal

AA # EDC-Flat Creek, CERIODAPHNIA DUBIA CHRONIC, REPROD
File: H:\TOXSTAT\MONTE\CKSMPLEC.   Transform: NO TRANSFORMATION

DUNNETT'S TEST - TABLE 1 OF 2   Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	MEAN CALCULATED IN ORIGINAL UNITS	T STAT	SIG
1	CONTROL	15.000	15.000		
2	6.25 % EFFLUENT	13.200	13.200	0.918	
3	12.5 % EFFLUENT	11.200	11.200	1.939	
4	25.0 % EFFLUENT	13.800	13.800	0.612	
5	50.0 % EFFLUENT	11.400	11.400	1.837	
6	100 % EFFLUENT	8.000	8.000	3.571	*

Dunnett table value = 2.31 (1 Tailed Value, P=0.05, df=40,5)

AA # EDC-Flat Creek, CERIODAPHNIA DUBIA CHRONIC, REPROD
File: H:\TOXSTAT\MONTE\CKSMPLEC. Transform: NO TRANSFORMATION

DUNNETT'S TEST - TABLE 2 OF 2 Ho:Control<Treatment

GROUP	IDENTIFICATION	NUM OF REPS	Minimum Sig Diff (IN ORIG. UNITS)	% of CONTROL	DIFFERENCE FROM CONTROL
1	CONTROL	10			
2	6.25 % EFFLUENT	10	4.528	30.2	1.800
3	12.5 % EFFLUENT	10	4.528	30.2	3.800
4	25.0 % EFFLUENT	10	4.528	30.2	1.200
5	50.0 % EFFLUENT	10	4.528	30.2	3.600
6	100 % EFFLUENT	10	4.528	30.2	7.000

AA # EDC-Flat Creek, CERIODAPHNIA DUBIA CHRONIC, REPROD
File: H:\TOXSTAT\MONTE\CKSMPLEC. Transform: NO TRANSFORMATION

STEEL'S MANY-ONE RANK TEST - Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	RANK SUM	CRIT. VALUE	df	SIG
1	CONTROL	15.000				
2	6.25 % EFFLUENT	13.200	94.50	75.00	10.00	
3	12.5 % EFFLUENT	11.200	84.00	75.00	10.00	
4	25.0 % EFFLUENT	13.800	94.00	75.00	10.00	
5	50.0 % EFFLUENT	11.400	83.00	75.00	10.00	
6	100 % EFFLUENT	8.000	63.50	75.00	10.00	*

Critical values use k = 5, are 1 tailed, and alpha = 0.05

Pimephales promelas **FATHEAD MINNOW** TEST 1000.0

WEIGHT DATA FOR LARVAL SURVIVAL AND GROWTH TEST

LAB # / #s:	NA			TEST DATES (BEGIN / END):	9/01-08/09
CLIENT:	EDC			WEIGHING DATE / TIME:	9/09/09, 1130
ANALYSTS:	KP			DRYING TEMP (DEGREES C):	60
SAMPLE ID:	EDC FLATCREEK SYNTHETIC			DRYING TIME (HOURS):	24

	REP#	FINAL DRY WEIGHT TIN+LARVAE (g)	INTIAL WEIGHT TIN (g)	TOTAL DRY WEIGHT OF LARVAE (g)	NUMBER OF LARVAE	DRY WEIGHT OF LARVAE (mg)	
CONTROL	A	0.98654	0.98248	0.00406	10	0.406	AVG DRY
	B	0.99623	0.99247	0.00376	10	0.376	WEIGHT (mg)
	C	1.00374	0.99986	0.00388	10	0.388	0.378
	D	1.00286	0.99980	0.00306	10	0.306	CV
0	E	0.98262	0.97849	0.00413	10	0.413	11.3
CONC:	A	0.97485	0.97113	0.00372	10	0.372	AVG DRY
	B	0.97141	0.96817	0.00324	10	0.324	WEIGHT (mg)
	C	0.97877	0.97508	0.00369	10	0.369	0.352
	D	0.96613	0.96293	0.00320	10	0.320	CV
6.25%	E	0.98052	0.97675	0.00377	10	0.377	7.9
CONC:	A	0.99216	0.98939	0.00277	10	0.277	AVG DRY
	B	0.97043	0.96743	0.00300	10	0.300	WEIGHT (mg)
	C	0.96914	0.96639	0.00275	10	0.275	0.311
	D	0.97918	0.97561	0.00357	10	0.357	CV
12.50%	E	0.97640	0.97294	0.00346	10	0.346	12.4
CONC:	A	0.97010	0.96704	0.00306	10	0.306	AVG DRY
	B	0.98059	0.97733	0.00326	10	0.326	WEIGHT (mg)
	C	0.98113	0.97746	0.00367	10	0.367	0.338
	D	0.96553	0.96168	0.00385	10	0.385	CV
25%	E	0.96651	0.96345	0.00306	10	0.306	10.7
CONC:	A	1.00172	0.99805	0.00367	10	0.367	AVG DRY
	B	0.98403	0.98073	0.00330	10	0.330	WEIGHT (mg)
	C	0.96039	0.95700	0.00339	10	0.339	0.382
	D	0.99354	0.98883	0.00471	10	0.471	CV
50%	E	0.98159	0.97756	0.00403	10	0.403	15.0
CONC:	A	0.97188	0.96707	0.00481	10	0.481	AVG DRY
	B	1.00007	0.99607	0.00400	10	0.400	WEIGHT (mg)
	C	0.96544	0.96083	0.00461	10	0.461	0.451
	D	0.97352	0.96889	0.00463	10	0.463	CV
100%	E	1.01882	1.01431	0.00451	10	0.451	6.8

CV = (STANDARD DEVIATION/MEAN)*100

REMARKS:

AA# EDC-Flat Creek, FATHEAD MINNOW GROWTH, CHRONIC, 9-1
File: H:\TOXSTAT\MONTE\CKSMPLGR.   Transform: ARC SINE(SQUARE ROOT(Y))

Shapiro - Wilk's test for normality

D = 0.042

W = 0.974

Critical W (P = 0.05) (n = 30) = 0.927
Critical W (P = 0.01) (n = 30) = 0.900

Data PASS normality test at P=0.01 level. Continue analysis.

AA# EDC-Flat Creek, FATHEAD MINNOW GROWTH, CHRONIC, 9-1
File: H:\TOXSTAT\MONTE\CKSMPLGR.   Transform: ARC SINE(SQUARE ROOT(Y))

Bartlett's test for homogeneity of variance
Calculated B1 statistic = 2.44

Table Chi-square value = 15.09 (alpha = 0.01, df = 5)
Table Chi-square value = 11.07 (alpha = 0.05, df = 5)

Data PASS B1 homogeneity test at 0.01 level. Continue analysis.

TITLE: AA# EDC-Flat Creek, FATHEAD MINNOW GROWTH, CHRONIC, 9-1
FILE: H:\TOXSTAT\MONTE\CKSMPLGR.
TRANSFORM: ARC SINE(SQUARE ROOT(Y))   NUMBER OF GROUPS: 6

GRP	IDENTIFICATION	REP	VALUE	TRANS VALUE
1	CONTROL	1	0.4060	0.6908
1	CONTROL	2	0.3760	0.6601
1	CONTROL	3	0.3880	0.6724
1	CONTROL	4	0.3060	0.5862
1	CONTROL	5	0.4130	0.6980
2	6.25 % EFFLUENT	1	0.3720	0.6560
2	6.25 % EFFLUENT	2	0.3240	0.6055
2	6.25 % EFFLUENT	3	0.3690	0.6529
2	6.25 % EFFLUENT	4	0.3200	0.6013
2	6.25 % EFFLUENT	5	0.3770	0.6611
3	12.5 % EFFLUENT	1	0.2770	0.5543
3	12.5 % EFFLUENT	2	0.3000	0.5796
3	12.5 % EFFLUENT	3	0.2750	0.5520
3	12.5 % EFFLUENT	4	0.3570	0.6404
3	12.5 % EFFLUENT	5	0.3460	0.6289
4	25 % EFFLUENT	1	0.3060	0.5862

4	25 % EFFLUENT	2	0.3260	0.6077
4	25 % EFFLUENT	3	0.3670	0.6508
4	25 % EFFLUENT	4	0.3850	0.6694
4	25 % EFFLUENT	5	0.3060	0.5862
5	50 % EFFLUENT	1	0.3670	0.6508
5	50 % EFFLUENT	2	0.3300	0.6119
5	50 % EFFLUENT	3	0.3390	0.6215
5	50 % EFFLUENT	4	0.4710	0.7564
5	50 % EFFLUENT	5	0.4030	0.6878
6	100 % EFFLUENT	1	0.4810	0.7664
6	100 % EFFLUENT	2	0.4000	0.6847
6	100 % EFFLUENT	3	0.4610	0.7464
6	100 % EFFLUENT	4	0.4630	0.7484
6	100 % EFFLUENT	5	0.4510	0.7363

AA# EDC-Flat Creek, FATHEAD MINNOW GROWTH, CHRONIC, 9-1
File: H:\TOXSTAT\MONTE\CKSMPLGR.   Transform: ARC SINE(SQUARE ROOT(Y))

ANOVA TABLE

SOURCE	DF	SS	MS	F
Between	5	0.062	0.012	7.146
Within (Error)	24	0.042	0.002	
Total	29	0.104		

Critical F value = 2.62 (0.05,5,24)
Since F > Critical F REJECT Ho: All equal

AA# EDC-Flat Creek, FATHEAD MINNOW GROWTH, CHRONIC, 9-1
File: H:\TOXSTAT\MONTE\CKSMPLGR.   Transform: ARC SINE(SQUARE ROOT(Y))

DUNNETT'S TEST - TABLE 1 OF 2   Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	MEAN CALCULATED IN ORIGINAL UNITS	T STAT	SIG
1	CONTROL	0.661	0.378		
2	6.25 % EFFLUENT	0.635	0.352	0.992	
3	12.5 % EFFLUENT	0.591	0.311	2.673	*
4	25 % EFFLUENT	0.620	0.338	1.573	
5	50 % EFFLUENT	0.666	0.382	-0.158	
6	100 % EFFLUENT	0.736	0.451	-2.842	

Dunnett table value = 2.36 (1 Tailed Value, P=0.05, df=24,5)

AA# EDC-Flat Creek, FATHEAD MINNOW GROWTH, CHRONIC, 9-1
File: H:\TOXSTAT\MONTE\CKSMPLGR.   Transform: ARC SINE(SQUARE ROOT(Y))

DUNNETT'S TEST - TABLE 2 OF 2   Ho:Control<Treatment

GROUP	IDENTIFICATION	NUM OF REPS	Minimum Sig Diff (IN ORIG. UNITS)	% of CONTROL	DIFFERENCE FROM CONTROL
1	CONTROL	5			
2	6.25 % EFFLUENT	5	0.059	15.7	0.025
3	12.5 % EFFLUENT	5	0.059	15.7	0.067
4	25 % EFFLUENT	5	0.059	15.7	0.040
5	50 % EFFLUENT	5	0.059	15.7	-0.004
6	100 % EFFLUENT	5	0.059	15.7	-0.073

CHEMICAL DATA SHEET FOR CHRONIC TOXICITY TESTING						*Ceriodaphnia Dubia*		
Lab #/ Sample ID		EDC FLAT CREEK SYNTHETIC				Test Start: 9/1/09		
Client:	EDC					Test End: 9/8/09		
		Day of Test						
		1	2	3	4	5	6	7	**notes/remarks**
Control	0%	1-Sep	2-Sep	3-Sep	4-Sep	5-Sep	6-Sep	7-Sep	
D.O. (mg/L)	INITIAL	8.8	8.7	8.7	8.5	8.5	8.5	8.4	
	FINAL	8.2	8	8.9	8.8	8.4	8		
pH (s.u.)	INITIAL	7.7	7.9	7.7	7.8	7.9	7.5	7.8	
	FINAL	8.4	8.2	8	7.9	7.7	8.1		
temp (C)	INITIAL	20	21.3	21.8	22.1	22.4	22.3	22.8	
	FINAL	25	25	25	22.5	25	25		
ALKALINITY (mg/L)		52	52	52	52	52	52	52	
HARDNESS (mg/L)		88	88	88	88	88	88	88	
CONDUCTIVITY (umhos/cm)		291	291	291	291	291	291	291	
CHLORINE (mg/L)		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
CONC:	**6.25%**								
D.O. (mg/L)	INITIAL	9	8.8	8.5	8.3	8.7	8.9	8.6	
	FINAL	8.2	8	8.8	9	8.5	7.9		
pH (s.u)	INITIAL	8.5	9.1	9	8.1	8	8	7.9	
	FINAL	8.4	8.4	8	8	8	8.1		
temp (C)	INITIAL	19.9	21.6	22	22.1	22.6	22.1	22.7	
	FINAL	25	25	25	22.5	25	25	25	
CONC:	**12.50%**								
D.O. (mg/L)	INITIAL	9	8.7	8.5	8.5	8.6	8.8	8.6	
	FINAL	8.1	8	8.7	8.8	8.5	7.8		
pH (mg/L)	INITIAL	8.5	9.4	9.3	8.2	8.1	8	8	
	FINAL	8.4	8.3	8	8	8	8.1		
temp (C)	INITIAL	19.9	21.7	21.9	22	22.5	22.1	22	
	FINAL	25	25	25	25	25	25		
CONC:	**25%**								
D.O. (mg/L)	INITIAL	8.9	8.5	8.5	8.5	8.5	8.7	8.6	
	FINAL	8.1	7.9	8.7	8.8	8.6	7.7		
pH (s.u.)	INITIAL	8.8	9.7	9.7	8.1	8.2	8.2	8.1	
	FINAL	8.4	8.3	8.1	8	8	8.1		
temp (C)	INITIAL	19.9	21.7	21.9	22.1	22.5	22.1	22.8	
	FINAL	25	25	25	22.5	25	25		
CONC:	**50%**								
D.O. (mg/L)	INITIAL	9	8.4	8.3	8.2	8.3	8.6	8.6	
	FINAL	8	7.9	8.7	8	8.6	7.8		
pH (s.u.)	INITIAL	9.2	10.2	10.2	8.1	8.4	8.4	8.7	
	FINAL	8.5	8.4	8.1	8	8.1	8.1		
temp (C)	INITIAL	19.9	21.9	21.8	22	22.4	22.2	22.8	
	FINAL	25	25	25	22.5	25	25		
CONC:	**100%**								
D.O. (mg/L)	INITIAL	9	8.1	8.2	7.6	8.2	8.5	8.6	
	FINAL	8	7.9	8.7	8.8	8.6	7.8		
pH (s.u.)	INITIAL	9.7	10.7	10.7	8	8.8	8.8	8.5	
	FINAL	8	8.6	8.2	8.1	8.1	8.1		
temp (C)	INITIAL	20.2	22.3	21.8	23	22.5	22.6	22.9	
	FINAL	25	25.8	25	22.5	25	25	25	
CONC:	**100%**								
ALKALINITY (mg/L)		110	110	110	110	110	110	110	
HARDNESS (mg/L)		44	44	44	44	44	44	44	
CONDUCTIVITY (umhos/cm)		990	990	990	990	990	990	990	
CHLORINE (mg/L)		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	

CHEMICAL DATA SHEET FOR CHRONIC TOXICITY TESTING							*Pimephales promelas*		
Lab #/ Sample ID		EDC FLAT CREEK SYNTHETIC				Test Start: 9/1/09			
Client:	EDC					Test End: 9/8/09			
		Day of Test							
		1	**2**	**3**	**4**	**5**	**6**	**7**	**notes/remarks**
Control	0%	1-Sep	2-Sep	3-Sep	4-Sep	5-Sep	6-Sep	7-Sep	
D.O. (mg/L)	INITIAL	8.8	8.7	8.7	8.5	8.5	8.5	8.4	
	FINAL	8.2	8	8	8.3	8.4	8.1	8.1	
pH (s.u.)	INITIAL	7.7	7.9	7.7	7.8	7.9	7.5	7.8	
	FINAL	8.3	8.4	8	7.3	7.6	7.7	7.7	
temp (C)	INITIAL	20	21.3	21.8	22.1	22.4	22.3	22.8	
	FINAL	25	25	25	25	25	25	25	
ALKALINITY (mg/L)		52	52	52	52	52	52	52	
HARDNESS (mg/L)		88	88	88	88	88	88	88	
CONDUCTIVITY (umhos/cm)		291	291	291	291	291	291	291	
CHLORINE (mg/L)		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
CONC:	**6.25%**								
D.O. (mg/L)	INITIAL	9	8.8	8.5	8.3	8.7	8.9	8.6	
	FINAL	7.8	8	8.2	8	8.2	8.2	7.7	
pH (s.u)	INITIAL	8.5	9.1	9	8.1	8	8	7.9	
	FINAL	8.3	8.4	7.9	7.3	7.8	7.5	8.1	
temp (C)	INITIAL	19.9	21.6	22	22.1	22.6	22.1	22.7	
	FINAL	25	25	25	22.5	25	25	25	
CONC:	**12.50%**								
D.O. (mg/L)	INITIAL	9	8.7	8.5	8.5	8.6	8.8	8.6	
	FINAL	7.7	8.2	8.2	8	8.1	8.2	7.7	
pH (mg/L)	INITIAL	8.5	9.4	9.3	8.2	8.1	8	8	
	FINAL	8.2	8.4	7.9	7.4	7.9	7.6	8.1	
temp (C)	INITIAL	19.9	21.7	21.9	22	22.5	22.1	22	
	FINAL	25	25	25	25	25	25	25	
CONC:	**25%**								
D.O. (mg/L)	INITIAL	8.9	8.5	8.5	8.5	8.5	8.7	8.6	
	FINAL	7.7	8	8.2	8	8.2	8.2	7.7	
pH (s.u.)	INITIAL	8.8	9.7	9.7	8.1	8.2	8.2	8.1	
	FINAL	8.1	8.4	7.9	7.6	7.9	7.7	8.1	
temp (C)	INITIAL	19.9	21.7	21.9	22.1	22.5	22.1	22.8	
	FINAL	25	25	25	22.5	25	25	25	
CONC:	**50%**								
D.O. (mg/L)	INITIAL	9	8.4	8.3	8.2	8.3	8.6	8.6	
	FINAL	7.7	8	8.1	8	8.1	8.3	7.7	
pH (s.u.)	INITIAL	9.2	10.2	10.2	8.1	8.4	8.4	8.7	
	FINAL	8.1	8.4	8	7.6	7.9	7.7	8.1	
temp (C)	INITIAL	19.9	21.9	21.8	22	22.4	22.2	22.8	
	FINAL	25	25	25	22.5	25	25	25	
CONC:	**100%**								
D.O. (mg/L)	INITIAL	9	8.1	8.2	7.6	8.2	8.5	8.6	
	FINAL	7.5	7.4	8	8	8	8.3	7.7	
pH (s.u.)	INITIAL	9.7	10.7	10.7	8	8.8	8.8	8.5	
	FINAL	8	8.7	8.1	7.7	8	7.9	8.2	
temp (C)	INITIAL	20.2	22.3	21.8	23	22.5	22.6	22.9	
	FINAL	25	25.8	25	22.5	25	25	25	
CONC:	**100%**								
ALKALINITY (mg/L)		110	110	110	110	110	110	110	
HARDNESS (mg/L)		44	44	44	44	44	44	44	
CONDUCTIVITY (umhos/cm)		990	990	990	990	990	990	990	
CHLORINE (mg/L)		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	

EDC Haynes

Bench Sheets

Statistical Analysis

Chemistry Bench Sheets

Pimephales promelas **FATHEAD MINNOW** TEST 1000.0

WEIGHT DATA FOR LARVAL SURVIVAL AND GROWTH TEST

LAB # / #s:	NA	TEST DATES (BEGIN / END):	9/01-08/09
CLIENT:	EDC	WEIGHING DATE / TIME:	9/09/09, 1130
ANALYSTS:	KP	DRYING TEMP (DEGREES C):	60
SAMPLE ID:	HAYNES SYNTHETIC	DRYING TIME (HOURS):	24

	REP#	FINAL DRY WEIGHT TIN+LARVAE (g)	INTIAL WEIGHT TIN (g)	TOTAL DRY WEIGHT OF LARVAE (g)	NUMBER OF LARVAE	DRY WEIGHT OF LARVAE (mg)	
CONTROL	A	0.98654	0.98248	0.00406	10	0.406	AVG DRY
	B	0.99623	0.99247	0.00376	10	0.376	WEIGHT (mg)
	C	1.00374	0.99986	0.00388	10	0.388	0.378
	D	1.00286	0.99980	0.00306	10	0.306	CV
0	E	0.98262	0.97849	0.00413	10	0.413	11.3
CONC:	A	0.98990	0.98616	0.00374	10	0.374	AVG DRY
	B	0.98477	0.98119	0.00358	10	0.358	WEIGHT (mg)
	C	0.96272	0.95916	0.00356	10	0.356	0.344
	D	0.96052	0.95761	0.00291	10	0.291	CV
6.25%	E	0.98702	0.98362	0.00340	10	0.340	9.3
CONC:	A	0.98555	0.98188	0.00367	10	0.367	AVG DRY
	B	0.99221	0.98835	0.00386	10	0.386	WEIGHT (mg)
	C	0.97774	0.97430	0.00344	10	0.344	0.354
	D	0.99300	0.99019	0.00281	10	0.281	CV
12.50%	E	0.97451	0.97057	0.00394	10	0.394	12.8
CONC:	A	0.98913	0.98426	0.00487	10	0.487	AVG DRY
	B	0.99613	0.99267	0.00346	10	0.346	WEIGHT (mg)
	C	0.98511	0.98176	0.00335	10	0.335	0.388
	D	0.98695	0.98297	0.00398	10	0.398	CV
25%	E	0.97845	0.97471	0.00374	10	0.374	15.6
CONC:	A	0.97046	0.96592	0.00454	10	0.454	AVG DRY
	B	0.97549	0.97140	0.00409	10	0.409	WEIGHT (mg)
	C	0.96206	0.95737	0.00469	10	0.469	0.470
	D	0.97171	0.96723	0.00448	10	0.448	CV
50%	E	0.98326	0.97757	0.00569	10	0.569	12.7
CONC:	A	0.99361	0.98773	0.00588	10	0.588	AVG DRY
	B	0.98321	0.97770	0.00551	10	0.551	WEIGHT (mg)
	C	0.96396	0.95851	0.00545	10	0.545	0.564
	D	0.96514	0.96006	0.00508	10	0.508	CV
100%	E	0.97406	0.96779	0.00627	10	0.627	8.0

CV = (STANDARD DEVIATION/MEAN)*100

REMARKS:

AA# EDC-UTA, FATHEAD MINNOW GROWTH, CHRONIC, 9-1-09
File: H:\TOXSTAT\MONTE\CKSMPLGR.   Transform: ARC SINE(SQUARE ROOT(Y))

Shapiro - Wilk's test for normality

D = 0.060

W = 0.961

Critical W (P = 0.05) (n = 30) = 0.927
Critical W (P = 0.01) (n = 30) = 0.900

Data PASS normality test at P=0.01 level. Continue analysis.

AA# EDC-UTA, FATHEAD MINNOW GROWTH, CHRONIC, 9-1-09
File: H:\TOXSTAT\MONTE\CKSMPLGR.   Transform: ARC SINE(SQUARE ROOT(Y))

Bartlett's test for homogeneity of variance
Calculated B1 statistic = 1.65

Table Chi-square value = 15.09 (alpha = 0.01, df = 5)
Table Chi-square value = 11.07 (alpha = 0.05, df = 5)

Data PASS B1 homogeneity test at 0.01 level. Continue analysis.

TITLE: AA# EDC-UTA, FATHEAD MINNOW GROWTH, CHRONIC, 9-1-09
FILE: H:\TOXSTAT\MONTE\CKSMPLGR.
TRANSFORM: ARC SINE(SQUARE ROOT(Y))   NUMBER OF GROUPS: 6

GRP	IDENTIFICATION	REP	VALUE	TRANS VALUE
1	CONTROL	1	0.4060	0.6908
1	CONTROL	2	0.3760	0.6601
1	CONTROL	3	0.3880	0.6724
1	CONTROL	4	0.3060	0.5862
1	CONTROL	5	0.4130	0.6980
2	6.25 % EFFLUENT	1	0.3740	0.6580
2	6.25 % EFFLUENT	2	0.3580	0.6414
2	6.25 % EFFLUENT	3	0.3560	0.6393
2	6.25 % EFFLUENT	4	0.2910	0.5698
2	6.25 % EFFLUENT	5	0.3400	0.6225
3	12.5 % EFFLUENT	1	0.3670	0.6508
3	12.5 % EFFLUENT	2	0.3860	0.6704
3	12.5 % EFFLUENT	3	0.3440	0.6267
3	12.5 % EFFLUENT	4	0.2810	0.5587
3	12.5 % EFFLUENT	5	0.3940	0.6786
4	25 % EFFLUENT	1	0.4870	0.7724

4	25 % EFFLUENT	2	0.3460	0.6289
4	25 % EFFLUENT	3	0.3350	0.6172
4	25 % EFFLUENT	4	0.3980	0.6827
4	25 % EFFLUENT	5	0.3740	0.6580
5	50 % EFFLUENT	1	0.4540	0.7393
5	50 % EFFLUENT	2	0.4090	0.6939
5	50 % EFFLUENT	3	0.4690	0.7544
5	50 % EFFLUENT	4	0.4480	0.7333
5	50 % EFFLUENT	5	0.5690	0.8546
6	100 % EFFLUENT	1	0.5880	0.8739
6	100 % EFFLUENT	2	0.5510	0.8365
6	100 % EFFLUENT	3	0.5450	0.8305
6	100 % EFFLUENT	4	0.5080	0.7934
6	100 % EFFLUENT	5	0.6270	0.9138

AA# EDC-UTA, FATHEAD MINNOW GROWTH, CHRONIC, 9-1-09
File: H:\TOXSTAT\MONTE\CKSMPLGR. Transform: ARC SINE(SQUARE ROOT(Y))

ANOVA TABLE

SOURCE	DF	SS	MS	F
Between	5	0.186	0.037	14.865
Within (Error)	24	0.060	0.002	
Total	29	0.245		

Critical F value = 2.62 (0.05,5,24)
Since F > Critical F REJECT Ho: All equal

AA# EDC-UTA, FATHEAD MINNOW GROWTH, CHRONIC, 9-1-09
File: H:\TOXSTAT\MONTE\CKSMPLGR. Transform: ARC SINE(SQUARE ROOT(Y))

DUNNETT'S TEST - TABLE 1 OF 2 Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	MEAN CALCULATED IN ORIGINAL UNITS	T STAT	SIG
1	CONTROL	0.661	0.378		
2	6.25 % EFFLUENT	0.626	0.344	1.117	
3	12.5 % EFFLUENT	0.637	0.354	0.774	
4	25 % EFFLUENT	0.672	0.388	-0.327	
5	50 % EFFLUENT	0.755	0.470	-2.963	
6	100 % EFFLUENT	0.850	0.564	-5.953	

Dunnett table value = 2.36 (1 Tailed Value, P=0.05, df=24,5)

AA# EDC-UTA, FATHEAD MINNOW GROWTH, CHRONIC, 9-1-09
File: H:\TOXSTAT\MONTE\CKSMPLGR. Transform: ARC SINE(SQUARE ROOT(Y))

DUNNETT'S TEST - TABLE 2 OF 2 Ho:Control<Treatment

GROUP	IDENTIFICATION	NUM OF REPS	Minimum Sig Diff (IN ORIG. UNITS)	% of CONTROL	DIFFERENCE FROM CONTROL
1	CONTROL	5			
2	6.25 % EFFLUENT	5	0.071	18.7	0.034
3	12.5 % EFFLUENT	5	0.071	18.7	0.023
4	25 % EFFLUENT	5	0.071	18.7	-0.010
5	50 % EFFLUENT	5	0.071	18.7	-0.092
6	100 % EFFLUENT	5	0.071	18.7	-0.186

SURVIVAL DATA FOR FATHEAD MINNOW LARVAL SURVIVAL AND GROWTH TEST

LAB # / SAMPLE ID			TEST START	DATE 9/01/09			TI TIME		1610			
CLIENT	EDC HAYNES SYNTHETIC		TEST END	DATE 9/8/2009			TIME		1505			
AGE AND SOURCE OF MINNOWS												
		D A Y (NUMBER SURVIVING)							SURVIVAL			
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	10	10	10	10	10	10	10	100		
	B	10	10	10	10	10	10	10	10	100		
	C	10	10	10	10	10	10	10	10	100		
	D	10	10	10	10	10	10	10	10	100		
0	E	10	10	10	10	10	10	10	10	100	100	0
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	10	10	10	10	10	10	10	100		
	B	10	10	10	10	10	10	10	10	100		
	C	10	10	10	10	10	10	10	10	100		
	D	10	10	9	9	9	9	9	9	90		
6.25%	E	10	10	10	10	10	10	10	10	100	98	
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	10	10	10	10	10	10	10	100		
	B	10	10	10	10	10	10	10	10	100		
	C	10	10	9	9	9	9	9	9	90		
	D	10	10	9	9	9	9	9	9	90		
12.50%	E	10	10	10	10	10	10	10	10	100	96	
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	10	10	10	10	10	10	10	100		
	B	10	10	10	10	10	10	10	100	100		
	C	10	10	9	9	9	9	9	9	90		
	D	10	10	10	10	10	10	10	10	100		
25%	E	10	10	10	10	10	10	10	100	100	98	
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	10	10	10	10	10	10	10	100		
	B	10	10	10	10	10	10	10	10	100		
	C	10	10	10	10	10	10	10	10	100		
	D	10	10	10	10	10	10	10	10	100		
50%	E	10	10	10	10	10	10	10	10	100	100	
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	10	10	10	10	10	10	10	100		
	B	10	10	10	10	10	10	10	10	100		
	C	10	10	10	10	10	10	10	10	100		
	D	10	8	8	8	8	8	8	8	80		
100%	E	10	10	10	10	10	10	10	10	100	96	9.32
ANALYST		KP	KP	KP	KP	KP	KP	SB	KP			
DATE:		9/1/2009	9/2/2009	9/3/2009	9/4/2009	9/5/2009	9/6/2009	9/7/2009	9/8/2009			
TIME:		1610	1310	1340	1440	910	1030	1030	1505			

CV = PERCENT COEFFICIENT OF VARIATION: STANDARD DEVIATION/MEAN * 100

AA# EDC-Haynes, FATHEAD MINNOW SURVIVAL, CHRONIC
File: H:\TOXSTAT\MONTE\CKSMPLEF.   Transform: ARC SINE(SQUARE ROOT(Y))

Shapiro - Wilk's test for normality

D = 0.149

W = 0.761

Critical W (P = 0.05) (n = 30) = 0.927
Critical W (P = 0.01) (n = 30) = 0.900

Data FAIL normality test. Try another transformation.

Warning - The first three homogeneity tests are sensitive to non-normal data and should not be performed.

AA# EDC-Haynes, FATHEAD MINNOW SURVIVAL, CHRONIC
File: H:\TOXSTAT\MONTE\CKSMPLEF.   Transform: ARC SINE(SQUARE ROOT(Y))

Hartley's test for homogeneity of variance
Bartlett's test for homogeneity of variance

These two tests can not be performed because at least one group has zero variance.

Data FAIL to meet homogeneity of variance assumption.
Additional transformations are useless.

TITLE: AA# EDC-Haynes, FATHEAD MINNOW SURVIVAL, CHRONIC
FILE: H:\TOXSTAT\MONTE\CKSMPLEF.
TRANSFORM: ARC SINE(SQUARE ROOT(Y))   NUMBER OF GROUPS: 6

GRP	IDENTIFICATION	REP	VALUE	TRANS VALUE
1	CONTROL	1	1.0000	1.4120
1	CONTROL	2	1.0000	1.4120
1	CONTROL	3	1.0000	1.4120
1	CONTROL	4	1.0000	1.4120
1	CONTROL	5	1.0000	1.4120
2	6.25 % EFFLUENT	1	1.0000	1.4120
2	6.25 % EFFLUENT	2	1.0000	1.4120
2	6.25 % EFFLUENT	3	1.0000	1.4120
2	6.25 % EFFLUENT	4	0.9000	1.2490
2	6.25 % EFFLUENT	5	1.0000	1.4120

3	12.5 % EFFLUENT	1	1.0000	1.4120
3	12.5 % EFFLUENT	2	1.0000	1.4120
3	12.5 % EFFLUENT	3	0.9000	1.2490
3	12.5 % EFFLUENT	4	0.9000	1.2490
3	12.5 % EFFLUENT	5	1.0000	1.4120
4	25.0 % EFFLUENT	1	1.0000	1.4120
4	25.0 % EFFLUENT	2	1.0000	1.4120
4	25.0 % EFFLUENT	3	0.9000	1.2490
4	25.0 % EFFLUENT	4	1.0000	1.4120
4	25.0 % EFFLUENT	5	1.0000	1.4120
5	50 % EFFLUENT	1	1.0000	1.4120
5	50 % EFFLUENT	2	1.0000	1.4120
5	50 % EFFLUENT	3	1.0000	1.4120
5	50 % EFFLUENT	4	1.0000	1.4120
5	50 % EFFLUENT	5	1.0000	1.4120
6	100 % EFFLUENT	1	1.0000	1.4120
6	100 % EFFLUENT	2	1.0000	1.4120
6	100 % EFFLUENT	3	1.0000	1.4120
6	100 % EFFLUENT	4	0.8000	1.1071
6	100 % EFFLUENT	5	1.0000	1.4120

AA# EDC-Haynes, FATHEAD MINNOW SURVIVAL, CHRONIC
File: H:\TOXSTAT\MONTE\CKSMPLEF.   Transform: ARC SINE(SQUARE ROOT(Y))

STEEL'S MANY-ONE RANK TEST - Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	RANK SUM	CRIT. VALUE	df	SIG
1	CONTROL	1.412				
2	6.25 % EFFLUENT	1.379	25.00	16.00	5.00	
3	12.5 % EFFLUENT	1.347	22.50	16.00	5.00	
4	25.0 % EFFLUENT	1.379	25.00	16.00	5.00	
5	50 % EFFLUENT	1.412	27.50	16.00	5.00	
6	100 % EFFLUENT	1.351	25.00	16.00	5.00	

Critical values use k = 5, are 1 tailed, and alpha = 0.05

Ceriodaphnia dubia **SURVIVAL AND REPRODUCTION TEST**

Discharger:	EDC	Lab Number/s	
Location:	HAYNES SYNTHETIC	na	
	prepared 9/1/09		

Analyst: KP
Test Start - Date/ Time: 9/1/2009 1600
Test Stop - Date/Time: 9/8/2009 0910

Conc %	Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/Adult	Analyst
Conc 1		Replicate													
0	1	0	0	0	0	0	0	0	0	0	0	0			KP
	2	0	0	0	0	0	0	0	0	0	0	0			KP
	3	0	0	0	1	4	4	2	3	2	0	16			
	4	1	0	4	0	0	0	0	2	0	2	9			
	5	8	3	7	5	5	4	4	7	7	5	55			KP
	6	9	9	4	3	8	2	9	10	8	8	70			KP
	7												10		
	8													15	
	Total	18	12	15	9	17	10	15	22	17	15	150		CV	25.9153

Conc %	Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/Adult	Analyst
Conc 2		Replicate													
6.25	1	0	0	0	0	0	0	0	0	0	0	0			
	2	0	0	0	0	0	0	0	0	0	0	0			
	3	0	0	3	2	3	5	2	2	2	0	19			
	4	0	3	0	0	0	0	1	0	1	0	5			
	5	5	8	2	1	0	0	4	6	6	5	37			
	6	7	4	7	5	0	7	8	9	7	8	62			
	7												10		
	8													12.3	
	Total	12	15	12	8	3	12	15	17	16	13	123		CV	33.8591

Conc %	Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/Adult	Analyst
Conc 3		Replicate													
12.5	1	0	0	0	0	0	0	0	0	0	0	0			
	2	0	0	0	0	0	0	0	0	0	0	0			
	3	0	4	2	0	3	2	3	2	3	1	20			
	4	3	0	0	0	2	0	2	4	3	5	19			
	5	6	2	5	2	0	4	5	6	8	7	45			
	6	7	3	9	2	0	6	5	10	7	5	54			
	7												10		
	8													13.8	
	Total	16	9	16	4	5	12	15	22	21	18	138		CV	45.0339

X= DEAD; Y= MALE

Conc %	Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/Adult	Analyst
Conc 4		Replicate													
25	1	0	0	0	0	0	0	0	0	0	0	0			
	2	0	0	0	0	0	0	0	0	0	0	0			
	3	0	1	0	1	0	0	0	2	2	2	8			
	4	1	3	0	2	2	4	0	0	0	4	16			
	5	3	7	7	3	5	7	4	4	7	8	55			
	6	6	11	7	5	4	8	5	9	5	9	69			
	7												10		
	8													14.8	
	Total	10	22	14	11	11	19	9	15	14	23	148		CV	33.679

Conc %	Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/Adult	Analyst
Conc 5		Replicate													
50	1	0	0	0	0	0	0	0	0	0	0	0			
	2	0	0	0	0	0	0	0	0	0	0	0			
	3	0	0	1	0	0	0	2	0	2	0	5			
	4	0	2	0	0	2	0	0	0	0	0	4			
	5	8	7	5	3	3	2	7	4	3	1	43			
	6	5	7	0	3	2	6	4	9	5	5	46			
	7												10		
	8													9.8	
	Total	13	16	6	6	7	8	13	13	10	6	98		CV	37.815

Conc %	Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/Adult	Analyst
Conc 6		Replicate													
100	1	0	0	0	0	0	0	0	0	0	0	0			
	2	0	0	0	0	0	0	0	0	0	0	0			
	3	1	0	2	0	0	0	0	2	0	0	5			
	4	3	0	2	0	0	2	1	0	0	1	9			
	5	1	4	3	3	4	2	3	4	0	5	29			
	6	6	2	10	3	8	6	2	8	1	5	51			
	7												10		
	8													9.4	
	Total	11	6	17	6	12	10	6	14	1	11	94		CV	49.696

```
AA # EDC-Haynes, CERIODAPHNIA DUBIA CHRONIC, REPROD
File: H:\TOXSTAT\MONTE\CKSMPLEC.        Transform: NO TRANSFORMATION

Shapiro - Wilk's test for normality
-------------------------------------------------------------------------------

        ******** Shapiro - Wilk's Test is aborted ********

This test can not be performed because total number of replicates
is greater than 50.

Total number of replicates =   60

-------------------------------------------------------------------------------


AA # EDC-Haynes, CERIODAPHNIA DUBIA CHRONIC, REPROD
File: H:\TOXSTAT\MONTE\CKSMPLEC.        Transform: NO TRANSFORMATION

-------------------------------------------------------------------------------
Bartlett's test for homogeneity of variance
Calculated B1 statistic =   19.23

-------------------------------------------------------------------------------
Table Chi-square value =   15.09  (alpha = 0.01, df =   5)
Table Chi-square value =   11.07  (alpha = 0.05, df =   5)

Data FAIL B1 homogeneity test at 0.01 level. Try another transformation.
```

FISHER'S EXACT TEST

IDENTIFICATION	NUMBER OF ALIVE	NUMBER OF DEAD	NUMBER OF TOTAL ANIMALS
CONTROL	10	0	10
6.25	10	0	10
TOTAL	20	0	20

CRITICAL FISHER'S VALUE (10,10,10) (p=0.05) IS 6. b VALUE IS 10.
Since b is greater than 6 there is no significant difference between CONTROL and TREATMENT at the 0.05 level.

FISHER'S EXACT TEST

IDENTIFICATION	NUMBER OF ALIVE	NUMBER OF DEAD	NUMBER OF TOTAL ANIMALS
CONTROL	10	0	10
12.5	10	0	10
TOTAL	20	0	20

CRITICAL FISHER'S VALUE (10,10,10) (p=0.05) IS 6. b VALUE IS 10.
Since b is greater than 6 there is no significant difference between CONTROL and TREATMENT at the 0.05 level.

FISHER'S EXACT TEST

IDENTIFICATION	NUMBER OF ALIVE	NUMBER OF DEAD	NUMBER OF TOTAL ANIMALS
CONTROL	10	0	10
25	10	0	10

TOTAL	20	0	20

CRITICAL FISHER'S VALUE (10,10,10) (p=0.05) IS 6.   b VALUE IS 10.
Since b is greater than 6 there is no significant difference between CONTROL and TREATMENT at the 0.05 level.

FISHER'S EXACT TEST

IDENTIFICATION	NUMBER OF ALIVE	DEAD	TOTAL ANIMALS
CONTROL	10	0	10
50	10	0	10
TOTAL	20	0	20

CRITICAL FISHER'S VALUE (10,10,10) (p=0.05) IS 6.   b VALUE IS 10.
Since b is greater than 6 there is no significant difference between CONTROL and TREATMENT at the 0.05 level.

FISHER'S EXACT TEST

IDENTIFICATION	NUMBER OF ALIVE	DEAD	TOTAL ANIMALS
CONTROL	10	0	10
100	10	0	10
TOTAL	20	0	20

CRITICAL FISHER'S VALUE (10,10,10) (p=0.05) IS 6.   b VALUE IS 10.
Since b is greater than 6 there is no significant difference between CONTROL and TREATMENT at the 0.05 level.

SUMMARY OF FISHER'S EXACT TESTS

	NUMBER	NUMBER	SIG

GROUP	IDENTIFICATION	EXPOSED	DEAD	(P=.05)
	CONTROL	10	0	
1	6.25	10	0	
2	12.5	10	0	
3	25	10	0	
4	50	10	0	
5	100	10	0	

TITLE: AA # EDC-Haynes, CERIODAPHNIA DUBIA CHRONIC, REPROD
FILE: H:\TOXSTAT\MONTE\CKSMPLEC.
TRANSFORM: NO TRANSFORMATION NUMBER OF GROUPS: 6

GRP	IDENTIFICATION	REP	VALUE	TRANS VALUE
1	CONTROL	1	18.0000	18.0000
1	CONTROL	2	12.0000	12.0000
1	CONTROL	3	15.0000	15.0000
1	CONTROL	4	9.0000	9.0000
1	CONTROL	5	17.0000	17.0000
1	CONTROL	6	10.0000	10.0000
1	CONTROL	7	15.0000	15.0000
1	CONTROL	8	22.0000	22.0000
1	CONTROL	9	17.0000	17.0000
1	CONTROL	10	15.0000	15.0000
2	6.25 % EFFLUENT	1	12.0000	12.0000
2	6.25 % EFFLUENT	2	15.0000	15.0000
2	6.25 % EFFLUENT	3	12.0000	12.0000
2	6.25 % EFFLUENT	4	8.0000	8.0000
2	6.25 % EFFLUENT	5	3.0000	3.0000
2	6.25 % EFFLUENT	6	12.0000	12.0000
2	6.25 % EFFLUENT	7	15.0000	15.0000
2	6.25 % EFFLUENT	8	47.0000	47.0000
2	6.25 % EFFLUENT	9	16.0000	16.0000
2	6.25 % EFFLUENT	10	13.0000	13.0000
3	12.5 % EFFLUENT	1	16.0000	16.0000
3	12.5 % EFFLUENT	2	9.0000	9.0000
3	12.5 % EFFLUENT	3	16.0000	16.0000
3	12.5 % EFFLUENT	4	4.0000	4.0000
3	12.5 % EFFLUENT	5	5.0000	5.0000
3	12.5 % EFFLUENT	6	12.0000	12.0000
3	12.5 % EFFLUENT	7	15.0000	15.0000
3	12.5 % EFFLUENT	8	22.0000	22.0000
3	12.5 % EFFLUENT	9	21.0000	21.0000
3	12.5 % EFFLUENT	10	18.0000	18.0000
4	25.0 % EFFLUENT	1	10.0000	10.0000
4	25.0 % EFFLUENT	2	22.0000	22.0000
4	25.0 % EFFLUENT	3	14.0000	14.0000
4	25.0 % EFFLUENT	4	11.0000	11.0000
4	25.0 % EFFLUENT	5	11.0000	11.0000
4	25.0 % EFFLUENT	6	19.0000	19.0000
4	25.0 % EFFLUENT	7	9.0000	9.0000
4	25.0 % EFFLUENT	8	15.0000	15.0000

4	25.0 % EFFLUENT	9	14.0000	14.0000
4	25.0 % EFFLUENT	10	23.0000	23.0000
5	50.0 % EFFLUENT	1	13.0000	13.0000
5	50.0 % EFFLUENT	2	16.0000	16.0000
5	50.0 % EFFLUENT	3	6.0000	6.0000
5	50.0 % EFFLUENT	4	6.0000	6.0000
5	50.0 % EFFLUENT	5	7.0000	7.0000
5	50.0 % EFFLUENT	6	8.0000	8.0000
5	50.0 % EFFLUENT	7	13.0000	13.0000
5	50.0 % EFFLUENT	8	13.0000	13.0000
5	50.0 % EFFLUENT	9	10.0000	10.0000
5	50.0 % EFFLUENT	10	6.0000	6.0000
6	100 % EFFLUENT	1	11.0000	11.0000
6	100 % EFFLUENT	2	6.0000	6.0000
6	100 % EFFLUENT	3	17.0000	17.0000
6	100 % EFFLUENT	4	6.0000	6.0000
6	100 % EFFLUENT	5	12.0000	12.0000
6	100 % EFFLUENT	6	10.0000	10.0000
6	100 % EFFLUENT	7	6.0000	6.0000
6	100 % EFFLUENT	8	14.0000	14.0000
6	100 % EFFLUENT	9	1.0000	1.0000
6	100 % EFFLUENT	10	11.0000	11.0000

AA # EDC-Haynes, CERIODAPHNIA DUBIA CHRONIC, REPROD
File: H:\TOXSTAT\MONTE\CKSMPLEC. Transform: NO TRANSFORMATION

ANOVA TABLE

SOURCE	DF	SS	MS	F
Between	5	363.683	72.737	1.726
Within (Error)	54	2275.300	42.135	
Total	59	2638.983		

Critical F value = 2.45 (0.05,5,40)
Since F < Critical F FAIL TO REJECT Ho: All equal

AA # EDC-Haynes, CERIODAPHNIA DUBIA CHRONIC, REPROD
File: H:\TOXSTAT\MONTE\CKSMPLEC. Transform: NO TRANSFORMATION

DUNNETT'S TEST - TABLE 1 OF 2 Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	MEAN CALCULATED IN ORIGINAL UNITS	T STAT	SIG
1	CONTROL	15.000	15.000		
2	6.25 % EFFLUENT	15.300	15.300	-0.103	
3	12.5 % EFFLUENT	13.800	13.800	0.413	
4	25.0 % EFFLUENT	14.800	14.800	0.069	
5	50.0 % EFFLUENT	9.800	9.800	1.791	
6	100 % EFFLUENT	9.400	9.400	1.929	

Dunnett table value = 2.31 (1 Tailed Value, P=0.05, df=40,5)

AA # EDC-Haynes, CERIODAPHNIA DUBIA CHRONIC, REPROD
File: H:\TOXSTAT\MONTE\CKSMPLEC. Transform: NO TRANSFORMATION

DUNNETT'S TEST - TABLE 2 OF 2 Ho:Control<Treatment

GROUP	IDENTIFICATION	NUM OF REPS	Minimum Sig Diff (IN ORIG. UNITS)	% of CONTROL	DIFFERENCE FROM CONTROL
1	CONTROL	10			
2	6.25 % EFFLUENT	10	6.706	44.7	-0.300
3	12.5 % EFFLUENT	10	6.706	44.7	1.200
4	25.0 % EFFLUENT	10	6.706	44.7	0.200
5	50.0 % EFFLUENT	10	6.706	44.7	5.200
6	100 % EFFLUENT	10	6.706	44.7	5.600

AA # EDC-Haynes, CERIODAPHNIA DUBIA CHRONIC, REPROD
File: H:\TOXSTAT\MONTE\CKSMPLEC. Transform: NO TRANSFORMATION

STEEL'S MANY-ONE RANK TEST - Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	RANK SUM	CRIT. VALUE	df	SIG
1	CONTROL	15.000				
2	6.25 % EFFLUENT	15.300	90.50	75.00	10.00	
3	12.5 % EFFLUENT	13.800	101.50	75.00	10.00	
4	25.0 % EFFLUENT	14.800	100.00	75.00	10.00	
5	50.0 % EFFLUENT	9.800	71.50	75.00	10.00	*
6	100 % EFFLUENT	9.400	73.00	75.00	10.00	*

Critical values use k = 5, are 1 tailed, and alpha = 0.05

CHEMICAL DATA SHEET FOR CHRONIC TOXICITY TESTING						*Pimephales promelas*			
Lab #/ Sample ID		EDC HAYNES				Test Start: 9/1/09			
Client:	EDC					Test End: 9/8/09			
		Day of Test							
		1	**2**	**3**	**4**	**5**	**6**	**7**	**notes/remarks**
Control	0%	1-Sep	2-Sep	3-Sep	4-Sep	5-Sep	6-Sep	7-Sep	
D.O. (mg/L)	INITIAL	8.8	8.7	8.7	8.5	8.5	8.5	8.4	
	FINAL	7.6	8	8	8.1	8.4	8.4	8.1	
pH (s.u.)	INITIAL	7.7	7.9	7.7	7.8	7.9	7.5	7.8	
	FINAL	8	8.7	8	7.6	7.6	7.7	7.8	
temp (C)	INITIAL	20	21.3	21.8	22.1	22.4	22.3	22.8	
	FINAL	25	25	25	22.5	25	25	25	
ALKALINITY (mg/L)		52	52	52	52	52	52	52	
HARDNESS (mg/L)		88	88	88	88	88	88	88	
CONDUCTIVITY (umhos/cm)		291	291	291	291	291	291	291	
CHLORINE (mg/L)		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
CONC:	**6.25%**								
D.O. (mg/L)	INITIAL	8.8	8.6	8.5	8.4	8.5	8.6	8.5	
	FINAL	7.6	8	8	8.1	8.3	8.1	7.6	
pH (s.u)	INITIAL	8.6	8.4	8.3	8.3	7.9	7.7	7.9	
	FINAL	8.6	8.3	7.9	7.6	7.8	7.6	8.1	
temp (C)	INITIAL	20.8	21.4	22.1	22.3	22.4	22.4	22.3	
	FINAL	25	25	25	25	25	25	25	
CONC:	**12.50%**								
D.O. (mg/L)	INITIAL	8.9	8.5	8.6	8.5	8.6	8.5	8.5	
	FINAL	7.6	8.1	8	8	7.9	8.1	7.6	
pH (mg/L)	INITIAL	8.6	9.7	8.3	8.3	7.9	7.7	7.9	
	FINAL	8.5	8.2	7.9	7.6	7.8	7.8	8.1	
temp (C)	INITIAL	20.6	21.4	21.9	22.5	22.3	22.4	22.4	
	FINAL	25	25	25	25	25	25	25	
CONC:	**25%**								
D.O. (mg/L)	INITIAL	8.9	8.4	8.5	8.5	8.5	8.5	8.5	
	FINAL	7.6	7.9	7.9	8.1	7.2	8	7.7	
pH (s.u.)	INITIAL	8.9	9.3	8.3	8.2	8	7.8	8	
	FINAL	8.4	8.2	8	7.7	7.8	7.8	8.1	
temp (C)	INITIAL	20.5	21.5	21.8	22.5	22.5	22.4	22.4	
	FINAL	25	25	25	25	25	25	25	
CONC:	**50%**								
D.O. (mg/L)	INITIAL	8.9	8.7	8.1	8.4	8.4	8.5	8.5	
	FINAL	7.7	7.8	8	8	7.7	7.9	7.7	
pH (s.u.)	INITIAL	9.4	10.5	8.2	8.1	7.9	7.8	8	
	FINAL	8.4	8.2	8	7.7	7.8	7.8	8.1	
temp (C)	INITIAL	20.5	21.5	22	22.6	22.4	22.4	22.5	
	FINAL	25	25	25	25	25	25	25	
CONC:	**100%**								
D.O. (mg/L)	INITIAL	8.9	7.9	7.9	8.2	8.2	8.5	8.4	
	FINAL	7.7	7.8	8	8.1	7.7	7.9	7.7	
pH (s.u.)	INITIAL	9.6	10.8	8.1	8	7.9	8	8	
	FINAL	8.4	8.5	8	7.8	7.8	7.8	8	
temp (C)	INITIAL	20.6	21.6	28.3	22.6	22.3	22.3	22.6	
	FINAL	25	25	25	25	25	25	25	
CONC:	**100%**								
ALKALINITY (mg/L)		86	86	86	86	86	86	86	
HARDNESS (mg/L)		62	62	62	62	62	62	62	
CONDUCTIVITY (umhos/cm)		1524	1524	1524	1524	1524	1524	1524	
CHLORINE (mg/L)		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	

CHEMICAL DATA SHEET FOR CHRONIC TOXICITY TESTING					*Ceriodaphnia Dubia*				
Lab #/ Sample ID		EDC HAYNES			Test Start: 9/1/09				
Client:	EDC				Test End: 9/8/09				
		Day of Test							
		1	2	3	4	5	6	7	**notes/remarks**
Control	0%	1-Sep	2-Sep	3-Sep	4-Sep	5-Sep	6-Sep	7-Sep	
D.O. (mg/L)	INITIAL	8.8	8.7	8.5	8.5	8.5	8.5	8.4	
	FINAL	8.2	8	8.7	9.1	8.3	7.5		
pH (s.u.)	INITIAL	7.7	7.9	8.3	7.8	7.9	7.5	7.8	
	FINAL	8.6	8.4	7.9	7.8	7.7	7.9		
temp (C)	INITIAL	20	21.3	22.1	22.1	22.4	22.3	22.8	
	FINAL	25	25	25	22.5	25	25		
ALKALINITY (mg/L)		52	52	52	52	52	52	52	
HARDNESS (mg/L)		88	88	88	88	88	88	88	
CONDUCTIVITY (umhos/cm)		291	291	291	291	291	291	291	
CHLORINE (mg/L)		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
CONC:	**6.25%**								
D.O. (mg/L)	INITIAL	8.8	8.6	8.5	8.4	8.5	8.6	8.5	
	FINAL	8.2	8	8.7	8.9	8.4	7.7		
pH (s.u)	INITIAL	8.6	8.4	8.3	8.3	7.9	7.7	7.9	
	FINAL	8.5	8.4	8	8	7.8	8		
temp (C)	INITIAL	20.8	21.4	22.1	22.3	22.4	22.4	22.3	
	FINAL	25	25	25	25	25	25	25	
CONC:	**12.50%**								
D.O. (mg/L)	INITIAL	8.9	8.5	8.6	8.5	8.6	8.5	8.5	
	FINAL	8	8.1	8.6	8.9	8.7	7.8		
pH (mg/L)	INITIAL	8.6	9.1	8.3	8.3	7.9	7.7	7.9	
	FINAL	8.5	8.3	8	8	7.9	7.9		
temp (C)	INITIAL	20.6	21.4	21.9	22.5	22.3	22.4	22.4	
	FINAL	25	25	25	25	25	25		
CONC:	**25%**								
D.O. (mg/L)	INITIAL	8.9	8.4	8.5	8.5	8.5	8.5	8.8	
	FINAL	7.9	7.9	8.7	8.9	8.7	7.9		
pH (s.u.)	INITIAL	8.9	9.3	8.3	8.2	8	7.8	8	
	FINAL	8.4	8.3	8.1	8	7.9	7.9		
temp (C)	INITIAL	20.5	21.5	21.8	22.5	22.4	22.4	22.4	
	FINAL	25	25	25	25	25	25		
CONC:	**50%**								
D.O. (mg/L)	INITIAL	8.9	8.7	8.1	8.4	8.4	8.5	9.5	
	FINAL	7.8	7.9	8.6	8.9	8.8	7.4		
pH (s.u.)	INITIAL	9.4	10.5	8.2	8.1	7.9	7.8	8	
	FINAL	8.5	8.3	8	8	7.9	8		
temp (C)	INITIAL	20.5	21.5	22	22.6	22.4	22.4	22.5	
	FINAL	25	25	25	25	25	25	25	
CONC:	**100%**								
D.O. (mg/L)	INITIAL	8.9	7.9	7.9	8.2	8.2	8.5	8.4	
	FINAL	7.8	7.8	8.7	8.9	8.8	7.6		
pH (s.u.)	INITIAL	9.6	10.8	8.1	8	7.9	8	8	
	FINAL	8.7	8.5	8.1	8	7.9	8		
temp (C)	INITIAL	20.6	21.6	22.3	22.6	22.3	22.3	22.6	
	FINAL	25	25	25	25	25	25	25	
CONC:	**100%**								
ALKALINITY (mg/L)		86	86	86	86	86	86	86	
HARDNESS (mg/L)		62	62	62	62	62	62	62	
CONDUCTIVITY (umhos/cm)		1524	1524	1524	1524	1524	1524	1524	
CHLORINE (mg/L)		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	

Synthetic Salt Preparation

Bench Sheet

Lab Report

EDC-001											
	0907190-01		0907190-02		0907190-03		0907190-04				
	001		UTA		Flat CR		Haynes				atomic
	mg/L	target	mg/L	target	mg/L	target	mg/L	target			weight
Chloride	28	23	25.2	16	100	165	485	360			35
Sulfate	28.8	125	28.4	80	43.3	67	39	55			96
Sodium	57		60.5		102		239				23
Potassium	7		6.93		9.14		13.3				39
Calcium	10.9		10.5		18.2		47.2				40
Magnesium	2.75		2.96		5.05		12.5				24.3
Carbonate(CO3)	3		<5		<5		<5				60
Nitrate(No3)	0.637		4.14		1.8		1.85				62
TDS	230	475	240	315	370	560	960	855			
			mg	mg	mg	mg	mg	mg	mg	mg	mg
compound	g/mole	mg/L	Na	CL	K	SO4	Ca	Mg	CO3	NO3	TDS
Sodium Chloride(NaCl)	58	0	0	0	0	0	0	0	0	0	0
Sodium Sulfate(Na2SO4)	142	185	59.929577	0	0	125.07042	0	0	0	0	185
Sodium Carbonate(Na2CO3)	106	165	71.603774	0	0	0	0	0	93.39623	0	165
Potassium Chloride(KCl)	75	0	0	0	0	0	0	0	0	0	0
Potassium Sulfate(K2SO4)	174	6.5	0	0	2.9137931	3.5862069	0	0	0	0	6.5
Potassium Carbonate(K2CO3)	138	25	0	0	14.130435	0	0	0	10.86957	0	25
Calcium Chloride(CaCl2)	110	28	0	10.18182	0	0	17.818182	0	0	0	28
Calcium Sulfate(CaSO4)	136	0	0	0	0	0	0	0	0	0	0
Magnesium Chloride(MgCl2)	94.3	20	0	14.84624	0	0	0	5.153765	0	0	20
Magnesium Sulfate(MgSO4)	120.3	0	0	0	0	0	0	0	0	0	0
we have these chemicals		Sum:	131.53335	25.02805	17.044228	128.65663	17.818182	5.153765	104.2658	0	429.5
		existing	57	28	7	28.8	10.9	2.75	3	0.637	230
		Target		23		125					475
ratio to sodium		existing	1		0.122807		0.1912281	0.048246			
theoretical			1		0.129581		0.1354651	0.039182			
EDC 001 concentrates to make for biomonitoring						I weighed	amount	final	final		
		mg/L	mg/ 24 L	mg/30L	conc/ 1 liter		added	volume	concentration		
Sodium Chloride(NaCl)	58	0	0	0	0	0	100	3000	0		
Sodium Sulfate(Na2SO4)	142	185	4440	5550	5550	5.55	100	3000	185		
Sodium Carbonate(Na2CO3)	106	165	3960	4950	4950	4.95	100	3000	165		
Potassium Chloride(KCl)	75	0	0	0	0	0	100	3000	0		
Potassium Sulfate(K2SO4)	174	6.5	156	195	195	0.195	100	3000	6.5		
Potassium Carbonate(K2CO3)	138	25	600	750	750	0.75	100	3000	25		
Calcium Chloride(CaCl2)	110	28	672	840	840	1.114	100	3000	28		
Calcium Sulfate(CaSO4)	136	0	0	0	0	0	100	3000	0		
Magnesium Chloride(MgCl2)	94.3	20	480	600	600	1.286	100	3000	20		
Magnesium Sulfate(MgSO4)	120.3	0	0	0	0	0	100	3000	0		
Magnesium Chloride(MgCl2)*6H2O		42.7	1025	1281	1281						
Calcium Chloride(CaCl2)*2H2O		37.2	892	1115	1115						
Add enough of dilute lead standard											
to be 0.054 mg/L					1.62	1.62 mls	100	3000	0.054		
add 1.62 mls of 1000 ppm											

EDC-UTA

	0907190-01		0907190-02		0907190-03		0907190-04		
	001		UTA		Flat CR		Haynes		atomic
	mg/L	target	mg/L	target	mg/L	target	mg/L	target	weight
Chloride	28	23	25.2	16	100	165	485	360	35
Sulfate	28.8	125	28.4	80	43.3	67	39	55	96
Sodium	57		60.5		102		239		23
Potassium	7		6.93		9.14		13.3		39
Calcium	10.9		10.5		18.2		47.2		40
Magnesium	2.75		2.96		5.05		12.5		24.3
Carbonate(CO3)	3		<5		<5		<5		60
Nitrate(No3)	0.637		4.14		1.8		1.85		62
TDS	230	475	240	315	370	560	960	855	

compound	g/mole	mg/L	mg Na	mg CL	mg K	mg SO4	mg Ca	mg Mg	mg CO3	mg NO3	mg TDS				
Sodium Chloride(NaCl)	58	7	2.775862	4.224138	0	0	0	0	0	0	7		58	0.396552	0.603448
Sodium Sulfate(Na2SO4)	142.04	82	26.56338	0	0	55.4366197	0	0	0	0	82		142	0.323944	0.676056
Sodium Carbonate(Na2CO3)	106	129	55.98113	0	0	0	0	0	73.01887	0	129		106	0.433962	0.566038
Potassium Chloride(KCl)	74.551	8	0	3.733333	4.16	0	0	0	0	0	7.893333		75	0.466667	0.52
Potassium Sulfate(K2SO4)	174.259	4	0	0	1.793103	2.20689655	0	0	0	0	4		174	0.448276	0.551724
Potassium Carbonate(K2CO3)	138	7	0	0	3.956522	0	0	0	3.043478	0	7		138	0.565217	0.434783
Calcium Chloride(CaCl2)	110	22	0	8	0	0	14	0	0	0	22		110	0.363636	0.636364
Calcium Sulfate(CaSO4)	136.4	0	0	0	0	0	0	0	0	0	0		136	0.705882	0.294118
Magnesium Chloride(MgCl2)	95.2	0	0	0	0	0	0	0	0	0	0		94.3	0.742312	0.257688
Magnesium Sulfate(MgSO4)	120.4	23	0	0	0	18.3541147	0	4.645885	0	0	23		120.3	0.798005	0.201995
		Sum:	85.32037	15.95747	9.909625	75.997631	14	4.645885	76.06235	0	281.8933				
		existing	60.5	25.2	6.93	28.4	10.5	2.96	<5	4.14	240				
		Target		16		80					315				
ratio to sodium		existing	1		0.114545		0.173554	0.048926							
theoretical			1		0.116146		0.164087	0.054452							

EDC-UTA- concentrate for biomonitoring

compound	g/mole	mg/L	mg/ 24 L	mg/30L	conc/ 1 liter	I weighed	amount added	final volume	final concentration
Sodium Chloride(NaCl)	58	7	168	210	210	0.21	100	3000	7
Sodium Sulfate(Na2SO4)	142.04	82	1968	2460	2460	2.46	100	3000	82
Sodium Carbonate(Na2CO3)	106	129	3096	3870	3870	3.87	100	3000	129
Potassium Chloride(KCl)	74.551	8	192	240	240	0.241	100	3000	8
Potassium Sulfate(K2SO4)	174.259	4	96	120	120	0.12	100	3000	4
Potassium Carbonate(K2CO3)	138	7	168	210	210	0.21	100	3000	7
Calcium Chloride(CaCl2)	110	22	528	660	660	0.876	100	3000	22
Calcium Sulfate(CaSO4)	136.4	0	0	0	0	0	100	3000	0
Magnesium Chloride(MgCl2)	95.2	0	0	0	0	0	100	3000	0
Magnesium Sulfate(MgSO4)	120.4	23	552	690	690	0.69	100	3000	23
Calcium Chloride*2H2O		29.2	700.8	876	876				
Magnesium Chloride*6H2O		0.0	0	0	0				
Add enough lead standard					0.9	0.9 mls	100	3000	0.03
to be 0.030 mg/L									
add .9 mls of 1000 ppm standard									

EDC- Flat CR

	0907190-01		0907190-02		0907190-03		0907190-04			
	001		UTA		Flat CR		Haynes			atomic
	mg/L	target	mg/L	target	mg/L	target	mg/L	target		weight
Chloride	28	23	25.2	16	100	165	485	360		35
Sulfate	28.8	125	28.4	80	43.3	67	39	55		96
Sodium	57		60.5		102		239			23
Potassium	7		6.93		9.14		13.3			39
Calcium	10.9		10.5		18.2		47.2			40
Magnesium	2.75		2.96		5.05		12.5			24.3
Carbonate(CO3)	3		<5		<5		<5			60
Nitrate(No3)	0.637		4.14		1.8		1.85			62
TDS	230	475	240	315	370	560	960	855		

compound	g/mole	mg/L	mg Na	mg CL	mg K	mg SO4	mg Ca	mg Mg	mg CO3	mg NO3	mg TDS				
Sodium Chloride(NaCl)	58	240	95.17241	144.8276	0	0	0	0	0	0	240		58	0.396552	0.603448
Sodium Sulfate(Na2SO4)	142	30	9.71831	0	0	20.28169	0	0	0	0	30		142	0.323944	0.676056
Sodium Carbonate(Na2CO3)	106	149	64.66038	0	0	0	0	0	84.33962	0	149		106	0.433962	0.566038
Potassium Chloride(KCl)	75	7	0	3.266667	3.64	0	0	0	0	0	6.906667		75	0.466667	0.52
Potassium Sulfate(K2SO4)	174	18	0	0	8.068966	9.9310345	0	0	0	0	18		174	0.448276	0.551724
Potassium Carbonate(K2CO3)	138	8	0	0	4.521739	0	0	0	3.478261	0	8		138	0.565217	0.434783
Calcium Chloride(CaCl2)	110	45	0	16.36364	0	0	28.63636	0	0	0	45		110	0.363636	0.636364
Calcium Sulfate(CaSO4)	136	0	0	0	0	0	0	0	0	0	0		136	0.705882	0.294118
Magnesium Chloride(MgCl2)	94.3	4	0	2.969247	0	0	0	1.030753	0	0	4		94.3	0.742312	0.257688
Magnesium Sulfate(MgSO4)	120.3	40	0	0	0	31.9202	0	8.0798	0	0	40		120.3	0.798005	0.201995
		Sum:	169.5511	167.4271	16.2307	62.132924	28.63636	9.110553	87.81788	0	540.9067				
		existing	102	100	9.14	43.3	18.2	5.05	<5	1.8	370				
		Target		165		67					560				
ratio to sodium		existing	1		0.089608		0.178431	0.04951							
theoretical			1		0.095728		0.168895	0.053733							

EDC- Flat CR-concentrate for biomonitoring

			mg/ 24 L	mg/30L	conc/ 1 liter	I weighed	amount added	final volume	final concentration
Sodium Chloride(NaCl)	58	240	5760	7200	7200	7.200	100	3000	240
Sodium Sulfate(Na2SO4)	142	30	720	900	900	0.990	100	3000	30
Sodium Carbonate(Na2CO3)	106	149	3576	4470	4470	4.470	100	3000	149
Potassium Chloride(KCl)	75	7	168	210	210	0.211	100	3000	7
Potassium Sulfate(K2SO4)	174	18	432	540	540	0.541	100	3000	18
Potassium Carbonate(K2CO3)	138	8	192	240	240	0.241	100	3000	8
Calcium Chloride(CaCl2)	110	45	1080	1350	1350	1.793	100	3000	45
Calcium Sulfate(CaSO4)	136	0	0	0	0	0	100	3000	0
Magnesium Chloride(MgCl2)	94.3	4	96	120	120	0.258	100	3000	4
Magnesium Sulfate(MgSO4)	120.3	40	960	1200	1200	1.200	100	3000	40
Calcium Chloride*2H20		59.7	1433	1792	1792				
Magnesium Chloride(MgCl2)		8.5	205	256	256				

EDC- Haynes

	0907190-01		0907190-02		0907190-03		**0907190-04**			atomic
	001		UTA		Flat CR		**Haynes**			weight
	mg/L	target	mg/L	target	mg/L	target	**mg/L**	target		
Chloride	28	23	25.2	16	100	165	485	360		35
Sulfate	28.8	125	28.4	80	43.3	67	39	55		96
Sodium	57		60.5		102		239			23
Potassium	7		6.93		9.14		13.3			39
Calcium	10.9		10.5		18.2		47.2			40
Magnesium	2.75		2.96		5.05		12.5			24.3
Carbonate(CO3)	3		<5		<5		<5			60
Nitrate(No3)	0.637		4.14		1.8		1.85			62
TDS	230	475	240	315	370	560	960	855		

compound	g/mole	mg/L	mg Na	mg CL	mg K	mg SO4	mg Ca	mg Mg	mg CO3	mg NO3	mg TDS			
Sodium Chloride(NaCl)	58	510	202.2414	307.7586	0	0	0	0	0	0	510	58	0.396552	0.603448
Sodium Sulfate(Na2SO4)	142.04	29	9.394366	0	0	19.605634	0	0	0	0	29	142	0.323944	0.676056
Sodium Carbonate(Na2CO3)	106	140	60.75472	0	0	0	0	0	79.24528	0	140	106	0.433962	0.566038
Potassium Chloride(KCl)	74.551	7	0	3.266667	3.64	0	0	0	0	0	6.906667	75	0.466667	0.52
Potassium Sulfate(K2SO4)	174.259	17	0	0	7.62069	9.3793103	0	0	0	0	17	174	0.448276	0.551724
Potassium Carbonate(K2CO3)	138	10	0	0	5.652174	0	0	0	4.347826	0	10	138	0.565217	0.434783
Calcium Chloride(CaCl2)	110	84	0	30.54545	0	0	53.45455	0	0	0	84	110	0.363636	0.636364
Calcium Sulfate(CaSO4)	136.4	0	0	0	0	0	0	0	0	0	0	136	0.705882	0.294118
Magnesium Chloride(MgCl2)	95.2	31	0	23.01166	0	0	0	7.988335	0	0	31	94.3	0.742312	0.257688
Magnesium Sulfate(MgSO4)	120.4	29	0	0	0	23.142145	0	5.857855	0	0	29	120.3	0.798005	0.201995
		Sum:	272.3905	364.5824	16.91286	52.127089	53.45455	13.84619	83.59311	0	856.9067			
		existing	239	485	13.3	39	47.2	12.5	<5	1.85	960			
		Target		360		55					855			
ratio to sodium		existing	1		0.055649		0.19749	0.052301						
theoretical			1		0.062091		0.196242	0.050832						

EDC- Hayne biomonitoring concentrate

compound	g/mole	mg/L	mg/ 24 L	mg/30L	conc/ 1 liter	I weighed	amount added	final volume	final concentration
Sodium Chloride(NaCl)	58	510	12240	15300	15300	15.300	100	3000	510
Sodium Sulfate(Na2SO4)	142.04	29	696	870	870	0.870	100	3000	29
Sodium Carbonate(Na2CO3)	106	140	3360	4200	4200	4.200	100	3000	140
Potassium Chloride(KCl)	74.551	7	168	210	210	0.211	100	3000	7
Potassium Sulfate(K2SO4)	174.259	17	408	510	510	0.510	100	3000	17
Potassium Carbonate(K2CO3)	138	10	240	300	300	0.302	100	3000	10
Calcium Chloride(CaCl2)	110	84	2016	2520	2520	3.344	100	3000	84
Calcium Sulfate(CaSO4)	136.4	0	0	0	0	0	100	3000	0
Magnesium Chloride(MgCl2)	95.2	31	744	930	930	1.987	100	3000	31
Magnesium Sulfate(MgSO4)	120.4	29	696	870	870	0.870	100	3000	29
Calcium Chloride*2H20		111.5	2676	3345	3345				
Magnesium Chloride(MgCl2)*6H2O		66.2	1588	1985	1985				

Arkansas Analytical Inc.

11701 I-30 Bldg 1, Ste 115 - Little Rock, AR 72209
501-455-3233 Fax 501-455-6118

12 September 2009

Norma James
Arkansas Analytical, Inc.
11701 I-30, Bldg 1, Suite 115
Little Rock, AR 72209

RE: EDC

SDG Number: 0909014

Enclosed are the results of analyses for samples received by the laboratory on 01-Sep-09 16:38. If you have any questions concerning this report, please feel free to contact me.

Sample Receipt Information:

Custody Seals	
Containers Intact	
COC/Labels Agree	
Preservation Confirmed	
Received On Ice	
Temperature on Receipt	

Sincerely,

Norma James
President

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12 September 2009

Norma James
Arkansas Analytical, Inc.
11701 I-30, Bldg 1, Suite 115
Little Rock, AR 72209
Project: EDC

Date Received: 01-Sep-09 16:38

ANALYTICAL RESULTS

Lab Number:	**0909014-01**
Sample Name:	**EDC - 001**
Date/Time Collected:	**9/1/09 10:00**
Sample Matrix:	**Water**

Anions	Units	Result	Date/Time Analyzed	Batch	Method
Chloride	mg/L	**28.1**	9/3/09 9:10	A909018	300.0/9056A
Sulfate as SO4	mg/L	**109**	9/3/09 9:10	A909018	300.0/9056A

Dissolved Metals 200.7	Units	Result	Date/Time Analyzed	Batch	Method
Calcium	mg/L	**9.27**	9/3/09 11:28	A909024	EPA 200.7
Magnesium	mg/L	**4.72**	9/3/09 11:31	A909024	EPA 200.7
Potassium	mg/L	**23.6**	9/3/09 11:29	A909024	EPA 200.7
Sodium	mg/L	**128**	9/3/09 11:32	A909024	EPA 200.7

Total Metals	Units	Result	Date/Time Analyzed	Batch	Method
Calcium	mg/L	**8.47**	9/3/09 11:27	A909024	200.7
Lead	mg/L	**0.049**	9/3/09 11:33	A909024	200.7
Magnesium	mg/L	**4.73**	9/3/09 11:30	A909024	200.7
Potassium	mg/L	**24.4**	9/3/09 11:28	A909024	200.7
Sodium	mg/L	**150**	9/3/09 11:31	A909024	200.7

Wet Chemistry	Units	Result	Date/Time Analyzed	Batch	Method
TDS	mg/L	**410**	9/3/09 16:45	A909067	2540C
TSS	mg/L	< 1.0	9/4/09 8:00	A909054	2540D

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12 September 2009

Norma James
Arkansas Analytical, Inc.
11701 I-30, Bldg 1, Suite 115
Little Rock, AR 72209
Project: EDC

Date Received: 01-Sep-09 16:38

ANALYTICAL RESULTS

Lab Number:	**0909014-02**
Sample Name:	**EDC - UTA**
Date/Time Collected:	**9/1/09 10:00**
Sample Matrix:	**Water**

Anions	Units	Result	Date/Time Analyzed	Batch	Method
Chloride	mg/L	**17.7**	9/3/09 9:10	A909018	300.0/9056A
Sulfate as SO4	mg/L	**79.0**	9/3/09 9:10	A909018	300.0/9056A

Dissolved Metals 200.7	Units	Result	Date/Time Analyzed	Batch	Method
Calcium	mg/L	**6.85**	9/3/09 11:28	A909024	EPA 200.7
Magnesium	mg/L	**4.12**	9/3/09 11:31	A909024	EPA 200.7
Potassium	mg/L	**13.2**	9/3/09 11:29	A909024	EPA 200.7
Sodium	mg/L	**81.5**	9/3/09 11:32	A909024	EPA 200.7

Total Metals	Units	Result	Date/Time Analyzed	Batch	Method
Calcium	mg/L	**6.47**	9/3/09 11:27	A909024	200.7
Lead	mg/L	**0.026**	9/3/09 11:33	A909024	200.7
Magnesium	mg/L	**4.04**	9/3/09 11:30	A909024	200.7
Potassium	mg/L	**13.7**	9/3/09 11:28	A909024	200.7
Sodium	mg/L	**92.0**	9/3/09 11:31	A909024	200.7

Wet Chemistry	Units	Result	Date/Time Analyzed	Batch	Method
TDS	mg/L	**300**	9/3/09 16:45	A909067	2540C
TSS	mg/L	< 1.0	9/4/09 8:00	A909054	2540D

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Norma James
Arkansas Analytical, Inc.
11701 I-30, Bldg 1, Suite 115
Little Rock, AR 72209
Project: EDC

Date Received: 01-Sep-09 16:38

ANALYTICAL RESULTS

Lab Number:	**0909014-03**
Sample Name:	**EDC - Flat CR**
Date/Time Collected:	**9/1/09 10:00**
Sample Matrix:	**Water**

Anions	Units	Result	Date/Time Analyzed	Batch	Method
Chloride	mg/L	**157**	9/3/09 9:10	A909018	300.0/9056A
Sulfate as SO4	mg/L	**61.3**	9/3/09 9:10	A909018	300.0/9056A

Dissolved Metals 200.7	Units	Result	Date/Time Analyzed	Batch	Method
Calcium	mg/L	**15.8**	9/3/09 11:28	A909024	EPA 200.7
Magnesium	mg/L	**7.92**	9/3/09 11:31	A909024	EPA 200.7
Potassium	mg/L	**23.6**	9/3/09 11:29	A909024	EPA 200.7
Sodium	mg/L	**166**	9/3/09 11:32	A909024	EPA 200.7

Total Metals	Units	Result	Date/Time Analyzed	Batch	Method
Calcium	mg/L	**15.0**	9/3/09 11:27	A909024	200.7
Lead	mg/L	< 0.022	9/3/09 11:33	A909024	200.7
Magnesium	mg/L	**7.67**	9/3/09 11:30	A909024	200.7
Potassium	mg/L	**25.0**	9/3/09 11:28	A909024	200.7
Sodium	mg/L	**200**	9/3/09 11:31	A909024	200.7

Wet Chemistry	Units	Result	Date/Time Analyzed	Batch	Method
TDS	mg/L	**510**	9/3/09 16:45	A909067	2540C
TSS	mg/L	< 1.0	9/4/09 8:00	A909054	2540D

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12 September 2009

Norma James
Arkansas Analytical, Inc.
11701 I-30, Bldg 1, Suite 115
Little Rock, AR 72209
Project: EDC

Date Received: 01-Sep-09 16:38

ANALYTICAL RESULTS

Lab Number: 0909014-04
Sample Name: EDC - Haynes
Date/Time Collected: 9/1/09 10:00
Sample Matrix: Water

Anions	Units	Result	Date/Time Analyzed	Batch	Method
Chloride	mg/L	**378**	9/3/09 9:10	A909018	300.0/9056A
Sulfate as SO4	mg/L	**50.6**	9/3/09 9:10	A909018	300.0/9056A

Dissolved Metals 200.7	Units	Result	Date/Time Analyzed	Batch	Method
Calcium	mg/L	**28.4**	9/3/09 11:28	A909024	EPA 200.7
Magnesium	mg/L	**13.4**	9/3/09 11:31	A909024	EPA 200.7
Potassium	mg/L	**26.8**	9/3/09 11:29	A909024	EPA 200.7
Sodium	mg/L	**282**	9/3/09 11:32	A909024	EPA 200.7

Total Metals	Units	Result	Date/Time Analyzed	Batch	Method
Calcium	mg/L	**28.1**	9/3/09 11:27	A909024	200.7
Lead	mg/L	< 0.022	9/3/09 11:33	A909024	200.7
Magnesium	mg/L	**13.2**	9/3/09 11:30	A909024	200.7
Potassium	mg/L	**28.4**	9/3/09 11:28	A909024	200.7
Sodium	mg/L	**331**	9/3/09 11:31	A909024	200.7

Wet Chemistry	Units	Result	Date/Time Analyzed	Batch	Method
TDS	mg/L	**810**	9/3/09 16:45	A909067	2540C
TSS	mg/L	< 1.0	9/4/09 8:00	A909054	2540D

QUALITY CONTROL RESULTS

Anions -- Batch: A909018 (Water)
Prepared: 02-Sep-09 10:37 By: WF -- Analyzed: 02-Sep-09 15:31 By: WF

Analyte	BLK	LCS / LCSD	MS / MSD	Dup	RPD	Qualifiers
Chloride	<0.500 mg/L	94.0% / NA	94.8% / 95.9%		1.02%	
Sulfate as SO4	<0.500 mg/L	100% / NA	101% / 100%		0.932%	

Wet Chemistry -- Batch: A909054 (Water)
Prepared: 04-Sep-09 08:00 By: AP -- Analyzed: 04-Sep-09 08:00 By: AP

Analyte	BLK	LCS / LCSD	MS / MSD	Dup	RPD	Qualifiers
TSS	<1.0 mg/L	86.5% / 90.4%	NA / NA		4.35%	

Wet Chemistry -- Batch: A909067 (Water)
Prepared: 03-Sep-09 16:45 By: AP -- Analyzed: 03-Sep-09 16:45 By: AP

Analyte	BLK	LCS / LCSD	MS / MSD	Dup	RPD	Qualifiers
TDS	<1.0 mg/L	94.0% / 98.0%	NA / NA		4.17%	

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12 September 2009

Norma James
Arkansas Analytical, Inc.
11701 I-30, Bldg 1, Suite 115
Little Rock, AR 72209
Project: EDC

Date Received: 01-Sep-09 16:38

All Analysis performed according to EPA approved methodology when available:
SW 846, Revised December, 1996; EPA 600/4-79-020, Revised March, 1983; Standard Methods, 20th Edition.
Instrument calibration and quality control samples performed at or above frequency specified in analytical method.

Reviewed by: Norma James

Norma James
President

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Arkansas Analytical Inc.
11701 Interstate 30, Bldg. 1, Ste. 115
Little Rock, AR 72209
PHONE: 501-455-3233
FAX: 501-455-6118

CHAIN OF CUSTODY RECORD

CLIENT INFORMATION	Project Description	Turnaround Time	Preservation Codes:	
AR Analytical		24 Hour	1. Cool, 4 Degrees Centigrade	4. Thiosulfate for Dechlorination
		48 Hour	2. Sulfuric Acid (H_2SO_4), pH < 2	5. Hydrochloric Acid(HCl)
	Reporting Information	72 Hour	3. Nitric Acid (HNO_3), pH < 2	6. Sodium Hydroxide (NaOH), pH > 12
	Telephone:	Routine (5 Day)	TEST PARAMETERS	Bottle Type Code
	Fax:	Preservative Code:		G = Glass; P = Plastic
	Email:	Bottle Type:		V = Septum; A = Amber

Sampler(s) Signature

Sampler(s) Printed

Field Number	SAMPLE COLLECTION Date/s	Time/s	Grab	Comp	Number of Bottles	Sample Matrix	SAMPLE IDENTIFICATION/ DESCRIPTION	Na K Mg Ca	Pb	TDS. TSS	Cl SO4	d Na. d K.	d Mg. d Ca				Arkansas Analytical Work Order Number: 0909014-
	9-1-09	10:00AM			2	W	EDC-001	✓	✓	✓	✓	✓	✓				01
	↓	↓			2	↓	EDC-UTA	✓	✓	✓	✓	↓	↓				02
	↓	↓			2	↓	EDC-Flat CR	✓	✓	✓	✓	↓	↓				03
	↓	↓			2	↓	EDC-Haynes	✓	✓	✓	✓	↓	↓				04

1. Relinquished by: (Signature)	Date/Time	2. Received by: (Signature)
3. Relinquished by: (Signature)	**Date/Time**	**4. Received by lab: (Signature)**
Jessie Redican	9/1/09 1638	Sydney James

SAMPLE CONDITION UPON RECEIPT IN LAB

1. CUSTODY SEALS: ____Yes ____No
2. CONTAINERS CORRECT: ____Yes ____No
3. COC/LABELS AGREE: ____Yes ____No
4. PRESERVATION CONFIRMED: ____Yes ____No
5. RECEIVED ON ICE: ____Yes ____No
6. TEMPERATURE ON RECEIPT:

FOR COMPLETION BY LAB ONLY

REMARKS / SAMPLE COMMENTS

P.O. Number -

Appendix

Original lab data sheets

Survi- 100

SURVIVAL DATA FOR FATHEAD MINNOW LARVAL SURVIVAL AND GROWTH TEST

LAB # / SAMPLE ID		TEST START	DATE 9/1/09 TIME 1415
CLIENT	EDC-001	TEST END	DATE 9/8/09 TIME 1150
AGE AND SOURCE OF MINNOWS			

	REP #	start	1	2	3	4	5	6	7	SURVIVAL %	MEAN %	CV
CONC:	A	10	10	10	10	10	10	10	10	100	100	0.00
	B		10							100		
	C		10							100		
	D		10							100		
	E		10							100		
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	10	10	10	10	10	10	10	100	100	
	B		10	10	10			10	10	100		
	C		10	10	10			10	10	100		
	D		10	10	10			10	10	100		
	E		10	10	10			10	10	100		
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	10	10	10	10	10	10	10	100	98	
	B		9	9	9	9	9	9	9	90		
	C		10	10	10	10	10	10	10	100		
	D		10	10	10			10	10	100		
	E		10	10	10			10	10	100		
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	10	10	9	9	9	9	9	90	96	
	B		10	10	10	10	10	10	10	100		
	C		10	10	10			10	10	100		
	D		10	10	10			10	10	100		
	E		9	9	9	9	9	9	9	90		
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	10	10	10	10	10	10	10	100	100	
	B		10	10	10			10	10	100		
	C		10	10	10			10	10	100		
	D		10	10	10			10	10	100		
	E		10	10	10			10	10	100		
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	9	9	9	9	9	9	9	90	94	5.83
	B		10	10	10	10	10	10	10	100		
	C		10	10	10			10	10	100		
	D		9 10	9 10	10			10	9	90		
	E		9	9	9	9	9	9	9	90		
ANALYST		KP	KP	KP	KP	mg	mg	ct	KP			
DATE:		9/1/09	9/2/09	9/3/09	9/4/09	9.5.09	9/6/09	9.7.09	9/8/09			
TIME:		1415	1545	1705	1325	0935	1040	1100	1150			

CV = PERCENT COEFFICIENT OF VARIATION: STANDARD DEVIATION/MEAN * 100

Surv. 100%
Repro 100%

Cerodaphnia dubia

SURVIVAL AND REPRODUCTION TEST

Discharger:
Location: EDC-001
Date Sample Collected:
Lab Number/s

Analyst: KP
Test Start - Date/ Time: 9/1/09 1430
Test Stop - Date/Time: 9/7/09, 0930

Conc 1

%	Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
0	1	0	0	0	0	0	0	0	0	0	0	0			KP
	2	0	0	0	0	0	0	0	0	0	0	0			KP
	3	0	0	5	0	3	3	0	0	0	2	13			
	4	2	3	0	2	0	0	0	5	3	8	~~18~~ 23			
	5	3	5	3	4	3	0	0	7	8	10	43			KP
	6	8	11	7	10	7	8	x0	10	7	2	70	9		KP
	7														
	8												x̄=	16.6	
	Total	13	19	15	16	13	11	x0	22	18	22	149	CV=	~~23~~ 23.0	

Conc 2

%	Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
6.25	1	0	0	0	0	0	0	0	0	0	0	0			
	2	0	0	0	0	0	0	0	0	0	0	0			
	3	0	2	0	2	0	2	0	0	0	3	9			
	4	0	0	3	1	4	0	4	5	6	0	23			
	5	5	6	7	4	4	1	5	7	7	7	53			
	6	5	9	8	11	10	3	8	0	12	12	78	10		
	7														
	8														
	Total	10	17	13	18	18	11	17	12	25	22	163			

Conc 3

%	Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
12.5	1	0	0	0	0	0	0	0	0	0	0	0			
	2	0	0	0	0	0	0	0	0	0	0	0			
	3	0	2	0	2	2	0	0	X0	0	0	6			
	4	2	0	4	0	0	1	0	–	2	0	9			
	5	5	4	5	4	6	0	7	–	3	6	40			
	6	7	6	11	5	7	10	12	–	7	9	74	9		
	7														
	8														
	Total	14	12	20	11	15	11	19	X0	12	15	129			

X= DEAD; Y= MALE

Conc 4

%	Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
25	1	0	0	0	0	0	0	0	0	0	0	0			
	2	0	0	0	0	0	0	0	0	0	0	0			
	3	4	0	0	0	0	0X	0	0	0	0	4			
	4	0	0	5	0	2	0	3	3	0	0	13			
	5	7	4	6	5	8	3	7	4	6	5	55			
	6	6	9	2	14	3	7	11	6	9	7	74	10		
	7														
	8														
	Total	17	13	13	19	13	10	21	13	15	12	146			

Conc 5

%	Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
50	1	0	0	0	0	0	0	0	0	0	0	0			
	2	0	0	0	0	0	0	0	0	0	0	0			
	3	0	0	2	0	0	2	0	0	0	0	4			
	4	5	0	0	0	0	6	3	4	4	3	25			
	5	4	5	7	0	6	5	8	3	2	4	44			
	6	4	6	6	7	7	8	12	12	10	10	82	10		
	7														
	8														
	Total	13	11	15	7	13	21	23	19	16	17	155			

Conc 6

%	Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
100	1	0	0	0	0	0	x0	0	0	0	0	0			
	2	0	0	0	0	0	0	0	0	0	0	0			
	3	0	0	0	0	2	–	0	0	0	0	2			
	4	4	5	0	5	4	–	2	4	0	0	24			
	5	3	5	7	3	4	–	2	4	0	2	30			
	6	4	4	7	12	6	–	6	8	0	7	54	9		
	7														
	8														
	Total	11	14	14	20	16	x0	10	16	0	9	110			

x̄ = ~~13.8~~ 12.2
CV = 26.6

Pimephales promelas **FATHEAD MINNOW** TEST 1000.0

WEIGHT DATA FOR LARVAL SURVIVAL AND GROWTH TEST

LAB # / #s:	TEST DATES (BEGIN / END): 9/1-8/09
CLIENT: EDC-001	WEIGHING DATE / TIME: 9/9/09, 1130
ANALYSTS:	DRYING TEMP (DEGREES C): 60
SAMPLE ID:	DRYING TIME (HOURS): 24

	REP#	FINAL DRY WEIGHT TIN+LARVAE (g)	INTIAL WEIGHT TIN (g)	TOTAL DRY WEIGHT OF LARVAE (g)	NUMBER OF LARVAE	DRY WEIGHT OF LARVAE (mg)	
CONTROL	A 1	0.98654	.98248				AVG DRY WEIGHT (mg)
	B 2	0.99623	.99247				
	C 3	1.00374	.99986				CV
	D 4	1.00286	.99980				
	E 5	0.98262	.97849				
CONC:	A 31	0.98935	.98517				AVG DRY WEIGHT (mg)
	B 32	0.98835	.98392				
	C 33	0.96200	.95775				CV
	D 34	0.96836	.96391				
	E 35	0.99183	.98756				
CONC:	A 36	1.~~10~~01071	1.00629				AVG DRY WEIGHT (mg)
0.96670	B 37	~~0.96934~~	.96258				
	C 38	0.97363	.96860				CV
	D 39	0.98075	.97625				
	E 40	0.97897	.97397				
CONC:	A 41	0.97104	.96656				AVG DRY WEIGHT (mg)
	B 42	0.97829	.97347				
	C 43	0.97141	.96700				CV
	D 44	0.96965	.96528				
	E 45	0.96572	.96101				
CONC:	A 46	0.97358	.97391				AVG DRY WEIGHT (mg)
	B 47	0.97912	.97440				
	C 48	0.96689	.96266				CV
	D 49	0.97360	.96917				
	E 50	0.97064	.96641				
CONC:	A 51	0.99229	.98787				AVG DRY WEIGHT (mg)
	B 52	0.96819	.96324				
	C 53	0.97467	.96792				CV
	D 54	1.014343	1.00919				
	E 55	0.97707	.97164				

CV = (STANDARD DEVIATION/MEAN)*100

REMARKS:

CHEMICAL DATA SHEET FOR CHRONIC TOXICITY TESTING — Cerodaphnia Dubia

Lab # / Sample ID		Test Start (Date/Time)	
Client	EDG01	Test End (Date/Time)	

		1	2	3	4	5	6	7	notes/remarks
		Day of Test							
Control	0%	9/1	9/2	9/3	9/4	9/5	9/6		
D.O. (mg/L)	INITIAL	88	87	87	85	8.5	8.5	84	Start pH adjust 9/3/07
	FINAL	81	81	8.6	9.0	8.3	77		
pH (s.u.)	INITIAL	77	79	77	78	7.9	7.5	78	
	FINAL	78	82	7.0	7.9	7.7	81		
temp (C)	INITIAL	20.0	213	218	221	22.4	22.3	228	
	FINAL	250	250	25.0	25	25	250		
ALKALINITY (mg/L)		52	→					→	
HARDNESS (mg/L)		88	→					→	
CONDUCTIVITY (umhos/cm)		291	→					→	
CHLORINE (mg/L)		<0.05	→					→	
CONC:	6.25%								
D.O. (mg/L)	INITIAL	89	86	85	84	8.5	8.6	8.4	
	FINAL	81	79	8.8	8.9	8.7	78		
pH (s.u)	INITIAL	86	88	85	86	8.1	7.8	7.9	
	FINAL	80	83	7.4	8.0	7.8	81		
temp (C)	INITIAL	19.7	220	220	228	22.5	22.1	24.7	
	FINAL	250	250	25	25	25	250		
CONC:	12.5%								
D.O. (mg/L)	INITIAL	89	86	85	84	8.5	8.5	8.4	
	FINAL	80	79	8.8	8.9	8.4	76		
pH (mg/L)	INITIAL	88	94	85	86	8.2	7.9	8.0	
	FINAL	80	83	7.6	8.0	7.9	8.1		
temp (C)	INITIAL	19.8	220	220	225	22.4	22.1	24.6	
	FINAL	250	250	25	25	25	250		
CONC:	25.0%								
D.O. (mg/L)	INITIAL	88	85	85	85	8.5	8.5	8.5	
	FINAL	78	79	8.8	8.8	8.5	76		
pH (s.u.)	INITIAL	91	98	86	86	8.1	8.0	8.1	
	FINAL	82	83	7.8	8.0	7.9	8.1		
temp (C)	INITIAL	19.9	220	220	225	22.4	22.0	24.6	
	FINAL	250	250	25	25	25	250		
CONC:	50.0%								
D.O. (mg/L)	INITIAL	89	8.2	84	83	8.4	8.5	8.6	
	FINAL	78	79	8.8	8.8	8.1	77		
pH (s.u.)	INITIAL	90	10.4	86	86	8.3	8.3	8.2	
	FINAL	84	84	8.0	8.1	7.5	8.1		
temp (C)	INITIAL	20.0	221	219	227	22.4	22.0	24.4	
	FINAL	250	250	25	25	25	250		
CONC:	100%								
D.O. (mg/L)	INITIAL	89	86	86	87	8.4	8.4	8.6	
	FINAL	77	79	8.7	8.9	8.5	77		
pH (s.u.)	INITIAL	99	10.9	88	87	8.4	8.7	8.6	
	FINAL	88	87	8.9	8.2	8.0	82		
temp (C)	INITIAL	20.3	221	219	236	22.4	22.0	24.7	
	FINAL	250	250	25	25	25	250		
CONC:	**100%**								
ALKALINITY (mg/L)		162	→					→	
HARDNESS (mg/L)		42	→					→	
CONDUCTIVITY (umhos/cm)		778	→					→	
CHLORINE (mg/L)		<0.05	→					→	

CHEMICAL DATA SHEET FOR CHRONIC TOXICITY TESTING

Fathead Minnow

Lab # / Sample ID

Client: FDC 001

Test Start (Date/Time)

Test End (Date/Time)

		Day of Test 1	2	3	4	5	6	7	notes/remarks
Control	0%	9/1	9/2	9/3	9/4	9/5	9/6	9-7	
D.O. (mg/L)	INITIAL	88	87	87	85	8.5	8.5	84	
	FINAL	82	80	80	8.3	84	84	81	
pH (s.u.)	INITIAL	77	79	77	78	7.9	7.5	79	
	FINAL	80	82	80	7.4	76	77	77	
temp (C)	INITIAL	20.0	213	218	221	22.4	22.3	229	
	FINAL	250	250	250	25	25	250	250	
ALKALINITY (mg/L)		52							
HARDNESS (mg/L)		88							
CONDUCTIVITY (umhos/cm)		291							
CHLORINE (mg/L)		<0.05							
CONC:	6.25								
D.O. (mg/L)	INITIAL	89	86	85	84	8.5	8.6	8.4	
	FINAL	82	81	82	8.3	8.2	8.2	80	
pH (s.u)	INITIAL	86	88	85	86	8.1	7.8	7.9	
	FINAL	80	86	82	7.4	7.6	7.3	78	
temp (C)	INITIAL	19.7	220	220	228	22.5	22.1	24.7	
	FINAL	250	250	250	25	25	25	250	
CONC:	12.5								
D.O. (mg/L)	INITIAL	89	86	85	84	8.5	8.5	8.4	
	FINAL	80	80	81	7.6	8.1	8.1	77	
pH (mg/L)	INITIAL	88	94	85	86	8.2	7.9	8.0	
	FINAL	81	79	82	7.5	7.6	7.5	80	
temp (C)	INITIAL	19.8	220	220	225	22.4	22.1	24.6	
	FINAL	250	250	250	25	25	25	250	
CONC:	25.0								
D.O. (mg/L)	INITIAL	88	85	85	85	8.5	8.5	8.5	
	FINAL	80	79	81	7.6	8.1	8.1	76	
pH (s.u.)	INITIAL	91	98	86	86	8.1	8.0	8.1	
	FINAL	82	80	82	7.6	7.8	7.8	80	
temp (C)	INITIAL	19.9	220	220	225	22.4	22.0	24.6	
	FINAL	250	250	250	25	25	25	250	
CONC:	50.0								
D.O. (mg/L)	INITIAL	89	82	84	83	8.4	8.5	8.6	
	FINAL	78	79	81	7.6	7.9	8.0	77	
pH (s.u.)	INITIAL	90	10.4	86	86	8.3	8.3	8.2	
	FINAL	82	82	8.2	7.6	7.8	7.7	81	
temp (C)	INITIAL	20.0	221	219	227	22.4	22.0	24.9	
	FINAL	250	250	250	25	25	25	250	
CONC:	100.0								
D.O. (mg/L)	INITIAL	89	80	86	77	8.4	8.4	8.6	
	FINAL	76	79	80	7.5	7.9	8.1	77	
pH (s.u.)	INITIAL	99	10.9	88	87	8.4	8.7	8.6	
	FINAL	89	9.1	8.2	7.8	7.9	7.9	82	
temp (C)	INITIAL	203	221	219	230	22.4	22.0	24.2	
	FINAL	250	250	250	25	25	25	250	
CONC:	**100%**								
ALKALINITY (mg/L)		162							
HARDNESS (mg/L)		42							
CONDUCTIVITY (umhos/cm)		778							
CHLORINE (mg/L)		<0.05							

Surv: 100%
Repro: 100%

SURVIVAL AND REPRODUCTION TEST

Cerodaphnia dubia

Discharger: EDC UTA

Location:

Date Sample Collected:

Lab Number/s

Analyst: K9

Test Start - Date/ Time: 9/7/09 1520

Test Stop - Date/Time: 9/8/09, 0850

Conc 1 — % 0

Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
1	0	0	0	0	0	0	0	0	0	0	0			KP
2	0	0	0	0	0	0	0	0	0	0	0			KP
3	0	0	0	4	5	0	3	2	0	0	14			
4	3	5	5	0	0	1	4	4	3	3	28			
5	5	7	9	5	8	3	7	6	3	7	60			KP
6	7	9	5	8	8	7	9	10	9	8	80	10		KP
7														
8														
Total	15	21	19	17	21	11	23	22	15	18	182		$\bar{x}$=	18.2
													CV=	20.7

Conc 2 — % 6.25

Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
1	0	0	0	0	0	0	0	0	0	0	0			
2	0	0	0	0	0	0	0	0	0	0	0			
3	0	1	0	0	4	0	2	1	3	0	11			
4	3	1	0	4	6	5	4	2	1	0	26			
5	8	5	1	4	0	7	7	6	8	6	52			
6	7	8	6	10	7	11	10	4	7	5	75	10		
7														
8														
Total	18	15	7	18	17	23	23	13	19	11	164			

Conc 3 — % 12.5

Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
1	0	0	0	0	0	0	0	0	0	0	0			
2	0	0	0	0	0	0	0	0	0	0	0			
3	0	1	0	1	0	0	0	1	2	0	5			
4	4	4	3	0	3	5	7	3	4	4	37			
5	7	8	5	9	0	5	7	9	8	6	64			
6	6	9	12	8	6	9	9	7	10	9	85	10		
7														
8														
Total	17	22	20	18	9	19	23	20	24	19	191			

X= DEAD; Y= MALE

Conc 4 — % 25

Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
1	0	0	0	0	0	0	0	0	0	0	0			
2	0	0	0	0	0	0	0	0	0	0	0			
3	0	0	0	0	0	0	1	2	0	0	3			
4	4	5	2	4	4	2	4	0	2	1	30 28			
5	6	7	5	5	2	7	7	8	10	9	66			
6	7	11	6	8	12	7	6	9	7	4	77	10		
7														
8														
Total	17	23	13	17	18	16	18	19	19	14	174			

Conc 5 — % 50

Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
1	0	0	0	0	0	0	0	0	0	0	0			
2	0	0	0	0	0	0	0	0	0	0	0			
3	0	1	0	0	0	0	1	1	0	2	5			
4	4	2	3	2	2	3	0	0	3	4	23			
5	6	6	4	8	6	5	5	3	5	2	50			
6	3	11	7	7	9	9	8	7	8	6	75	10		
7														
8														
Total	13	20	14	17	17	17	14	11	16	14	153			

Conc 6 — % 100

Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
1	0	0	0	0	x0	0	0	0	0	0	0			
2	0	0	0	0	–	0	0	0	0	0	0			
3	0	4	2	0	–	0	3	0	2	1	12			
4	6	0	2	4	–	5	3	5	0	3	28			
5	5	8	6	9	–	5	4	2	6	3	48			
6	6	12	9	9	–	5	7	10	9	5	72	9		
7														
8														
Total	17	24	19	22	x0	15	17	17	17	12	160			

$\bar{x}$=17.8
CV=20.0

Surv: 100

SURVIVAL DATA FOR FATHEAD MINNOW LARVAL SURVIVAL AND GROWTH TEST

LAB # / SAMPLE ID	TEST START	DATE 9/1/09	TIME 1515	
CLIENT EDC UTA	TEST END	DATE 9/8/09	TIME 1130	
	AGE AND SOURCE OF MINNOWS			

		D A Y (NUMBER SURVIVING)								SURVIVAL		
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	10	10	10	10	10	10	10	100	100	
	B		10	10	10			10	10	100		
	C		10	10	10			10	10	100		
	D		10	10	10			10	10	100		
	E		10	10	10			10	10	100		
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	10	10	10	10	10	10	10	100	100	
	B		10	10	10			10	10	100		
	C		10	10	10			10	10	100		
	D		10	10	10			10	10	100		
	E		10	10	10			10	10	100		
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	10	10	10	10	10	10	10	100	98	
	B		10	10	10			10	10	100		
	C		10	10	10			10	9	90		
	D		10	10	10			10	10	100		
	E		10	10	10			10	10	100		
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	10	10	10	10	10	10	10	100	100	
	B		10	10	10			10	10	100		
	C		10	10	10			10	10	100		
	D		10	10	10			10	10	100		
	E		10	10	10			10	10	100		
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	10	10	10	10	10	10	10	100	98	
	B		10	10	10			10	10	100		
	C		10	10	10			10	10	100		
	D		10	10	10			10	10	100		
	E		10	10	10			10	9	90		
	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
CONC:	A	10	10	10	10	10	10	10	10	100	94	14.3
	B		10	10	10			10	10	100		
	C		10	10	10			10	10	100		
	D		10	10	10			10	10	100		
	E		8	8	8	8	8	~~10~~ 8	7	70		
ANALYST		KP	KP	KP	KP	mg	mg	SB	KP			
DATE:		9/1/09	9/2/09	9/3/09	9/4/09	9-5-09	9-5-09	9-7-09	9/8/09			
TIME:		1515	1445	1025	1005	1000	1115	1235	1130			

CV = PERCENT COEFFICIENT OF VARIATION: STANDARD DEVIATION/MEAN * 100

Pimephales promelas | **FATHEAD MINNOW** | TEST 1000.0

WEIGHT DATA FOR LARVAL SURVIVAL AND GROWTH TEST

LAB # / #s: ____

CLIENT: EDC-UTA

ANALYSTS: ____

SAMPLE ID: ____

TEST DATES (BEGIN / END): ____

WEIGHING DATE / TIME: ____

DRYING TEMP (DEGREES C): ____

DRYING TIME (HOURS): ____

	REP#	FINAL DRY WEIGHT TIN+LARVAE (g)	INTIAL WEIGHT TIN (g)	TOTAL DRY WEIGHT OF LARVAE (g)	NUMBER OF LARVAE	DRY WEIGHT OF LARVAE (mg)	
CONTROL	A 1	0.98654	.98248				AVG DRY WEIGHT (mg)
	B 2	0.99623	.99247				
	C 3	1.00374	.99986				
	D 4	1.00786	.99980				CV
	E 5	0.98262	.97849				
CONC:	A 6	1.00476	1.00088				AVG DRY WEIGHT (mg)
	B 7	0.99007	.98691				
	C 8	1.00911	1.00518				
	D 9	1.00250	.99831				CV
	E 10	0.97503	.97078				
CONC:	A 11	1.01143	1.00777				AVG DRY WEIGHT (mg)
	B 12	0.98569	.98254				
	C 13	0.98765	.98411				
	D 14	0.97774	.97469				CV
	E 15	1.00228	.99858				
CONC:	A 16	~~0.97864~~ 0.98259	.97900				AVG DRY WEIGHT (mg)
	B 17	0.97564	.97122				
	C 18	1.01316	1.00887				
	D 19	1.00283	.99870				CV
	E 20	0.99551	.99129				
CONC:	A 21	0.99983	.99534				AVG DRY WEIGHT (mg)
	B 22	1.00060	.99653				
	C 23	0.98915	.98489				
	D 24	0.99922	.99545				CV
	E 25	1.01027	1.00498				
CONC:	A 26	1.00054	.99624				AVG DRY WEIGHT (mg)
	B 27	1.00091	.99688				
	C 28	0.99733	.99321				
	D 29	~~1.01130~~ 0.99075	.98730				CV
	E 30	1.00555	1.00150				

CV = (STANDARD DEVIATION/MEAN)*100

REMARKS:

CHEMICAL DATA SHEET FOR CHRONIC TOXICITY TESTING									Cerodaphnia Dubia
Lab # / Sample ID						Test Start (Date/Time)	9/1/09		
Client	EDC UTH					Test End (Date/Time)	9/8/09		
		Day of Test							
		1	2	3	4	5	6	7	notes/remarks
Control		9/1	9/2	9/3	9/4	9/5	9.6	9/7	
D.O. (mg/L)	INITIAL	88	87	87	85	8.5	8.5	84	
	FINAL	82	82	8.6	8.0	8.2	76		
pH (s.u.)	INITIAL	77	79	77	78	7.9	7.5	78	
	FINAL	79	84	7.7	7.8	7.8	79		
temp (C)	INITIAL	200	213	218	221	22.4	223	228	
	FINAL	250	250	250	25	25	250		
ALKALINITY (mg/L)		52	→						
HARDNESS (mg/L)		88	→						
CONDUCTIVITY (umhos/cm)		291	→						
CHLORINE (mg/L)		<0.05	→						
CONC:									
D.O. (mg/L)	INITIAL	88	86	87	86	8.7	91	8.5	
	FINAL	81	82	8.6	7.8	8.3	75		
pH (s.u)	INITIAL	77	88	84	79	7.7	79	7.9	
	FINAL	78	84	7.8	7.8	7.8	79		
temp (C)	INITIAL	19.9	220	218	222	22.6	220	22.9	
	FINAL	250	250	250	25	25	250		
CONC:									
D.O. (mg/L)	INITIAL	88	86	86	86	8.6	88	8.6	
	FINAL	80	80	8.7	7.8	8.3	74		
pH (mg/L)	INITIAL	79	94	92	80	8.0	80	7.9	
	FINAL	79	8.4	7.9	7.9	8.0	79		
temp (C)	INITIAL	19.7	226	217	223	22.5	219	23.2	
	FINAL	250	250	250	25	25	250		
CONC:									
D.O. (mg/L)	INITIAL	88	85	85	85	8.5	87	8.4	
	FINAL	77	78	8.7	7.9	8.2	76		
pH (s.u.)	INITIAL	83	98	96	82	8.0	80	8.0	
	FINAL	79	84	8.0	7.9	8.0	80	8.0	
temp (C)	INITIAL	19.9	226	218	224	22.5	219	23.4	
	FINAL	250	250	250	25	25	250		
CONC:									
D.O. (mg/L)	INITIAL	88	82	83	84	8.4	86	8.6	
	FINAL	77	78	8.7	7.6	8.4	77		
pH (s.u.)	INITIAL	91	10.4	10.0	87	8.2	81	8.0	
	FINAL	81	85	8.0	7.9	8.1	80	8	
temp (C)	INITIAL	20.1	221	219	226	22.4	219	23.4	
	FINAL	250	250	250	25	25	250		
CONC:									
D.O. (mg/L)	INITIAL	89	80	79	80	8.0	86	8.6	
	FINAL	71	77	8.7	7.7	8.4	77		
pH (s.u.)	INITIAL	97	10.9	10.7	85	8.5	82	8.1	
	FINAL	85	88	8.2	8.0	8.1	81		
temp (C)	INITIAL	20.4	221	221	227	22.5	221	23.7	
	FINAL	250	250	250	25	25	250		
CONC:	**100%**								
ALKALINITY (mg/L)		90	→						
HARDNESS (mg/L)		32	→						
CONDUCTIVITY (umhos/cm)		557	→						
CHLORINE (mg/L)		<0.05	→						

Fathead Minnow

CHEMICAL DATA SHEET FOR CHRONIC TOXICITY TESTING

~~Ceriodaphnia Dubia~~

Lab # / Sample ID

Test Start (Date/Time) 9/1/09

Client EDC-UT

Test End (Date/Time) 9/8/09

		Day of Test							
		1	2	3	4	5	6	7	notes/remarks
Control	MHS551	9/1	9/2	9/3	9/4	9/5	9/6	9/7	
D.O. (mg/L)	INITIAL	88	87	87	85	8.5	8.5	84	pH adjusted
	FINAL	82	80	80	8.0	8.4	8.4	81	
pH (s.u.)	INITIAL	77	79	77	78	7.9	7.5	7.9	9/3/09
	FINAL	80	82	80	7.8	7.6	7.7	77	
temp (C)	INITIAL	20.0	213	218	221	22.4	22.3	22.9	→
	FINAL	250	250	250	25.0	25	25	250	
ALKALINITY (mg/L)		52							
HARDNESS (mg/L)		88							
CONDUCTIVITY (umhos/cm)		291							
CHLORINE (mg/L)		<0.05							
CONC:									
D.O. (mg/L)	INITIAL	88	86	87	86	8.7	9.1	8.5	—
	FINAL	81	80	80	7.8	8.3	8.4	80	
pH (s.u)	INITIAL	77	88	84	79	7.7	7.9	7.9	
	FINAL	79	83	80	7.8	7.7	7.8	75	
temp (C)	INITIAL	19.9	220	218	222	22.6	22.0	22.9	
	FINAL	250	250	250	25	25	25	250	
CONC:									
D.O. (mg/L)	INITIAL	88	86	86	86	8.6	8.8	8.6	
	FINAL	80	79	80	7.8	8.2	8.4	80	
pH (mg/L)	INITIAL	79	94	~~97~~ 86	80	8.0	8.0	7.9	
	FINAL	78	83	81	7.9	7.7	7.8	74	
temp (C)	INITIAL	19.7	220	217	223	22.5	21.9	23.2	
	FINAL	250	250	250	25	25	25	250	
CONC:									
D.O. (mg/L)	INITIAL	88	85	85	85	8.5	8.7	8.6	
	FINAL	78	79	79	7.9	8.2	8.3	76	
pH (s.u.)	INITIAL	83	98	~~96~~ 86	82	8.0	8.0	8.0	
	FINAL	79	83	81	7.9	7.8	7.9	74	
temp (C)	INITIAL	19.9	220	218	224	22.5	21.9	23.4	
	FINAL	250	250	250	25	25	25	250	
CONC:									
D.O. (mg/L)	**INITIAL**	88	82	83	84	8.4	8.6	8.6	
	FINAL	77	79	77	7.6	8.1	8.5	76	
pH (s.u.)	INITIAL	91	10.4	~~10.1~~ 88	87	8.2	8.1	8.0	
	FINAL	83	84	82	7.9	7.9	8.10	74	
temp (C)	INITIAL	20.1	221	219	226	22.4	21.9	23.4	
	FINAL	250	250	250	25	25	25	250	
CONC:									
D.O. (mg/L)	**INITIAL**	89	86	79	80	8.0	8.6	8.6	
	FINAL	77	78	76	7.7	8.1	8.4	~~8.~~75	
pH (s.u.)	INITIAL	97	10.9	~~10.7~~ 89	85	8.4	8.2	8.1	
	FINAL	86	92	82	8.0	8.0	8.0	76	
temp (C)	INITIAL	20.4	221	221	227	22.5	22.1	23.2	
	FINAL	250	250	250	25	25	25	250	
CONC:	**100%**								
ALKALINITY (mg/L)		90							
HARDNESS (mg/L)		32							
CONDUCTIVITY (umhos/cm)		551							
CH**LORINE** (mg/L)		<0.05							

-surv; 100

SURVIVAL DATA FOR FATHEAD MINNOW LARVAL SURVIVAL AND GROWTH TEST

LAB # / SAMPLE ID		TEST START DATE 9/1/09	TIME 1545
CLIENT	EDC-Flat Creek	TEST END DATE 9/8/09	TIME 1430
AGE AND SOURCE OF MINNOWS			

D A Y (NUMBER SURVIVING) — SURVIVAL

CONC:	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
	A	10	10	10	10	10	10	10	10	100	100	0.00
	B							10	10	100		
	C							10	10	100		
	D							10	10	100		
	E							10	10	100		

CONC:	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
	A	10	10	10	10	10	10	10	10	100	98	
	B		10	10	10	10		10	10	100		
	C		10	10	10	10		10	10	100		
	D		9	9	9	9	9	9	9	90		
	E		10	10	10	10	10	10	10	100		

CONC:	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
	A	10	10	10	10	10	10	10	10	100	94	
	B		10	10	10	10	10	10	9	90		
	C		10	9	9	9	9	9	8	80		
	D		10	10	10	10	10	10	10	100		
	E		10	10	10	10	10	10	10	100		

CONC:	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
	A	10	9	9	9	9	9	9	9	90	98	
	B		10	10	10	10	10	10	10	100		
	C		10	10	10			10	10	100		
	D		10	10	10			10	10	100		
	E		10	10	10			10	10	100		

CONC:	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
	A	10	10	10	10	10	10	10	10	100	94	
	B		10	10	10			10	9	90		
	C		10	10	10			10	9	90		
	D		10	10	10			10	10	100		
	E		10	10	10			10	9	90		

CONC:	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
	A	10	10	10	10	10	10	10	10	100	94	9.52
	B		10	10	10	10	10	10	10	100		
	C		9	9	9	9	9	9	9	90		
	D		10	10	10	10	10	10	10	100		
	E		8	8	8	8	8	8	8	80		
ANALYST		KP	KP	KP	KP	mg	mg	SBU	KP			
DATE:		9/1/09	9/2/09	9/2/09	9/4/09	9-5-09	9-6-09	9-7-09	9/8/09			
TIME:		1545	1355	1140	1045	0950	1100	1105	1430			

CV = PERCENT COEFFICIENT OF VARIATION: STANDARD DEVIATION/MEAN * 100

Surv: 100%
Repro: 50%

Cerodaphnia dubia

SURVIVAL AND REPRODUCTION TEST

Discharger: EDC Flatcreek
Location:
Date Sample Collected:
Lab Number/s

Analyst: KP
Test Start - Date/ Time: 9/1/09 1535
Test Stop - Date/Time: 9/8/09 0950

Conc 1 — 0 %

Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
1	0	0	0	0	0	0	0	0	0	0	0			KP
2	0	0	0	0	0	0	0	0	0	0	0			KP
3	3	4	0	0	2	0	0	3	0	4	16			
4	0	2	2	Ø2	2	5	3	8	2	0	26			
5	5	3	6	6	7	0	1	0	4	3	30			KP
6	0	10	7	6	11	8	10	11	10	5	78	10		
7														
8												$\bar{x}$=	150	
Total	8	19	15	14	17	13	14	22	16	12	150	CV=	25.7	

Conc 4 — 25 %

Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
1	0	0	0	0	0	0	0	0	0	0	0			
2	0	0	0	0	0	0	0	0	0	0	0			
3	3	0	0	0	4	4	1	4	40	Ø4	20			
4	0	4	2	3	5	4	3	3	2	0	26			
5	7	5	2	6	0	1	3	1	4	2	26			
6	6	7	7	0	8	7	6	12	7	6	66	10		
7														
8														
Total	11	16	11	9	17	16	13	20	13	12	138			

Conc 2 — 6.25 %

Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
1	0	0	0	0	0	0	0	0	0	0	0			
2	0	0	0	0	0	0	0	0	0	0	0			
3	3	0	0	0	3	0	4	3	4	5	22			
4	0	3	1	3	6	3	0	7	0	0	18 23			
5	1	7	4	3	0	6	1	7	7	6	42			
6	3	1	9	0	10	9	2	5	10	1	50	10		
7														
8											137			
Total	7	11	14	6	19	18	7	17	21	12	132			

Conc 5 — 50 %

Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
1	0	0	0	0	0	0	0	0	0	0	0			
2	0	0	0	0	0	0	0	0	0	0	0			
3	0	4	3	0	2	2	0	3	0	0	14			
4	3	0	0	3	1	6	2	0	2	2	19			
5	5	4	3	3	5	1	1	5	2	6	35			
6	8	9	5	2	0	5	0	4	6	7	46	10		
7														
8														
Total	16	17	11	8	8	14	3	12	10	15	114			

Conc 3 — 12.5 %

Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
1	0	0	0	0	0	0	0	0	0	0	0			
2	0	0	0	0	0	0	0	0	0	0	0			
3	0	0	0	0	2	0	0	4	0	2	8			
4	0	3	2	2	4	1	2	3	3	2	22			
5	2	3	1	2	2	1	1	1	5	1	19			
6	0	4	10	0	7	6	9	9	10	8	63	10		
7														
8														
Total	2	10	13	4	15	8	12	17	18	13	112			

Conc 6 — 100 %

Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
1	0	0	0	0	0	0	0	0	0	0	0			
2	0	0	0	0	0	0	0	0	0	0	0			
3	0	0	0	0	1	0	0	3	3	0	7			
4	3	0	23	1	0	0	1	0	0	0	8			
5	4	0	0	2	1	0	0	5	7	4	23			
6	1	4	0	7	9	5	4	2	4	6	42	10		
7														
8														
Total	8	4	3	10	11	5	5	10	14	10	80			

X= DEAD; Y= MALE

$\bar{x}$ = 8.0
CV= 44.9

2007

Pimephales promelas **FATHEAD MINNOW** TEST 1000.0

WEIGHT DATA FOR LARVAL SURVIVAL AND GROWTH TEST

LAB # / #s:	TEST DATES (BEGIN / END): 9/1-8/09
CLIENT: FDC- Flat Creek	WEIGHING DATE / TIME: 9/9/09, 1130
ANALYSTS:	DRYING TEMP (DEGREES C): 60
SAMPLE ID:	DRYING TIME (HOURS): 24

	REP#	FINAL DRY WEIGHT TIN+LARVAE (g)	INTIAL WEIGHT TIN (g)	TOTAL DRY WEIGHT OF LARVAE (g)	NUMBER OF LARVAE	DRY WEIGHT OF LARVAE (mg)	
CONTROL	A 1	0.98654	0.98248				AVG DRY WEIGHT (mg)
	B 2	0.99623	0.99247				
	C 3	1.00374	0.99986				
	D 4	1.00286	0.99980				CV
	E 5	0.98262	0.97849				
CONC:	A 81	0.97485	.97113				AVG DRY WEIGHT (mg)
	B 82	0.97141	.96817				
	C 83	0.97877	.97508				
	D 84	0.96613	.96293				CV
	E 85	0.98052	.97675				
CONC:	A 86	0.99216	.98939				AVG DRY WEIGHT (mg)
	B 87	0.97043	.96743				
	C 88	0.96914	.96639				
	D 89	0.97918	.97561				CV
	E 90	0.97640	.97294				
CONC:	A 91	0.97010	.96704				AVG DRY WEIGHT (mg)
	B 92	0.98059	.97733				
	C 93	0.98113	.97746				
	D 94	0.96553	.96168				CV
	E 95	0.96651	.96345				
CONC:	A 96	1.00172	.99805				AVG DRY WEIGHT (mg)
0.98403	B 97	~~0.98070~~	.98073				
0.96039	C 98	~~0.99218~~	.95700				
	D 99	0.99354	.98883				CV
	E 100	0.98159	.97756				
CONC:	A 101	0.97188	.96707				AVG DRY WEIGHT (mg)
	B 102	1.00007	.99607				
	C 103	0.96544	.96083				
	D 104	0.97352	.96889				CV
	E 105	1.01882	1.01431				

CV = (STANDARD DEVIATION/MEAN)*100

REMARKS:

CHEMICAL DATA SHEET FOR CHRONIC TOXICITY TESTING									Fathead Minnow
Lab # / Sample ID									
Client	EDC-Flat Creek				Test Start (Date/Time)	9/1/09			
					Test End (Date/Time)	9/8/09			
		Day of Test							
		1	2	3	4	5	6	7	notes/remarks
Control	0%	9/1	9/2	9/3	9/4	9/5	9/6	9/7	
D.O. (mg/L)	INITIAL	88	87	87	85	8.5	8.5	8.4	
	FINAL	82	80	80	8.3	8.4	88	81	
pH (s.u.)	INITIAL	77	79	77	78	7.9	7.5	7.8	
	FINAL	83	84	80	7.3	7.6	8.1/7.7	77	
temp (C)	INITIAL	20.0	215	218	221	22.4	22.3	22.8	
	FINAL	250	250	250	22.5	250	250	250	
ALKALINITY (mg/L)		52							
HARDNESS (mg/L)		88							
CONDUCTIVITY (umhos/cm)		291							
CHLORINE (mg/L)		<0.05							
CONC:	6.25%								
D.O. (mg/L)	INITIAL	90	88	85	83	8.7	8.9	8.6	
	FINAL	78	80	82	8.0	8.2	8.2	8.6 77	
pH (s.u)	INITIAL	85	91	90	81	8.0	8.0	7.9	
	FINAL	83	84	79	7.3	7.8	7.5	81	
temp (C)	INITIAL	19.9	216	220	221	22.6	22.1	22.7	
	FINAL	250	250	250	22.5	25	25	250	
CONC:	12.5%								
D.O. (mg/L)	INITIAL	90	87	85	85	8.6	8.8	8.6	
	FINAL	77	82	82	8.0	8.1	8.2	77	
pH (mg/L)	INITIAL	85	94	93	82	8.1	8.0	8.0	
	FINAL	82	84	79	7.4	7.9	7.6	81	
temp (C)	INITIAL	199	217	219	220	22.4	22.1	22.7	
	FINAL	250	250	250	22.5	25	25	250	
CONC:	25.0%								
D.O. (mg/L)	INITIAL	89	85	85	85	8.5	8.7	8.6	
	FINAL	77	80	82	8.0	8.2	8.2	77	
pH (s.u.)	INITIAL	88	97	97	81	8.2	8.2	8.1	
	FINAL	81	84	79	7.6	7.9	7.7	81	
temp (C)	INITIAL	19.9	217	219	221	22.3	22.1	22.8	
	FINAL	250	250	250	22.5	25	25	250	
CONC:	50.0%								
D.O. (mg/L)	INITIAL	90	84	83	82	8.3	8.6	8.6	
	FINAL	77	80	81	8.0	8.1	8.1	77	
pH (s.u.)	INITIAL	9.2	10.2	10.2	81	8.4	8.4	8.2	
	FINAL	81	84	80	7.6	7.9	7.7	81	
temp (C)	INITIAL	19.9	219	218	220	22.4	22.2	22.8	
	FINAL	250	250	250	22.5	25	25	250	
CONC:	100%								
D.O. (mg/L)	INITIAL	9.0	81	82	76	8.2	8.5	8.6	
	FINAL	75	79	80	8.0	8.0	8.3	77	
pH (s.u.)	INITIAL	9.7	10.7	10.7	80	8.8	8.8	8.5	
	FINAL	80	87	81	7.7	8.0	7.9	82	
temp (C)	INITIAL	20.2	223	218	230	22.5	22.6	22.9	
	FINAL	250	250	250	22.5	25	25	250	
CONC:	**100%**								
ALKALINITY (mg/L)		110							
HARDNESS (mg/L)		44							
CONDUCTIVITY (umhos/cm)		990							
CHLORINE (mg/L)		<0.05							

CHEMICAL DATA SHEET FOR CHRONIC TOXICITY TESTING									Cerodaphnia Dubia
Lab # / Sample ID					Test Start (Date/Time)		9/1/09		
Client	EDC-Flat Creek				Test End (Date/Time)		9/8/09		
		Day of Test							
		1	2	3	4	5	6	7	notes/remarks
Control		9/1	9/2	9/3	9/4	9/5	9/6	9/7	
D.O. (mg/L)	INITIAL	88	87	87	85	8.5	8.5	84	
	FINAL	80	80	8.9	8.8	8.4	80		
pH (s.u.)	INITIAL	77	79	77	78	7.9	7.5	78	
	FINAL	84	82	8.0	7.9	7.7	81		
temp (C)	INITIAL	20.0	21.3	21.8	22.1	22.4	22.3	22.8	
	FINAL	25.0	25.0	25	25	25	25.0		
ALKALINITY (mg/L)		52 →							
HARDNESS (mg/L)		88 →							
CONDUCTIVITY (umhos/cm)		291 →							
CHLORINE (mg/L)		<0.05 →							
CONC:									
D.O. (mg/L)	INITIAL	96	88	85	83	8.7	8.9	86	
	FINAL	82	80	8.8	9.0	7.8	7.9		
pH (s.u)	INITIAL	85	91	90	81	8.0	8.8	79	
	FINAL	84	83	8.0	8.0	8.0	81		
temp (C)	INITIAL	19.9	21.6	22.0	22.1	22.6	22.1	22.7	
	FINAL	25.0	25.0	25	25	25	25.0		
CONC:									
D.O. (mg/L)	INITIAL	96	87	85	85	8.6	8.8	86	
	FINAL	81	80	8.7	8.8	8.5	78		
pH (mg/L)	INITIAL	85	94	93	82	8.1	8.0	80	
	FINAL	84	83	8.0	8.0	8.0	81		
temp (C)	INITIAL	19.9	21.7	21.9	22.0	22.4	22.1	22.7	
	FINAL	25.0	25.0	25	25	25	25.0		
CONC:									
D.O. (mg/L)	INITIAL	89	85	85	85	8.5	8.7	86	
	FINAL	81	79	8.7	8.8	8.6	77		
pH (s.u.)	INITIAL	88	97	97	81	8.2	8.2	81	
	FINAL	84	83	8.1	8.0	8.0	8.1		
temp (C)	INITIAL	19.9	21.7	21.9	22.1	22.3	22.1	22.8	
	FINAL	25.0	25.0	25	25	25	25.0		
CONC:									
D.O. (mg/L)	INITIAL	90	84	83	82	8.3	8.6	86	
	FINAL	80	79	8.7	8.8	8.6	78		
pH (s.u.)	INITIAL	92	10.2	10.2	81	8.4	8.4	82	
	FINAL	85	84	8.1	8.0	8.1	81		
temp (C)	INITIAL	19.9	21.9	21.8	22.0	22.4	22.2	22.8	
	FINAL	25.0	25.0	25	25	25	25.0		
CONC:									
D.O. (mg/L)	INITIAL	96	81	82	76	8.2	8.5	86	
	FINAL	80	79	8.7	8.8	8.6	78		
pH (s.u.)	INITIAL	97	10.7	10.7	80	8.8	8.8	85	
	FINAL	80	86	8.2	8.1	8.1	8.1		
temp (C)	INITIAL	20.7	22.3	21.8	23.0	22.5	22.6	22.9	
	FINAL	25.0	25.6	25	25	25	25.0		
CONC:	100%								
ALKALINITY (mg/L)		110 →							
HARDNESS (mg/L)		44 →							
CONDUCTIVITY (umhos/cm)		990 →							
CHLORINE (mg/L)		<0.05 →							

Pimephales promelas **FATHEAD MINNOW** TEST 1000.0

WEIGHT DATA FOR LARVAL SURVIVAL AND GROWTH TEST

LAB # / #s:	TEST DATES (BEGIN / END):
CLIENT: EDC – Haynes	WEIGHING DATE / TIME:
ANALYSTS:	DRYING TEMP (DEGREES C):
SAMPLE ID:	DRYING TIME (HOURS):

	REP#	FINAL DRY WEIGHT TIN+LARVAE (g)	INTIAL WEIGHT TIN (g)	TOTAL DRY WEIGHT OF LARVAE (g)	NUMBER OF LARVAE	DRY WEIGHT OF LARVAE (mg)	
CONTROL	A 1	0.98654	.98248				AVG DRY WEIGHT (mg)
	B 2	0.99623	.99247				
	C 3	1.00374	.99986				
	D 4	1.00286	.99980				CV
	E 5	0.98462	.97849				
CONC:	A 56	0.98990	.98616				AVG DRY WEIGHT (mg)
	B 57	0.98477	.98119				
	C 58	0.96272	.95916				
	D 59	0.96052	.95761				CV
	E 60	~~0.98177~~ 0.98702	.98362				
CONC:	A 61	0.98555	.98188				AVG DRY WEIGHT (mg)
	B 62	0.99221	.98835				
	C 63	0.97774	.97430				
	D 64	~~0.99613~~ 0.99300	.99019				CV
	E 65	0.97451	.97057				
CONC:	A 66	0.98913	.98426				AVG DRY WEIGHT (mg)
	B 67	0.99613	.99267				
	C 68	0.98511	.98176				
	D 69	0.98695	.98297				CV
	E 70	0.97845	.97471				
CONC:	A 71	0.97046	.96592				AVG DRY WEIGHT (mg)
	B 72	0.97549	.97140				
	C 73	0.96206	.95737				
	D 74	0.97171	.96723				CV
	E 75	0.98326	.97757				
CONC:	A 76	0.99361	.98773				AVG DRY WEIGHT (mg)
	B 77	0.98321	.97770				
	C 78	0.96396	.95851				
	D 79	0.96514	.96006				CV
	E 80	0.97406	.96779				

CV = (STANDARD DEVIATION/MEAN)*100

REMARKS:

Surv: 100

SURVIVAL DATA FOR FATHEAD MINNOW LARVAL SURVIVAL AND GROWTH TEST

LAB # / SAMPLE ID		TEST START	DATE 9/1/09 TIME 1610
CLIENT	EDC-Haynes	TEST END	DATE 9/8/09 TIME 1505
AGE AND SOURCE OF MINNOWS			

D A Y (NUMBER SURVIVING) — SURVIVAL

CONC:	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
	A	10	10	10	10	10	10	10	10	100	100	0.00
	B									100		
	C									100		
	D									100		
	E									100		

CONC:	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
	A	10	10	10	10	10	10	10	10	100	98	
	B		10	10	10				10	100		
	C		10	10	10				10	100		
	D		10	10	9	9	9	9	9	90		
	E		10	10	10	10	10	10	10	100		

CONC:	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
	A	10	10	10	10	10	10	10	10	100	96	
	B		10	10	10	10	10	10	10	100		
	C		10	10	9	9	9	9	9	90		
	D		10	10	9	9	9	9	9	90		
	E		10	10	10	10	10	10	10	100		

CONC:	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
	A	10	10	10	10	10	10	10	10	100	98	
	B		10	10	10	10	10	10	10	100		
	C		10	9	9	9	9	9	9	90		
	D		10	10	10	10	10	10	10	100		
	E		10	10	10	10	10	10	10	100		

CONC:	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
	A	10	10	10	10	10	10	10	10	100	100	
	B		10	10	10				10	100		
	C		10	10	10				10	100		
	D		10	10	10				10	100		
	E		10	10	10				10	100		

CONC:	REP #	start	1	2	3	4	5	6	7	%	MEAN %	CV
	A	10	10	10	10	10	10	10	10	100	96	9.32
	B		10	10	10				10	100		
	C		10	10	10				10	100		
	D		8	8	8	8	8	8	8	80		
	E		10	10	10	10	10	10	10	100		
ANALYST		KP	KP	KP	KP	mg	mg	CA	KP			
DATE:		9/1/09	9/2/09	9/3/09	9/4/09	9/5/09	9/6/09	9-7-09	9/8/09			
TIME:		1610	1310	1340	1440	0910	1030	1030	1505			

CV = PERCENT COEFFICIENT OF VARIATION: STANDARD DEVIATION/MEAN * 100

Surv: 100%
repro: 25%

Cerodaphnia dubia

SURVIVAL AND REPRODUCTION TEST

Discharger: FDC – Haynes
Location:
Date Sample Collected:
Lab Number/s

Analyst: KP
Test Start - Date/ Time: 9/1/09 1600
Test Stop - Date/Time: 9/8/09, 0910

Conc 1

%	Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
0	1	0	0	0	0	0	0	0	0	0	0	0			KP
	2	0	0	0	0	0	0	0	0	0	0	0			KP
	3	0	0	0	1	4	4	2	3	2	0	16			
	4	1	0	4	0	0	0	0	2	0	2	9			
	5	8	3	7	5	5	4	4	7	7	5	55			
	6	9	9	4	3	8	2	9	10	8	8	70	10		
	7														
	8														
	Total	18	12	15	9	17	10	15	22	17	15	150			

Conc 2

%	Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
6.25	1	0	0	0	0	0	0	0	0	0	0	0			
	2	0	0	0	0	0	0	0	0	0	0	0			
	3	0	0	3	2	3	5	2	2	2	0	19			
	4	0	3	0	0	0	0	1	0	1	0	5			
	5	5	8	2	1	0	0	4	6	6	5	37			
	6	7	4	7	5	0	7	8	9	7	8	62	10		
	7														
	8														
	Total	12	15	12	8	3	12	15	17	16	13	123			

Conc 3

%	Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
12.5	1	0	0	0	0	0	0	0	0	0	0	0			
	2	0	0	0	0	0	0	0	0	0	0	0			
	3	0	4	2	0	3	2	3	2	3	1	20			
	4	3	0	0	0	2	0	2	4	3	5	19			
	5	6	2	5	2	0	4	5	6	8	7	45			
	6	7	3	9	2	0	6	5	10	7	5	54	10		
	7														
	8														
	Total	16	9	16	4	5	12	15	22	21	18	138			

X= DEAD; Y= MALE

Conc 4

%	Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
25	1	0	0	0	0	0	0	0	0	0	0	0			
	2	0	0	0	0	0	0	0	0	0	0	0			
	3	0	1	0	1	0	0	0	2	2	2	8			
	4	1	3	0	2	2	4	0	0	0	4	16			
	5	3	7	7	3	5	7	4	4	7	8	55			
	6	6	11	7	5	4	8	5	9	5	9	69			
	7														
	8														
	Total	10	22	14	11	11	19	9	15	14	23	148			

Conc 5

%	Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
50	1	0	0	0	0	0	0	0	0	0	0	0			
	2	0	0	0	0	0	0	0	0	0	0	0			
	3	0	0	1	0	0	0	2	0	2	0	5			
	4	0	2	0	0	2	0	0	0	0	0	4			
	5	8	7	5	3	3	2	7	4	3	1	43			
	6	5	7	0	3	2	6	4	9	5	5	46			
	7														
	8														
	Total	13	16	6	6	7	8	13	13	10	6	98			

Conc 6

%	Day	A	B	C	D	E	F	G	H	I	J	No. of Young	No. of Adult	Young/ Adult	Analyst
100	1	0	0	0	0	0	0	0	0	0	0	0			
	2	0	0	0	0	0	0	0	0	0	0	0			
	3	1	0	2	0	0	0	0	2	0	0	5			
	4	3	0	2	0	0	2	1	0	0	1	9			
	5	1	4	3	3	4	2	3	4	0	5	29			
	6	6	2	10	3	8	6	2	8	1	5	51			
	7														
	8														
	Total	11	6	17	6	12	10	6	14	1	11	94			

$\bar{X} = 9.4$

$CV = 49.7$

2007

CHEMICAL DATA SHEET FOR CHRONIC TOXICITY TESTING									Cerodaphnia Dubia
Lab # / Sample ID					Test Start (Date/Time)		9/1/09		
Client	EDC Haynes				Test End (Date/Time)		9/8/09		
		Day of Test							
		1	2	3	4	5	6	7	notes/remarks
Control		9/1	9/2	9/3	9/4	9/5	9.6	9/7	
D.O. (mg/L)	INITIAL	83	87	85	85	[illegible]	8.5	84	
	FINAL	82	80	8.7	9.1	8.3	75		
pH (s.u.)	INITIAL	77	79	83	78	7.9	7.5	78	
	FINAL	86	84	7.9	7.8	7.7	7.9		
temp (C)	INITIAL	20.0	21.3	22.1	22.1	22.4	22.3	22.8	
	FINAL	250	250	25	25	25	250		
ALKALINITY (mg/L)		57							
HARDNESS (mg/L)		88							
CONDUCTIVITY (umhos/cm)		291							
CHLORINE (mg/L)		<0.05							
CONC:									
D.O. (mg/L)	INITIAL	88	86	86	84	8.5	8.6	85	
	FINAL	82	86	8.7	8.9	8.4	77		
pH (s.u)	INITIAL	86	84	83	83	7.9	7.7	79	
	FINAL	85	84	8.0	8.0	7.8	80		
temp (C)	INITIAL	20.8	21.4	22.1	22.3	22.4	22.4	22.3	
	FINAL	250	250	25	25	25	250		
CONC:									
D.O. (mg/L)	INITIAL	8.9	85	86	85	8.6	8.5	85	
	FINAL	80	80	8.6	8.9	8.7	78		
pH (mg/L)	INITIAL	86	91	83	83	7.9	7.7	79	
	FINAL	85	83	8.0	8.0	7.9	79		
temp (C)	INITIAL	20.6	21.4	21.9	22.5	22.3	22.4	22.4	
	FINAL	250	250	25	25	25	250		
CONC:									
D.O. (mg/L)	INITIAL	89	84	85	85	8.5	8.5	88	
	FINAL	79	79	8.7	8.9	8.7	79		
pH (s.u.)	INITIAL	89	9.3	83	82	8.0	7.8	80	
	FINAL	84	83	8.1	8.0	7.9	79		
temp (C)	INITIAL	20.5	21.5	21.8	22.5	22.4	22.4	22.4	
	FINAL	250	250	25	25	25	250		
CONC:									
D.O. (mg/L)	INITIAL	89	8.2	81	84	8.4	8.5	93	
	FINAL	78	79	8.6	8.9	8.8	74		
pH (s.u.)	INITIAL	94	10.5	82	81	7.9	7.8	80	
	FINAL	85	83	8.0	8.0	7.9	80		
temp (C)	INITIAL	20.5	21.5	22.0	22.6	22.4	22.4	22.5	
	FINAL	250	250	25	25	25	250		
CONC:									
D.O. (mg/L)	INITIAL	89	79	79	82	8.2	8.5	84	
	FINAL	78	79	8.7	8.9	8.8	76		
pH (s.u.)	INITIAL	96	10.8	81	80	7.9	8.0	80	
	FINAL	87	84	8.1	8.0	7.9	8.0		
temp (C)	INITIAL	20.6	21.6	22.3	22.6	22.3	22.3	22.6	
	FINAL	250	250	25	25	25	250		
CONC:	**100%**								
ALKALINITY (mg/L)		86							
HARDNESS (mg/L)		62							
CONDUCTIVITY (umhos/cm)		1524							
CHLORINE (mg/L)		<0.05							

CHEMICAL DATA SHEET FOR CHRONIC TOXICITY TESTING

Fathead Minnow

Lab # / Sample ID

Client: EDC Haynes

Test Start (Date/Time): 9/1/09

Test End (Date/Time): 9/8/09

		Day of Test 1	2	3	4	5	6	7	notes/remarks
Control		9/1	9/2	9/3	9/4	9/5	9/6	9/7	
D.O. (mg/L)	INITIAL	88	87	85	85	8.5	8.5	84	
	FINAL	76	8.0	8.7	8.1	84	84	81	
pH (s.u.)	INITIAL	77	79	77	78	7.9	7.5	78	
	FINAL	80	82	86	7.6	76	77	78	
temp (C)	INITIAL	20.0	213	218	221	22.4	22.3	228	
	FINAL	250	250	250	25	25	250	250	
ALKALINITY (mg/L)		57							
HARDNESS (mg/L)		88							
CONDUCTIVITY (umhos/cm)		291							
CHLORINE (mg/L)		<0.05							
CONC:									
D.O. (mg/L)	INITIAL	88	84	85	84	8.5	8.6	8.5	
	FINAL	76	80	80	8.1	8.3	8.1	76	
pH (s.u)	INITIAL	86	84	83	83	7.9	7.7	7.9	
	FINAL	86	83	79	7.6	7.8	7.6	81	
temp (C)	INITIAL	20.8	214	2.21	223	22.4	22.4	22.3	
	FINAL	250	250	250	25	25	26	250	
CONC:									
D.O. (mg/L)	INITIAL	89	85	86	85	8.6	8.5	8.5	
	FINAL	76	81	80	8.0	7.9	8.1	76	
pH (mg/L)	INITIAL	86	9.1	83	83	7.9	7.7	7.9	
	FINAL	85	82	79	7.6	7.8	7.8	81	
temp (C)	INITIAL	20.6	214	219	225	22.3	22.4	22.4	
	FINAL	250	250	250	25	25	26	250	
CONC:									
D.O. (mg/L)	INITIAL	89	84	85	85	8.5	8.5	8.5	
	FINAL	76	79	79	8.1	7.2	8.0	77	
pH (s.u.)	INITIAL	89	93	83	8.2	8.0	7.8	8.0	
	FINAL	84	82	80	7.7	7.8	7.8	8.1	
temp (C)	INITIAL	20.5	215	218	225	22.5	22.4	22.4	
	FINAL	250	250	250	25	25	25	250	
CONC:									
D.O. (mg/L)	INITIAL	89	82	81	84	8.4	8.5	8.5	
	FINAL	77	78	80	8.0	7.7	7.9	77	
pH (s.u.)	INITIAL	9.4	10.5	82	8.1	7.9	7.8	8.0	
	FINAL	84	82	80	7.7	7.8	7.8	8.1	
temp (C)	INITIAL	20.5	21.5	22.0	226	22.4	22.4	22.5	
	FINAL	250	250	250	25	25	25	250	
CONC:									
D.O. (mg/L)	INITIAL	89	79	79	82	8.2	8.5	8.4	
	FINAL	77	78	80	8.1	7.7	7.9	77	
pH (s.u.)	INITIAL	9.6	16.8	81	8.0	7.9	8.0	8.0	
	FINAL	84	85	80	7.8	7.8	7.8	8.0	
temp (C)	INITIAL	20.6	216	223	226	22.3	22.3	22.6	
	FINAL	250	250	250	25	25	25	250	
CONC: 100%									
ALKALINITY (mg/L)		86							
HARDNESS (mg/L)		62							
CONDUCTIVITY (umhos/cm)		1524							
CHLORINE (mg/L)		<0.05							

Attachment F

GRI Model Results

EDCC STR Results

D/S outfall 001

GRI-FW STR (TM) Program
Version 1.02

PREDICTED LC50s FOR THE TEST SOLUTION

	LC50 Conc. (ppm)	LC50 % of Solution	Predicted % Surv in 100% Solution
Ceriodaphnia 24h:	Cannot Calc	Cannot Calc	100.0
Ceriodaphnia 48h:	Cannot Calc	Cannot Calc	99.9
Daphnia 24h:	Cannot Calc	Cannot Calc	99.5
Daphnia 48h:	Cannot Calc	Cannot Calc	99.4
Fathead Minnow 24h:	Cannot Calc	Cannot Calc	99.5
Fathead Minnow 48h:	Cannot Calc	Cannot Calc	99.4
Fathead Minnow 96h:	Cannot Calc	Cannot Calc	98.5

Press any key to continue...

Downstream Outfall 001 with approved 3rd party criteria substituted

GRI-FW STR (TM) Program
Version 1.02

PREDICTED LC50s FOR THE TEST SOLUTION

	LC50 Conc. (ppm)	LC50 % of Solution	Predicted % Surv in 100% Solution
Ceriodaphnia 24h:	Cannot Calc	Cannot Calc	99.9
Ceriodaphnia 48h:	Cannot Calc	Cannot Calc	99.9
Daphnia 24h:	Cannot Calc	Cannot Calc	99.4
Daphnia 48h:	Cannot Calc	Cannot Calc	99.3
Fathead Minnow 24h:	Cannot Calc	Cannot Calc	99.5
Fathead Minnow 48h:	Cannot Calc	Cannot Calc	99.4
Fathead Minnow 96h:	Cannot Calc	Cannot Calc	98.4

Press any key to continue...

UTA with July 15, 2009 concentrations

GRI-FW STR (TM) Program
Version 1.02

PREDICTED LC50s FOR THE TEST SOLUTION

	LC50 Conc. (ppm)	LC50 % of Solution	Predicted % Surv in 100% Solution
Ceriodaphnia 24h:	Cannot Calc	Cannot Calc	100.0
Ceriodaphnia 48h:	Cannot Calc	Cannot Calc	99.9
Daphnia 24h:	Cannot Calc	Cannot Calc	99.5
Daphnia 48h:	Cannot Calc	Cannot Calc	99.4
Fathead Minnow 24h:	Cannot Calc	Cannot Calc	99.5
Fathead Minnow 48h:	Cannot Calc	Cannot Calc	99.4
Fathead Minnow 96h:	Cannot Calc	Cannot Calc	98.5

Press any key to continue...

UTA Reach with approved 3rd party dissolved minerals

GRI-FW STR (TM) Program
Version 1.02

PREDICTED LC50s FOR THE TEST SOLUTION

	LC50 Conc. (ppm)	LC50 % of Solution	Predicted % Surv in 100% Solution
Ceriodaphnia 24h:	Cannot Calc	Cannot Calc	100.0
Ceriodaphnia 48h:	Cannot Calc	Cannot Calc	99.9
Daphnia 24h:	Cannot Calc	Cannot Calc	99.5
Daphnia 48h:	Cannot Calc	Cannot Calc	99.4
Fathead Minnow 24h:	Cannot Calc	Cannot Calc	99.5
Fathead Minnow 48h:	Cannot Calc	Cannot Calc	99.4
Fathead Minnow 96h:	Cannot Calc	Cannot Calc	98.4

Press any key to continue...

Flat Creek Reach with July 15, 2009 concentrations

GRI-FW STR (TM) Program
Version 1.02

PREDICTED LC50s FOR THE TEST SOLUTION

	LC50 Conc. (ppm)	LC50 % of Solution	Predicted % Surv in 100% Solution
Ceriodaphnia 24h:	Cannot Calc	Cannot Calc	100.0
Ceriodaphnia 48h:	Cannot Calc	Cannot Calc	99.9
Daphnia 24h:	Cannot Calc	Cannot Calc	99.3
Daphnia 48h:	Cannot Calc	Cannot Calc	99.0
Fathead Minnow 24h:	Cannot Calc	Cannot Calc	99.5
Fathead Minnow 48h:	Cannot Calc	Cannot Calc	99.4
Fathead Minnow 96h:	Cannot Calc	Cannot Calc	98.4

Press any key to continue...

Flat Creek Reach with approved 3rd party dissolve led mineral concentrations.

GRI-FW STR (TM) Program
Version 1.02

PREDICTED LC50s FOR THE TEST SOLUTION

	LC50 Conc. (ppm)	LC50 % of Solution	Predicted % Surv in 100% Solution
Ceriodaphnia 24h:	Cannot Calc	Cannot Calc	99.9
Ceriodaphnia 48h:	Cannot Calc	Cannot Calc	99.8
Daphnia 24h:	Cannot Calc	Cannot Calc	99.1
Daphnia 48h:	Cannot Calc	Cannot Calc	98.8
Fathead Minnow 24h:	Cannot Calc	Cannot Calc	99.4
Fathead Minnow 48h:	Cannot Calc	Cannot Calc	99.3
Fathead Minnow 96h:	Cannot Calc	Cannot Calc	98.2

Press any key to continue...

Haynes Creek Reach with July 15, 2009 concentrations

GRI-FW STR (TM) Program
Version 1.02

PREDICTED LC50s FOR THE TEST SOLUTION

	LC50 Conc. (ppm)	LC50 % of Solution	Predicted % Surv in 100% Solution
Ceriodaphnia 24h:	Cannot Calc	Cannot Calc	99.7
Ceriodaphnia 48h:	Cannot Calc	Cannot Calc	99.0
Daphnia 24h:	Cannot Calc	Cannot Calc	98.2
Daphnia 48h:	Cannot Calc	Cannot Calc	97.3
Fathead Minnow 24h:	Cannot Calc	Cannot Calc	99.2
Fathead Minnow 48h:	Cannot Calc	Cannot Calc	98.9
Fathead Minnow 96h:	Cannot Calc	Cannot Calc	97.4

Press any key to continue...

Haynes Creek reach with approved 3rd party dissolved minerals

GRI-FW STR (TM) Program
Version 1.02

PREDICTED LC50s FOR THE TEST SOLUTION

	LC50 Conc. (ppm)	LC50 % of Solution	Predicted % Surv in 100% Solution
Ceriodaphnia 24h:	Cannot Calc	Cannot Calc	99.8
Ceriodaphnia 48h:	Cannot Calc	Cannot Calc	99.5
Daphnia 24h:	Cannot Calc	Cannot Calc	98.6
Daphnia 48h:	Cannot Calc	Cannot Calc	97.9
Fathead Minnow 24h:	Cannot Calc	Cannot Calc	99.3
Fathead Minnow 48h:	Cannot Calc	Cannot Calc	99.0
Fathead Minnow 96h:	Cannot Calc	Cannot Calc	97.7

Press any key to continue...

Double concentrations

GRI-FW STR (TM) Program
Version 1.02

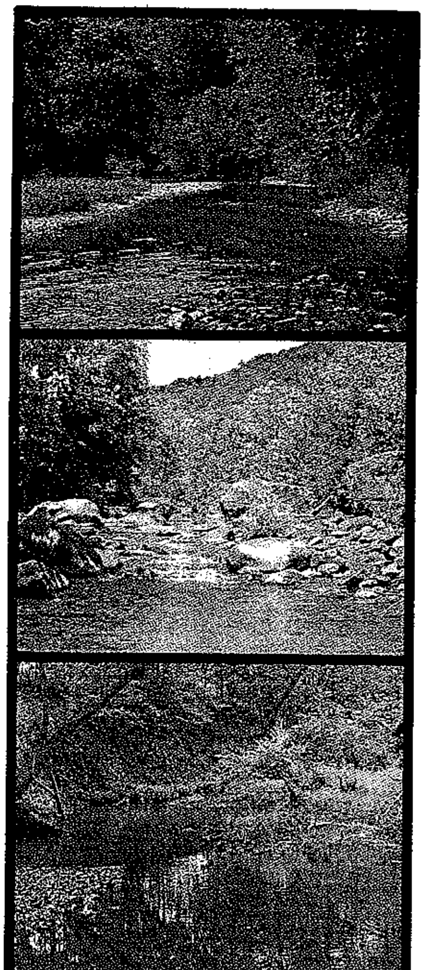
PREDICTED LC50s FOR THE TEST SOLUTION

	LC50 Conc. (ppm)	LC50 % of Solution	Predicted % Surv in 100% Solution
Ceriodaphnia 24h:	Cannot Calc	Cannot Calc	97.4
Ceriodaphnia 48h:	Cannot Calc	Cannot Calc	94.1
Daphnia 24h:	Cannot Calc	Cannot Calc	96.7
Daphnia 48h:	Cannot Calc	Cannot Calc	94.4
Fathead Minnow 24h:	Cannot Calc	Cannot Calc	98.6
Fathead Minnow 48h:	Cannot Calc	Cannot Calc	98.1
Fathead Minnow 96h:	Cannot Calc	Cannot Calc	95.6

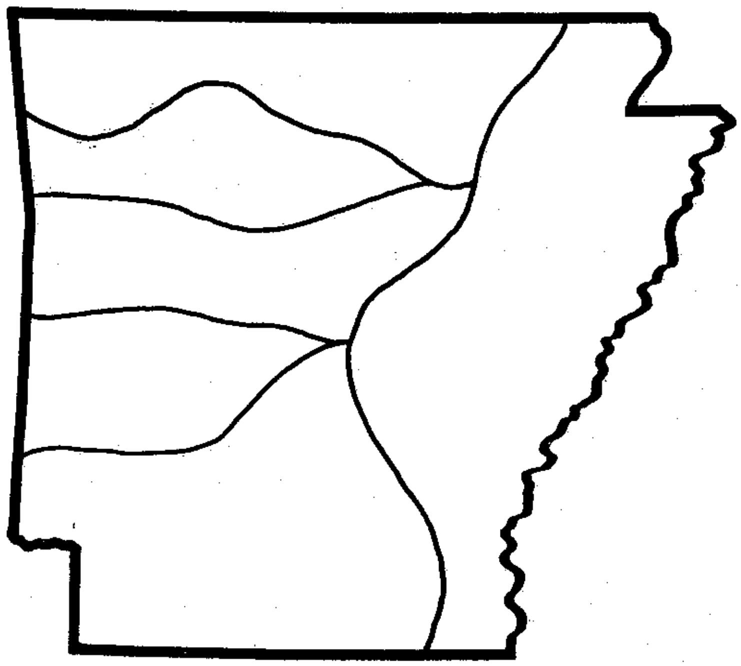
Press any key to continue...

Attachment H

References



Physical, Chemical, and Biological Characteristics of Least-Disturbed Reference Streams in Arkansas' Ecoregions



Volume I: Data Compilation

State of Arkansas
Department of Pollution Control and Ecology

Physical, Chemical and Biological Characteristics of Least-Disturbed Reference Streams in Arkansas' Ecoregions

Volume I - Data Compilation

I. INTRODUCTION

The goal of the Clean Water Act of 1972 (PL 92-500) is to assure that the Nation's waters are "fishable/swimmable." Such a simply stated goal could lead one to think that this would also be a simple task. Such might even have been the case in the early 1970's, when billions of tax dollars were spent in an effort to achieve this ambitious goal. Initially, the assumption was that cleaning up the nation's surface waters would automatically assure that they were "fishable/swimmable." One of the more important things learned during early efforts to control water quality was that minimal, subtle effects of man's activities can have dramatic effects on the beneficial uses of water.

Water uses are often adversely affected without degradation of water quality. Activities which alter the stream habitat may affect water uses as much as actual degradation of the water quality. This understanding has added significant complications to the task.

In the development of this project, it was realized that accurate measurements of relatively undisturbed stream habitat conditions as well as water quality must be obtained in order to evaluate the total impact of various land uses and other activities on streams. Measurement techniques have been standardized with the hope that the resulting information from various sites can be used on a more uniform basis and that valid comparisons can be made. This study attempts to transcend the narrow perspective regarding water quality standards and use a broader approach considering all aspects - chemical, physical and the resulting biological factors - of specific streams.

Purpose

This project was designed to provide a sound scientific basis for development, review, and adoption of water quality standards. At present, water quality standards are often nationwide values which do not recognize seasonal or regional variations in water quality. Many of the cleanest streams and lakes in Arkansas have naturally occurring water quality values that are substandard according to those national values. In numerous instances where the standard is incorrect, valuable resources have been spent to reach a goal which is not attainable.

The suspected disparity between the water quality standards and actual water quality values led to the conclusion that a study should be undertaken to identify water quality conditions in least-impaired streams within the different ecoregions of Arkansas. Least-impaired streams are those which have the least amount of disturbance (in terms of agriculture, silviculture, or other similar activities) and the fewest pollution sources in their watersheds. Such a study would provide valuable background information to measure the effects of dischargers and nonpoint pollution sources, and to provide the information necessary to derive appropriate water quality standards and designate realistic uses.

The very framework of any state water quality regulatory agency is the "standards" by which it regulates and manages the state's resources. By necessity, the standards must be correct in order to do an efficient and effective job.

Concept and Hypothesis of Study

Arkansas is a state with many diverse landforms which are distinctly divided into major ecoregions. This diversity in landforms significantly influences the biological, physical, and chemical nature of the streams draining these regions. The size of a watershed also influences a stream's characteristics. Therefore, the study was structured to evaluate streams with different watershed sizes within the different ecoregions. Seasonal variations within the streams were also evaluated.

To summarize, the basic concept for the study is to evaluate the physical, chemical, and biological characteristics of least-disturbed streams in watersheds of various sizes within each of the ecoregions. By determining the characteristics for regionally specific, least-disturbed characteristics. The regions defined herein were selected because each generally met the criteria described above. For the purpose of this study the regions are:

1. The Mississippi Alluvial Plain (hereinafter referred to as the Delta) occupying roughly the eastern one-third of the state;

2. The Gulf Coastal Plain, in the south central and southwestern part of the state;

3. The Arkansas River Valley, in the west central and central part of the state;

4. The Ouachita Mountains, in the west central part of the state;

5. The Ozark Highlands, in the northern part of the state; and

6. The Boston Mountains, in the north central part of the state.

The six ecoregions and the reference stream sample sites are shown on the map on the following page. For the purposes of this study, Crowley's Ridge, which is usually regarded as a distinct region, was not included. The Ridge contains only a small number of minor streams which are unique to it. A full discussion of the ecoregions and their characteristics is presented in other sections of this report.

Watershed Size Selection

A range of watershed sizes, from about 20 square miles to approximately 500 square miles, was selected. This range of areas included all possible beneficial uses for the streams. The preliminary size groups of watersheds were: 20 to 50 square miles, 100 to 200 square miles, and 300 to 500 square miles. Plans were to collect data over a three-year period so that streams in each drainage area size group would be represented. The order of sampling was from the smallest to the largest watershed size within each specific ecoregion.

Climate

Arkansas has a moist, temperate climate with an average annual rainfall that varies from approximately 44 inches in the northwestern part of the state to 50-52 inches in the streams, the Department will have a much better idea of the characteristics of other streams within the region. This will help to develop realistic water quality standards and designated uses for all streams.

Planning of Study

To develop a workplan for the study it was necessary to:

1. Define the ecoregions;

2. Select a range of watershed sizes;

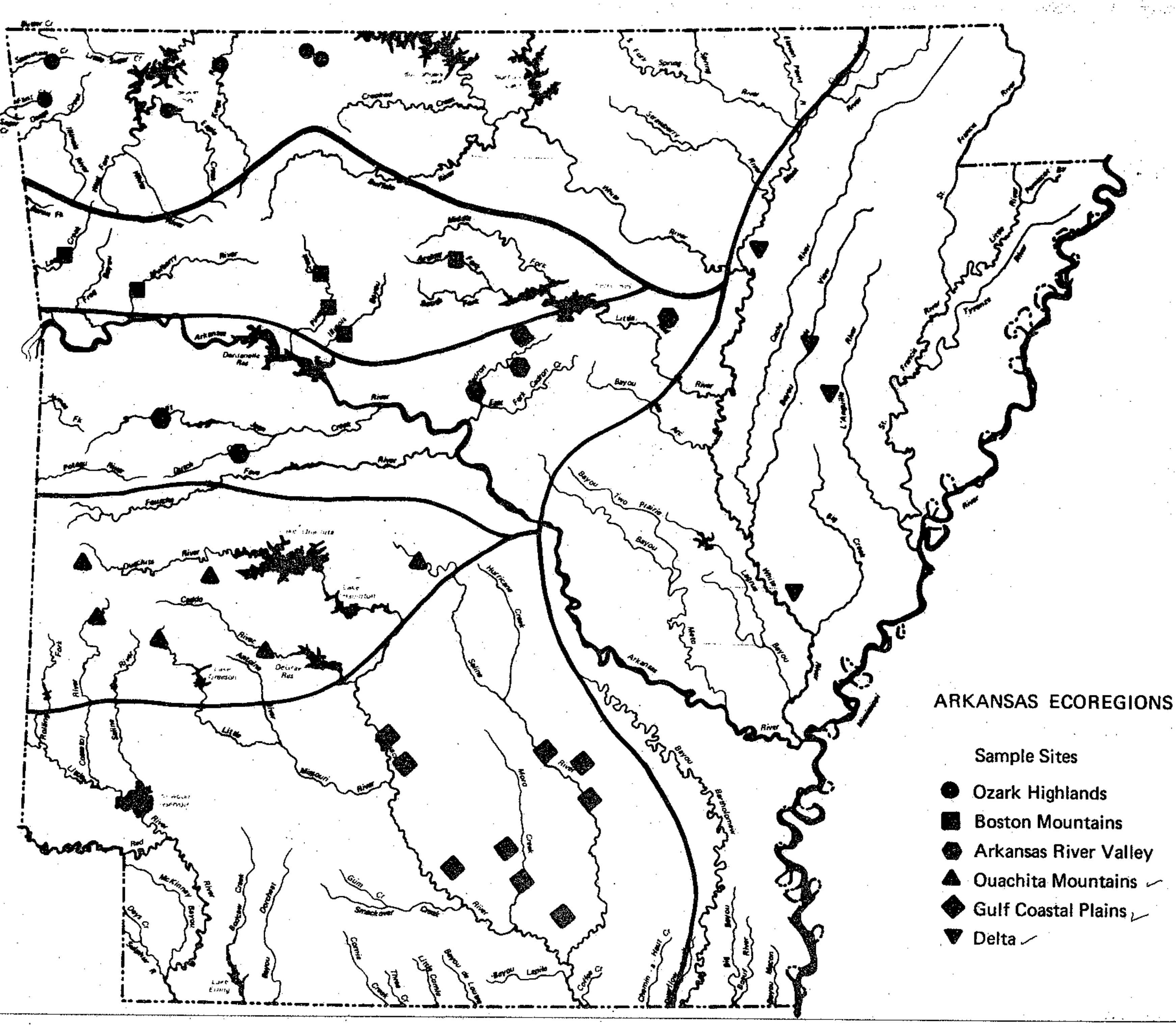
3. Select those seasons of the year which would be the most critical from a water quality standpoint, particularly regarding dissolved oxygen; and

4. Develop a method for selecting streams within each ecoregion which would have the least amount of disruption and fewest pollution sources in their watersheds, and whose watersheds would also be most typical for a given ecoregion.

Defining Ecoregions

The basic approach for selecting the regions and finally the specific sites to be investigated was taken from a paper entitled, "A Synoptic Approach For Regionalizing Aquatic Ecosystems" by J. M. Omernik, M. A. Shirazi, and R. M. Hughes (1981). In this paper, Omernik explains that the current approach to ecosystem classifications consider ecosystem components as a total entity, not as separate items such as energy, water, air, soil, biota and human culture. The authors are presently developing a framework for assessing the biological and chemical quality of surface waters for the nation. The immediate objective is to develop a better understanding of the geographical patterns of interrelationships involving surface water-related ecosystem components, using available data and rationales.

The approach utilizes topography, soils, potential natural vegetation and land use to characterize ecoregions based on: (1) determining the predominant general unifying characteristic of an ecoregion; (2) calculating and mapping the extent of combinations of these characteristics; (3) selecting areas that appear to be most typical, generally typical, and atypical of each ecoregion; and (4) identifying broad homogeneous areas that appear to have similar


ARKANSAS ECOREGIONS
Sample Sites
Ozark Highlands
Boston Mountains
Arkansas River Valley
Ouachita Mountains
Gulf Coastal Plains
Delta
Arkansas River
White River
Bayou Bartholomew
Saline River
Moro Creek
Ouachita River
Caddo River
Little Missouri River
Red River
Fourche
Petit Jean
Buffalo
L'Anguille
St. Francis
Cache
Bayou Meto
Bayou Two Prairie
Strawberry
Spring River
Eleven Point R.
Mulberry River
Lee Creek
Illinois River
Crooked Creek
Dardanelle Res.
Hurricane Creek
Smackover Creek
Gum Cr.
McKinney Bayou
Days Cr.
Big Creek
Little River
Tyronza
Cossatot
Rolling Fork
Poteau River
Cadron

central, southern, and southeastern portions of the state. During the summer, precipitation usually falls as scattered thundershowers. Most of the precipitation occurs as general rain and some snow during the late fall, winter and early spring.

Mean monthly rainfall is well distributed throughout the year. Winter and spring are the wettest times of the year and late summer and fall are the driest times of the year, although monthly totals during the summer and fall still average about three inches each month. Higher evapotranspiration rates and lower rainfall cause stream flows to be lowest during the late summer period.

Average air temperatures show little variation across the state. Maximum temperatures occasionally exceed 100°F (38°C) during July and August. Winters are short, but minimum temperatures, which usually occur in January or February, sometimes approach 0°F (-18°C).

Maximum stream temperatures usually occur in July and range from about 82°F (28°C) to 90°F (32°C) depending on the amount of solar radiation received, depth and other factors (NOAA, 1976).

Selection of Critical Survey Periods

Two sampling periods were selected. The first was late summer when water temperatures are normally at a maximum and flows are near minimum. At this time, dissolved oxygen should be the lowest. The second period was during the spring when fish spawning was occurring and dissolved oxygen requirements for fish reproduction would be critical. The late summer surveys were conducted in August and early September. The springtime period was chosen by monitoring stream temperature to determine when fish spawning began. This was usually in late March.

Site Selection Methodology

Least-disturbed streams within the state were selected by reviewing the location of known dischargers (ADPC&E 1984 305(b) report) and utilizing the extensive field experience of Department staff to exclude streams with known pollution sources. All potential "least-disturbed" watersheds were then outlined on a map. Additional review of these potential sites for nonpoint source pollution problems eliminated many sites. The scope of the project limited the number of sites which could be investigated over a three-year period.

The initial goal of site selection was to confine sites to the "most typical" areas (Omernik, et al., 1981) of the previously described ecoregions. In the selection process, however, the staff discovered that sites in some regions would have to be located within "generally typical" sections, since too few least-disturbed streams could be found in the most typical region. Finally, extensive field evaluations of the potential sites were conducted to confirm their suitability for final selection as representative streams.

Initiating the Study

Once the plans and concepts were finalized, a workplan and grant request were submitted to Region 6 EPA for a grant to fund the study under the provisions of Section 205(j) of the Clean Water Act. The workplan and grant were approved and the study was initiated in the summer of 1983. Subsequent workplans and grants have allowed the Department to continue the necessary field work through 1984, 1985, and during the field efforts during the spring of 1986. This report includes the data from the various size watersheds from the six ecoregions of Arkansas for the entire project.

II. SAMPLING METHODOLOGY

Overview

Each stream survey consisted of a one-week work schedule in which physical, chemical and biological parameters were evaluated. Two sites per region were sampled during the same week. The spring and summer surveys varied slightly due to differing conditions, but the basic schedule was similar. Methods described in subsequent sections are currently accepted in stream-study research projects. The daily field schedule was as follows:

- Monday - D.O. monitors were set up and calibrated at each stream.

- Tuesday - D.O. monitors were checked and calibrated, and general conditions were recorded, including time, weather, D.O. readings and temperature.

    - The chemical grab samples were taken and stored on ice, then transported to the lab via car or plane.

    - Dye study was performed.

    - Flow measurements were taken and a staff gauge was installed.

    - A detailed physical evaluation was done.

    - The macroinvertebrate survey was conducted.

- Wednesday - D.O. meters were checked and calibrated.

    - Fish collection was performed at one site.

    - Staff gauge measurements were taken.

- Thursday - D.O. meters were checked and calibrated.

    - Fish collection was performed at the second site.

    - Staff gauge measurements were taken.

- Friday - Flow was recorded and D.O. meters were checked and calibrated, then closed down.

Parameters Evaluated

Continuous Dissolved Oxygen (D.O.)

Dissolved oxygen (D.O.) was measured continuously during the survey using two (or more) Yellow Springs Instruments (YSI) Model 56 Dissolved Oxygen Monitors. These meters were placed on the streambank with the probe and stirrer in a pool (at mid-depth) and in a riffle. The meters were secured in place and camouflaged to prevent tampering or movement of the devices.

A typical D.O. meter installation would involve:

1. Measure the D.O. of the stream using the Azide Modification of the Winkler Method, perform duplicate titrations, record value;
2. Calibrate YSI Model 57 D.O. meter (portable), record;
3. Set YSI Model 56 D.O. monitors in place;
4. Calibrate using portable meter, record value;
5. Record D.O., temperature, time, date, location, meter I.D. number and calibrations;
6. Secure monitor with ropes and cover with garbage bags.

Subsequent calibrations of the continuous monitors included adjustment of the monitor to compensate for drift or changing the D.O. probe membrane due to damage. Continuous D.O. and temperature data were automatically recorded on a strip chart; times and dates were manually recorded on the strip chart by the survey crew. The time and date information was used to verify the clock (i.e., chart speed) of the D.O. monitor.

After the surveys on all six physiographic regions were completed, the data from the strip charts for each site were transcribed onto forms at fifteen-minute intervals. The data were then typed into computer files.

The computer was used to: (1) generate the percent saturation of dissolved oxygen based on temperature and measured D.O.; (2) correct the data to meet calibration adjustments; (3) calculate daily maximums, minimums and averages, and; (4) produce graphs of the data.

Chemical Parameters

Samples for chemical analyses were collected during the second day of the survey week. Three separate grab samples were secured at least 1 hour apart within an 8-hour period. Samples were taken just upstream of the reach used for physical evaluation (transects). Proper location was important because sediment stirred up from the streambed could greatly affect the chemical analyses. One such interference was noted and subsequently invalidated.

Two 1000-ml containers (one for chemical analyses and one which was lightproof for chlorophyll $\bar{a}$) were used to collect water at mid-depth from each sampling locale for each sampling time. A small volume from one container was filtered through a Gelman glass-fiber filter and stored in a 4-ml vial. The waste filtrate was discarded. One sterilized glass bottle (100 ml) was used to collect water for fecal coliform analysis.

At the time of collection, the following items were recorded: time, date, sample number, dissolved oxygen, pH, temperature, stream name and initials of sampler. This data was also recorded on field sheets for backup purposes. The pH was measured with an ORION RESEARCH digital pH meter, Model 211.

All sample containers were stored on ice and sent to the ADPC&E laboratory by automobile or airplane. Upon arrival at ADPC&E, the samples were prepared for analysis in accordance with STANDARD METHODS, 14th ed.

Laboratory personnel performed the following analyses:

- Coliform bottle - Fecal Coliform
- Filtrate - Ammonia-Nitrogen and Ortho-phosphate
- Dark Bottle - Chlorophyll $\bar{a}$
- Light Bottle - Turbidity, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Biochemical Oxygen Demand-5-day and 20-day (BOD_5 and BOD_{20}), Total Phosphorus, Nitrate + Nitrite Nitrogen, Chloride, Sulfate, Total Iron, Specific Conductivity, Alkalinity, Hardness and Manganese

All analyses were performed in accordance with STANDARD METHODS, 14th ed., as specified in the Quality Assurance Project Plan for the Section 205(j) Project.

Physical Parameter Evaluation

Numerous measurements were made in completing a physical evaluation. These measurements were normally done on Tuesday of each week during the field survey. The drainage area of the test site was determined from 7½' USGS quadrangle maps prior to going to the field. The land use within the watershed was determined using the latest available information from the Soil Conservation Service (SCS).

Stream Flow Measurements - Stream flow is an important parameter in two ways:

(1) All other physical, chemical, and biological measurements are related to stream flow. The assumption is made that the combination of the lowest flow and highest instream temperature occur during late summer within a yearly cycle and, therefore, determine critical conditions.

(2) The actual site chosen to measure the flow determined the reach of stream to be used in making other physical measurements.

Stream flow was measured on the second day of the survey. A Marsh-McBirney Model 201 Portable Water Current Meter was used with a graduated rod which measured depth and held the flow probe at 60% depth. The width of the cross-section was measured with a Lufkin cloth tape (100 ft. or 50 ft.). At the time of the flow measurement, a staff gauge was set in place and readings were recorded daily. Flow data were recorded in field books and on field sheets. Calculations were performed after the survey using computer programs to calculate flow (in CFS) and sketch stream cross-sections.

The site selected for flow measurements was chosen on the basis of the most uniform streambed cross-section. This helped to assure the best measurements since non-uniform streambeds may cause errors in velocity and depth. Some man-made structures (bridges and culverts) were used as flow measurement sites while other flows were simply taken instream.

The location used as the flow measurement site was also the basis for the physical transect survey. The length of the transect reach to be studied was equal to 15 times the width of the stream at the flow measurement site.

Normally, ten transects were marked off within the stream reach. Sometimes, due to the uniform nature of the stream, fewer transects were sufficient to provide adequate physical information.

Stream Gradient - Stream gradient was determined by calculating the vertical drop in elevation per unit distance on a 7½' USGS quadrangle map which covered the area of the sample site.

Mean Channel Width - Mean channel width was determined by calculating the arithmetic mean of the transects measured between the normal high water marks.

Mean Stream Width - Mean stream width was determined by calculating the arithmetic mean of the transects measured from water's edge to water's edge.

Mean Stream Velocity (Dye Study) - Stream velocity was determined by putting fluorescent dye in the stream and timing its flow through a representative stream reach. From this information, an average velocity was calculated.

Estimated Mean Depth - Mean stream depth was determined by estimating the mean depth based on the observations made during the transect survey.

Stream Substrate - The composition of the stream substrate was determined along each transect line from streamside to streamside. A cloth tape is stretched across the stream channel and each 1-foot division of the measuring tape was projected by eye to the stream bottom. The predominant type of substrate found within these 1-foot divisions were recorded on the field survey form. The categories of substrate types include (EPA, 1982):

Bedrock	
Large Boulders	>45 cm
Boulders	25-45 cm
Rubble	6-25 cm
Gravel	6-60 mm
Sand	.06-6 mm
Mud/silt	<.06 mm

In addition to the substrate type, an estimation of the "percent embeddedness" was recorded for each transect. Embeddedness measures the degree to which the larger substrate particles are surrounded or covered by fine sediment. This measurement was given as a percent of the surface area of the larger particles that were covered by sediment.

In-stream Cover - Cover, relative to fishery needs, was measured much like the substrate type. While the tape was being used to measure the individual transect stream widths, the observer measured the cover types which predominated in each one-foot interval. Categories included: undercut bank, brush, logs, debris, overhanging vegetation and inundated vegetation. If inundated vegetation was present, a vegetation density code was utilized to account for surface, mid-depth and bottom coverage.

Pool/Riffle - Each transect was recorded as either a riffle or one of three categories of pools (deep, moderate and shallow).

Riparian Area - Data was generated concerning the riparian area outside the stream channel in order to make valid comparisons between sites. A ten-foot extension of each transect on either side of the channel was used to record the percentage of trees, shrubs, grasses and forbs, and rock or dirt.

Bank Stability - Both banks of each transect were classed according to the following:

S - stable, little evidence of new bank sluffing scars
M - moderately stable, new bank sluffing scars
U - unstable, extensive new bank sluffing conditions apparent

Percent Canopy - The amount of canopy along the tape measurements of each transect was recorded. The total amount of canopy was divided by the total width to record a percent measurement.

Macroinvertebrate Sampling

The benthic macroinvertebrate community of each site was used to further describe the total aquatic ecosystem within each study area. Qualitative samples of the benthos were collected over a pre-determined period of time using a Turtox Indestructible dip net and sampling all available microhabitats present within the stream reach.

After collection, samples were initially sorted using a #30 U. S. standard mesh seive. Benthos were then hand-picked from all material retained by the seive and preserved in 70% ethanol at streamside. Final separation, identification, and enumeration were completed in the lab. Identification was to the species level whenever possible. For each study site, a complete tabulation of taxa, numbers of individuals and their percent composition is contained in Appendix A.

The qualitative samples were used to taxonomically characterize the aquatic community, identify indicator taxa and determine relative abundances of taxa and ecological types. The Dice Index (EPA, 1983), Qualitative Similarity Index and Common Taxa Index (ADPC&E, 1986), three qualitative similarity indices, were calculated to determine the similarity between samples. The Dice Index is the most applicable (Boesch, 1977) and is frequently utilized by stream investigators (Cairns and Dickson, 1971; Johnson and Brinkhurst, 1971; Kaesler and Cairns, 1972; and Foerster, 1974). The last two indices are variations of other qualitative indices that were developed for use with the Arkansas biomonitoring program (ADPC&E, 1986).

In addition, community parameters developed to indicate overall community "health" were calculated for all collections. These included Shannon-Wiener diversity index (Wihlm and Dorris, 1968) and indices of evenness, variety and dominance (ADPC&E, 1984).

During the summer 1983 surveys, the benthic collections were conducted over a one-hour time period. This included collection, sorting, picking and preserving of benthos. After analysis of the summer benthic collections, it was apparent that the 1-hour time period was not sufficient to collect a representative sample of the benthic community.

At the beginning of the spring 1984 surveys, the benthic collection was modified. The time of collecting was reduced to 30 minutes and included only collecting. The processes of sorting, picking and preserving were not timed, nor were they limited to a certain time period. Sorting and picking continued until all discernible organisms were collected from the sample. This generally exceeded 4 hours.

Fish Collection Procedures

A variety of fish-collecting techniques was necessary to overcome the wide range of physical and chemical conditions of the waters sampled. Major factors which influence collecting include flows, water depth, in-stream obstructions, water turbidity, temperature and conductivity.

Under conditions of warm water temperature and very low flows, the fish toxicant, rotenone, was used. Concentrations of active ingredient between 0.05 and 0.10 mg/l were dispersed into the sample area by first mixing powdered rotenone with water to a paste-like consistency, then treating the sample area by throwing the mixture by hand or allowing the current to disperse it. Where substantial flows existed through the sample area, the rotenone was detoxified at the lower end of the sample area by treating with approximately 2 mg/l potassium permanganate. Fishes affected by the rotenone were dipped from the water by workers wading through the area. Normally, 4 to 6 people spent 3 to 4 hours picking up fish. Sample areas were checked for additional fish the following day, but significant numbers of fish were rarely found after the first day.

Electrofishing gear was used at sample sites where the majority of the water was wadable, the water was relatively clear and access from pool to pool was possible by flat-bottomed boat or canoe. A variety of shockers were used depending on availability of gear and physical characteristics of the sample stream. Gasoline-powered generators of the following types were utilized: (1) Homelite and Ag-tronic 3500-watt, 120/240 volt, single phase; (2) Dayton 2000-watt, 115-volt, single phase with a Powerstat variable voltage transformer (120 to 240 volts). This gear was transported through the sample area in a flat-bottomed boat or a canoe. The electrodes were hand-held by workers wading the shallow water. Fish collectors also waded while picking up stunned fish with dip nets.

Occasionally, shallow riffle areas were collected by placing a seine across the bottom of the riffle and shocking the area upstream. The gravel and rubble in the riffles were kicked and rolled by electrode-handlers to dislodge stunned fish from the bottom and allowing them to drift downstream into the net. In most cases the electrodes were connected directly to the generator output outlet. On one occasion, a boat-mounted shocker with the Ag-tronic generator and a Smith-Root variable voltage pulsator was used. Pulsed D.C. current up to 500 volts with 30 to 60 pulses per second was utilized during springtime sampling under conditions of high water and increased turbidity. Results were limited.

Backpack-mounted electrofishing gear was sometimes used in very small streams with flows too low to transport heavier gear from one pool to another. This equipment was composed of an Aqua Bug 300 gasoline-powered generator with an output capacity of 300 watts of 120-volt alternating current.

The techniques for electrofishing were intended to cover as much of the stream and as many micro-habitats as possible. Depth of water was normally the limiting factor. The distance of stream covered varied from one-fourth to three-quarters of a mile depending on the extent of unworkable pools. When the fish species being collected and their abundance were obviously being duplicated with continuous sampling, shocking was terminated at that site. Trammel and hoop nets were used for springtime collections when flows were normally too high and water too deep for electrofishing. Monofilament trammel nets were used which had bar-mesh sizes of 1½, 2, 2½, 3 and 3½ inches. They were hobbled to four feet deep and the total length of each net was 100 feet. Also, hoop nets of 1 and 1½ inch mesh with hoops of two to three feet diameter were utilized. This gear was usually fished over a period of several days and was generally ineffective in collecting large numbers or numerous species of fish.

A complete list of scientific and common names of fishes (AFS, 1970) collected during this phase of the study is contained in Appendix B. Hereafter, text references to these fishes will be by common name only except in tables. The species considered to be most sensitive to environmental changes are designated in this appendix.

Due to collecting gear selectivity, the influence of physical conditions and natural occurrences of large numbers of individuals, the number of individuals collected was not used as a primary parameter in evaluating the population. Instead, each species collected was given a relative abundance number based on the observations of all collectors experienced and knowledgeable in fish identification and ecology. These numbers were either verified or modified after separation, identification and enumeration of the preserved specimens.

The observed relative abundance value was particularly useful for the electrofishing collections since often large numbers of fishes were stunned but could not be netted by the workers. Also, some species were so abundant and extremely vulnerable to electrofishing that continued collection of these individuals was unnecessary. The criteria for assigning relative abundance values to a species are given in Appendix C. Since these values are determined for three different size groups for each species, i.e., adults, intermediates and young, the maximum value for a species is 12 with a minimum of one.

The Shannon-Wiener dominance diversity index (Shannon and Weaver, 1963), the index of evenness (Pielou, 1975) and most of the other metrics were calculated using the relative abundance values.

GULF COASTAL PLAIN ECOREGION

The Gulf Coastal Plain lies in the southern one-third of the state, generally south of a line from Little Rock to Texarkana and west of Bayou Bartholomew. Surface geology consists of gravel, sand, silt and clay deposits of ocean-bed origin dating from Cretaceous through Tertiary Periods of 135 million to 70 million years ago.

Soils in this region have moderate to high permeability. Topography consists of gently rolling hills with local relief of typically less than 100 feet.

Streams in this region are meandering with low to moderate gradients. They consist of pool/riffle combinations, and stream bottoms are generally composed of sand, gravel and silt. Water color is distinctively "coffee-colored."

Native vegetation is loblolly and shortleaf pine and bottomland hardwoods. Much of the natural forest has been converted to loblolly pine monocultures. Land use is predominantly silviculture, followed by agriculture.

Most of this region's major waterways originate in the Ouachita Mountains and drain through the Gulf Coastal Region. The lower Ouachita, Saline and Little Missouri Rivers have their headwaters in the Ouachita Mountains but also drain areas of the Gulf Coastal Plains. Moro Creek is the only major waterway which begins and ends entirely within the region.

Streams selected to represent the Gulf Coastal Region along with the size of the watershed above the selected site are:

Whitewater Creek	23 mi^2
Big Creek	59 mi^2
Derrieusseaux Creek	148 mi^2
Bayou Freeo	156 mi^2
Hudgin Creek	187 mi^2
L'Aigle Creek	232 mi^2
Moro Creek	451 mi^2

Two additional streams, which received most of their critical season flow from groundwater systems, are also included within the discussion on the Gulf Coastal Region. These streams are:

East Fork Tulip Creek	46 mi^2
Cypress Creek	73 mi^2

The initial year's sampling of the Tulip Creek and Cypress Creek watersheds reflects what is now clearly seen as an atypical situation. Recent works published by R. A. Hunrich (USGS, 1983) indicate that some streams within the Gulf Coastal Plains region maintain a year-round flow.

WHITEWATER CREEK

Whitewater Creek begins in the northeast part of Calhoun County and flows in a general southeasterly direction to its confluence with Moro Creek near Tinsman, Arkansas. The sampling site on Whitewater Creek was located at the Highway 274 bridge in the NE ¼ of Section 20, R 12 W, T 12 S (Figure GC-1).

General Site Discussion

Watershed Size - The watershed size of Whitewater Creek above the Highway 274 bridge is 23 mi^2.

Geology - Surface geology in the Whitewater Creek drainage is basically composed of Terrace deposits of the Pleistocene period.

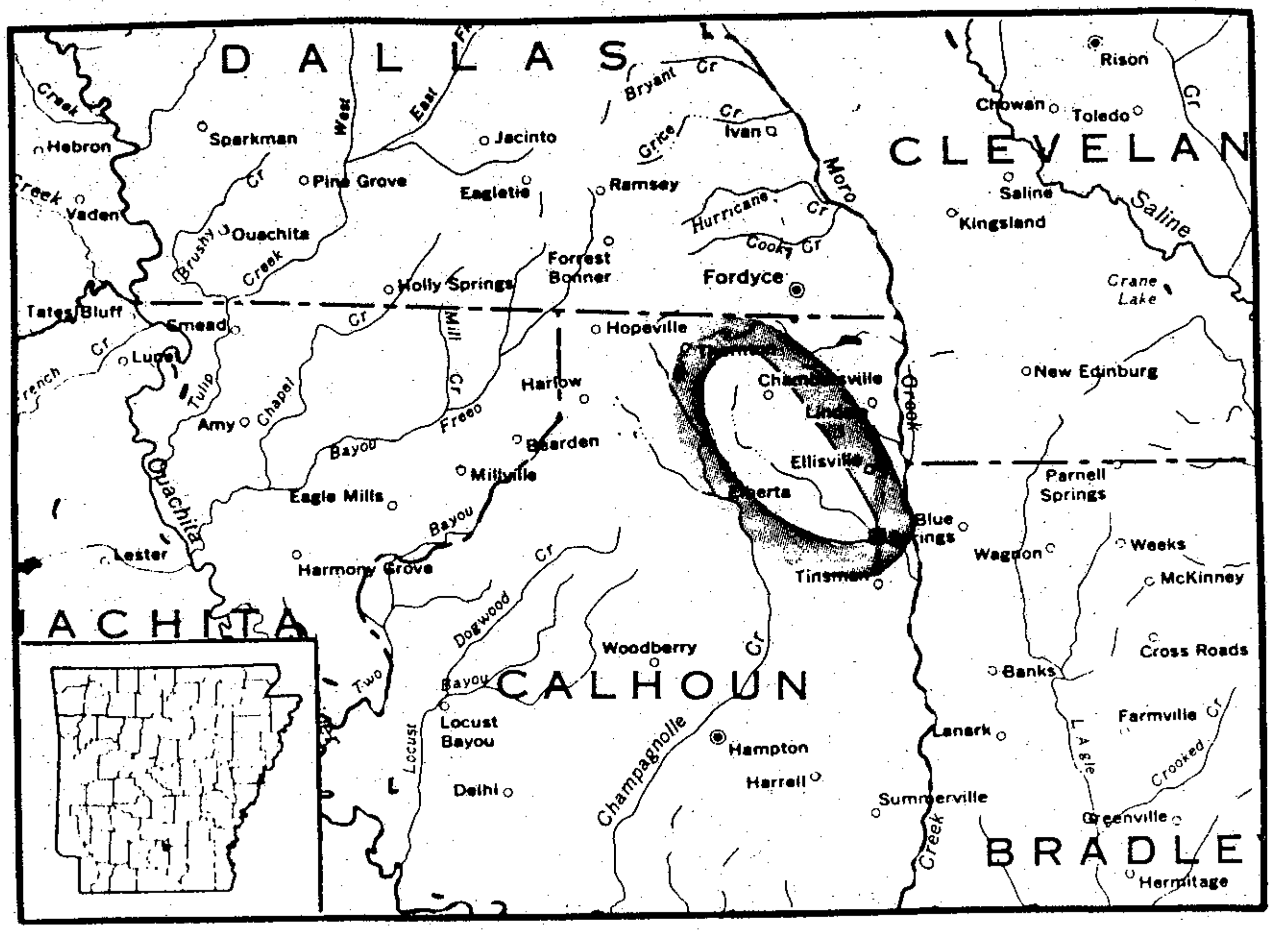
Topography - Topography within the watershed is composed of generally level to gently rolling sand hills directly adjacent to the creek.

Soil Types - The immediate headwater section of Whitewater Creek is dominated by the Savannah-Ruston-Smithdale soil association. This association is made up of moderately well-drained and well-drained, nearly level to moderately sloping, loamy soils on uplands. These soils, formed in thick beds of loamy marine sediments, are found on hilltops and hillsides of the Coastal Plains and are used mainly as woodlands and pastures. The lower section of Whitewater Creek is dominated by the Amy-Smithton-Pheba soil association which is composed of poorly drained and somewhat poorly drained, level to nearly level, loamy soils on uplands. These soils also formed in thick beds of loamy marine sediments and are used mainly as woodlands. Both soil associations ae strongly acid to very strongly acid. There is a severe erosion hazard in the Savannah-Ruston-Smithdale association. Although not prone to erosion, the main limiting factor of the Amy-Smithton-Pheba association is wetness.

Flora - The upland areas within the Whitewater Creek watershed are dominated by pine trees. Other flora identified in the riparian community included sweetgum, elm, hickory, hornbeam, mulberry, maple, black gum and various oak tree species.

Land Use - Land use within the watershed is 91% forestland and 7% agriculture, according to the Soil Conservation Service. The predominant agricultural use is pastureland. The Whitewater Creek watershed has a very low level of man-induced disturbance and is a representative least-disturbed stream in the Gulf Coastal Region.

Figure GC- 1



1 inch equals approximately 8 miles

10 0 10 20 30 40 Miles

10 0 10 20 30 40 50 Kilometers

WHITEWATER CREEK: Drainage area 23 square miles ■ Survey site ▒ Survey area

Stream Characteristics - The 1983 USGS stream flow map shows Whitewater Creek to have a Q_{7-10} low flow of zero. During any given year, the flow will normally drop to zero, leaving a series of enduring pools within the stream channel. This is common throughout the Gulf Coastal Region. During the summer survey, conditions on Whitewater Creek were typical of the enduring pool situation. Some of the more significant physical characteristics observed during the survey included the deeply cut stream channel with sandy banks, sandy substrate, low stream gradient, high percentage of instream cover (brush, logs and debris) and high percentage of stream canopy.

Methodology and Sampling Results

The summer stream survey was conducted during the week of August 12-16, 1985; the spring survey was conducted during the week of April 1-4, 1986. Due to laboratory difficulties, the chlorophyll $\bar{a}$, fecal coliform and iron measurements were made on May 27, 1986.

Continuous Dissolved Oxygen

Summer - Due to the number of sites observed during this week of sampling, only one meter was used to monitor the temperature and dissolved oxygen at this site. The meter was set up at approximately 11 a.m. on Monday, August 12, 1986, and ran through the remainder of the week, performing satisfactorily throughout the sampling period. The sample site was located approximately 150 yards upstream of the Highway 274 bridge. Whitewater Creek was in an enduring pool situation and the meter was measuring the temperature and dissolved oxygen within one of these pools. The meter was checked daily for calibration. Results obtained during the survey are displayed in Figure GC-2, which shows the recorded temperature, dissolved oxygen and dissolved oxygen saturation. The maximum and minimum D.O. were 4.7 mg/l and 0.2 mg/l, respectively, averaging 2.6 mg/l. Similar to other Gulf Coastal dissolved oxygen graphs, the highest values appear contrary to normal photosynthetic activity in that they occur just after midnight. Summertime D.O. saturations ranged from 10-40% during the survey period.

Spring - On March 31, 1986, a continuously recording D.O. meter was set up at the same location used during the summer survey. Unlike the pooled conditions of summer, Whitewater Creek was flowing, although the early spring of 1986 was atypically dry and stream flows were below normal. Flow was measured to be 2.3 cfs at the time of the survey. Figure GC-3 displays the D.O., temperature and percent saturation. The maximum and minimum D.O. were 6.4 mg/l and 4.8 mg/l, respectively, averaging 5.5 mg/l over the survey period. Due to the low spring flow encountered at this site, the D.O. values were slightly lower than expected.

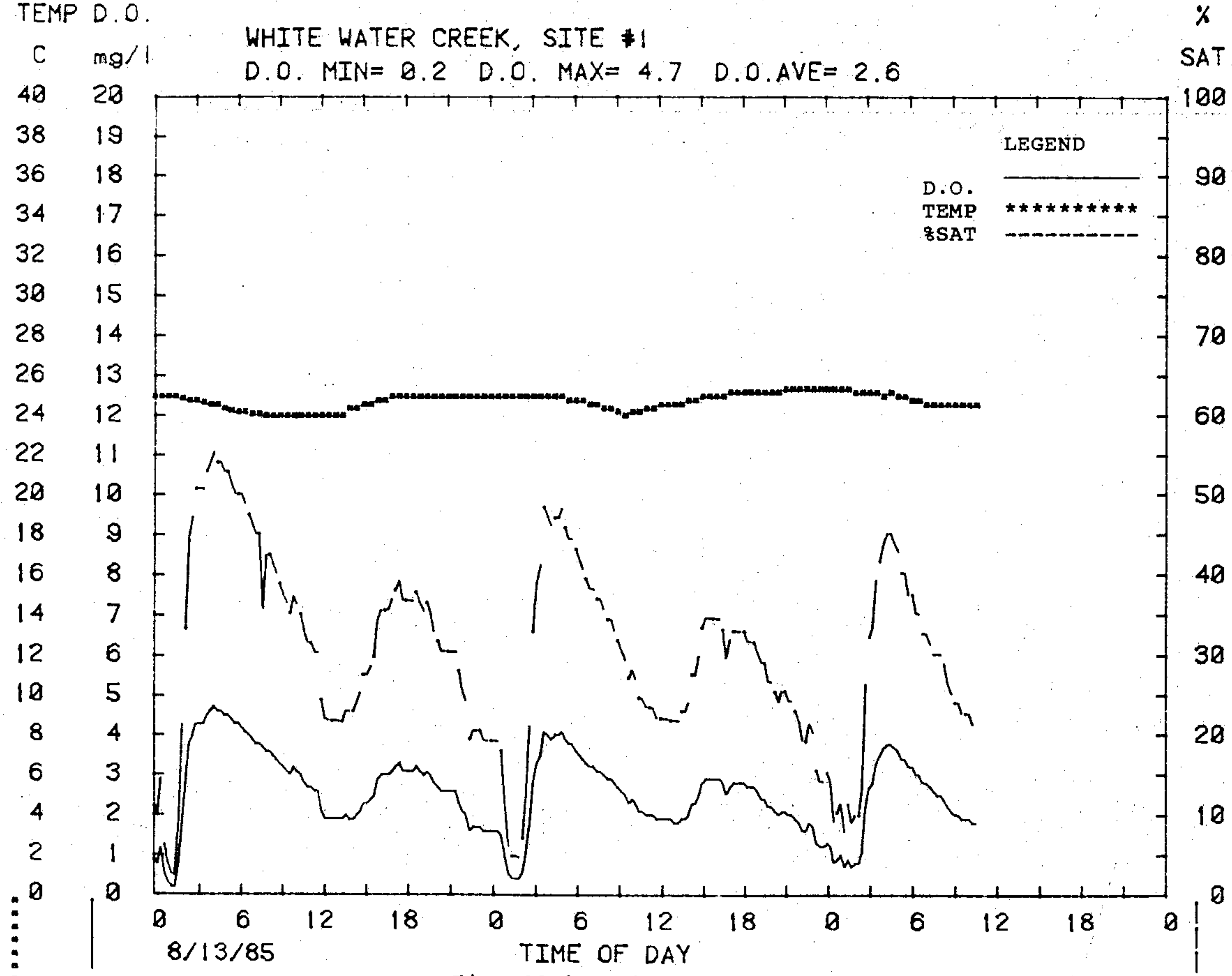


Fig. GC-2. Dissolved Oxygen Plot

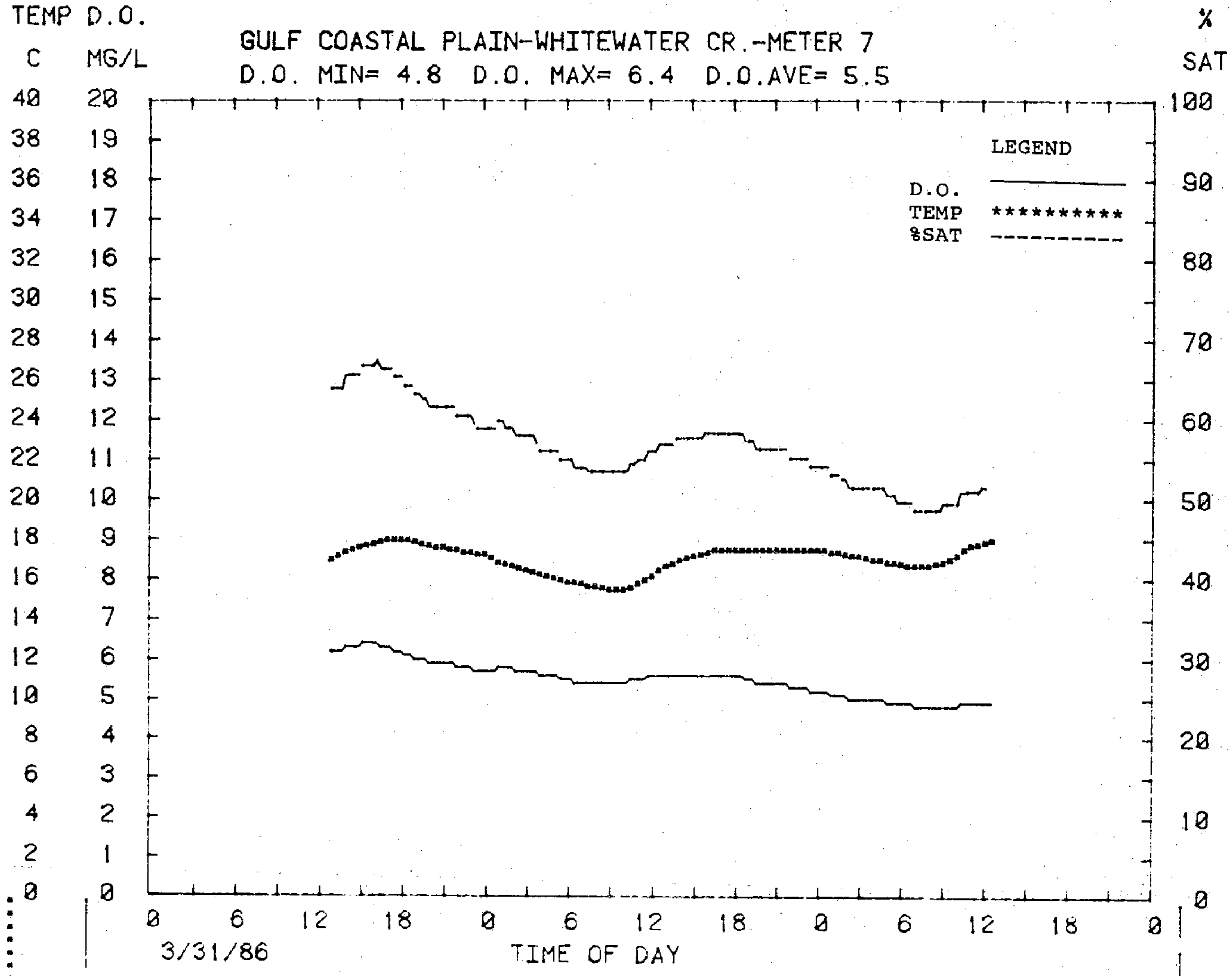


Fig. GC-3. Dissolved Oxygen Plot

Dissolved oxygen percent saturation averaged approximately 60%.

Chemical Parameters

Summer - Chemical data collected during the summer sampling period on August 13, 1985, is displayed on Table GC-1. The seasonal enduring pool status of Whitewater Creek appears to have a significant influence on the water chemistry. The high flows of spring introduce an abundance of organic maaterials from the forest floor and, as the flow recedes, these materials are left to decompose in the enduring pools. Some anaerobic digestion is also apparent as evidenced by the release of hydrogen sulfide gas during any streambed disturbance. The BOD_5 and BOD_{20} were 3.5 mg/l and 6.9 mg/l, respectively, indicating moderate biological activity to be occurring within the water column. Although the nutrient measurements were extremely low, the lentic condition of the stream enhanced phytoplankton growth, as indicated by the chlorophyll $\bar{a}$ concentrations measured. Mineral quality in Whitewater Creek reveals very low levels of sulfates (9 mg/l), chlorides (4 mg/l) and total dissolved solids (66 mg/l). Alkalinity and hardness measurements indicate that Whitewater Creek has very "soft" water with little buffering capacity. The characteristic dark brown water of the Gulf Coastal Region was evident at this site. This characteristic color is thought to be a condition related to the specific soil types within the watershed and the leaching of tannins, lignins and perhaps iron from the leaf litter and soils. Turbidity measurements indicate the water is relatively clear (6 NTUs). The test for fecal coliform bacteria revealed the presence of 92 colonies per 100 ml of water tested. This concentration meets the primary contact standard in Regulation No. 2, Arkansas Water Quality Standards.

Spring - The spring samples were collected on April 1, 1986. Results are shown in Table GC-2. Water quality measured during the spring sampling was significantly different in some respects from the summer samples. Most significant was the volume of water or flow available during the spring. The stream was now actually a flowing stream as opposed to a series of enduring pools which were found during the summer. The available flow is thought to be the predominant reason for the observed changes in water quality. The pH measurement was slightly more acidic during the spring sampling. BODs, both 5-day and 20-day, were approximately one-half the concentrations measured during the summer conditions. Chlorophyll $\bar{a}$ concentrations were reduced to one-half of those values found during the summer. Nutrient levels were very low and showed no significant change from the summer survey. Mineral quality parameters, such as chlorides, sulfates and total dissolved solids, increased

Table GC-1

STREAM RECLASSIFICATION SURVEY

Chemical Results

Physiographic Region: Gulf Coastal Plain

Stream: Whitewater Creek

Drainage Area: 23 square miles

Station Description: Hwy. 274 in Section 20, T 12 S, R 12 W, Calhoun County

Date: August 13, 1985

PARAMETER	TIME COLLECTED 11:30	11:45	12:00	AVERAGE
Q, cfs	0	0	0	No Flow
Temperature, °C	25	25	25	25
pH	7.0	6.9	6.9	6.9
Turbidity, ntu	7	5	34	6*
TSS, mg/l	8	8	69	8*
TDS, mg/l	64	66	66	66
BOD-5, mg/l	2.9	3.1	4.7	3.5
BOD-20, mg/l	6.4	7.3	7.2	6.9
T.Phos., mg/l	0.11	0.11	0.14	0.12
PO4-P, mg/l	0.04	0.04	0.04	0.04
NO2+NO3-N, mg/l	0.01	<0.01	0.01	0.01
NH3-N, mg/l	0.04	0.02	0.04	0.03
Cl-, mg/l	4	3.5	4	3.7
SO4=, mg/l	8	9	9	9
Fe, mg/l	0.14	0.15	0.21	0.17
Conductivity, μmho	68	70	66	68
Alkalinity, mg/l	25	30	27	27
T. Hardness, mg/l	24	28	34	28
Chlorophyll a, μg/l	8.6	12.9	5.1	8.8
Fecal Coliform	-	-	92	92

Dissolved Oxygen Data for 13 Aug 1985		
	Site 1	
Average	2.8	
Minimum	0.2	
Maximum	4.7	

*Third sample was discarded from average total.

Table GC-2

STREAM RECLASSIFICATION SURVEY

Chemical Results

Physiographic Region: Gulf Coastal Plain

Stream: Whitewater Creek

Drainage Area: 23 square miles

Station Description: Hwy. 274 in Section 20, T 12 S, R 12 W
Calhoun County

Date: April 1, 1986

PARAMETER	TIME COLLECTED 11:25	12:15	13:15	AVERAGE
Q, cfs	2.3	2.3	2.3	2.3
Temperature, °C	17	17	17	17
pH	6.50	6.32	6.32	6.4
Turbidity, ntu	8	8	8	8
TSS, mg/l	8	10	10	9
TDS, mg/l	94	93	94	94
BOD-5, mg/l	1.6	1.4	1.7	1.6
BOD-20, mg/l	4.5	4.3	4.5	4.4
T.Phos., mg/l	-	-	-	-
PO4-P, mg/l	<0.01	<0.01	<0.01	<0.01
NO2+NO3-N, mg/l	0.01	0.01	<0.01	0.01
NH3-N, mg/l	0.01	0.01	0.02	0.01
Cl -, mg/l	13	14	13	13
SO4 =, mg/l	14	13	13	13
Fe, mg/l	2.4	2.4	2.3	2.4*
Conductivity, µmho	82	80	77	80
Alkalinity, mg/l	12	11	10	11
T. Hardness, mg/l	22	22	20	21
Chlorophyll a, µg/l	-	-	4.18	4.18*
Fecal Coliform	-	-	108	108*

Dissolved Oxygen Data for 1 Apr 1986		
	Meter 7	
Average	5.5	
Minimum	5.2	
Maximum	5.8	

*These samples were collected on Aug 27th, 1986.

slightly during the higher flows of spring. Fecal coliform bacteria concentrations remained essentially the same for both sampling periods. Turbidity measurements were also the same during both sampling periods.

Physical Parameters

Physical evaluations were made during the week of August 12-16, 1986. Whitewater Creek had reached a routine critical condition for the annual cycle. The stream had essentially stopped flowing, forming a standing waterbody in the immediate streambed. Whitewater Creek is generally characteristic of other Gulf Coastal streams with its low stream gradient, high percentage of instream fishery cover (brush, logs and debris), and moderate canopy covering the stream (Table GC-3).

Macroinvertebrate Populations

Eighty taxa representing 15 orders were identified from the summer-spring benthic samples collected from Whitewater Creek (Table A-5, Appendix A). Numerically, the dominant orders were Decapoda, Coleoptera, Diptera and Odonata, comprising 22%, 18%, 15% and 12% of the organisms, respectively. Taxonomically, the benthic community was predominantly beetles, odonates and true flies. These three orders accounted for 60% of the taxa collected. The dominant taxa common to both samples were *Palaemonetes kadiakensis* (18%), *Peltodytes* (6%), *Caenis* (5%) and *Uvarus* (4%).

The comparative indices demonstrated that substantial differences existed between the summer and spring benthic community (Table GC-4). These differences were the result of natural seasonal variation which occurs in stable, balanced benthic populations. Of the 80 taxa identified from both samples, 60 were identified from the summer and 58 from the spring benthic samples. Of those, 38 taxa were present in both samples and comprised 77.5% of all organisms. The 22 and 20 taxa unique to the summer and spring samples comprised only 30% and 16% of their associated benthic communities, respectively. Two of the five dominant taxa of the summer benthic community were not collected in the spring sample. However, all taxa characterized as dominant in the spring population were also collected in the summer.

Numerically, the dominant orders of the summer sample were Diptera (26%), Coleoptera (20%), Odonata (14%) and Decapoda (4%). However, taxonomically, Coleoptera was represented by twice the number of taxa than any other group. The dominant taxa of the summer sample were *Palaemonetes kadiakensis* (10%), *Peltodytes* (9%), *Tanypus* (6%), and *Sialis* and *Palpomyia* (4%).

Table GC-3

STREAM RECLASSIFICATION SURVEY

Physical Results

Stream:	Whitewater Creek
Date:	8/12/85
Drainage Area:	23 Square Miles
Watershed Land Use:	7% Agriculture 91% Forest 2% Other
Stream Gradient:	2.8 fpm
Mean Channel Width:	29 feet
Mean Stream Width:	15 feet
Mean Stream Velocity:	NA
Observed Flow:	No Flow
Average Substrate Type:	100% Sand
Mean Instream Cover:	32% Brush, Logs, Debris 1% Overhanging Vegetation
Riffle/Pool Ratio of Transects:	100% Shallow Pool
Mean Bank Overstory Cover:	85% Trees 38% Shrubs
Mean Bank Ground Cover:	58% Grass and Forbs 42% Dirt
Mean Bank Stability:	90% Moderate 10% Unstable
Mean Stream Canopy:	96% Canopy
Comments:	

The dominant orders of the spring sample were Decapoda (31%), Coleoptera (17%), and Odonata and Amphipoda (9%). Like the summer sample, the spring sample was taxonomically dominated by beetles. The dominant taxa of the spring were Palamonetes kadiakensis (26%), Caenis and Uvarus (6%) and Cambarinae (5%).

The community parameters indicated a well-balanced, stable benthic community with very high diversity indices (Table GC-4). The percentage composition of functional groups also indicated a balanced trophic structure within the benthic assemblage. The macroinvertebrate community of Whitewater Creek was composed predominantly of taxa which exhibit wide tolerances to most water quality parameters. The presence of abundant instream cover and emergent vegetation provides sufficient microhabitat for the species diversification exhibited by these samples. However, the absence (or reduced number) of taxa considered to be characteristic of naturally high quality water can be attributed to reduced riffle habitat, due primarily to impediment of flow by beaver activity within the watershed.

Table GC-4. Community Analysis of Benthic Samples from Whitewater Creek - 30 minute Qualitative Samples, 1984-1985

COMMUNITY PARAMETERS	Summer	Spring	Combined
Total # Organisms	630	732	1362
Total # Taxa	60	58	80
Diversity	5.024	4.5585	5.1943
Index of Evenness	0.4292	0.4922	0.4435
Index of Dominance	0.8506	0.7782	0.8216
Index of Variety	6.3446	5.9901	7.5878
COMPARATIVE INDICES			
Dice Index (range 0-1)		0.64	
Common Taxa Index (range 0-1)		0.63	
Qualitative Similarity Index (range 0-100)		38.0	

Fish Populations

Summer - A pool approximately 80 yards long and 20 feet wide with an average depth of 1.5 feet was treated with 3.5 pounds of 5% rotenone on August 8, 1985. There was no measurable flow and numerous beaver dams created the pool areas. Approximately 15 man-hours were spent collecting the dying fish.

A total of 419 individuals were collected which had a relative abundance value of 149.5 and a diversity index of 4.33. Table GC-5 shows the 25 species of fish collected at this site. All but one was collected in the summer sample. This population was dominated by Centrarchidae, particularly the flier and warmouth; however, small longear were numerically the most abundant sunfish. Macroinvertebrate feeding fishes made up warmouth; however, small longear were numerically the most abundant sunfish. Macroinvertebrate feeding fishes made up over 90% of the population and no primary feeding fishes were collected (Table GC-6). Only one sensitive fish species, the Creole darter, was taken.

Spring - Three trammel nets were set overnight at this site on March 31, 1986. The nets were 1½", 2", and 2¼" square mesh. A dry winter and early spring caused flows to be as low as 2 cfs during the sample period and beaver dams were further retarding flows. Low inflows also caused water temperatures to begin warming earlier than normal.

Water temperatures fluctuated between 16 and 18°C during the spring sample period. Nets caught only seven fish weighing a total of 6.8 pounds. These included chain pickerel, spotted suckers, bowfin and yellow bullhead. The low water levels and beaver dams may have temporarily restricted the movement of fishes in the stream. Examination of gonads indicated that bowfin, spotted suckers and chain pickerel had completed spawning or were still in the process. The yellow bullheads were in early stages of gonad maturation.

Table GC-5. Fishes Collected from Whitewater Creek with Relative Abundance Values

Species		R.A. VALUE
Centrarchus macropterus	Flier	12.0
Lepomis gulosus	Warmouth	12.0
Aphredoderus sayanus	Pirate perch	10.0
Elassoma zonatum	Banded pygmy sunfish	9.0
Esox americanus	Grass pickerel	9.0
Lepomis megalotis	Longear	9.0
Minytrema melanops	Spotted sucker	9.0
Etheostoma gracile	Slough darter	9.0
Etheostoma proeliare	Cypress darter	9.0
Gambusia affinis	Mosquitofish	9.0
Fundulus olivaceus	Blackspotted topminnow	7.5
Notropis umbratilis	Redfin shiner	6.0
Erimyzon oblongus	Creek chubsucker	6.0
Lepomis cyanellus	Green sunfish	6.0
Lepomis punctatus	Spotted sunfish	5.0
Lepomis macrochirus	Bluegill	4.0
Fundulus notatus	Blackstripe topminnow	4.0
Etheostoma whipplei	Redfin darter	4.0
Lepomis symmetricus	Bantam sunfish	3.0
Amia calva	Bowfin	3.0
Etheostoma chlorosomum	Bluntnose darter	1.0
*Etheostoma collettei	Creole darter	1.0
Micropterus salmoides	Largemouth bass	1.0
Ictalurus natalis	Yellow bullhead	1.0
Esox niger	Chain pickerel	S

* - Sensitive species
S - collected in spring sample only

Table GC-6. Summary of Fish Population Parameters from Whitewater Creek

Total Species Collected	25.0
Total Number of Individuals	419.0
Total Relative Abundance Value	149.5
Relative Abundance Diversity Index	4.33

Population Parameters	No. Sp.	% R.A.V.
CYPRINIDAE	1.0	4.0
CATOSTOMIDAE	2.0	10.0
ICTALURIDAE	1.0	0.7
CENTRARCHIDAE	9.0	40.8
PERCIDAE	5.0	16.1
Macroinvertebrate Feeders	21.0	91.3
Carnivores	4.0	8.7
Sensitive Species	1.0	0.7

BIG CREEK

Big Creek begins in southwest Jefferson County and flows south into Cleveland County. The sample site for Big Creek was located at the Highway 133 bridge in Section 37, R 10 W, T 8 S (Figure GC-4).

General Site Discussion

Watershed Size - The watershed size of Big Creek above the highway bridge is 59 mi^2.

Geology - Surface geology in the Big Creek watershed is composed predominantly of deposits of the Jackson group of the Eocene period. The immediate streambed and floodplain are composed of recent alluvium deposits.

Topography - Topography within the Big Creek watershed is generally level to gently rolling sand hills with broad streamside wetland areas directly adjacent to the creek.

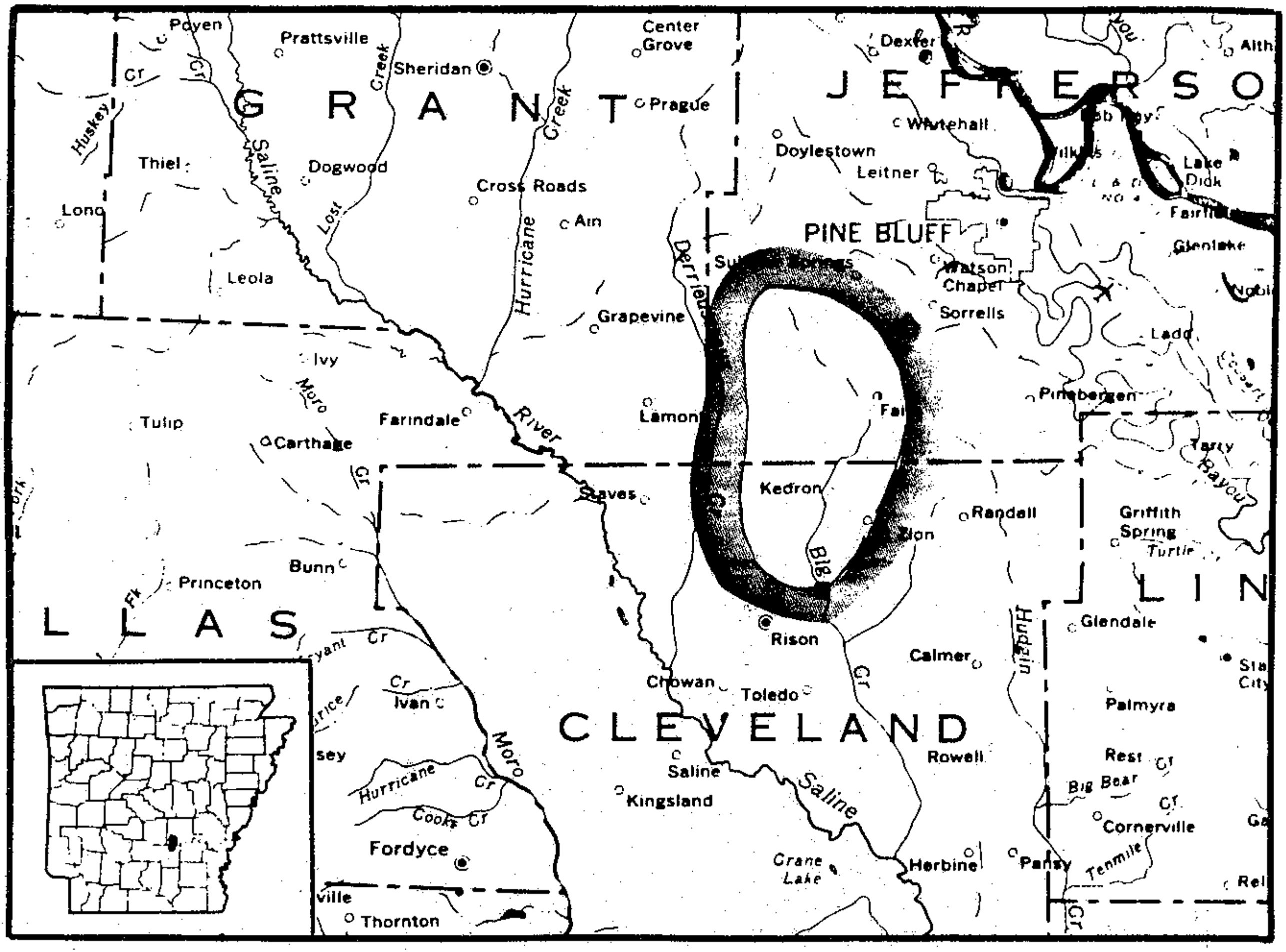
Soil Types - Soil types within the upper drainage of Big Creek are predominantly the Pheba-Savannah-Amy association. This association is composed of poorly drained to moderately well-drained, level to gently sloping, loamy soils on uplands and stream terraces. The lower portion of the watershed beginning at the Jefferson-Cleveland County line, is predominantly the Tippah-Pheba-Boswell association. This association is composed of nearly level to moderately steep, moderately well-drained and somewhat poorly drained soils that have a loamy or clayey subsoil on uplands. The immediate floodplain of Big Creek consists of the Wehadkee-Ochlockonee-Collins association. This association is nearly level, poorly drained to well-drained, frequently flooded soils on bottomlands.

Flora - Loblolly pine and sweetgum trees dominate the forest in the upland areas of the basin. The lower overflow wetland areas are dominated by oak, hickory, beech and cypress trees.

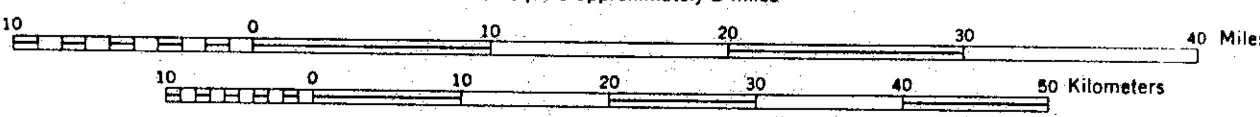
Land Use - Land use within the watershed is 88% forest and 12% agriculture, according to the Soil Conservation Service. The predominant agricultural use is pastureland. The Big Creek watershed has a very low level of man-induced disturbance and is, therefore, a good site to measure least-impaired conditions for the Gulf Coastal Region.

Stream Characteristics - The 1983 USGS stream flow map shows Big Creek to have a Q_{7-10} of zero. This is typical of most Gulf Coastal streams in late summer. These streams quit flowing and develop a series of enduring pools.

Figure GC-4



1 inch equals approximately 8 miles



BIG CREEK: Drainage area 59 square miles ■ Survey site ▒ Survey area

During the survey, Big Creek was in this enduring pool stage. Significant physical characteristics include the deeply cut, meandering stream channel, sandy substrate, low stream gradient, high percentage of instream cover (brush, logs and debris) and high percentage of stream canopy.

Methodology and Sampling Results

The summer stream survey was conducted during the week of August 4, 1986; the spring survey was conducted during the week of March 31, 1986.

Continuous Dissolved Oxygen

Summer - The continuously recording meter was set up at approximately noon on August 4, 1986, 75 yards downstream of the Highway 133 bridge. This sample site was an enduring pool with no obvious flow entering or leaving. Depth at the sampling location was approximately 24 inches, with the probe monitoring the dissolved oxygen and temperature at mid-depth or approximately 12 inches. The meter was checked and calibrated daily. The average D.O. at this site was 1.3 mg/l with a maximum of 2.2 mg/l and a minimum of 0.5 mg/l. The D.O. percent saturation ranged from 10-20% during the sample period (Figure GC-5).

Spring - On March 31, 1986, at approximately 11 a.m., two continuously recording meters were set up to monitor the dissolved oxygen and temperature during the week. Site #1 was located approximately 75 yards downstream of the Highway 133 bridge in a large pool. The depth of the stream was 3 feet and the probe was placed at mid-depth. This meter functioned properly until 1500 hours the second day. Figure GC-6 displays the results of this location. The average D.O. was 5.1 mg/l with a maximum of 6.0 mg/l and a minimum of 3.8 mg/l. The percent saturation ranged from 40-50%. Site #2 was located approximately 100 yards upstream of the Highway 133 bridge and off the main stream in a side channel. This side channel was only about one foot deep. Figure GC-7 displays the results of this location. The average D.O. was 3.4 mg/l with a maximum of 4.6 mg/l and a minimum of 2.4 mg/l. The percent saturation ranged from 30-40%.

This sampling was conducted during what were probably atypical spring conditions. Flow conditions were much lower than normal due to a very dry spring. Flow was measured at 0.5 cfs. This lack of rainfall was apparently causing the stream to approach the enduring pool stage of critical summer conditions, but with cooler water temperatures. These D.O. values are considered lower than normal spring conditions.

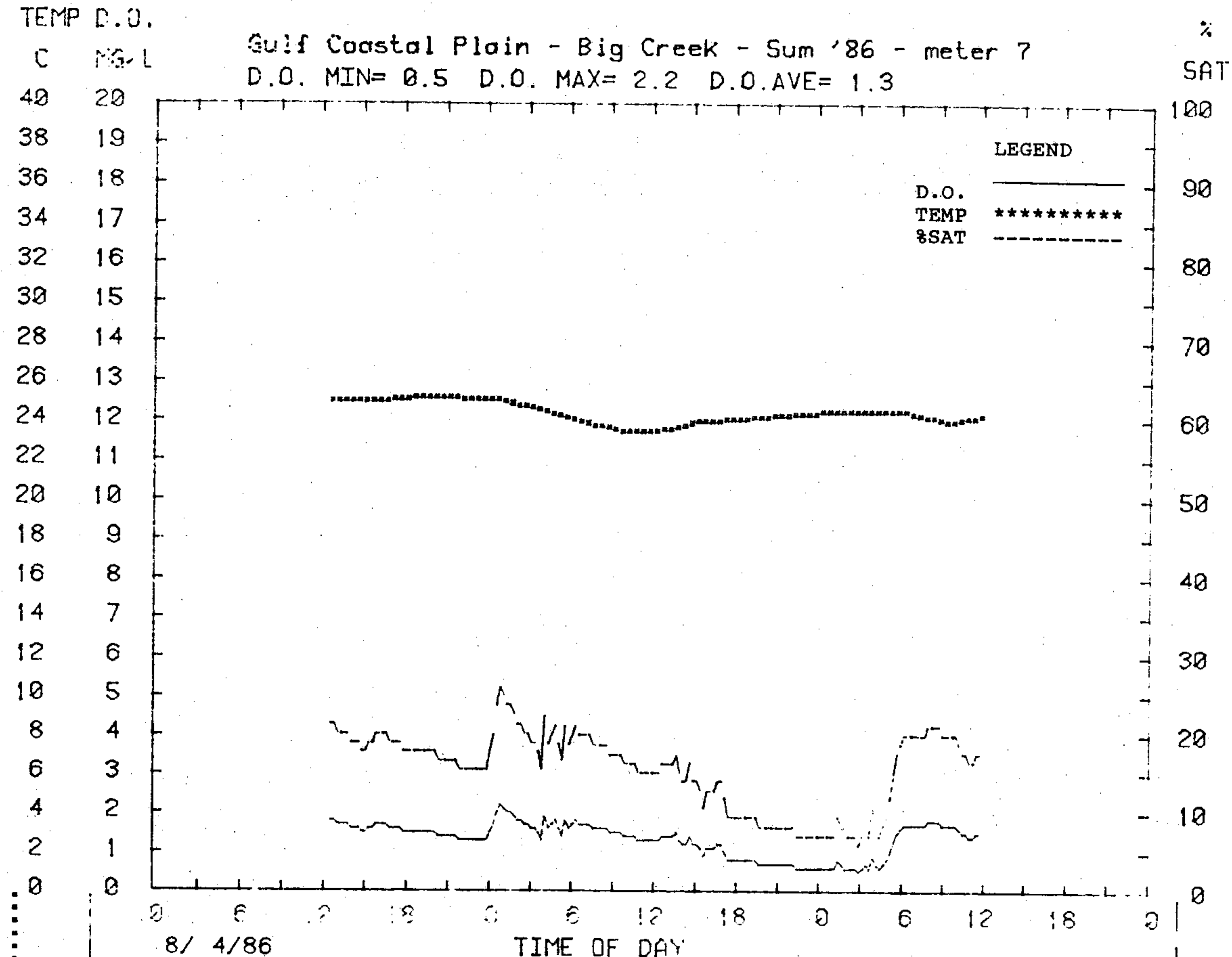


Fig. GC-5. Dissolved Oxygen Plot

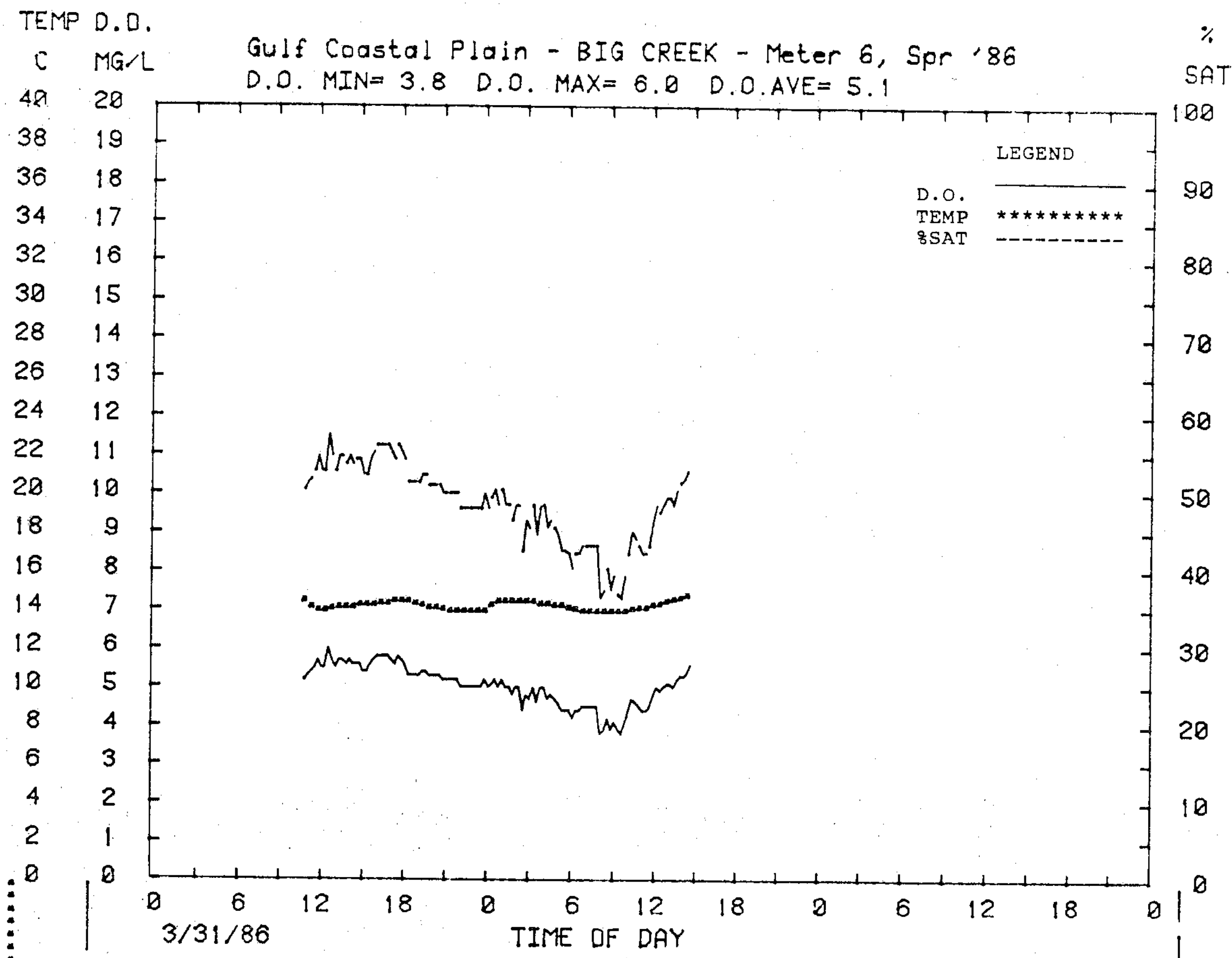


Fig. GC-6. Dissolved Oxygen Plot

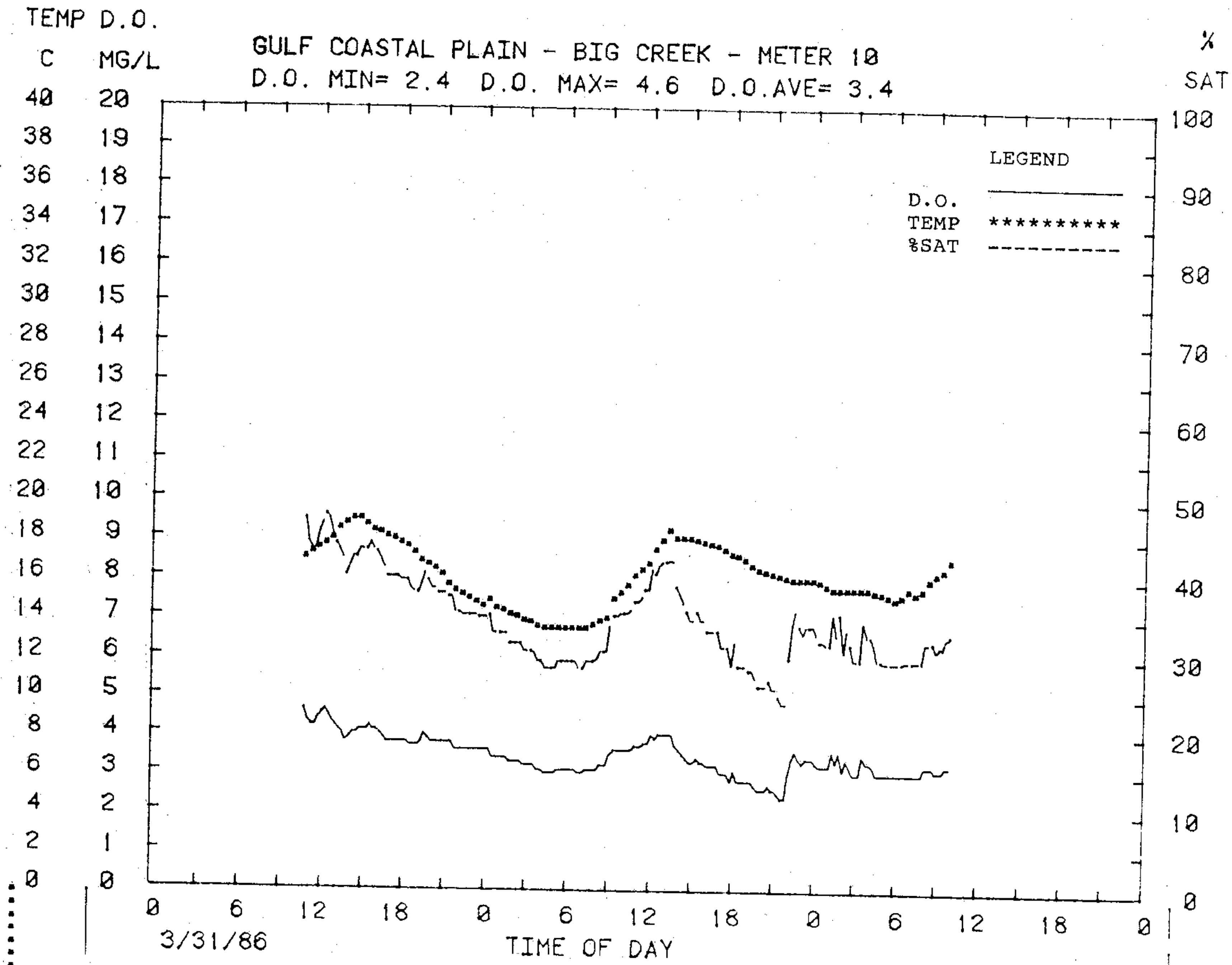


Fig. GC-7. Dissolved Oxygen Plot

Chemical Parameters

Summer - Chemical data collected during the summer sampling period on August 6, 1986, are displayed in Table GC-7. The BOD_5 and BOD_{20} were 2.6 mg/l and 5.0 mg/l, respectively, indicating some biological activity occurring within the water column. Although the nutrient measurements were extremely low, the lentic condition of the stream enhanced phytoplankton growths as evidenced by the 9.6 μg/l of chlorophyll $\bar{a}$ measured. Mineral quality analyses from Big Creek reveal very low levels of sulfates (14.6 mg/l), chlorides (3 mg/l) and total dissolved solids (62 mg/l). Alkalinity and hardness measurements indicate that Big Creek has very "soft" water with very little buffering capacity. The characteristic dark brown water of the Gulf Coastal Region was also evident at this site. This water coloration is thought to be related to the specific soil types within the watershed and the leaching of tannins, lignins and perhaps iron from the leaf litter and soils. The test for fecal coliforms reveals only 24 colonies per 100 ml of water, well within the standard for primary contact.

Spring - The spring samples were collected on April 1, 1986. Results are shown in Table GC-8. Water quality measured during the spring sampling period was only slightly different from the summer period. Even though the stream was actually flowing at 0.5 cfs, a "normal" condition would be much greater flow. Chemical parameters measured showed very little change from the summer analysis.

Physical Parameters

Physical evaluations were made during the week of August 6, 1985. Big Creek had reached a routine critical condition for the annual cycle. The stream had stopped flowing, forming standing water within the immediate streambed. Most of the secondary channels and sloughs off the main stream had already dried up. Table GC-9 displays the results of the physical evaluations on Big Creek. Many of these physical parameters can affect not only the use of the stream but the chemical characteristics as well. Characteristics which were common, not only to Big Creek, but also the region are: low stream gradient, high percentage of instream cover (brush, logs and debris) and moderate canopy covering the stream.

Macroinvertebrate Populations

Sixty-four (64) taxa representing 17 orders were identified from the combined summer and spring benthic samples (Table A-6, Appendix A). Numerically, the dominant orders, Coleoptera, Decapoda and Amphipoda comprised 19%, 16% and 16% of the sample, respectively. The dominant taxa were *Palaemonetes kadiakensis* (14%) and *Gammarus fasciatus* (12%). Taxonomically, Coleoptera and Odonata dominated the combined sample with 15 and 10 taxa, respectively. Other taxa, not numerically dominant but considered as ecologically characteristic of small least-disturbed Gulf Coastal streams, include *Crangonyx gracilis*, *Peltodytes* and *Sialis*.

Table GC-7

STREAM RECLASSIFICATION SURVEY

Chemical Results

Physiographic Region: Gulf Coastal Plain

Stream: Big Creek

Drainage Area: 59 square miles

Station Description: Hwy. 133 bridge Sec. 37, T 8 S, R 10 W

Date: August 6, 1986

PARAMETER	TIME COLLECTED			AVERAGE
	10:00	11:00	12:00	
Q, cfs	---	---	---	No Flow
Temperature, °C	24.2	24.2	24.2	24.2
pH	6.60	6.55	6.60	6.6
Turbidity, ntu	27	26	26	26
TSS, mg/l	14	11	13	13
TDS, mg/l	60	66	61	62.3
BOD-5, mg/l	2.5	2.1	3.2	2.6
BOD-20, mg/l	5.7	4.2	5.3	5.1
T.Phos., mg/l	0.07	0.06	0.07	0.07
PO4-P, mg/l	0.03	0.03	0.03	0.03
NO2+NO3-N, mg/l	0.02	0.02	0.02	0.02
NH3-N, mg/l	0.03	0.03	0.03	0.03
Cl -, mg/l	3	3.5	3	3.0
SO4 =, mg/l	12	14	18	15
Fe, mg/l	---	---	---	---
Conductivity μmho	59	60	56.7	59
Alkalinity, mg/l	15	19	15	16
T. Hardness, mg/l	24	24.2	24	24
Chlorophyll a, μg/l	3.2	4.2	21.4	9.6
Fecal Coliform	---	---	24	24

Dissolved Oxygen Data for August 6, 1986		
	pool	
Average	2.3	
Minimum	3.9	
Maximum	1.0	

Table GC-8

STREAM RECLASSIFICATION SURVEY

Chemical Results

Physiographic Region: Gulf Coastal Plain

Stream: Big Creek

Drainage Area: 59 square miles

Station Description: Hwy. 133 bridge, Section 32, T 8 S, R 10 W, Cleveland County

Date: April 1, 1986

PARAMETER	TIME COLLECTED 08:45	09:40	10:30	AVERAGE
Q, cfs	0.5	0.5	0.5	0.5
Temperature, °C	15.5	16.0	16.0	16.0
pH	6.15	6.19	6.06	6.1
Turbidity, ntu	12	13	11	12
TSS, mg/l	22	22	20	21
TDS, mg/l	111	120	116	116
BOD-5, mg/l	1.7	1.6	1.8	1.7
BOD-20, mg/l	5.1	4.8	4.8	4.9
T.Phos., mg/l	0.09	0.07	0.08	0.08
PO4-P, mg/l	0.01	0.01	0.01	0.01
NO2+NO3-N, mg/l	0.01	0.01	0.01	0.01
NH3-N, mg/l	0.03	0.02	0.01	0.02
Cl -, mg/l	9	9	9.5	9
SO4 =, mg/l	32	33	33	33
Fe, mg/l	2.4	2.5	2.4	2.4*
Conductivity, μmho	117	116	117	117
Alkalinity, mg/l	8	8	7	8
T. Hardness, mg/l	30	28	32	30
Chlorophyll a, μg/l	-	-	18.8	18.8*
Fecal Coliform	-	-	348	348*

Dissolved Oxygen Data for 1 Apr 1986	Meter 10	Meter 6**
Average	3.3	5.1
Minimum	2.4	3.8
Maximum	4.0	6.0

*These data were collected 27 May 1986.
**Meter 6 data is composite data for 31 Mar and 1 Apr.

Table GC-9

STREAM RECLASSIFICATION SURVEY

Physical Results

Stream:	Big Creek
Date:	8/6/85
Drainage Area:	59 Square Miles
Watershed Land Use:	12% Agriculture 88% Forest
Stream Gradient:	2.7 fpm
Mean Channel Width:	40 feet
Mean Stream Width:	6.4 feet (4 of 5 transects dry)
Mean Stream Velocity:	No Flow
Observed Flow:	No Flow
Average Substrate Type:	100% Sand
Mean Instream Cover:	13% Undercut Bank 16% Brush, Logs, Debris
Riffle/Pool Ratio of Transects:	100% Shallow Pool
Mean Bank Overstory Cover:	100% Trees 39% Shrubs
Mean Bank Ground Cover:	34% Grass and Forbs 64% Dirt
Mean Bank Stability:	90% Moderate 10% Unstable
Mean Stream Canopy:	100% Canopy
Comments:	

The summer vs. spring comparison of the benthic communities indicated their assemblages were more similar than dissimilar. The differences were directly associated with seasonal variation which is characteristic of invertebrate populations. Of the 64 taxa identified from the two samples, 43 and 52 taxa were identified from the summer and spring samples, respectively. Thirty-one (31) taxa identified from both samples accounted for 82% of all organisms collected. The 12 and 21 taxa unique to the summer and spring samples comprised only 10.6 and 24.6% of their respective samples.

Summer - The dominant orders of the summer samples were Decapoda (26%), Coleoptera (21%) and Amphipoda (10%). The dominant taxa included Palaemonetes kadiakensis (24%), Uvarus (9%), Lirceus hoppinae (8%), Gammarus fasciatus (7.2%) and Caenis (5.1%). Other taxa, not numerically dominant but ecologically characteristic, include Peltodytes, Neurocordulia and Sialis.

Spring - The dominant orders of the spring sample were Amphipoda (22%), Coleoptera (18.6%) and Isopoda (9.7%). The dominant taxa of the spring sample included Gammarus fasciatus (15%), Asellus dentadactylus, Caenis and Strophopteryx (6%) and Palaemonetes kadiakensis and Uvarus (5%). Four of the five dominant summer taxa were also dominant taxa of the spring sample.

The community parameters were characteristic of a balanced, stable benthic community (Table GC-11). The diversity indices (above 4.0) reflect the variation of habitat types within the stream segment. This was despite zero flow during summer critical conditions and minimum dissolved oxygen values of approximately 1.0 ppm. The majority of insects which were characteristic of this community exhibit wide ranges of tolerance for many water quality parameters. The benthic community of Big Creek demonstrates the ability of insect communities to adapt and flourish in ecosystems with somewhat less than "high quality" water.

Table GC-11. Community Anaylsis of Benthic Samples from Big Creek - 30 minute Qualitative Samples, 1985-1986

COMMUNITY PARAMETERS	Summer	Spring	Combined
Total # Organisms	375	458	833
Total # Taxa	43	52	64
Diversity	4.3133	4.7885	4.8561
Index of Evenness	0.5102	0.4732	0.4876
Index of Dominance	0.7949	0.8400	0.8093
Index of Variety	4.9119	5.7698	6.4934
COMPARATIVE INDICES			
Dice Index (range 0-1)			0.65
Common Taxa Index (range 0-1)			0.60
Qualitative Similarity Index (range 0-100)			53.0

Fish Populations

Summer - On August 7, 1985, approximately 250 feet of the stream was treated with 5 pounds of 5% rotenone. Overnight rains had produced a 1 to 3 cfs flow. Prior to that, there was no flow in the stream and water was restricted to small, enduring pools. Five men spent approximately 3 hours dipping fish from the sample area.

Table GC-11 lists the 23 species collected during the summer sample plus one additional species taken the following spring. A total of 338 individuals were collected with a relative abundance value of 135.5 and a diversity index of 4.27. The family Centrarchidae dominated the relative abundance of the fish population (Table GC-12). The flier and banded pygmy sunfish were relatively the most abundant sunfishes, and the pirate perch was numerically the most abundant species. The trophic feeding level of the population was dominated by macroinvertebrate feeders. An atypically large number of golden shiners increased the proportion of primary feeders in the population to 8.1%. Without the golden shiners, which are probably from bait releases or escapes from culture ponds in the watershed, the proportion of primary feeders would be 1.5%. Grass pickerel was the only predator species in the population. Two sensitive species were collected in the summer sample and one additional sensitive species was collected during spring sampling.

Spring - Three trammel nets, two 1½" and one 2" square mesh were set overnight at this site on April 1-2, 1986. Flows in the stream were very low and affected by numerous beaver dams. Flow was measured at 0.5 cfs and the water temperature was 17°C. Nets caught only seven spotted suckers. Electrofishing produced 9 species including one creole darter, a species which was not collected at this site the previous summer.

Gonad examinations indicated that the spotted suckers had completed spawning and that the blackside darters and the creole darter were in the final stage of gonad development prior to spawning. Atypically low springtime flows were probably limiting the use of this stream for fish spawning.

Table GC-11. Fishes Collected from Big Creek with Relative Abundance Values

Species		R.A. VALUE
Aphredoderus sayanus	Pirate perch	12.0
Centrarchus macropterus	Flier	10.0
Elassoma zonatum	Banded pygmy sunfish	9.0
Esox americanus	Grass pickerel	9.0
Etheostoma gracile	Slough darter	9.0
Notemigonus crysoleucas	Golden shiner	9.0

Table GC-11, cont.

Gambusia affinis	Mosquitofish	9.0
Erimyzon oblongus	Creek chubsucker	8.0
Lepomis gulosus	Warmouth	7.0
*_Percina maculata_	Blackside darter	7.0
Lepomis cyanellus	Green sunfish	6.5
Notropis chrysocephalus	Striped shiner	6.0
Notropis umbratilis	Redfin shiner	6.0
Fundulus olivaceus	Blackspotted topminnow	6.0
Lepomis macrochirus	Bluegill	5.5
Lepomis megalotis	Longear	5.5
Etheostoma chlorosomum	Bluntnose darter	2.0
Ictalurus natalis	Yellow bullhead	2.0
Etheostoma whipplei	Redfin darter	2.0
Hybognathus nuchalus	Silvery minnow	2.0
Notropis emiliae	Pugnose minnow	1.0
Minytrema melanops	Spotted sucker	1.0
*_Percina sciera_	Dusky darter	1.0
*_Etheostoma collettei_	Creole darter	S

* - Sensitive species
S - collected in spring sample only

Table GC-12. Summary of Fish Population Parameters from Big Creek

Total Species Collected	24.0
Total Number of Individuals	338.0
Total Relative Abundance Value	135.5
Relative Abundance Diversity Index	4.27

Population Parameters	No. Sp.	% R.A.V.
CYPRINIDAE	5.0	17.7
CATOSTOMIDAE	2.0	6.6
ICTALURIDAE	1.0	1.5
CENTRARCHIDAE	6.0	32.1
PERCIDAE	5.0	15.5
Primary Feeders	2.0	8.1
Macroinvertebrate Feeders	21.0	85.3
Carnivores	1.0	6.6
Sensitive Species	3.0	5.9

DERRIEUSSEAUX CREEK

The sample site on Derrieusseaux Creek is located in Cleveland County in Section 5, R 11 W, T 9 S, on a timber-access road south of Highway 35 (Figure GC-8). The creek begins in the southeast corner of Grant County and flows in a southerly direction down the Grant-Jefferson County line into Cleveland County. The sample site on Derrieusseaux is located less than two miles above its confluence with the Saline River.

General Site Discussion

Watershed size - The Derrieusseaux watershed consists of 148 mi^2 above the sample site location.

Geology - Surface geology in the Derrieusseaux Creek drainage is dominated by the Jackson Group deposited in the Eocene era of Tertiary age, while recent alluvium deposits form the present stream flood plain.

Topography - Land form topography is generally level to gently rolling, sand and clay hills with broad, streamside wetland areas directly adjacent to the creek.

Soil Types - The floodplain of Derrieusseaux Creek is dominated by the Wehadkee-Falaya association. These soils are nearly level, poorly drained and somewhat poorly drained and predominantly in bottomlands. They are generally low in natural fertility with slow permeability and medium available water capacity with a poor response to fertilizer. The uplands are dominated by the Tippah-Pheba-Boswell association. These soils are nearly level to moderately steep, moderately well-drained and somewhat poorly drained soils that have a loamy or clayey subsoil. They are moderately acid to very strongly acid.

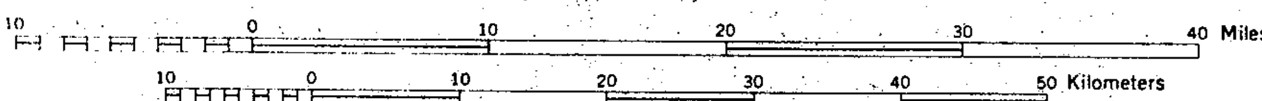
Flora - The upland areas of this drainage basin are managed for pine. Streamside overflow wetland areas are dominated by oak, hickory, beech and cypress.

Land Use - Land use in the basin, according to the Soil Conservation Service data, is 93% silviculture and 7% agriculture. Agricultural uses are predominantly pastureland. The basin has a low level of man-induced disturbances and represents a least-impaired stream in the Gulf Coastal Region.

Stream Characteristics - Derrieusseaux Creek is typical of the majority of Gulf Coastal streams in that, regardless of the size of the watershed, the stream is in an enduring pool situation during critical conditions in the average water year. The 1983 USGS map shows Derrieusseaux Creek to have a Q_{7-10} of zero. Significant physical characteristics include the deeply cut, sandy stream banks, sandy substrate, low

Figure GC-8

Scale 1:500,000
1 inch equals approximately 8 miles



DERRIEUSSEAUX CREEK: Drainage area 148 Square miles ■ Survey site ▒ Survey area stream gradient, high percentage of instream cover (brush, logs, debris) and high percentage of stream canopy.

Methodology and Sampling Results

The summer stream survey was conducted during the week of August 5-9, 1985; the spring survey took place during the week of March 25-29, 1985.

Continuous Dissolved Oxygen

Summer - The survey was initiated shortly after noon on August 5, 1985. Two continuously recording meters were set up within the same enduring pool, only a short distance apart. Since the pool was approximately 10 feet deep, different depths were monitored. Site #1 was set up to monitor mid-depth (approximately 5') and Site #2 was set up to monitor sub-surface. Both meters were operated continuously until after noon on August 8, 1985. Calibration was checked daily on both meters. Results for Site #1 are displayed in Figure GC-9. The average D.O. was 1.8 mg/l with a maximum of 2.3 mg/l and a minimum of 1.4 mg/l. At Site #2 (Figure GC-10), the average D.O. was 1.7 mg/l with a maximum of 3.3 mg/l and a minimum of 0.1 mg/l. Both sites ranged 20-30% saturation.

Spring - On March 26, 1985, two meters were set up to measure the dissolved oxygen and temperature in Derrieusseaux Creek. Unlike the pooled summer conditions, the creek was now flowing. Site #1 was placed in a riffle while Site #2 was placed in a pool. A review of Figures GC-11 and GC-12, which show dissolved oxygen, temperature and percent saturation, reveals little, if any, differences between the two sites. The flow was falling throughout the survey period and was measured to have fallen more than two feet. The spring and summer conditions are distinctly different. The flowing condition found during the spring is the dominant reason for the higher dissolved oxygen concentrations and higher percent saturations. Average dissolved oxygen concentrations during the spring survey were 7.5-7.8 mg/l with very small diurnal fluctuations. The percent saturation of dissolved oxygen during the spring survey averaged about 80%.

Chemical Parameters

Summer - The results of the chemical sampling on Derrieusseaux Creek on August 6, 1985, are displayed in Table GC-13. The BOD_5 and BOD_{20} were 3.3 mg/l and 8.1 mg/l, respectively, indicating some biological activity occurring within the water column. Although the nutrient measurements were extremely low, the lentic condition of the stream enhanced phytoplankton growths, as evidenced by the 14.2 μg/l of chlorophyll *a* measured. Mineral quality analyses from Derrieusseaux Creek reveal very low levels of sulfates (8 mg/l), chlorides

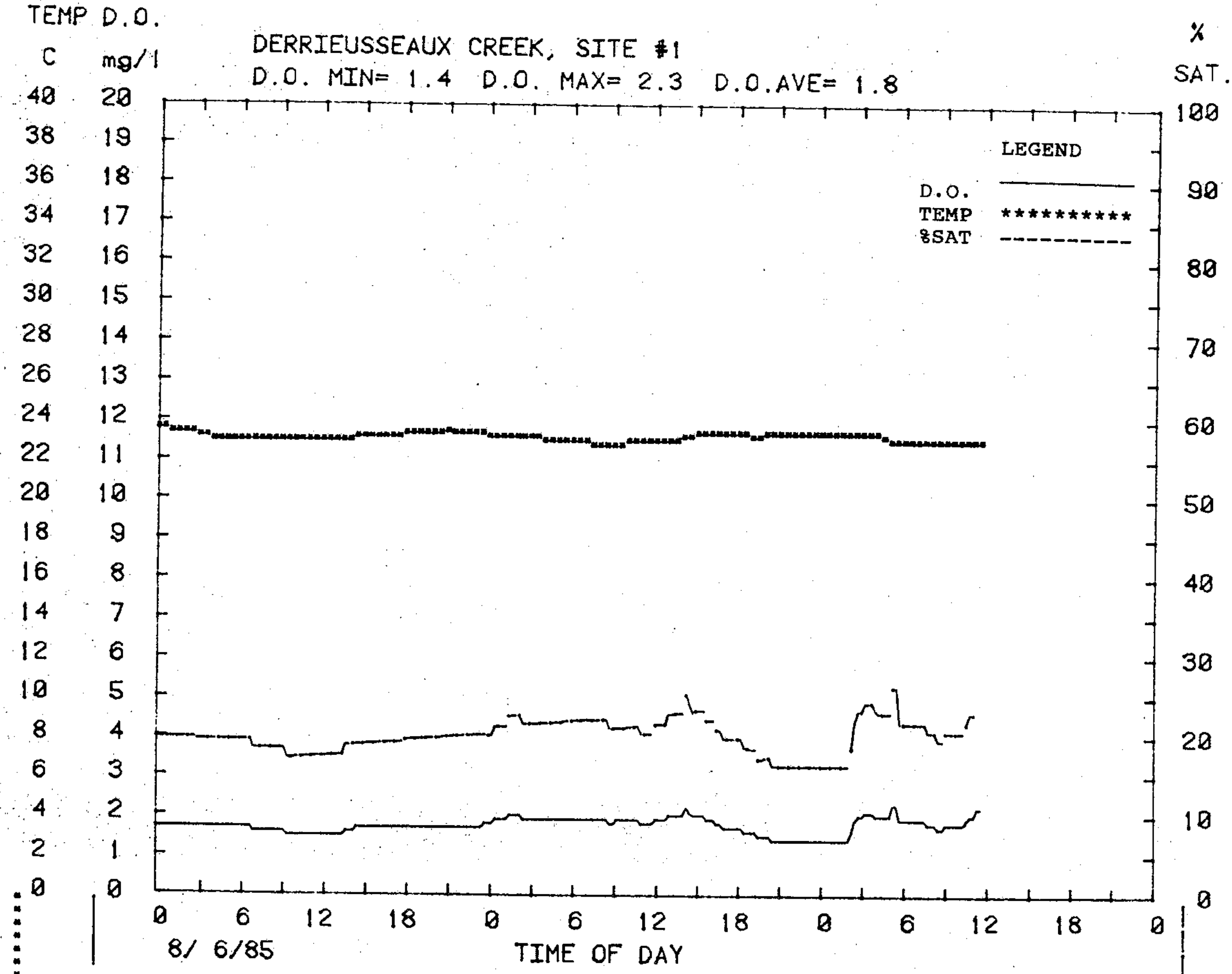


Fig. GC-9. Dissolved Oxygen Plot

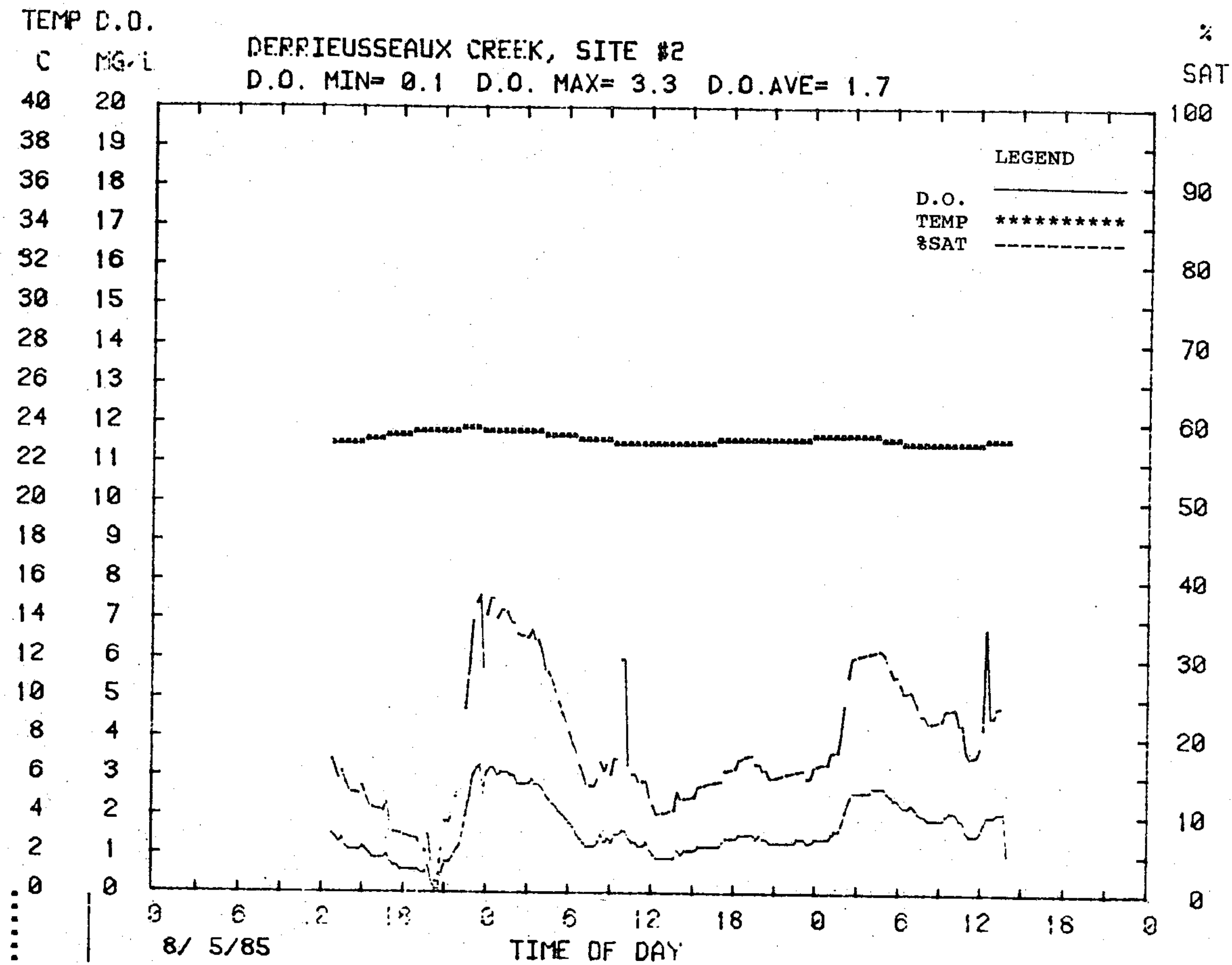


Fig. GC-10. Dissolved Oxygen Plot

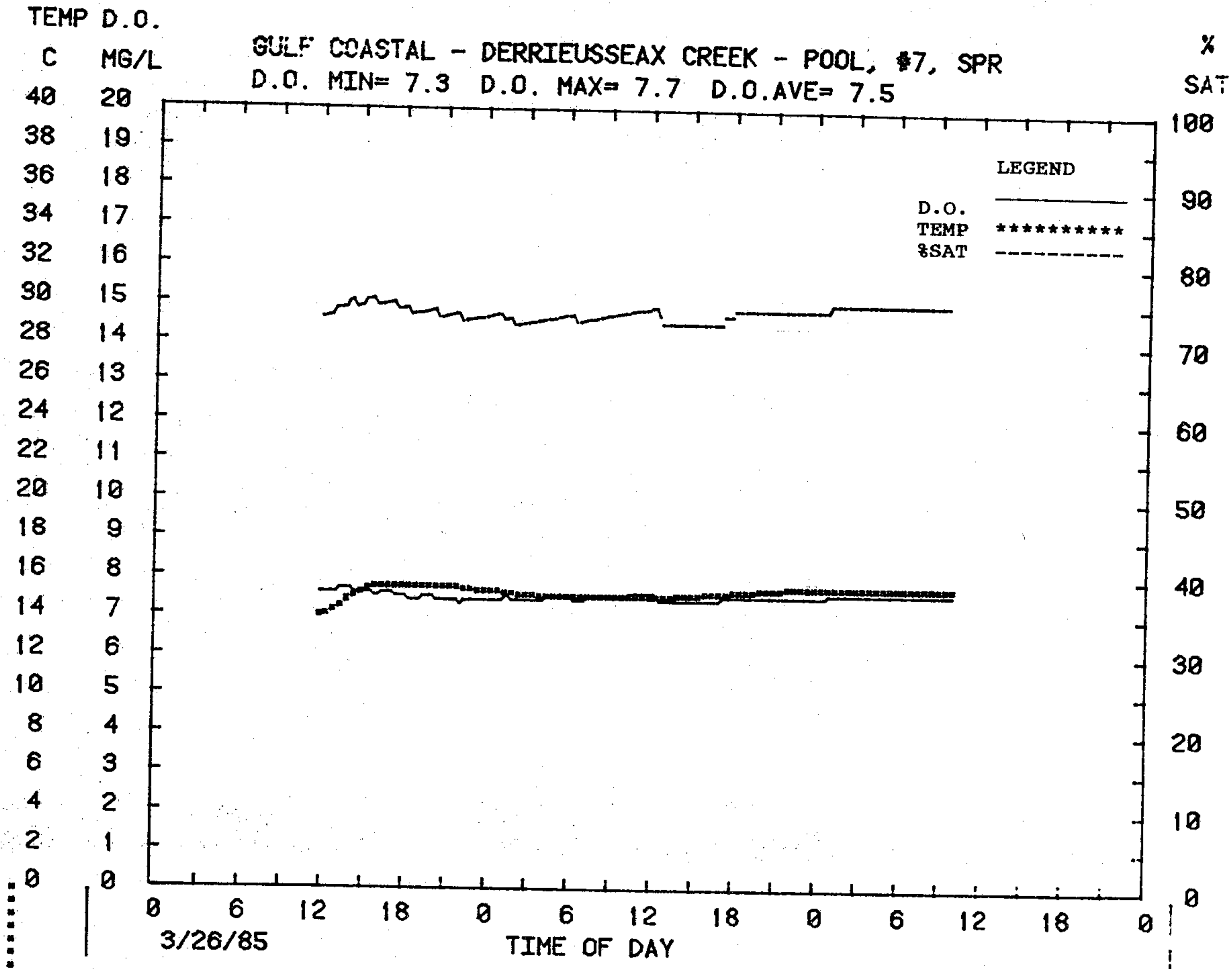


Fig. GC-11. Dissolved Oxygen Plot

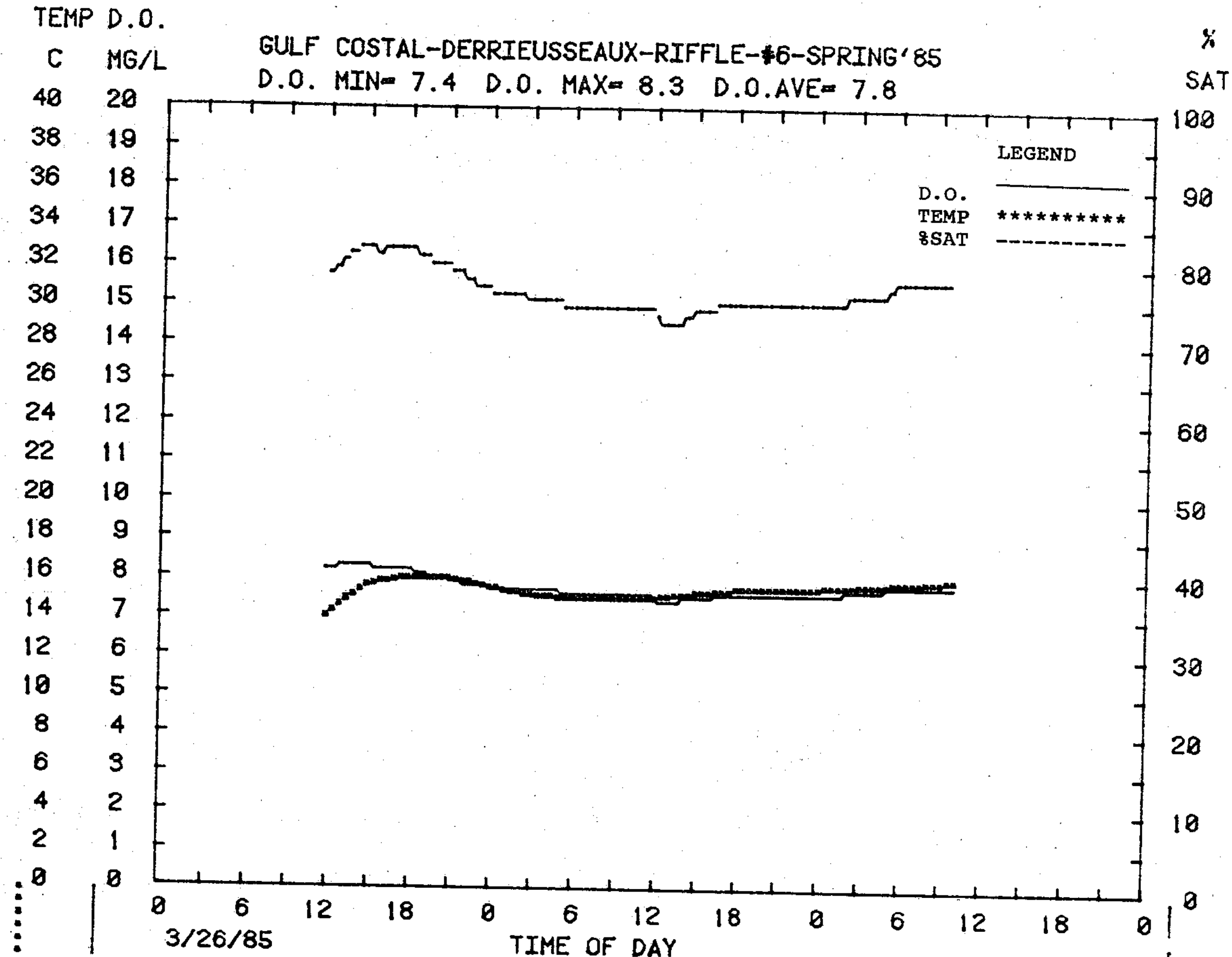


Fig. GC-12. Dissolved Oxygen Plot

Table GC-13

STREAM RECLASSIFICATION SURVEY

Chemical Results

Physiographic Region: Gulf Coastal Plain

Stream: Derrieusseaux Creek

Drainage Area: 148 Square Miles

Station Description: Timber company road in Section 5, T 9 S, R 11 W

Date: August 6, 1985

PARAMETER	TIME COLLECTED 09:40	10:40	11:45	AVERAGE
Q, cfs	0	0	0	No Flow
Temperature, °C	23	23	23	23
pH	6.7	6.7	6.7	6.7
Turbidity, ntu	7	8	6	7
TSS, mg/l	8	12	10	10
TDS, mg/l	66	64	67	65
BOD-5, mg/l	4.0	3.1	3.0	3.3
BOD-20, mg/l	9.3	7.8	7.2	8.1
T.Phos., mg/l	0.08	0.07	0.07	0.07
PO4-P, mg/l	0.03	0.04	0.03	0.03
NO2+NO3-N, mg/l	0.04	0.04	0.04	0.04
NH3-N, mg/l	0.07	0.06	0.06	0.06
Cl -, mg/l	5	4.5	3.5	4.3
SO4 =, mg/l	9	8	8	8
Fe, mg/l	0.25	0.5	0.2	0.31
Conductivity, μmho	83	83	84	83
Alkalinity, mg/l	-	-	-	-
T. Hardness, mg/l	36	36	42	38
Chlorophyll a, μg/l	18.7	14.6	9.4	14.2
Fecal Coliform	-	-	310	310

Dissolved Oxygen Data for 6 Aug 1985		
	Site 1	Site 2
Average	1.7	1.7
Minimum	1.5	0.9
Maximum	1.8	3.2

l) and total dissolved solids (65 mg/l). The total ss measurement was 38 mg/l, indicating "soft water." The :eristic dark brown water of the Gulf Coastal Region was 'ident at this site. This water coloration is thought ιυ be related to the specific soil types within the watershed and the leaching of tannins, lignins and perhaps iron from the leaf litter and soils. The test for fecal coliform bacteria indicated the presence of 310 colonies per 100 ml of water sampled. Since no known man-induced source of contamination is influencing this isolated pool on Derrieusseaux Creek, it is assumed that natural bacteria levels can at times exceed the primary contact standard.

Spring - The results of spring samples collected on March 27, 1985 are shown in Table GC-14. Water quality measured during the spring sampling was significantly different in some respects from the summer sample. Most significant was the volume of water or flow available. The stream was now actually a flowing stream instead of a series of enduring pools. This flow is felt to be the dominant reason for the observed changes. The pH was measured to be 5.8, again characteristic of the acidic soils found within the Gulf Coastal Region. BOD, both 5-day and 20-day, were approximately one-half the concentrations found during summer conditions. Chlorophyll $\bar{a}$ concentrations dropped to only trace amounts in the spring survey. Nutrient levels were extremely low and showed no significant change from the summer survey. Mineral concentrations were not significantly different with the exception of sulfates, which revealed slight increases with the higher flows. Fecal coliform bacteria concentrations were substantially lower during the spring survey compared to the summer concentrations, indicating little relationship to point or nonpoint pollution sources. Turbidity measurements were approximately three times higher than the summer measurements.

Physical Parameters

Physical evaluations were made during the week of August 6, 1985. Derrieusseaux Creek had reached a routine critical condition for the annual cycle. The stream had stopped flowing and the only water was found in the deeper enduring pools located in the streambed. All measurements were, by necessity, confined to these existing, pooled conditions. The immediate floodplains of these Gulf Coastal streams are typically very wide with numerous channels at higher flow conditions. Table GC-15 displays the results of the physical evaluation on Derrieusseaux Creek. Land use, topography, soil type, canopy and geology have been mentioned as directly affecting many of the chemical characteristics of the stream. Other characteristics of Derrieusseaux Creek which are also common to the region are sand banks, predominantly sand

Table GC-14

STREAM RECLASSIFICATION SURVEY

Chemical Results

Physiographic Region: Gulf Coastal Plain

Stream: Derrieusseaux Creek

Drainage Area: 148 Square Miles

Station Description: at end of tar road, NE 1/4, NE 1/4, Section 8, T 9 S, R 11 W, - Cleveland County

Date: March 27, 1985

PARAMETER	TIME COLLECTED			AVERAGE
	12:15	12:45	13:15	
Q, cfs	-	-	-	not taken
Temperature, °C	15	15	15	15
pH	6.0	5.5	5.8	5.8
Turbidity, ntu	30	24	25	26
TSS, mg/l	20	20	18	19
TDS, mg/l	70	71	67	69
BOD-5, mg/l	1.2	1.2	1.2	1.2
BOD-20, mg/l	3.2	3.2	3.2	3.2
T.Phos., mg/l	0.05	0.06	0.05	0.05
PO4-P, mg/l	0.04	0.04	0.04	0.04
NO2+NO3-N, mg/l	0.06	0.06	0.06	0.06
NH3-N, mg/l	0.03	0.03	0.03	0.03
Cl -, mg/l	3	3	5	4
SO4 =, mg/l	12	11	12	12
Fe -,mg/l	0.72	0.70	0.73	0.72
Conductivity,μmho	44	44	43	44
Alkalinity, mg/l	4	6	5	5
T. Hardness, mg/l	12	12	14	13
Chlorophyll a,μg/l	0.6	1.1	0.0	0.6
Fecal Coliform	-	-	80	80

Dissolved Oxygen Data for 27 Mar 1985		
	Pool	Riffle
Average	7.5	7.6
Minimum	7.4	7.4
Maximum	7.6	7.7

Table GC-15

STREAM RECLASSIFICATION SURVEY

Physical Results

Stream:	Derrieuseaux Creek
Date:	8/6/85
Drainage Area:	148 square miles
Watershed Land Use:	7% Agriculture 93% Forest
Stream Gradient:	3.4 fpm
Mean Channel Width:	50 feet
Mean Stream Width:	12 feet
Mean Stream Velocity:	NA
Observed Flow:	No Flow
Average Substrate Type:	4% Gravel 74% Sand 22% Mud/Silt
Mean Instream Cover:	2% Undercut Bank 41% Brush, Logs, Debris
Riffle/Pool Ratio of Transects:	60% Riffle 20% Deep Pool 20% Shallow Pool
Mean Bank Overstory Cover:	9% Trees 17% Shrubs
Mean Bank Ground Cover:	35% Grass and Forbes 65% Dirt
Mean Bank Stability:	30% Stable 40% Moderate 30% Unstable
Mean Stream Canopy:	88% Canopy
Comments:	

substrate, low stream gradient, and a high percentage of instream fishery cover (brush, logs, debris).

Due to the difficulty of making any physical measurements during the higher flows of spring, none were made.

Macroinvertebrate Populations

Eighty (80) taxa representing 18 orders were identified from the summer-spring benthic samples collected from Derrieusseaux Creek. The dominant orders, Coleoptera, Decapoda, Ephemeroptera, Isopoda and Hemiptera comprised 22.9%, 18.1%, 9.2%, 8.1% and 8.0% of the sample, respectively. The dominant taxa were Palaemonetes kadiakensis (15.0%), Lirceus hoppinae (8.1%), Uvarus (7.9%), Caenis (7.7%) and Sialis (7.3%). Other taxa considered as ecologically characteristic but not collected in significant numbers include Chauloides, Gammarus minus, and Peltodytes lengi (Table A-7, Appendix A). The qualitative comparative indices indicated some repetition of taxa between the samples (Table GC-16). Of the 80 taxa identified from the two samples, 29 were identified in both and these accounted for 75% of all organisms collected. There were 34 and 17 taxa unique to the summer and spring samples, comprising 33% and 16% of those samples, respectively. This reflects the natural seasonal variation of insect populations.

Summer - The dominant orders of the summer sample were Coleoptera (26.0%), Megaloptera (14.1%), Diptera (11.8%), Hemiptera (10.8%) and Ephemeroptera (8.8%). The dominant taxa of the summer benthic community were Sialis (14.1%), Celina (12.0%), Hespacorixia (6.8%), Caenis (6.5%) and Musculuim (6.1%)

Spring - The dominant orders of the spring sample were Decapoda (30.3%), Coleoptera (20.0%), Isopoda (14.0%), Ephemeroptera (9.5%) and Amphipoda (9.4%). The dominant taxa were Palaemonetes kadiakensis (25.4%), Lirceus hoppinae (14.0%), Uvarus (11.7%), Gammarus minus (8.9%) and Caenis (8.8%) (Table A-7, Appendix A). Although not in the same order of abundance, the summer and spring samples were dominated by 3 of the same orders, but only had one of the top 5 dominant taxa in common.

The community parameters of the combined samples indicate that the good water quality and the availability of diverse microhabitats has resulted in a healthy, well-balanced macroinvertebrate community. This was confirmed by the percentage distributions among the functional groups of insects and reflected the stability of the benthic community.

Table GC-16. Community Analysis of Benthic Samples from Derrieusseaux Creek - 30 Min. Qualitative Sample, 1984-1985

COMMUNITY PARAMETERS	Summer	Spring	Combined
Total # Organisms	801	1584	2385
Total # Taxa	63	46	80
Diversity	4.6516	3.5343	4.6401
Index of Evenness	0.8121	0.6398	0.7339
Index of Dominance	0.4458	0.6295	0.5108
Index of Variety	5.6015	4.6732	7.4234
COMPARATIVE INDICES			
Dice Index (range 0-1)		0.61	
Common Taxa Index (range 0-1)		0.46	
Qualitative Similarity Index (range 0-100)		33.0	

Fish Populations

Summer - The stream at this site contained only isolated pools with no surface flows between them. The area sampled was a large deep pool approximately 150 feet long and 30 feet wide with a maximum depth of about 10 feet. Additionally, a small, shallow, gravel-bottomed pool (40' X 5' X 6") upstream of the larger pool was sampled. Both areas were treated with 5% rotenone on August 7, 1985, and workers spent about 18 man-hours picking up fish from the sample area.

A total of 36 species of fish were collected from the area (Table GC-17). This included 760 individuals with a relative abundance value of 224 and a diversity index of 4.97. Centrarchidae was the dominant family and included nine species and one hybrid (Table GC-18). Six species of Percidae made up 14.5% of the population relative abundance. Many of these came from the small shallow gravel-bottom pool which had no carnivorous fish species. Macroinvertebrate feeding fishes comprised 79.9% of the population. Primary feeders and carnivores made up about equal portions of the remainder of the population. Only four sensitive species were collected, which totalled 7.8% of the population relative abundance.

Spring - Spring sampling at this site was done on March 26-27, 1985. Three 100-foot length trammel nets with square mesh size of 1½", 2" and 3½" were fished overnight. The streamflow was approximately 200 cfs and water temperature was 15°C. Only seven fishes with a total weight of 10.5 pounds were caught. Examination of the gonads of the captured fish indicated that bowfin had completed spawning, spotted suckers had partially completed spawning with some spawning in progress, and blacktail redhorse were in the early stages of spawning.

Table GC-17. Fishes Collected from Derrieusseaux Creek with Relative Abundance Values

Species		R.A. VALUE
Lepomis gulosus	Warmouth	12.0
Centrarchus macropterus	Flier	12.0
Ictalurus natalis	Yellow bullhead	12.0
Minytrema melanops	Spotted sucker	11.0
Lepomis megalotis	Longear	10.5
Etheostoma gracile	Slough darter	10.0
Aphredoderus sayanus	Pirate perch	9.0
Fundulus olivaceus	Blackspotted topminnow	9.0
Notropis umbratilis	Redfin shiner	9.0
Esox americanus	Grass pickerel	9.0
Notemigonus crysoleucas	Golden shiner	8.0
Lepomis macrochirus	Bluegill	7.5
Hybognathus nuchalus	Silvery minnow	7.0
**Moxostoma poecilurum*	Blacktail redhorse	7.0
Gambusia affinis	Mosquitofish	6.5
Amia calva	Bowfin	6.0
Etheostoma chlorosomum	Bluntnose darter	6.0
Hybognathus hayi	Cypress minnow	6.0
Etheostoma whipplei	Redfin darter	6.0
Notropis fumeus	Ribbon shiner	6.0
**Percina maculata*	Blackside darter	5.5
Erimyzon oblongus	Creek chubsucker	5.0
Lepomis cyanellus	Green sunfish	5.0
Lepomis punctatus	Spotted sunfish	5.0
Elassoma zonatum	Banded pygmy sunfish	4.0
Micropterus salmoides	Largemouth bass	4.0
Notropis texanus	Weed shiner	4.0
Esox niger	Chain pickerel	4.0
Noturus gyrinus	Tadpole madtom	4.0
**Percina sciera*	Dusky darter	4.0
Notropis emiliae	Pugnose minnow	3.0
Labidesthes sicculus	Brook silversides	2.0
Notropis chrysocephalus	Striped shiner	2.0
**Etheostoma collettei*	Creole darter	1.0
Pomoxis nigromaculatus	Black crappie	1.0
Lepomis hybrid	Hybrid sunfish	1.0

* - Sensitive species
S - collected in spring sample only

Table GC-18. Summary of Fish Population Parameters from Derrieusseaux Creek

Total Species Collected	36.0
Total Number of Individuals	760.0
Total Relative Abundance Value	224.0
Relative Abundance Diversity Index	4.97

Population Parameters	No. Sp.	% R.A.V.
CYPRINIDAE	8.0	20.1
CATOSTOMIDAE	3.0	10.3
ICTALURIDAE	2.0	7.1
CENTRARCHIDAE	10.0	27.7
PERCIDAE	6.0	14.5
Primary Feeders	3.0	10.7
Macroinvertebrate Feeders	28.0	79.9
Carnivores	5.0	9.4
Sensitive Species	4.0	7.8

BAYOU FREEO

Bayou Freeo begins in the southeast part of Dallas County and flows in a southerly direction into the northeast portion of Ouachita County, continuing a southwesterly flow to its confluence with the Ouachita River. The sample site for Bayou Freeo was located at a TAR road approximately two miles downstream of Highway 9. The specific site location was in the SW ¼, SW ¼ of Section 34, R 16 W, T 11 S (Figure GC-13).

General Site Discussion

Watershed Size - The watershed size of the Bayou Freeo drainage above the sample site is 156 mi^2.

Geology - Surface geology of the Bayou Freeo drainage is basically of three types. The headwater area is predominantly Claiborne Group deposits of Eocene Age, the lower drainage is terrace deposits of Pleistocene age. The immediate streambed and floodplain are composed of alluvium deposits of Quaternary Age.

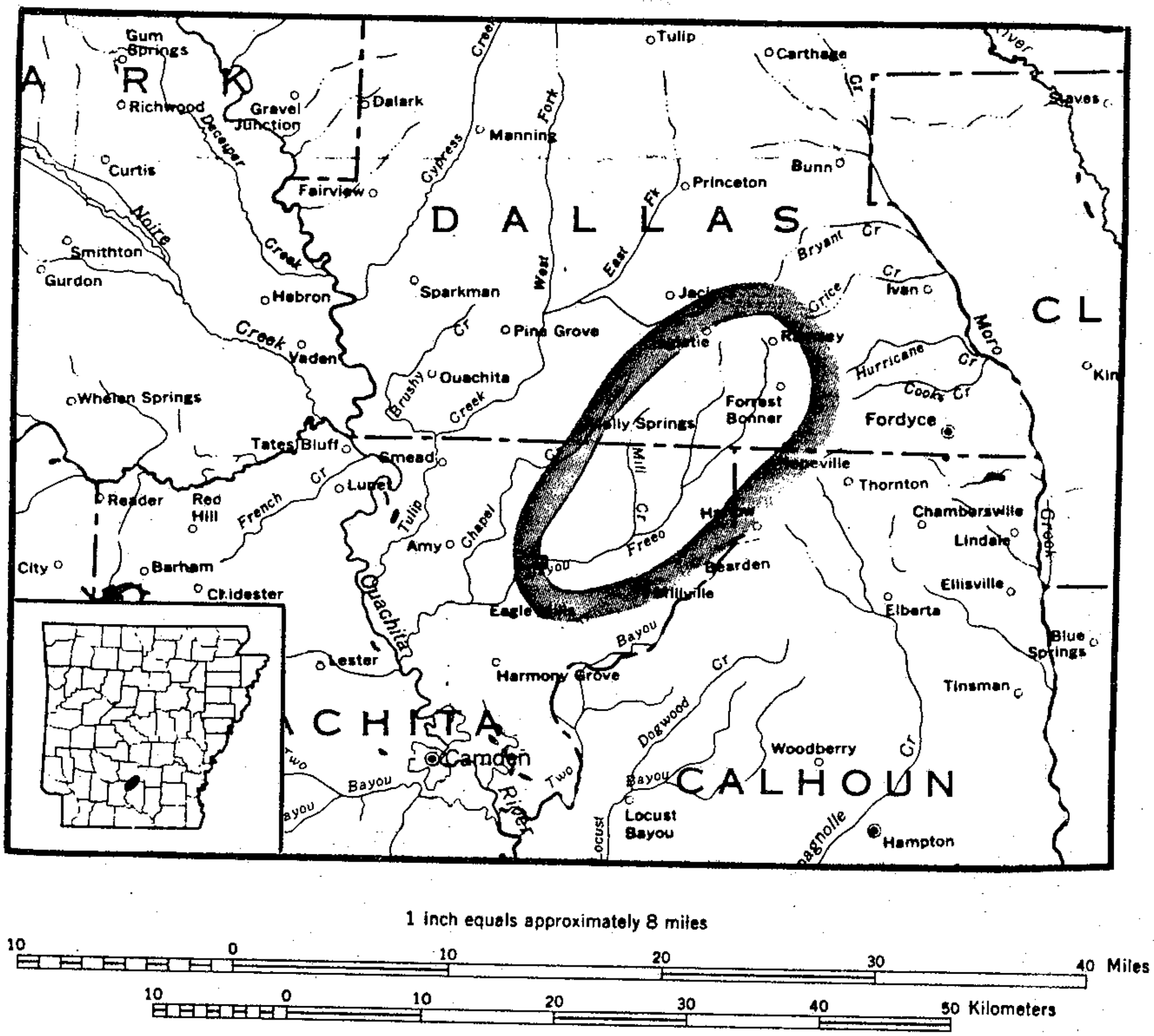
Topography - Topography within the watershed is generally level to gently rolling sand hills with broad streamside wetland areas directly adjacent to the creek.

Soil Types - The extreme fingertips of the headwater area drain a Sacul-Sawyer-Smithdale association, which is a moderately well-drained and well-drained, nearly level to moderately steep, loamy soil on uplands. The majority of the upper watershed drains the Amy-Smithton-Pheba association which is a poorly drained and somewhat poorly drained, level to nearly level, loamy soil on uplands. The mid-section of the watershed from the Ouachita-Dallas County line to the sample site drains a Norfolk-Canaba-Saffell association which is a well-drained, nearly level to moderately sloping, loamy and gravelly soil on gently rolling uplands.

Flora - Loblolly pine, shortleaf pine and sweetgum dominate the forestland in the upland areas of the basin. The lower areas are dominated by oak, hickory, beech and cypress.

Stream Characteristics - The 1983 USGS stream flow map shows Bayou Freeo to have a Q_{7-10} of zero. During the average year, flow normally drops to zero and an enduring pool situation occurs in typical Gulf Coastal streams. Conditions during the survey on Bayou Freeo were typical of this situation. Significant physical characteristics include the deeply cut stream channel with sandy banks, sandy to gravelly substrate, low stream gradient, high percentage of instream fishery cover (brush, logs and debris) and high percentage of stream canopy.

Figure GC-13



FREEO BAYOU: Drainage area 156 square miles ■ Survey site ▒ Survey area

Methodology and Sampling Results

The summer stream survey was conducted during the week of August 12-16, 1985; the spring survey was conducted during the week of March 31 - April 4, 1986.

Continuous Dissolved Oxygen

Summer - A continuously recording meter was set to monitor the dissolved oxyen and temperature of Bayou Freeo during this week in August. The meter site was located just slightly upstream of the concrete low water bridge on the first TAR downstream below Highway 9. The meter was checked daily and functioned properly with only minor calibration adjustments. Results of the dissolved oxygen and temperature measurements made during the week are displayed in Figure GC-14. This graph shows a range from 0.9 mg/l to 3.6 mg/l, averaging 1.8 mg/l over the survey period. The graph appears contrary to normal photosynthetic activity. The dissolved oxygen reached a critical minimum about 2100 hours, remaining at that concentration until about midnight. It rapidly increased to a maximum around 0300 hours, remained at this level until 0600 hours then declined until noon, stabilized slightly and gradually declined to the critical 2100 hours again. D.O. saturations ranged from 10-40% during the survey period.

Spring - On March 31, 1986, two meters were set up to measure the dissolved oxygen and temperature in Bayou Freeo. Site #1 was approximately 20 yards upstream of the low water bridge and Site #2 was approximately 50 yards below the low water bridge. Unlike the pooled-up situation of summer, Bayou Freeo was now flowing at 16 cfs. The staff gauge set up for the survey period indicated that the flow was falling slightly during this time. Figures GC-15 and GC-16 display the dissolved oxygen, temperature and percent saturation for both sites during the survey period. Similar results were recorded at both sites. Contrary to the summer season sampling, these results show the effects of increaseed flow and cooler water temperatures. Percent saturations range much higher, averaging near 70%. The actual graphs for dissolved oxygen show a very stable condition, averaging approximately 7 mg/l.

Chemical Parameters

Summer - Chemical data collected during the summer sampling period in Bayou Freeo are displayed in Table GC-19. Typical of the Gulf Coastal Region, the nutrient levels are quite low. Measurements of chlorophyll $\bar{a}$ indicate insignificant amounts of phytoplankton in Bayou Freeo. Mineral quality measured in Bayou Freeo reveals very low levels of sulfates (8 mg/l), chlorides (4.5 mg/l) and total dissolved solids (69 mg/l). Measurements of biological oxygen demand were slightly high; the BOD_5 was 2.2 mg/l and the BOD_{20} was 5.6 mg/l. Though the water was relatively clear (turbidity=12 NTUs), the characteristic dark brown or coffee color was prominent. This

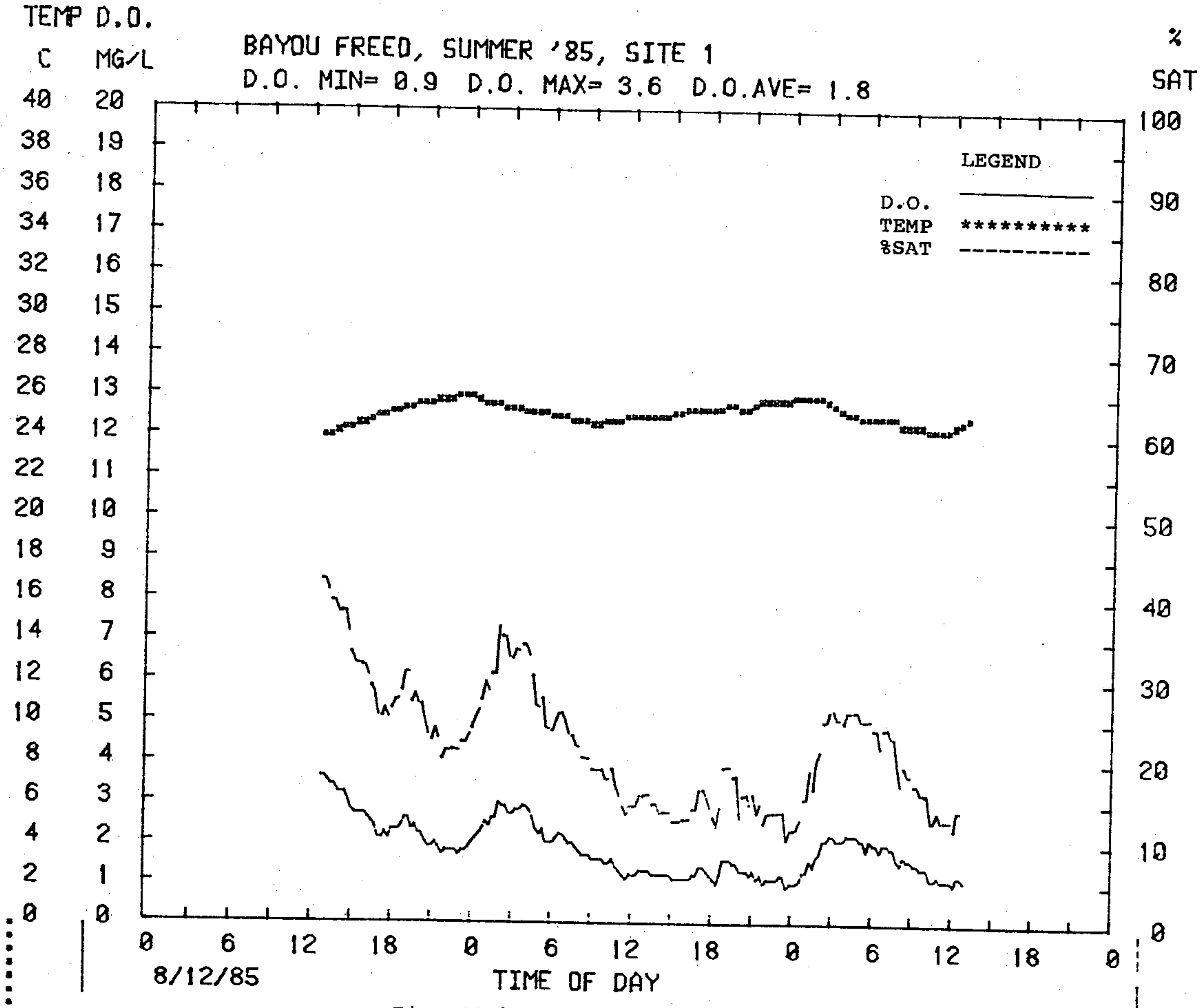


Fig. GC-14. Dissolved Oxygen Plot

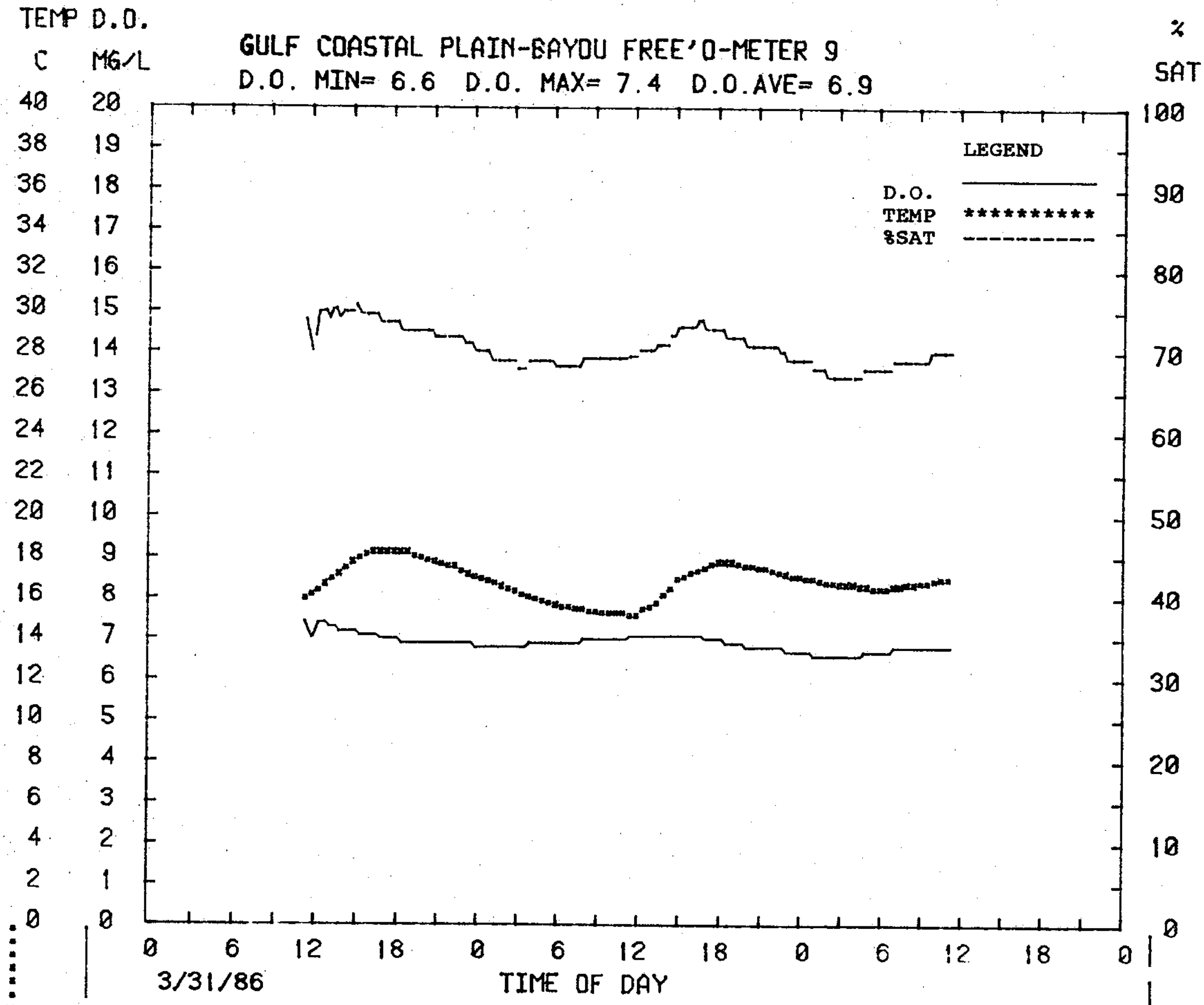


Fig. GC-15. Dissolved Oxygen Plot

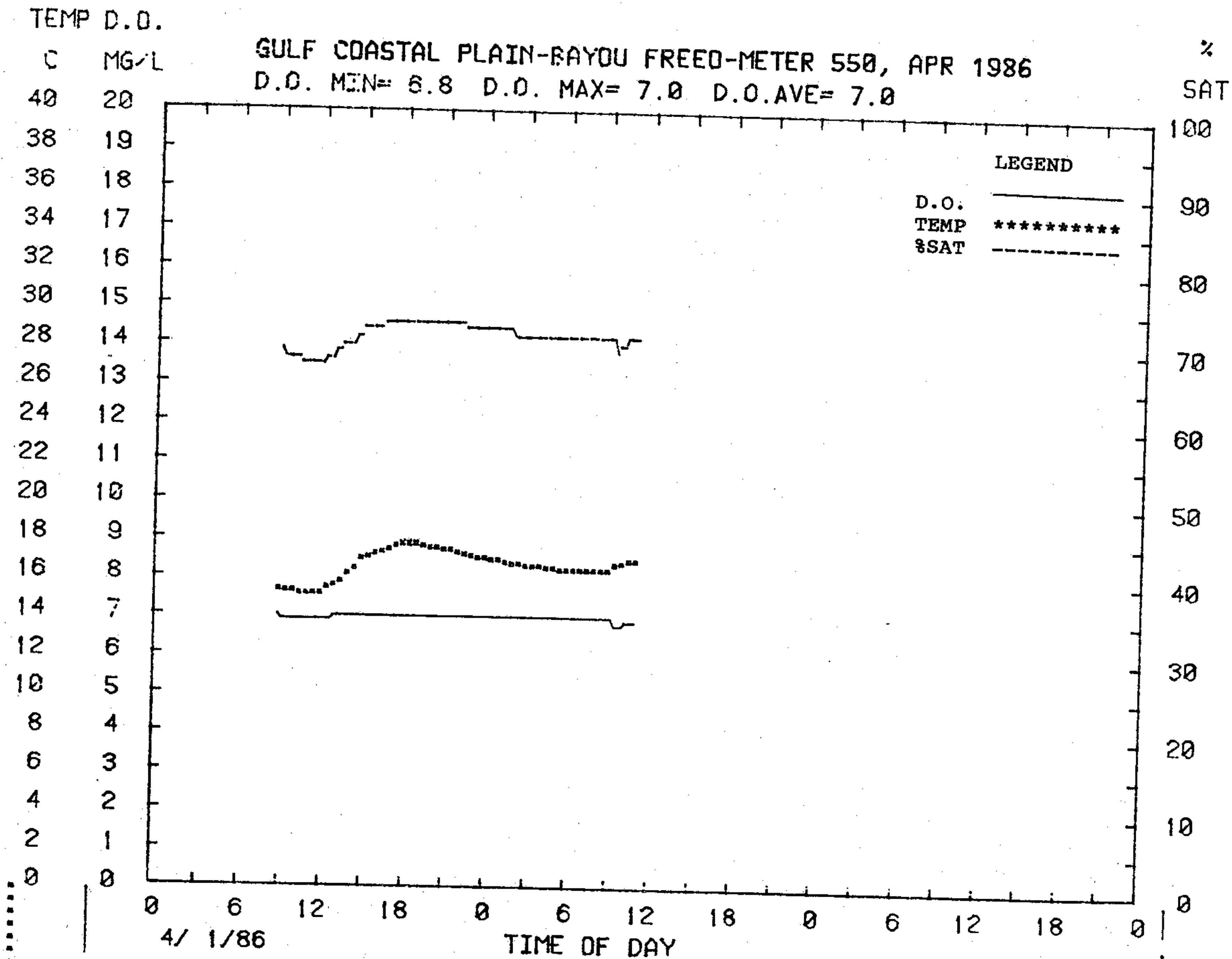


Fig. GC-16. Dissolved Oxygen Plot

Table GC-19

STREAM RECLASSIFICATION SURVEY

Chemical Results

Physiographic Region: Gulf Coastal Plain

Stream: Bayou Freeo

Drainage Area: 156 Square Miles

Station Description: Timber road in Section 34, T 11 S, R 16 W, Ouachita County

Date: August 13, 1985

PARAMETER	TIME COLLECTED 09:30	10:00	10:30	AVERAGE
Q, cfs	0	0	0	No Flow
Temperature, °C	25	25	25	25
pH	7.0	7.0	7.0	7.0
Turbidity, ntu	12	14	12	12
TSS, mg/l	12	10	9	10
TDS, mg/l	71	72	65	69
BOD-5, mg/l	2.3	2.1	2.4	2.2
BOD-20, mg/l	5.7	5.4	5.7	5.6
T.Phos., mg/l	0.12	0.09	0.09	0.10
PO4-P, mg/l	0.06	0.06	0.06	0.06
NO2+NO3-N, mg/l	0.07	0.06	0.07	0.07
NH3-N, mg/l	0.07	0.07	0.07	0.07
Cl -, mg/l	4	4.5	4.5	4.5
SO4 =, mg/l	8	8	8	8
Fe, mg/l	0.12	0.12	0.11	0.12
Conductivity,µmho	63	65	66	65
Alkalinity, mg/l	27	28	26	27
T. Hardness, mg/l	20	26	32	26
Chlorophyll a,µg/l	2.2	1.4	void	1.8
Fecal Coliform	-	-	52	52

Dissolved Oxygen Data for 13 Aug 1986		
	Site 1	
Average	1.2	
Minimum	0.9	
Maximum	3.0	

characteristic is thought to be related to the specific soil type within the watershed and the leaching of tannins, lignins and perhaps iron from the soils. The test for fecal coliform bacteria indicated a low level of coliform organisms present in Bayou Freeo.

Spring - Results of the spring samples collected on April 1, 1986, are shown in Table GC-20. The most significant condition of the spring survey was that the stream was now actually a flowing stream instead of a series of enduring pools as found during the summer sampling period. The pH measurement was slightly more acidic during the spring sampling period. The BODs, both 5-day and 20-day, were slightly less than the summer measurements. Chlorophyll $\bar{a}$ was present in only trace amounts during the spring season. Nutrient levels were very low in this sampling period. Sulfates, chlorides and total dissolved solids increased slightly with the higher flows, although not significantly. In contrast to the minerals, conductivity, alkalinity and total hardness decreased during the spring period. Fecal coliform measurements showed no significant change from the summer sampling and both spring and summer samples met the primary contact standard. The turbidity measurement was one-half that measured during the summer and both measurements were well within the water quality standard.

Physical Parameters

Physical evaluations were made during the week of August 12, 1985. Bayou Freeo had reached a routine critical condition for the annual cycle. The stream had essentially stopped flowing and formed standing water or enduring pools within the immediate streambed. The immediate floodplain of Bayou Freeo is flat with numerous side channels and sloughs which would contain water during higher flow conditions. Table GC-21 displays the results of the physical evaluation on Bayou Freeo. Land use, topography, soil types, geology, etc., have all been mentioned as directly affecting many of the chemical characteristics of the stream. Characteristics of Bayou Freeo which are also common to the region are: low stream gradient, high percentage of instream fishery cover (brush, logs and debris), and moderate canopy covering the stream.

Macroinvertebrate Populations

Sixty-eight (68) taxa representing 17 orders were identified from the summer and spring benthic communities (Table A-8, Appendix A). Numerically, the dominant orders were Decapoda (15%), Amphipoda (14%), Coleoptera (10%) and Ephemeroptera and Odonata (9%). The taxonomic distribution was uniformly distributed among several groups. The dominant taxa were *Hyalella azteca* and Cambarinae (7%), *Gammarus fasciatus* and *Palaemonetes kadiakensis* (6%) and *Sialis* (5%). Other taxa, not numerically dominant but considered ecologically characteristic of Bayou Freeo, include *Caenis*, *Libellula*

Table GC-20

STREAM RECLASSIFICATION SURVEY

Chemical Results

Physiographic Region: Gulf Coastal Plain

Stream: Bayou Freeo

Drainage Area: 156 square miles

Station Description: Timber road, Section 34, T 11 S, R 16 W, Ouachita County

Date: April 1, 1986

PARAMETER	TIME COLLECTED 09:20	10:27	11:00	AVERAGE
Q, cfs	16	16	16	16
Temperature, °C	17	17	17	17
pH	6.63	6.58	6.57	6.6
Turbidity, ntu	6	6	6	6
TSS, mg/l	6	6	6	6
TDS, mg/l	76	75	77	76
BOD-5, mg/l	1.3	1.4	1.2	1.3
BOD-20, mg/l	4.0	4.2	4.1	4.1
T.Phos., mg/l	-	-	-	-
PO4-P, mg/l	0.01	0.01	0.01	0.01
NO2+NO3-N, mg/l	0.01	0.07	0.01	0.03
NH3-N, mg/l	0.03	0.04	0.02	0.03
Cl -, mg/l	8	8.5	7.5	8
SO4 =, mg/l	10	8	8	9
Fe, mg/l	1.6	1.6	1.6	1.6*
Conductivity, μmho	58	58	56	57
Alkalinity, mg/l	13	11	9	11
T. Hardness, mg/l	16	16	18	17
Chlorophyll a, μg/l	-	-	0.65	0.65*
Fecal Coliform	-	-	48	48*

Dissolved Oxygen Data for 1 Apr 1986	Meter 550	Meter 9**
Average	7.0	6.9
Minimum	6.8	6.7
Maximum	7.0	7.1

*These data were collected 27 May 1986.
**Meter 550 data is a composite of Apr 1 and 2 data.

Table GC-21

STREAM RECLASSIFICATION SURVEY

Physical Results

Stream:	Bayou Freeo
Date:	8/12/85
Drainage Area:	156 square miles
Watershed Land Use:	7% agriculture 91% forest
Stream Gradient:	3.0 ft/mi
Mean Channel Width:	47 feet
Mean Stream Width:	26 feet
Mean Stream Velocity:	N/A
Observed Flow:	No Flow
Average Substrate Type:	36% gravel 64% sand
Mean Instream Cover:	74% brush, logs, debris
Riffle/Pool Ratio of Transects:	100% shallow pool
Mean Bank Overstory Cover:	100% trees 5% shrubs
Mean Bank Ground Cover:	44% grass and forbs 56% dirt
Mean Bank Stability:	90% moderate 10% unstable
Mean Stream Canopy:	100% stream canopy
Comments:	

auripennis, Ranatra buenoi and Uvarus. The summer and spring samples were distinctly more similar than dissimilar. Of the 68 taxa identified from the combined samples, 43 and 55 taxa were identified from the summer and spring samples, respectively. The 30 taxa present in both samples accounted for 71% of all organisms collected. The 13 and 25 taxa unique to the summer and spring samples comprised 19.2% and 33% of their respective samples.

Summer - Numerically, the dominant orders of the summer benthic community were Ephemeroptera (19%), Odonata (17%), Decapoda (15%), Hemiptera (12%) and Coleoptera (10%). The summer benthic community lacked a clear numerically dominant taxonomic assemblage. No taxa comprised greater than 10% of the organisms, but 8 taxa were present in quantities greater than 5% (Table A-8, Appendix A). Ecologically characteristic taxa of the summer benthic community were Caenis, Libellula auripennis, Palaemonetes kadiakensis and Sialis.

Spring - The dominant orders of the spring benthic community were Amphipoda (19%), Decapoda (15%) and Coleoptera (10%). The dominant taxa were Hyalella azteca (10.7%) and Cambarinae and Gammarus fasciatus (8.6%). Other taxa, not numerically dominant but considered as ecologically characteristic of the spring benthic community, include Isoperla mohri, Perlesta placida, Palaemonetes kadiakensis and Sialis.

The diversity index of the combined summer-spring sample was well above 5 and would tend to indicate very good water quality (Table GC-22). However, the average summer D.O. was 2.3 mg/l with no measurable flow. Bayou Freeo is a prime example of the ability of insect populations to adjust to natural adverse water conditions when sufficient habitats and adequate perennial water are available. The presence of numerous species found in high quality water is indicative of the ability of benthic populations to recover when conditions improve, even seasonally.

Table GC-22. Community Analysis of Benthic Samples from Bayou Freeo - 30 minute Qualitative Samples, 1984-1985

COMMUNITY PARAMETERS	Summer	Spring	Combined
Total # Organisms	302	653	955
Total # Taxa	43	55	68
Diversity	4.7845	4.9125	5.2423
Index of Evenness	0.4325	0.4529	0.4353
Index of Dominance	0.8817	0.8497	0.8612
Index of Variety	5.0981	5.7748	6.7817
COMPARATIVE INDICES			
Dice Index (range 0-1)		0.61	
Common Taxa Index (range 0-1)		0.31	
Qualitative Similarity Index (range 0-100)		40.0	

Fish Populations

Summer - This site was sampled with approximately 3 pounds of 5% active rotenone on August 8, 1985. The sample area was about 250 feet long, with an average width of 30 feet and an average depth of 2 feet. There was a very slight but almost unmeasurable flow. The water was brownish in color with a silver scum. Ten man-hours were used to pick up fish killed by the rotenone.

Thirty-two species of fish from a total of 470 specimens were taken at this site. The total relative abundance value was 176 with a diversity index of 4.72. A list of all species collected and their relative abundance value is given in Table GC-23. Both Centrarchidae and Percidae made up 26.1% of the total relative abundance value of the population. This included one hybrid, 8 species of sunfishes and 8 species of darters (Table GC-24). No primary feeding fishes were collected in this sample and over 93% of the population were macroinvertebrate feeders. Five sensitive species representing 15.3% of the population were also taken.

Spring - Three trammel nets were fished overnight at this site on March 31, 1986. Mesh sizes of the nets were 1½", 2" and 2¼" square. The water level was very low from the lack of early springtime rains. Water temperature was 17°C, and visibility into the water was about 12 inches. Only two spotted suckers were caught. One had completed spawning and the other was in the spawning process.

Table GC-23. Fishes Collected from Bayou Freeo with Relative Abundance Values

Species		R.A. VALUE
Aphredoderus sayanus	Pirate perch	12.0
Fundulus olivaceus	Blackspotted topminnow	10.5
Notropis umbratilis	Redfin shiner	10.5
Lepomis megalotis	Longear	10.0
Noturus gyrinus	Tadpole madtom	9.0
*Etheostoma collettei	Creole darter	9.0
Lepomis punctatus	Spotted sunfish	9.0
Esox americanus	Grass pickerel	9.0
*Percina maculata	Blackside darter	8.0
Gambusia affinis	Mosquitofish	7.5
Etheostoma whipplei	Redfin darter	7.0
Lepomis gulosus	Warmouth	7.0
*Percina sciera	Dusky darter	7.0
Centrarchus macropterus	Flier	6.0
Etheostoma proeliare	Cypress darter	6.0
Ictalurus natalis	Yellow bullhead	6.0
Etheostoma chlorosomum	Bluntnose darter	6.0
Erimyzon oblongus	Creek chubsucker	5.0

Table GC-23, cont.

Notropis atherinoides	Emerald shiner	4.5
Elassoma zonatum	Banded pygmy sunfish	4.0
Lepomis cyanellus	Green sunfish	4.0
Lepomis macrochirus	Bluegill	3.0
Minytrema melanops	Spotted sucker	3.0
Etheostoma gracile	Slough darter	2.0
**Moxostoma poecilurum*	Blacktail redhorse	2.0
Notropis emiliae	Pugnose minnow	2.0
Micropterus salmoides	Largemouth bass	2.0
Amia calva	Bowfin	1.0
Labidesthes sicculus	Brook silversides	1.0
Lepomis hybrid	Hybrid sunfish	1.0
**Etheostoma parvipinne*	Goldstripe darter	1.0
Notropis chrysocephalus	Striped shiner	1.0

* - Sensitive species

Table GC-24. Summary of Fish Population Parameters from Bayou Freeo

Total Species Collected	32.0
Total Number of Individuals	470.0
Total Relative Abundance Value	176.0
Relative Abundance Diversity Index	4.72

Population Parameters	No. Sp.	% R.A.V.
CYPRINIDAE	4.0	10.2
CATOSTOMIDAE	4.0	5.7
ICTALURIDAE	2.0	8.5
CENTRARCHIDAE	9.0	26.1
PERCIDAE	8.0	26.1
Primary Feeders	0.0	0.0
Macroinvertebrate Feeders	29.0	93.2
Carnivores	3.0	6.8
Sensitive Species	5.0	15.3

HUDGIN CREEK

Hudgin Creek begins in the south central part of Jefferson County and flows in a southerly direction along the eastern edge of Cleveland County, cuts across the southwest corner of Lincoln County into the northwest part of Drew County and continues a southerly flow to its confluence with the Saline River in Bradley County. The sample site for Hudgin Creek was located at the Highway 35 bridge in the SE¼, NW¼ of Section 29, R 8 W, T 11 S (Figure GC-17).

General Site Discussion

Watershed Size - The watershed size of Hudgin Creek above the highway bridge is 187 mi^2.

Geology - Surface geology in the Hudgin Creek drainage is basically of two types. The headwater area is predominantly terrace deposits of Quaternary age and the lower drainage is predominantly deposits from the Jackson Group of Eocene age. The immediate streambed and floodplain are recent alluvium deposits.

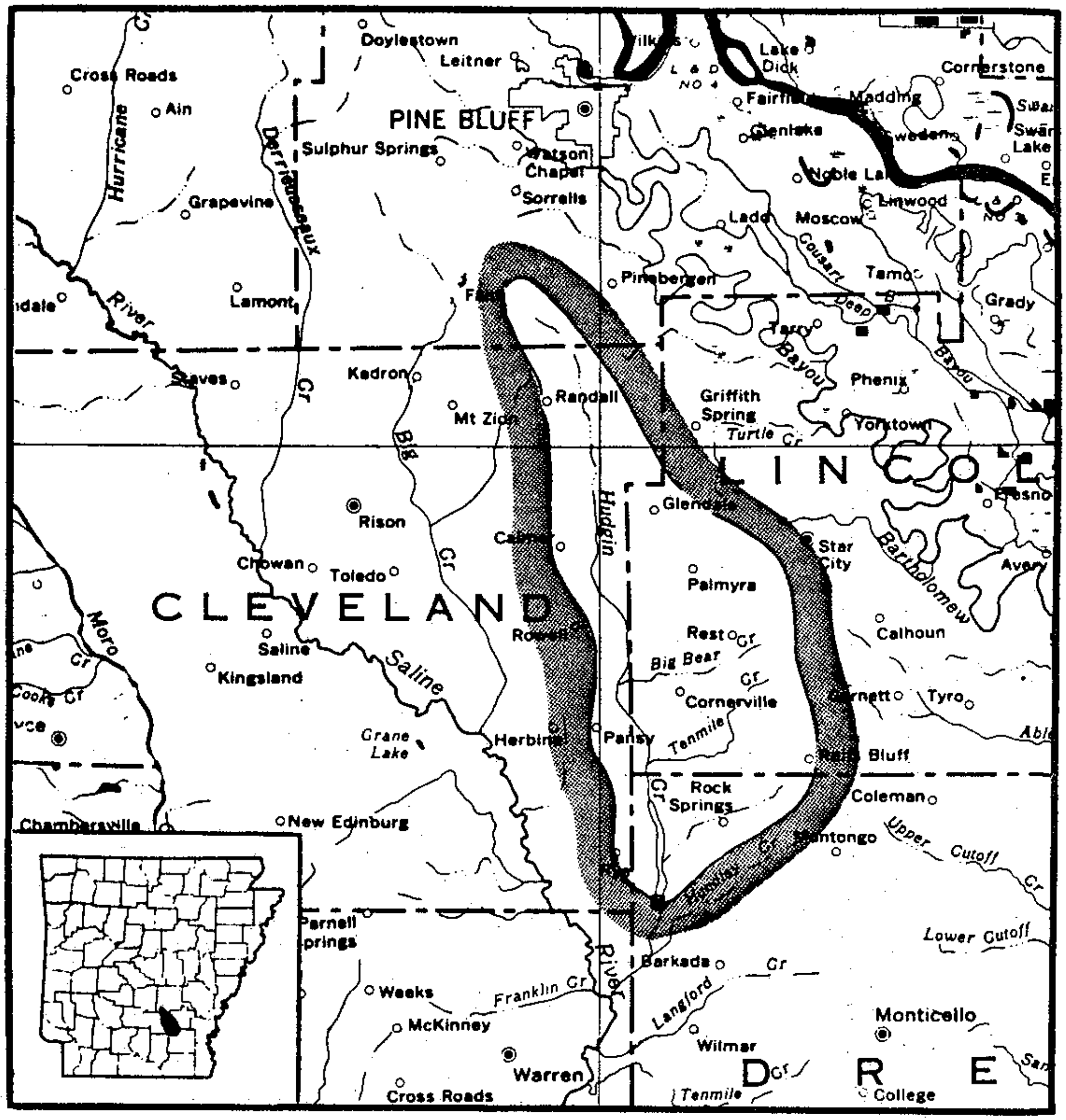
Topography - Topography within the watershed is generally level to gently rolling sand hills with broad streamside wetland areas directly adjacent to the creek.

Soil Types - The upper watershed of Hudgin Creek is in an area that is dominated by the Wehadkee-Ochlockonee-Colins and Tippah-Pheba-Boswell associations. The predominant soil association is the Tippah-Pheba-Boswell. This association consists of nearly level to moderately steep, moderately well-drained and somewhat poorly drained soils that have a loamy or clayey subsoil, found on upland areas. The Wehadkee-Ochlockonee-Collins association is nearly level, poorly drained to well-drained, frequently flooded soil predominantly found in bottomlands. The lower watershed of Hudgin Creek is composed of two additional soil associations, the Amy-Ouachita and the Tippah-Sacul-Amy. The Amy-Ouachita association is poorly drained to well-drained, level, loamy soils on floodplains of local streams. The Tippah-Sacul-Amy association is moderately well-drained and poorly drained, level to moderately sloping, loamy soils on uplands.

Flora - Loblolly pine and sweetgum trees dominate the forest in the upland areas of the basin. Low overflow wetland areas are dominated by oak, hickory, beech and cypress trees.

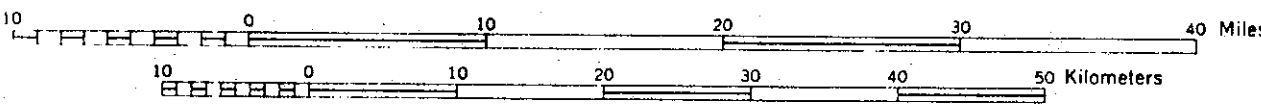
Land Use - Land use within the watershed is 75% forest and 25% agriculture, according to the Soil Conservation Service. The predominant agricultural use is pastureland. Overall, the watershed has a low level of man-induced disturbance and qualifies as least-impaired for this region.

Figure GC-17



Scale 1:500,000

1 inch equals approximately 8 miles



HUDGIN CREEK: Drainage area 187 square miles ■ Survey site ▒ Survey area

Stream Characteristics - The 1983 USGS stream flow map shows Hudgin Creek to have a Q_{7-10} of zero. During the average year, flow normally drops to zero and an enduring pool situation occurs in typical Gulf Coastal streams. Conditions during the survey on Hudgin Creek were typical of the enduring pool situation. Significant physical characteristics include the deeply cut stream channel with sandy banks, sandy substrate, low stream gradient, high percentage of instream cover (brush, logs and debris) and high percentage of stream canopy.

Methodology and Sampling Results

The summer stream survey was conducted during the week of August 5-9, 1985; the spring survey was conducted during the week of March 25-29, 1985.

Continuous Dissolved Oxygen

Summer - Three continuously recording meters were set up to monitor the dissolved oxygen and temperature throughout the week. These meters were set up shortly after noon on August 5, 1985. Site #1 was located approximately 75 yards downstream of the Highway 35 bridge, Site #2 was 30 yards upstream of the bridge and Site #3 was 75 yards upstream of the bridge. On the evening of August 7, 1985, Meter #550 located at Site #3 malfunctioned and was terminated. The two remaining meters worked satisfactorily for the entire survey. Due to the lack of flow in Hudgin Creek, both meters were measuring the dissolved oxygen and temperature of the pooled creek. Both meters were checked daily for calibration.

Results obtained during the summer survey are displayed in (Figures GC-18 and GC-19). Each graph displays the D.O., temperature and D.O. saturation for each meter for the survey period. No clear explanation can be offered for the apparent difference in the two graphic recordings. Site #1 recording shows a fairly stable dissolved oxygen graph with a range from 1.7 mg/l to 3.3 mg/l, averaging 2.3 mg/l over the survey period. Site #2 displays substantially more fluctuation with a range of 0.5 mg/l to 3.6 mg/l, averaging 1.6 mg/l over the survey period. The dissolved oxygen peaks appear contrary to normal photosynthetic activity in that they occur at or near midnight. Summertime D.O. saturations ranged from 10-40% during the survey period.

Spring - On March 26, 1985, two meters were set up to measure the dissolved oxygen and temperature in Hudgin Creek. Site #1 was located approximately 100 yards downstream of Highway 35 bridge and Site #2 was approximately 100 yards upstream of the bridge. Unlike the pooled conditions of summer, Hudgin Creek was now flowing. The staff gauge set up for the survey indicated that the creek fell 1.32' from March 26th to March 27th and then rose 1.12' on March 28th. Figures GC-20 and GC-21 display the dissolved oxygen, temperature and percent

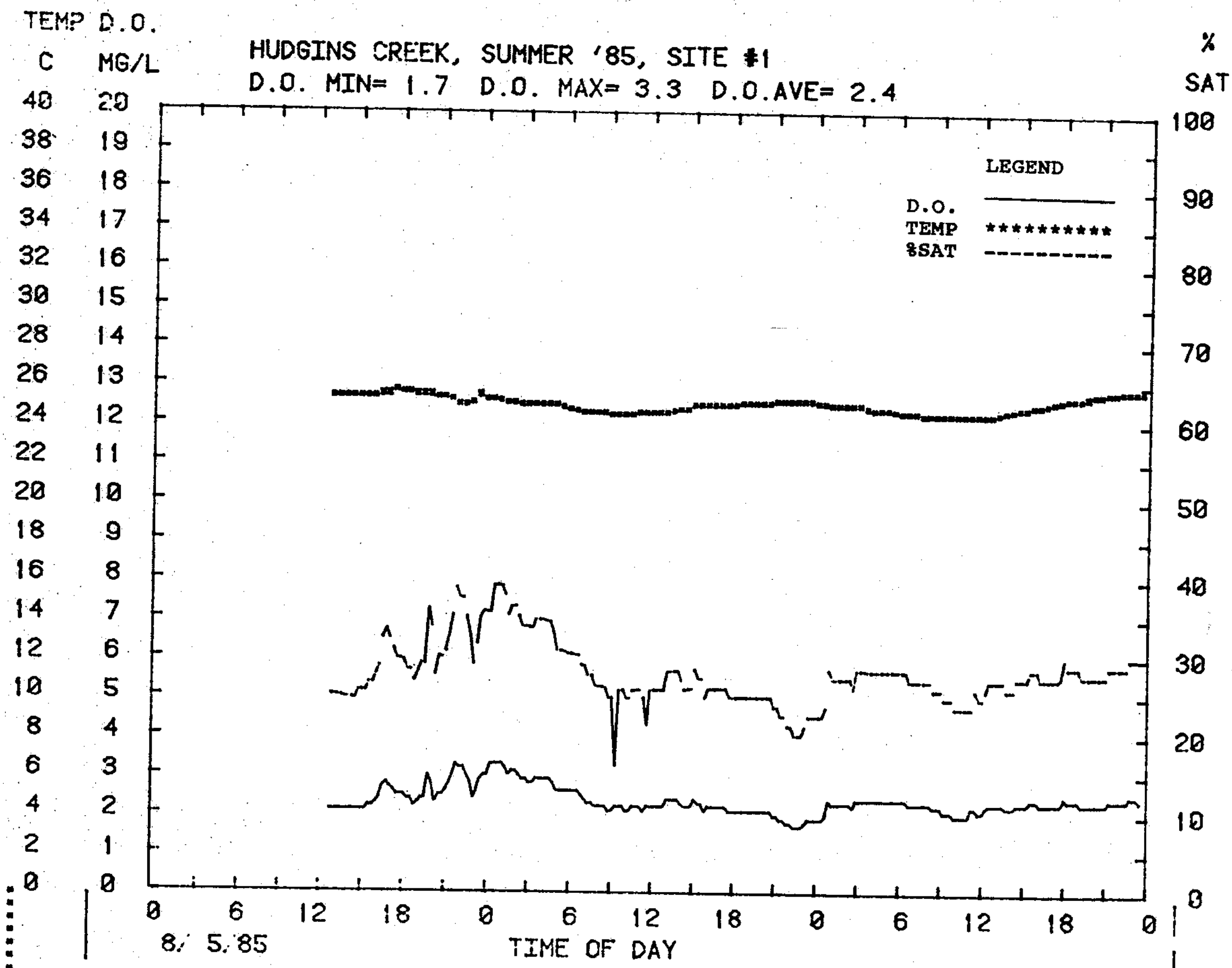


Fig. GC-18. Dissolved Oxygen Plot

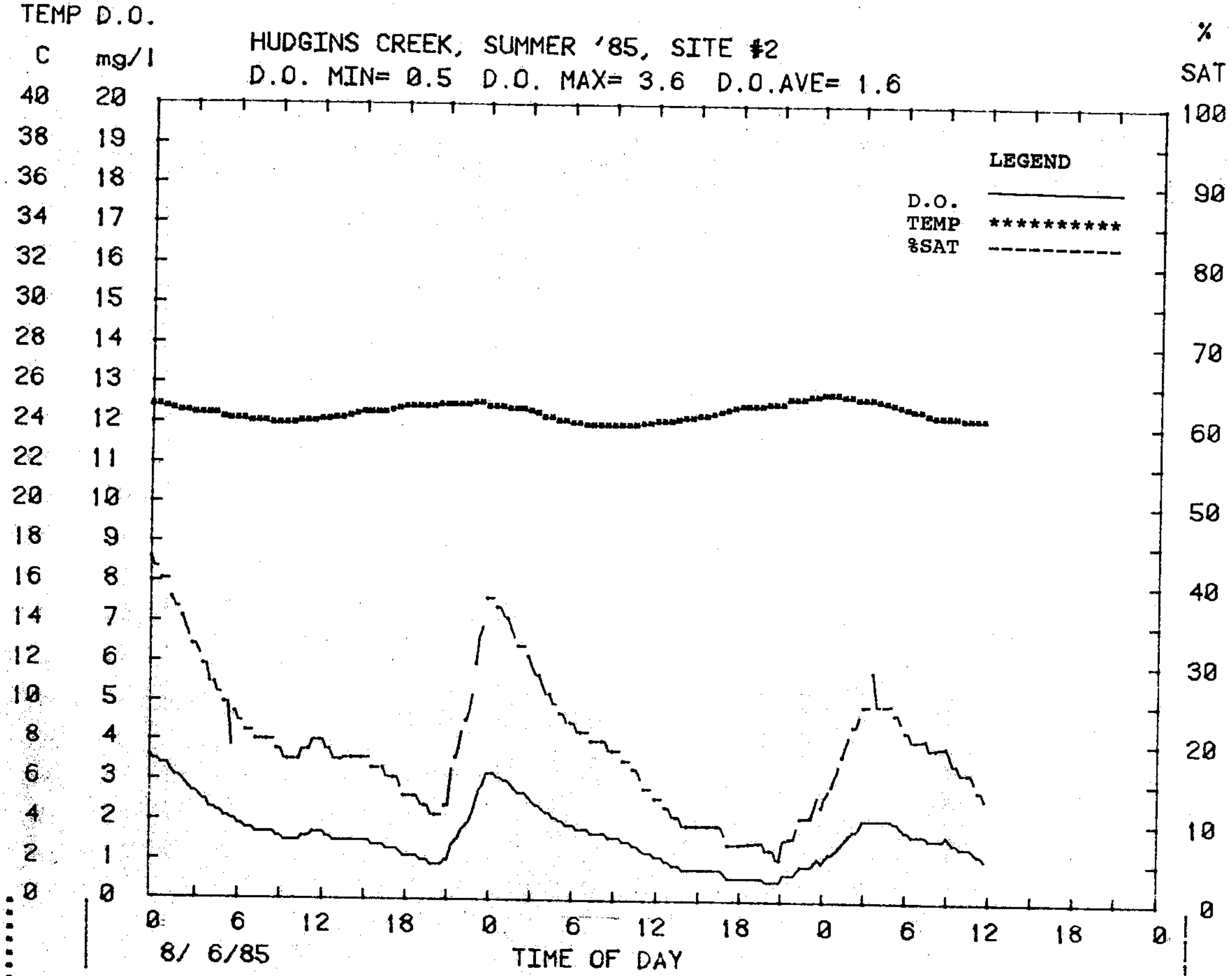


Fig. GC-19. Dissolved Oxygen Plot

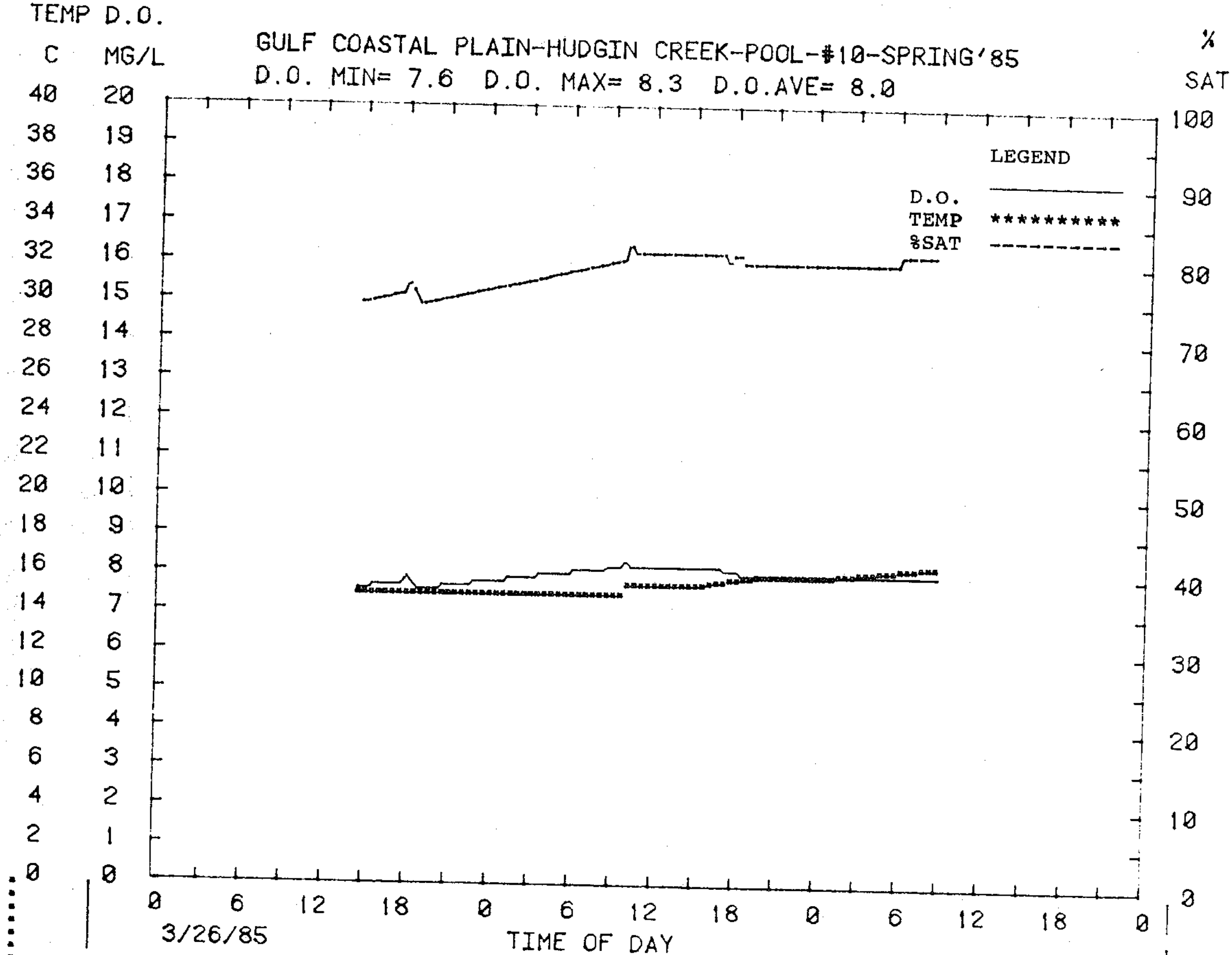


Fig. GC-20. Dissolved Oxygen Plot

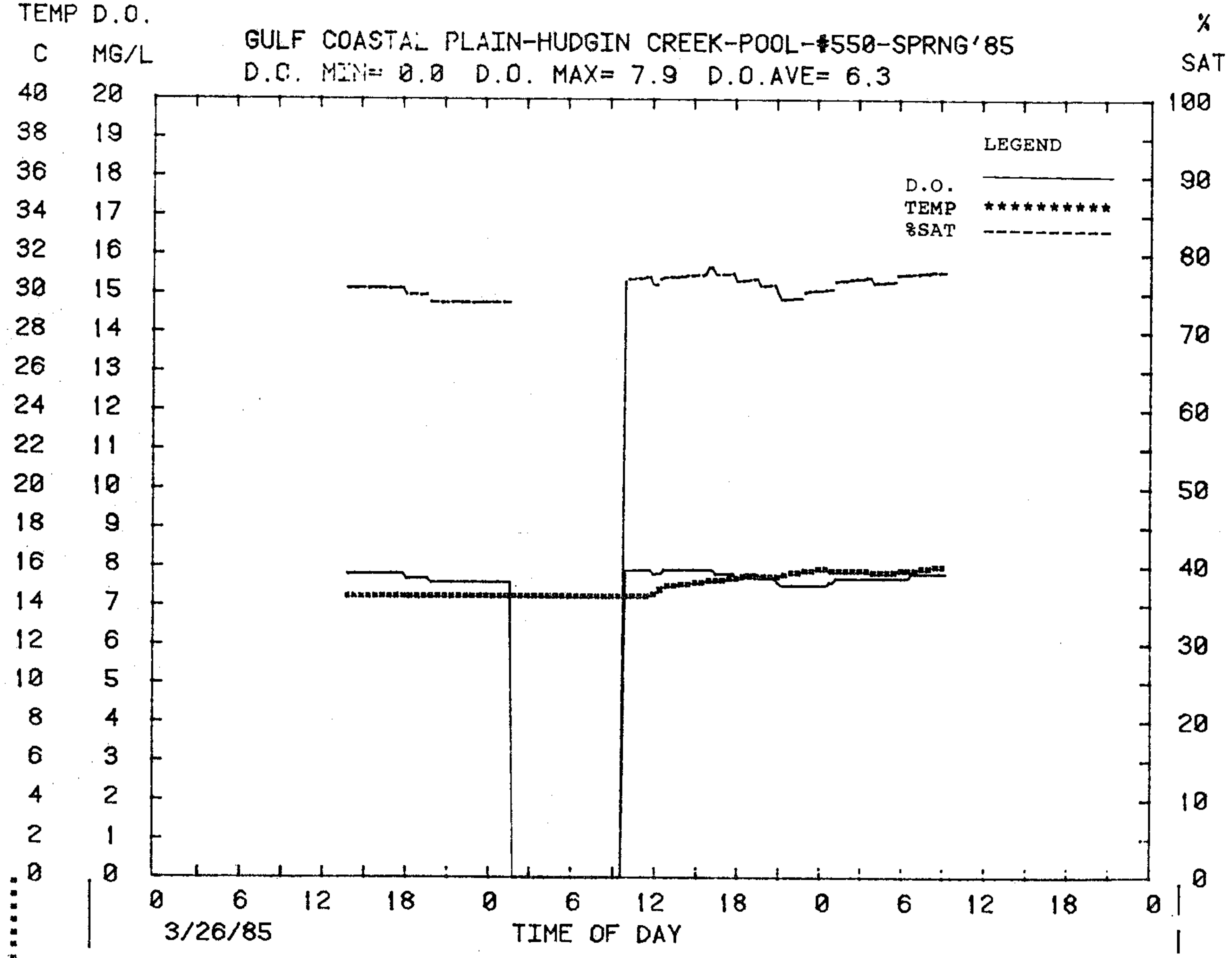


Fig. GC-21. Dis ved Oxygen Plot

saturation for both sites during the spring period.

No significant differences are shown between these two sites. These spring conditions are distinctly different from those observed during the summer period. Dissolved oxygen concentrations are much higher during these springtime conditions predominantly due to the additional flow. Average D.O. from both sites was approximately 8 mg/l. Dissolved oxygen percent saturation averaged approximately 80%.

Chemical Parameters

Summer - Chemical data collected during the summer sampling period in Hudgin Creek is typical of the Gulf Coastal Region (Table GC-25). Even though nutrient concentrations are quite low, the enduring pool stage which develops during summer appears to enhance phytoplankton growth. Chlorophyll $\bar{a}$ was measured to be 6.1 μg/l. The photosynthetic activity appears to exert a buffering effect on the normally acidic waters during these summer conditions.

Mineral quality measured in Hudgin Creek reveals very low levels of sulfates (10 mg/l), chlorides (5 mg/l) and total dissolved solids (81 mg/l). Measurements of biochemical oxygen demands were slightly high with the BOD_5 measuring 2.9 mg/l and the BOD_{20} measuring 6.8 mg/l. Even though the water was relatively clear (turbidity was only 8.5 NTUs), the characteristic dark brown or "coffee" color was prominent. This characteristic is thought to be a condition related to the specific soil type within the watershed and the leaching of tannins, lignins and perhaps iron from the soils. The test for fecal coliform bacteria indicated the presence of 200 colonies per 100 ml of water tested, which is the limit for primary contact. This location on Hudgin Creek appeared to be remote from any known source of fecal contamination. Thus, the fecal coliform test is probably measuring natural bacteria levels from organic matter.

Spring - The spring samples were collected on March 22, 1985. Results are shown in Table GC-26. Water quality measured during the spring sampling was considerably different in some respects from the summer samples. Most significant was the volume of water or flow available during the spring. The stream was now actually flowing instead of a series of enduring pools as found during the summer. This flow is the most probable reason for the differences in the spring water quality.

The pH measurement was slightly more acidic during the spring sampling. BODs, both 5-day and 20-day, were less than one-half the concentrations measured during the summer conditions. Chlorophyll $\bar{a}$ concentrations dropped to only trace amounts during the spring survey. Nutrient levels were

Table GC-25

STREAM RECLASSIFICATION SURVEY

Chemical Results

Physiographic Region: Gulf Coastal Plain

Stream: Hudgin Creek

Drainage Area: 187 Square Miles

Station Description: At Hwy. 35 bridge in Section 29, T 11 S, R 8 W

Date: August 6, 1985

PARAMETER	TIME COLLECTED 09:00	10:00	11:10	AVERAGE
Q, cfs	0.01	0.01	0.01	0.01
Temperature, °C	25	25	25	25
pH	6.9	6.9	6.8	6.9
Turbidity, ntu	8	9	22	8.5*
TSS, mg/l	12	9	59	10*
TDS, mg/l	80	79	83	81
BOD-5, mg/l	2.8	2.6	3.3	2.9
BOD-20, mg/l	6.6	6.3	7.5	6.8
T.Phos., mg/l	0.09	0.08	0.12	0.10
PO4-P, mg/l	0.04	0.04	0.05	0.04
NO2+NO3-N, mg/l	0.03	0.03	0.03	0.03
NH3-N, mg/l	0.02	0.03	0.01	0.02
Cl -, mg/l	4.5	5.0	5.0	5.0
SO4 =, mg/l	10	10	10	10
Fe, mg/l	0.2	NA	NA	0.2
Conductivity, µmho	105	104	95	101
Alkalinity, mg/l	-	-	-	-
T. Hardness, mg/l	40	42	40	40
Chlorophyll a, µg/l	6.5	2.6	9.4	6.1
Fecal Coliform	-	-	200	200

Dissolved Oxygen Data for 6 Aug 1985	Site 1	Site 2
Average	2.4	1.8
Minimum	1.7	0.9
Maximum	3.3	3.6

* Third sample was discarded from average.

Table GC-26

STREAM RECLASSIFICATION SURVEY

Chemical Results

Physiographic Region: Gulf Coastal Plain

Stream: Hudgin Creek
Drainage Area: 170 Square Miles

Station Description: at Highway. 35 bridge, SE 1/4, NW 1/4, Section 29, R 8 W, T 11 S - Drew County

Date: March 27, 1985

PARAMETER	TIME COLLECTED			AVERAGE
	08:55	09:40	10:15	
Q, cfs	-	-	-	not taken
Temperature, °C	15	15	15.5	15
pH	6.3	6.2	6.1	6.2
Turbidity, ntu	26	24	23	24
TSS, mg/l	18	18	20	19
TDS, mg/l	85	88	90	88
BOD-5, mg/l	1.0	0.9	0.9	0.9
BOD-20, mg/l	2.7	2.4	2.5	2.5
T.Phos., mg/l	0.05	0.04	0.06	0.05
PO4-P, mg/l	0.04	0.04	0.05	0.04
NO2+NO3-N, mg/l	0.13	0.12	0.14	0.13
NH3-N, mg/l	0.04	0.05	0.05	0.05
Cl -, mg/l	5	5.5	5	5
SO4 =, mg/l	26	25	24	25
Fe, mg/l	0.76	0.74	0.73	0.74
Conductivity,µmho	80	79	78	79
Alkalinity, mg/l	5	6	5	5
T. Hardness, mg/l	18	20	20	19
Chlorophyll a,µg/l	0.0	0.8	1.2	0.7
Fecal Coliform	-	-	16	16

Dissolved Oxygen Data for 27 Mar 1985		
	Pool	Riffle
Average	7.7	8.1
Minimum	7.5	7.8
Maximum	7.9	8.3

very low and showed no significant change from the summer survey. Mineral quality was not significantly different during the spring, with the exception of sulfates, which increased slightly with the higher flows. Fecal coliform bacteria concentrations were substantially lower during the spring survey, as compared to the summer period. With the much higher flow during the spring season, there is a much greater likelihood of bringing in nonpoint sources of contamination. Yet, to the contrary, the concentration of fecal coliform bacteria shows a significant decline from summer conditions. This is another indication that the higher concentrations found in summer are of natural origin. Turbidity measurements were approximately three times higher in spring than during summer, but still below the Water Quality Standard.

Physical Parameters

Summer - Physical evaluations were made during the week of August 6, 1985. Hudgin Creek had reached a routine critical condition for the annual cycle. The stream had essentially stopped flowing and had formed a standing body of water in the streambed. The immediate floodplain at Hudgin Creek appeared to be quite wide and flat with numerous channels and sloughs which would, at higher flows, be full of water. Table GC-27 displays the results of the physical evaluation on Hudgin Creek. Land use, topography, soil types, canopy and geology have been mentioned as directly affecting many of the chemical characteristics of the stream. Characteristics of Hudgin Creek, which are also common to the region, are low stream gradient, high percentage of instream fishery cover (brush, logs and debris) and moderate canopy covering the stream.

Spring - Due to the difficulty of making any physical measurements during the higher flows of spring, none were made.

Macroinvertebrate Populations

Seventy-eight (78) taxa representing 18 orders were identified from the summer-spring samples of the benthic community of Hudgin Creek. The dominant orders of the combined samples, Coleoptera, Decapoda, Amphipoda, Odonata and Ephemeroptera comprised 22.3%, 16.0%, 10.8%, 8.6% and 8.4% of the benthic community, respectively (Table A-9, Appendix A). The dominant taxa were Palaemonetes kadiakensis (10.5%), Hyalella azteca (9.9%), Sialis (7.2%), Celina augustata (5.5%) and Caenis (4.8%). Other taxa considered ecologically characteristic, but not collected in significant numbers include Peltodytes lengi, Cloeon rubropictum, Ascellus dentadactylus and Traienoides.

The qualitative comparative indices indicated that only slight similarities exist between the summer and spring benthic communities (Table GC-28). Of the 78 taxa identified from the combined samples, 26 were identified from both samples and

Table GC-27

STREAM RECLASSIFICATION SURVEY

Physical Results

Stream:	Hudgin Creek
Date:	8/6/85
Drainage Area:	187 Square Miles
Watershed Land Use:	26% Agriculture 74% Forest
Stream Gradient:	1.4 fpm
Mean Channel Width:	69 feet
Mean Stream Width:	32 feet
Mean Stream Velocity:	NA
Observed Flow:	.01 CFS
Average Substrate Type:	100% Mud/Silt
Mean Instream Cover:	55% Brush, Logs, Debris 3% Inundated Vegetation 1% Overhanging Vegetation
Riffle/Pool Ratio of Transects:	40% Deep Pool 40% Shallow Pool 20% Moderate Pool
Mean Bank Overstory Cover:	88% Trees 73% Shrubs
Mean Bank Ground Cover:	43% Grass and Forbes 57% Dirt
Mean Bank Stability:	10% Stable 70% Moderate 20% Unstable
Mean Stream Canopy:	68% Canopy
Comments:	

accounted for 68% of all organisms collected. There were 37 and 14 taxa unique to the summer and spring samples, respectively, and they comprised 38% and 23% of the numeric totals. The taxonomic differences reflected the natural seasonal variation of insect populations. However, the magnitude of variation may have been increased due to extremely high water conditions present during the spring survey.

Summer - The dominant groups of the summer sample were Coleoptera (18.9%), Amphipoda (13.9%), Decapoda (13.5%), Odonata (11.0%) and Megaloptera (10.3%). The dominant taxa of the summer sample were Hyalella azteca (13.9%), Palaemonetes kadiakensis (10.8%), Sialis (10.2%), Celina augustata (8.7%) and Ischnura (5.1%). The dominant groups of the spring sample were Coleoptera (29.3%), Decapoda (21.0%), Ephemeroptera (7.3%), Gastropoda (7.0%) and Isopoda (6.5%).

Spring - The dominant taxa of the spring sample were Uvarus (12.5%), Cambarinae (10.9%), Palaemonetes kadiakensis (9.9%) and Hydrovatus (8.1%).

The community parameters indicated an extremely balanced benthic community characteristic of good water quality and ample microhabitat. The high water conditions under which the spring sampling was conducted did not result in a reduced diversity. The reduction of taxa collected was offset by the reduction in total numbers of organisms collected. However, this may not be a true indication of the normal springtime benthic populations and is considerably lower than that recorded from other Gulf Coastal streams during the spring.

Table GC-28. Community Analysis of Benthic Samples from Hudgin Creek - 30 minute Qualitative Sample, 1984-1985

COMMUNITY PARAMETERS	Summer	Spring	Combined*
Total # Organisms	805	383	1188
Total # Taxa	64	40	78
Diversity	4.7779	4.4725	5.1559
Index of Evenness	0.7963	0.8403	0.8203
Index of Dominance	0.4374	0.3229	0.3949
Index of Variety	6.5265	4.5448	7.5384
COMPARATIVE INDICES			
Dice Index		0.51	
Common Taxa Index		0.41	
Qualitative Similarity Index (range 0-100)		34.0	

*Actual 1 hour sample

Fish Populations

Summer - Approximately 3 pounds of 5% active rotenone was used to treat a pool of about ¼ acre with an average depth of 2½ feet and a maximum depth of 5 feet. The area was sampled on August 6, 1985; there was no flow between pools and the water was a murky brown color with a noticeable surface scum.

Thirty-six species were identified from the 830 individuals collected, resulting in a total relative abundance value of 206.5 and a diversity index of 4.83. The species collected are listed in Table GC-29. The dominant fish family was Centrarchidae with 27.5% of the relative abundance. This was made up of eleven species and one hybrid. Six species of Cyprinidae comprised almost 20% of the population (Table GC-30). Primary feeding fishes made up 10.2% of the population but were represented by only two species, whereas seven species of carnivores made up 13.8% of the population. Three sensitive species comprised 3.6% of the population.

Spring - Three trammel nets with mesh sizes of 1½", 2" and 3½" square mesh were fished overnight on March 26, 1985. Flow was estimated near 300 cfs and water temperature was 15°C. Twenty-one specimens from six species with a total weight of 17.8 pounds were collected, including one species which was not taken in the summer sample. Gonad inspection of these fishes indicated that spotted suckers were in the process of spawning with spawning completed by some. Blacktail redhorse were in final stages of development. Largemouth bass, spotted bass and yellow bullhead showed advanced gonad development.

Table GC-29. Fishes Collected from Hudgin Creek with Relative Abundance Values

Species		R.A. VALUE
Aphredoderus sayanus	Pirate perch	12.0
Etheostoma chlorosomum	Bluntnose darter	12.0
Etheostoma gracile	Slough darter	12.0
Hybognathus nuchalus	Silvery minnow	12.0
Minytrema melanops	Spotted sucker	12.0
Fundulus olivaceus	Blackspotted topminnow	11.0
Lepomis gulosus	Warmouth	10.0
Micropterus salmoides	Largemouth bass	9.0
Lepomis macrochirus	Bluegill	9.0
Gambusia affinis	Mosquitofish	9.0
Hybognathus hayi	Cypress minnow	9.0
Centrarchus macropterus	Flier	8.0
Ictalurus natalis	Yellow bullhead	8.0
Amia calva	Bowfin	7.0
Notropis umbratilis	Redfin shiner	6.5
Lepomis megalotis	Longear	6.0
Notropis emiliae	Pugnose minnow	6.0

Table GC-29, cont.

*Percina maculata	Blackside darter	5.5
Esox niger	Chain pickerel	4.5
Fundulus notatus	Blackstripe topminnow	4.0
Notropis chrysocephalus	Striped shiner	4.0
Lepomis cyanellus	Green sunfish	4.0
Lepomis punctatus	Spotted sunfish	3.0
Esox americanus	Grass pickerel	3.0
Etheostoma whipplei	Redfin darter	3.0
Pomoxis nigromaculatus	Black crappie	2.0
Elassoma zonatum	Banded pygmy sunfish	2.0
*Etheostoma collettei	Creole darter	2.0
Micropterus punctulatus	Spotted bass	2.0
Noturus gyrinus	Tadpole madtom	2.0
Notropis fumeus	Ribbon shiner	2.0
Lepisosteus oculatus	Spotted gar	1.0
Erimyzon oblongus	Creek chubsucker	1.0
Lepomis microlophus	Redear	1.0
Lepomis hybrid	Hybrid sunfish	1.0
Percina caprodes	Logperch	1.0
*Moxostoma poecilurum	Blacktail redhorse	S

*Sensitive species
S - Species collected in spring sample only

Table GC-30. Summary of Fish Population Parameters from Hudgin Creek

Total Species Collected	37.0
Total Number of Individuals	830.0
Total Relative Abundance Value	206.5
Relative Abundance Diversity Index	4.83

Population Parameters	No. Sp.	% R.A.V.
CYPRINIDAE	6.0	19.1
CATOSTOMIDAE	2.0	6.3
ICTALURIDAE	2.0	4.8
CENTRARCHIDAE	12.0	27.6
PERCIDAE	6.0	17.2
Primary Feeders	2.0	10.2
Macroinvertebrate Feeders	28.0	76.0
Carnivores	7.0	13.8
Sensitive Species	3.0	3.6

L'AIGLE CREEK

L'Aigle Creek begins in southeast Cleveland County near New Edinburg and flows due south the length of Bradley County before its confluence with the Saline River. The sample site for L'Aigle Creek was located on a TAR in the NE¼ of Section 36, R 11 W, T 15 S (Figure GC-22).

General Site Discussion

Watershed Size - The watershed size of L'Aigle Creek above the sample station is 232 mi^2.

Geology - Surface geology in the L'Aigle Creek drainage is underlain byy the Cockfield Formation of Eocene Age with alluvial deposits of Quaternary Age covering the creekbed and banks. The lower watershed is composed of terrace deposits from the Pleistocene period. The immediate streambed and floodplain are recent alluvium deposits.

Topography - Topography within the L'Aigle Creek watershed is generally level to gently rolling sand hills with broad streamside wetland areas directly adjacent to the Creek.

Soil Types - The upper watershed of L'Aigle Creek is in an area that is dominated by the Savannah-Ruston-Saffell association. This association consists of nearly level to moderately steep soils on upland ridges and side slopes. The lower watershed is composed predominantly of Bibb silt loam and Myatt silt loam. Both of these are a gray colored soil of the bottomlands with poor drainage and a high water table.

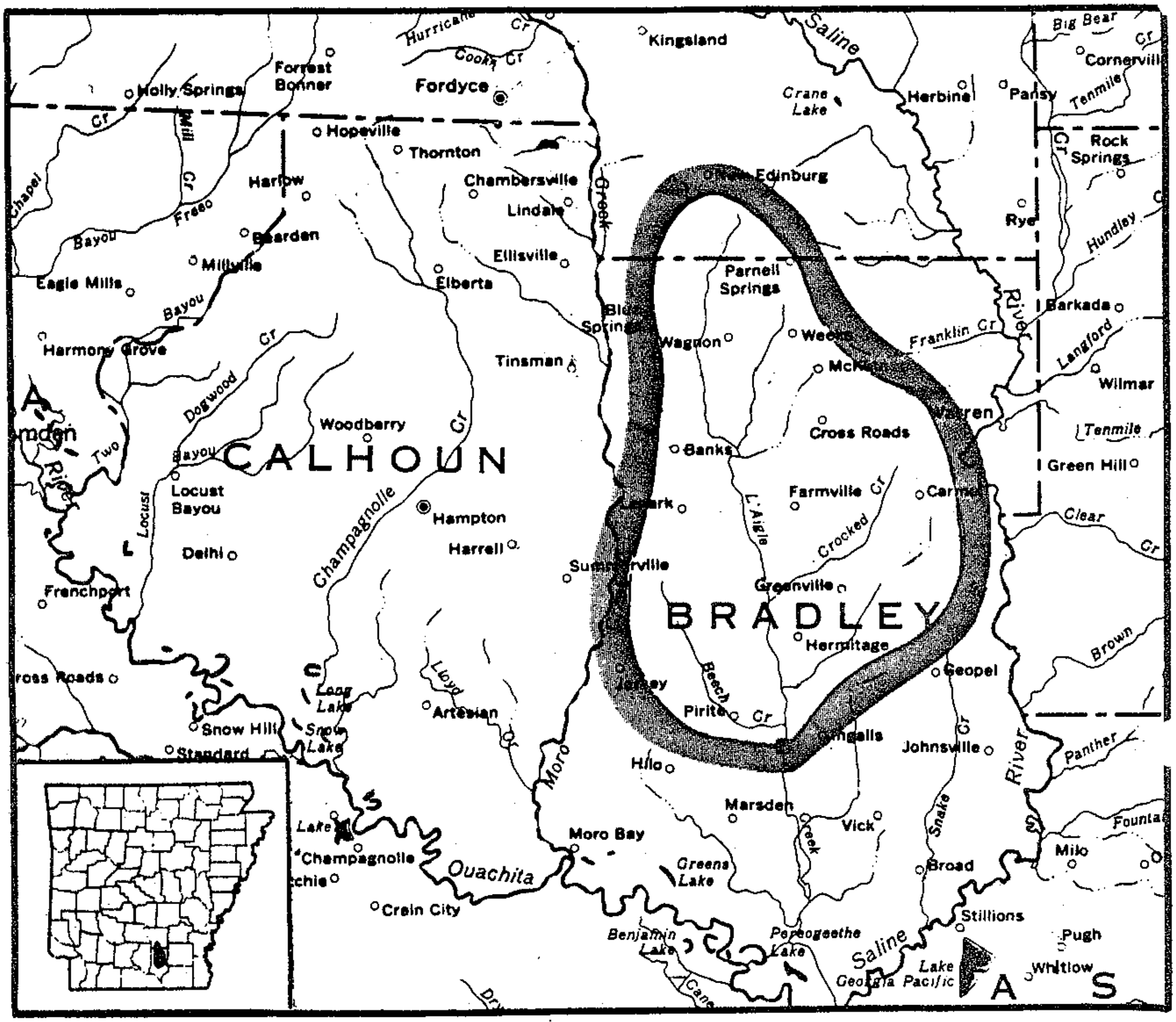
Flora - Loblolly pine and sweetgum trees dominate the forest in the upland areas of the basin. The low overflow wetland areas are dominated by oak, hickory, beech and cypress.

Land Use - Land use within the watershed is 91% forest and 7% agriculture, according to the Soil Conservation Service. The predominant agricultural use is pastureland. The L'Aigle Creek watershed has a very low level of man-induced disturbance and, therefore, is a good representative stream for the Gulf Coastal Region.

Stream Characteristics - The 1983 USGS stream flow map shows L'Aigle Creek to have a Q_{7-10} of zero. During an average year, the flow normally goes to zero and enduring pools develop. This appears to be a typical situation throughout the Gulf Coastal Region.

Conditions during the summer sampling period on L'Aigle Creek reflected the enduring pool situation. Significant physical characteristics include the deeply cut stream channel with sandy banks, sandy substrate, low stream gradient and high percentage of stream canopy.

Figure GC-22



1 inch equals approximately 8 miles

10	0	10	20	30	40 Miles

10	0	10	20	30	40	50 Kilometers

L'AIGLE CREEK: Drainage area 232 square miles ■ Survey site ▒ Survey area

Methodology and Sampling Results

The summer stream survey was conducted during the week of August 12-16, 1985; the spring survey was conducted during the week of March 24-28, 1986.

Continuous Dissolved Oxygen

Summer - Two continuously recording meters were set up to monitor the dissolved oxygen and temperature throughout the week. These meters were set up shortly after noon on August 12, 1985. Site #1 was approximately 50 yards upstream of the bridge, and Site #2 was located approximately 100 yards downstream of the bridge. Both meters were checked and calibrated daily. At Site #1, there were recurring problems with the pen sticking and the meter was subsequently pulled on August 14, 1985. At Site #2, a precipitate formed in the sampling probe on the second day; it was cleaned and a new membrane was installed before re-calibrating. Due to the lack of flow in L'Aigle Creek, both meters were measuring the dissolved oxygen and temperature of the pooled creek.

Results obtained during the survey week are displayed in Figures GC-23 and GC-24. Each graph displays the D.O., temperature and D.O. saturation for each meter for the survey period. Site #1 recording shows a fairly stable dissolved oxygen graph over the 24-hour period during which the meter functioned. The recording ranged from 1.8 mg/l to 2.8 mg/l with an average of 2.4 mg/l. Results from Site #2 displayed substantially more fluctuation with a range from 1.4 mg/l to 4.7 mg/l, averaging 2.4 mg/l over the survey period. The dissolved oxygen peaks are contrary to normal photosynthetic activity in that they occur at or near midnight and the minimums occur around noon. Summertime D.O. saturations ranged from 20-50% during the survey period.

Spring - On March 24, 1986, two meters were set up to measure the dissolved oxygen and temperature in L'Aigle Creek. Unlike the pooled conditions of summer, L'Aigle Creek was now flowing at approximately 189 cfs. Gauged estimates during the spring survey showed that the creek was falling steadily each day. Figures GC-25 and GC-26 display the dissolved oxygen, temperature and percent saturation for both sites during the survey. Graphs from both sites are relatively flat with minimum fluctuation. The dissolved oxygen concentrations are significantly higher during the spring conditions with both meters recording averages greater than 8.5 mg/l. The dissolved oxygen percent saturation averaged approximately 80%.

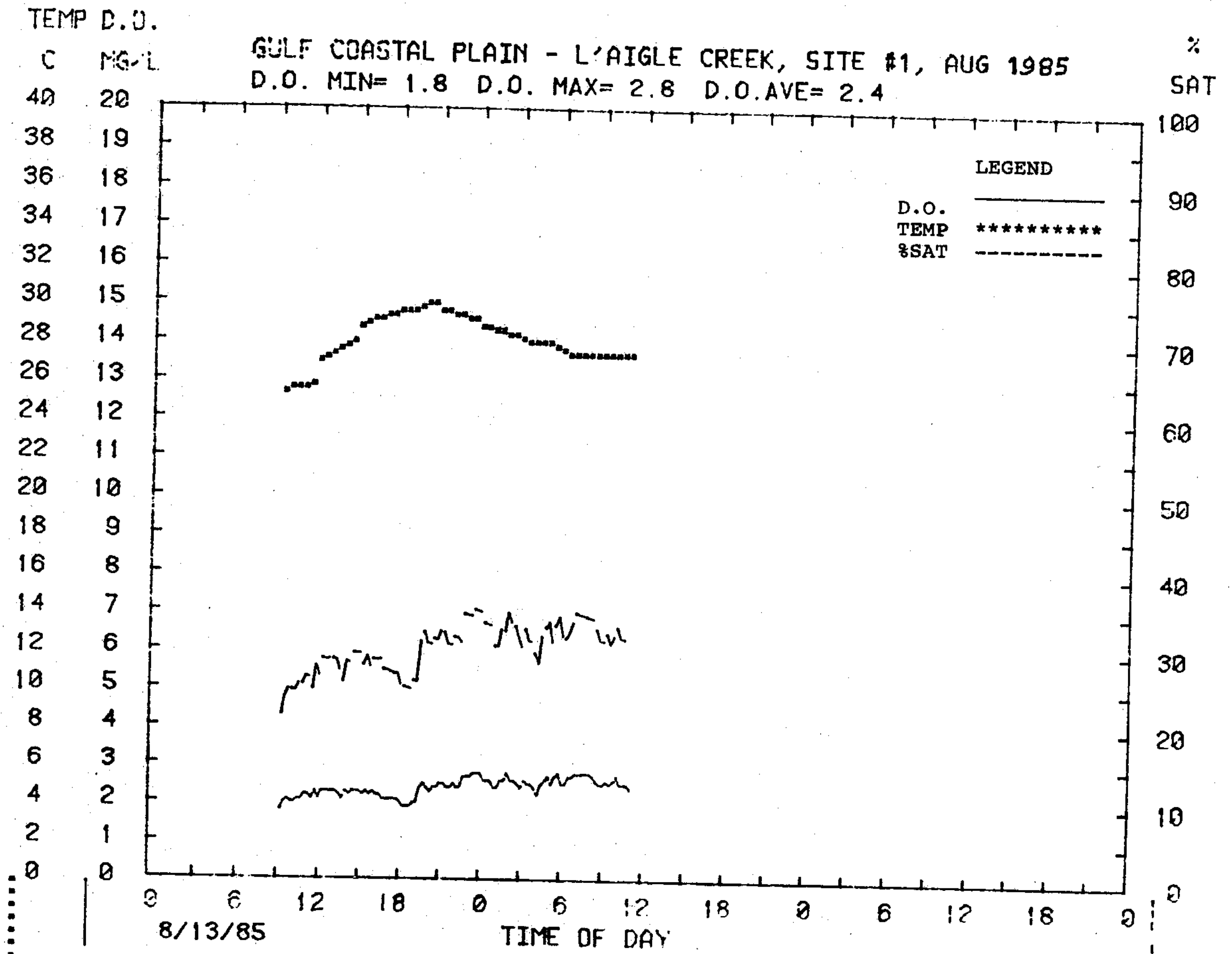


Fig. GC-23. Dissolved Oxygen Plot

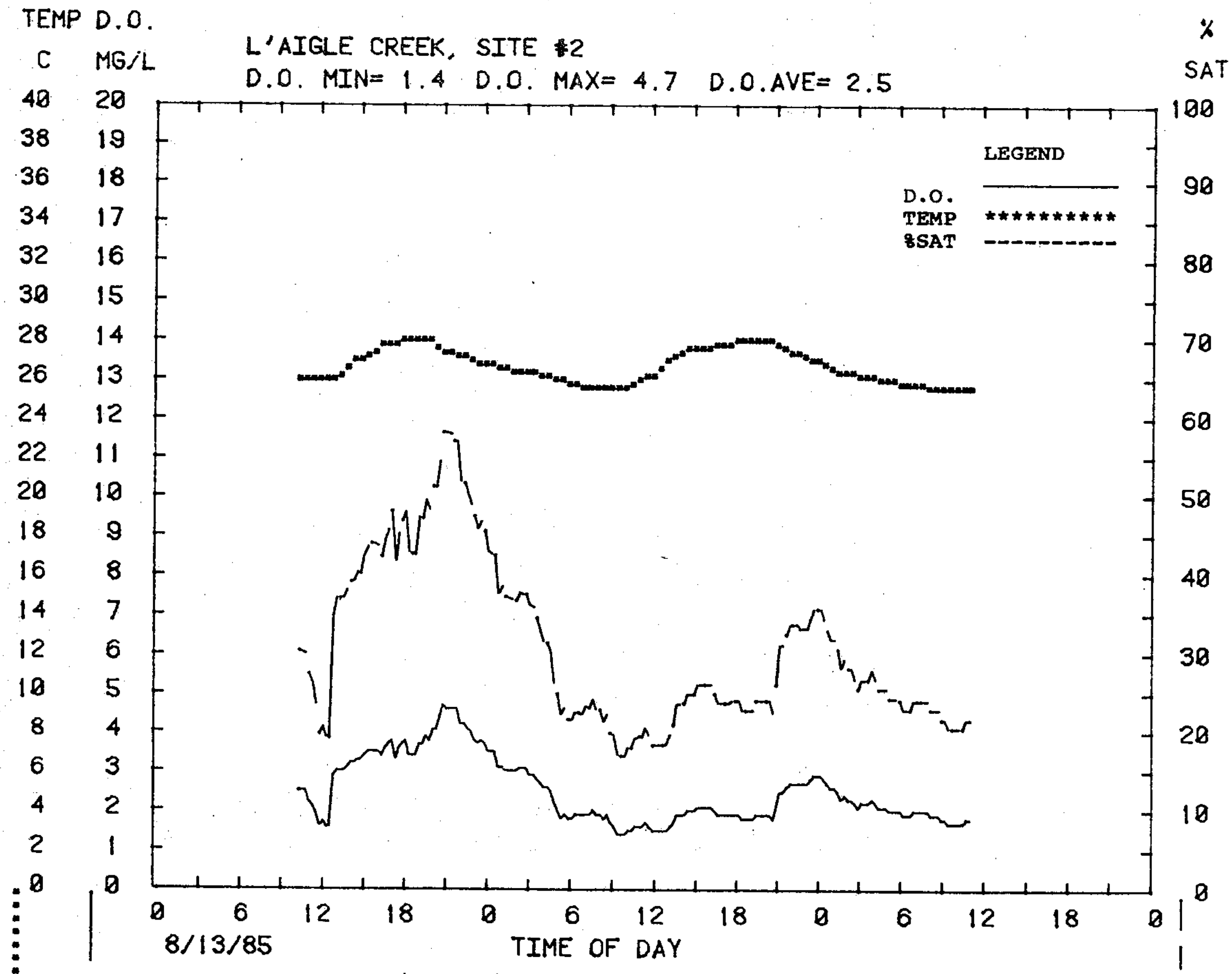


Fig. GC-24. Dissolved Oxygen Plot

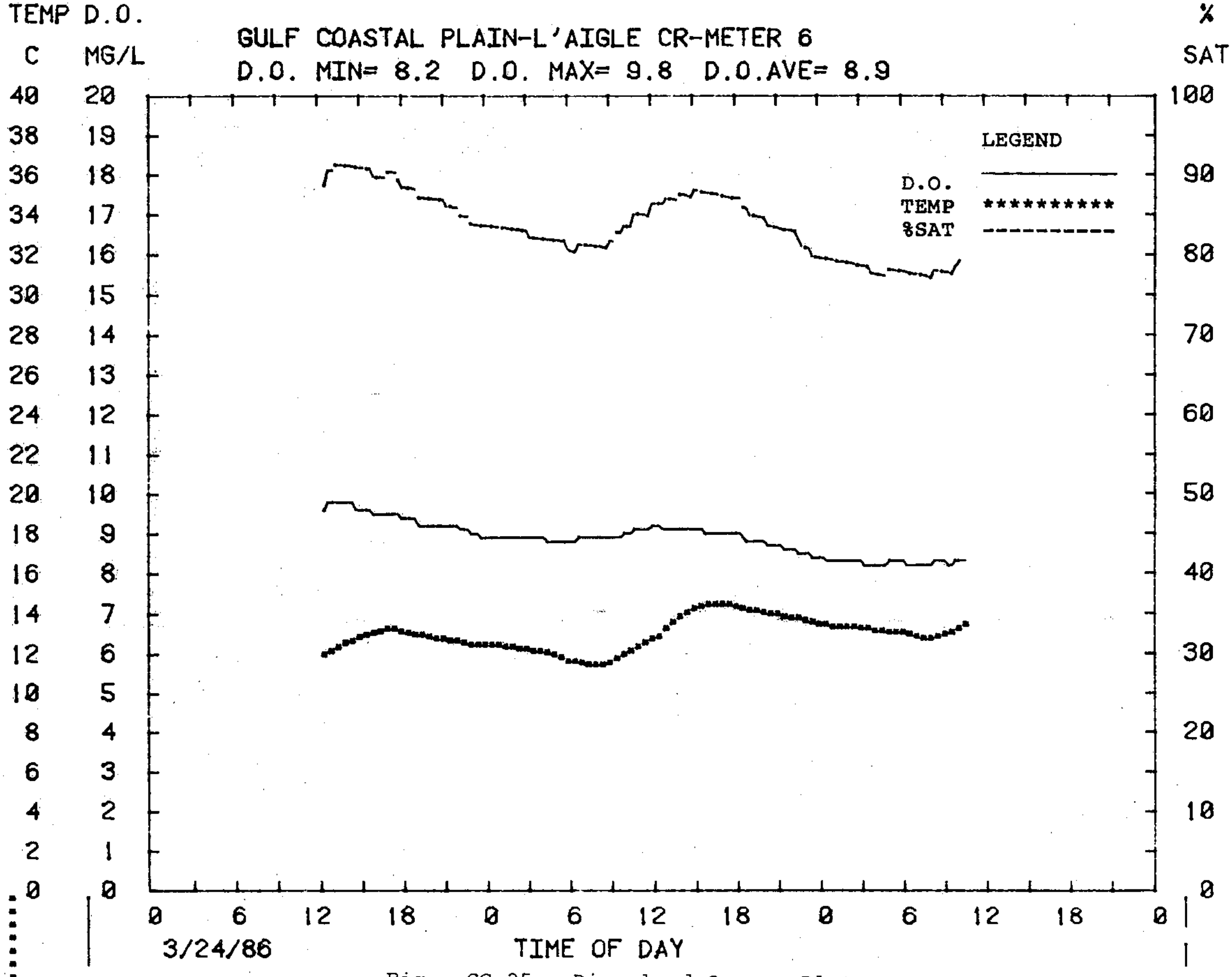


Fig. GC-25. Dissolved Oxygen Plot

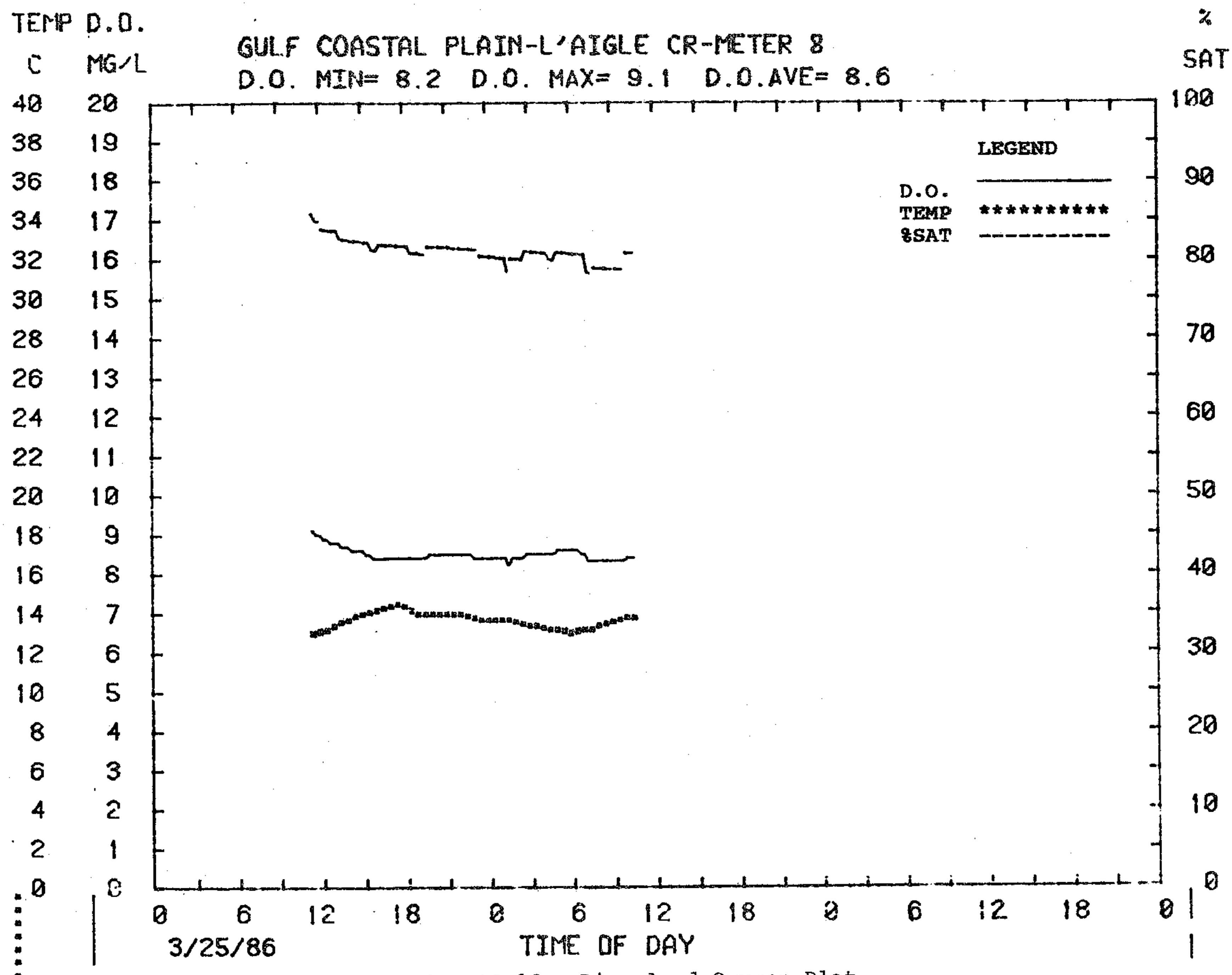


Fig. GC-26. Dissolved Oxygen Plot

Chemical Parameters

Summer - The chemical data shown for L'Aigle Creek is generally typical of other least-disturbed Gulf Coastal streams (Table GC-31). Because the predominant land use is forestland, the potential for nutrient contributions is minimal. This is reflected in the actual analysis for the various nutrients. Even with the low nutrient concentrations, there appears to be a significant phytoplankton population surviving in the enduring pools. Chlorophyll a measurements during the summer conditions averaged 12.3 μg/l. The photosynthetic activity of the phytoplankton appeared to buffer the normally acidic water to near neutral during these summer conditions. Mineral quality measured in L'Aigle Creek reveals very low concentrations of sulfates (9 mg/l), chlorides (5.5 mg/l) and total dissolved solids (64 mg/l). Measurements of biological oxygen demands were slightly high with the BOD_5 measuring 4 ppm and the BOD_{20} measuring 8.7 mg/l. Even though the water was relatively clear (turbidity was only 6.8 NTUs), the characteristic dark brown or "coffee" color was predominant. This characteristic is thought to be a condition related to the specific soil type within the watershed and the leaching of tannins, lignins and, perhaps, iron from these soils. The test for fecal coliforms indicated an insignificant number present and the stream is meeting the primary contact standard.

Spring - The spring samples were collected on March 25, 1986. Results are shown in Table GC-32. Water quality measured during the spring sampling period was only slightly different from the summer period. The most significant aspect of the stream was the volume of water. The stream was now flowing as opposed to the series of enduring pools found during the summer. The available flow is thought to be the main reason for the observed changes in water quality. The pH measurement was slightly more acidic during the spring sampling. BODs, both 5-day and 20-day, were less than one-half the concentrations measured during the summer period. Chlorophyll a concentrations dropped to only trace amounts during the spring survey. Nutrient levels were very low and showed no significant change from the summer period. Mineral quality measurements were very low with no significant change from the summer sampling. Fecal coliform concentrations increased slightly with the higher flow, but were well within the primary contact standard. Turbidity measurements were slightly higher in the spring sampling period, due to the added flow, but still well within water quality standards.

Physical Parameters

Physical evaluations were made during the week of August 12, 1985. L'Aigle Creek had reached a routine critical condition for the annual cycle. The stream had essentially stopped

Table GC-31

STREAM RECLASSIFICATION SURVEY

Chemical Results

Physiographic Region: Gulf Coastal Plain

Stream: L'Aigle Creek

Drainage Area: 232 Square Miles

Station Description: County road bridge in Section 36, T 15 S, R 11 W, Bradley County

Date: August 13, 1985

PARAMETER	TIME COLLECTED 08:30	09:45	10:45	AVERAGE
Q, cfs	0	0	0	No Flow
Temperature, °C	27	27	27	27
pH	6.6	7.0	6.9	6.8
Turbidity, ntu	7	11	11	9
TSS, mg/l	11	20	24	18
TDS, mg/l	59	67	66	64
BOD-5, mg/l	3.7	4.4	4.1	4.0
BOD-20, mg/l	7.6	9.7	8.9	8.7
T.Phos., mg/l	0.13	0.14	0.12	0.13
PO4-P, mg/l	0.06	0.06	0.06	0.06
NO2+NO3-N, mg/l	0.01	0.01	<0.01	0.01
NH3-N, mg/l	0.05	0.05	0.01	0.03
Cl -, mg/l	5	5.5	5.5	5.5
SO4 =, mg/l	10	9	9	9
Fe, mg/l	0.07	0.09	0.09	0.08
Conductivity, μmho	50	61	60	57
Alkalinity, mg/l	12	17	16	15
T. Hardness, mg/l	16	24	28	22
Chlorophyll a, μg/l	13.7	6.7	16.6	12.3
Fecal Coliform	-	-	20	20

Dissolved Oxygen Data for 13 - 14 Aug 1985	Site 1	Site 2
Average	2.4	2.2
Minimum	1.8	1.4
Maximum	2.8	3.7

Table GC-32

STREAM RECLASSIFICATION SURVEY

Chemical Results

Physiographic Region: Gulf Coastal Plain

Stream: L'Aigle Creek

Drainage Area: 232 square miles

Station Description: County road bridge, Section 36, T 15 S, R 11 W, Bradley County

Date: March 25, 1986

PARAMETER	TIME COLLECTED 09:30	10:55	11:35	AVERAGE
Q, cfs	189	189	189	189
Temperature, °C	13	13.5	14	13.5
pH	6.68	6.51	6.54	6.6
Turbidity, ntu	22	23	22	22
TSS, mg/l	20	12	12	15
TDS, mg/l	71	73	73	72
BOD-5, mg/l	1.4	1.3	1.3	1.3
BOD-20, mg/l	3.4	3.2	3.1	3.2
T.Phos., mg/l	0.06	0.07	0.07	0.07
PO4-P, mg/l	0.02	0.02	0.02	0.02
NO2+NO3-N, mg/l	0.07	0.07	0.07	0.07
NH3-N, mg/l	0.11	0.10	0.10	0.10
Cl -, mg/l	6.5	5.0	5.0	5.5
SO4 =, mg/l	9	11	11	10
Fe, mg/l	N/A	N/A	N/A	N/A
Conductivity, μmho	N/A	N/A	N/A	N/A
Alkalinity, mg/l	9	8	8	8
T. Hardness, mg/l	16	16	16	16
Chlorophyll a, μg/l	-	-	1.64	1.64
Fecal Coliform	-	-	100	100

Dissolved Oxygen Data for 25 Mar 1986	Meter 6	Meter 8
Average	8.9	8.6
Minimum	8.4	8.2
Maximum	9.2	9.1

flowing, forming standing water within the immediate streambed. Many of the secondary channels and sloughs off the main stream had already dried up. Table GC-33 contians the results of the physical evaluation on L'Aigle Creek. Many of these physical parameters can affect not only the use of the stream, but the chemical characteristics also. Characteristics which are common, not only to L'Aigle Creek but also the region, include: low stream gradient, high percentage of instream cover (brush, logs and debris) and moderate canopy covering the stream.

Macroinvertebrate Populations

Ninety-three (93) taxa representing 19 orders were identified from the summer and spring qualitative samples of the benthic community (Table A-10, Appendix A). Numerically, the dominant orders were Coleoptera, Odonata, Decapoda and Ephemeroptera, which comprised 19.6%, 16.9%, 16.3% and 15.2% of the organisms collected, respectively. Taxonomically, the dominant orders Coleoptera and Odonata were represented with 19 and 12 taxa, respectively. The dominant taxa were Palaemonetes kadiakensis (13.2%), Caenis (12.6%) and Uvarus (9.7%). Other taxa, not numerically dominant but considered ecologically characteristic of larger least-disturbed Gulf Coastal streams, include: Coptotomus, Hexagenia limbata, Libellula vibrans, Nigronia serricornis, Peltodytes and Sialis.

The comparative indices indicate significant homogenity between the summer-spring samples (Table GC-34). Of the 93 taxa identified from both sample, 73 and 72 were identified in the summer and spring samples, respectively. Of those, the 52 taxa identified from both samples comprised 88.6% of all organisms collected. The 21 and 20 taxa unique to the summer and spring samples, respectively, accounted for only 10.1% and 13.2% of those samples.

Summer - The dominant orders of the summer sample were Coleoptera, Odonata, Ephemeroptera and Decapoda, comprising 21.8%, 21.4% 20.5% and 10.7% of the sample, respectively. The dominant taxa were Caenis (17.6%), Uvarus (11.1%) and Palaemonetes kadiakensis (9.7%). Other taxa, not numerically dominant but ecologically characteristic and unique to the summer sample include Oecetis and Ranatra bueona.

Spring - The dominant orders of the spring benthic sample, Decapoda, Coleoptera and Amphipoda, comprised 25.8%, 15.9% and 10.4% of the sample, numerically. The dominant taxa of the spring benthic community were Palaemonetes kadiakensis (19.3%), Uvarus (23%) and Gammarus minus (8.7%). Other taxa, not numerically dominant but ecologically characteristic and unique to the spring sample include Haliplius, Nigronia serricornis and Perlesta placida. Two of the three dominant taxa of the spring sample were also dominants of the summer

Table GC-33

STREAM RECLASSIFICATION SURVEY

Physical Results

Stream:	L'aigle Creek
Date:	8/13/85
Drainage Area:	232 square miles
Watershed Land Use:	7% Agriculture 91% Forest 2% Other
Stream Gradient:	2.6 fpm
Mean Channel Width:	89 feet
Mean Stream Width:	34 feet
Mean Stream Velocity:	NA
Observed Flow:	No Flow
Average Substrate Type:	31% Gravel 66% Mud 3% Detritus
Mean Instream Cover:	.5% Undercut Bank 20% Brush, Logs, Debris
Riffle/Pool Ratio of Transects:	40% Deep Pool 60% Moderate Pool
Mean Bank Overstory Cover:	81% Trees 51% Shrubs
Mean Bank Ground Cover:	54% Grass and Forbs 46% Dirt
Mean Bank Stability:	40% Stable 20% Moderate 40% Unstable
Mean Stream Canopy:	47% Canopy
Comments:	

sample. In addition, the majority of the characteristic taxa were present in both samples.

The combined diversity was 5.0437 and indicates the complexity of the benthic community. The community parameters were not signficantly different from summer to spring. The benthic population was extremely diverse and balanced both numerically and taxonomically. This is a result of the microhabitat availability, good water quality and the undisturbed nature of the watershed. The benthic community could best be described as composed mainly of taxa which have demonstrated wide tolerance to water quality parameters with a limited number of taxa which are characteristic of "good" water quality.

Table GC-34. Community Anaylsis of Benthic Samples from L'Aigle Creek - 30 minute Qualitative Samples, 1985-1986

COMMUNITY PARAMETERS	Summer	Spring	Combined
Total # Organisms	1710	1002	2712
Total # Taxa	73	72	93
Diversity	4.6489	4.9712	5.0437
Index of Evenness	0.4098	0.4256	0.4099
Index of Dominance	0.7511	0.8057	0.7713
Index of Variety	6.7040	7.1223	8.0665
COMPARATIVE INDICES			
Dice Index (range 0-1)			0.72
Common Taxa Index (range 0-1)			0.71
Qualitative Similarity Index (range 0-100)			50.0

Fish Populations

Summer - The sample area at this location was an isolated pool approximately 250' X 20', with an average depth of three feet. Maximum depth was 6 feet and there was no flow between pools. Brush, logs and treetops were very abundant in the sample area. The pool was treated with 5 pounds of 5% active rotenone on August 14, 1985, and approximately 15 man-hours were spent picking up fish. The site was visited the following day and estimates made of the fish not recovered the first day.

Table GC-35 lists the 33 species of fish collected at this site with their relative abundance value. A total of 631 fish with a relative abundance value of 200 and a diversity index of 4.76 were collected. Centrarchidae was the dominant family of fishes taken. They comprised 32.3% of the relative abundance value (Table GC-36). Primary feeders made up only 3% of the population; however, 17% of the population was carnivorous fishes. Only two sensitive species were taken, which made up 4% of the total population. This population contained a very large percentage of harvestable size fish, such as grass and chain pickerel, warmouth and bluegill sunfish and largemouth bass.

Spring - Four trammel nets with mesh sizes of 1½" or 2" square were fished overnight at this site on March 25, 1986. The streamflow was about 150 cfs; the channel was full and the water level was falling. Water temperature was 12 to 14°C. Eighteen spotted suckers and four largemouth bass weighing a total of 36.4 pounds were taken. Gonad development in the largemouth bass was in an advanced but not final stage. However, the majority of the spotted suckers were in the spawning process with a few indicating completion of spawning.

Table GC-35. Fishes Collected from L'Aigle Creek with Relative Abundance Values

Species		R.A. VALUE
Ictalurus natalis	Yellow bullhead	12.0
Esox americanus	Grass pickerel	12.0
Minytrema melanops	Spotted sucker	12.0
Lepomis macrochirus	Bluegill	12.0
Lepomis gulosus	Warmouth	10.5
Centrarchus macropterus	Flier	10.5
Esox niger	Chain pickerel	10.0
Aphredoderus sayanus	Pirate perch	9.0
Fundulus olivaceus	Blackspotted topminnow	9.0
Gambusia affinis	Mosquitofish	9.0
Lepomis punctatus	Spotted sunfish	9.0
Micropterus salmoides	Largemouth bass	7.5
*Etheostoma collettei	Creole darter	7.0
Etheostoma gracile	Slough darter	7.0
Lepomis cyanellus	Green sunfish	6.0
Etheostoma whipplei	Redfin darter	6.0
Notropis fumeus	Ribbon shiner	6.0
Fundulus notatus	Blackstripe topminnow	6.0
Lepomis megalotis	Longear	6.0
Etheostoma chlorosomum	Bluntnose darter	4.5
Etheostoma proeliare	Cypress darter	4.5
Hybognathus hayi	Cypress minnow	4.0
Notropis atherinoides	Emerald shiner	4.0
Amia calva	Bowfin	2.5
Pomoxis nigromaculatus	Black crappie	2.0
Notropis texanus	Weed shiner	2.0
Erimyzon oblongus	Creek chubsucker	2.0
Notropis emiliae	Pugnose minnow	2.0
Notemigonus crysoleucas	Golden shiner	2.0
Noturus gyrinus	Tadpole madtom	1.0
Elassoma zonatum	Banded pygmy sunfish	1.0
Labidesthes sicculus	Brook silversides	1.0
*Percina sciera	Dusky darter	1.0

*Sensitive species

Table GC-36. Summary of Fish Population Parameters from L'Aigle Creek

Total Species Collected	33.0
Total Number of Individuals	631.0
Total Relative Abundance Value	200.0
Relative Abundance Diversity Index	4.76

Population Parameters	No. Sp.	% R.A.V.
CYPRINIDAE	6.0	10.0
CATOSTOMIDAE	2.0	7.0
ICTALURIDAE	2.0	6.5
CENTRARCHIDAE	9.0	32.3
PERCIDAE	6.0	15.0
Primary Feeders	2.0	3.0
Macroinvertebrate Feeders	26.0	80.0
Carnivores	5.0	17.0
Sensitive Species	2.0	4.0

MORO CREEK

Moro Creek begins in the northeast corner of Dallas County flowing south and forming the Dallas-Cleveland, Calhoun-Cleveland and Bradley-Calhoun county lines before its confluence with the Ouachita River. The sample site for Moro Creek was located at the Highway 160 bridge (Figure GC-27).

General Site Discussion

Watershed Size - The watershed size of Moro Creek above the highway bridge is 423 mi^2.

Geology - Surface geology in the Moro Creek watershed is composed of two main types. The headwater area is underlain by deposits of the Cockfield Formation of Eocene Age with alluvial deposits of Quaternary Age covering the creek bed and banks.

Topography - Topography within the Moro watershed is generally level to gently rolling sand hills with broad streamside wetland areas directly adjacent to the creek.

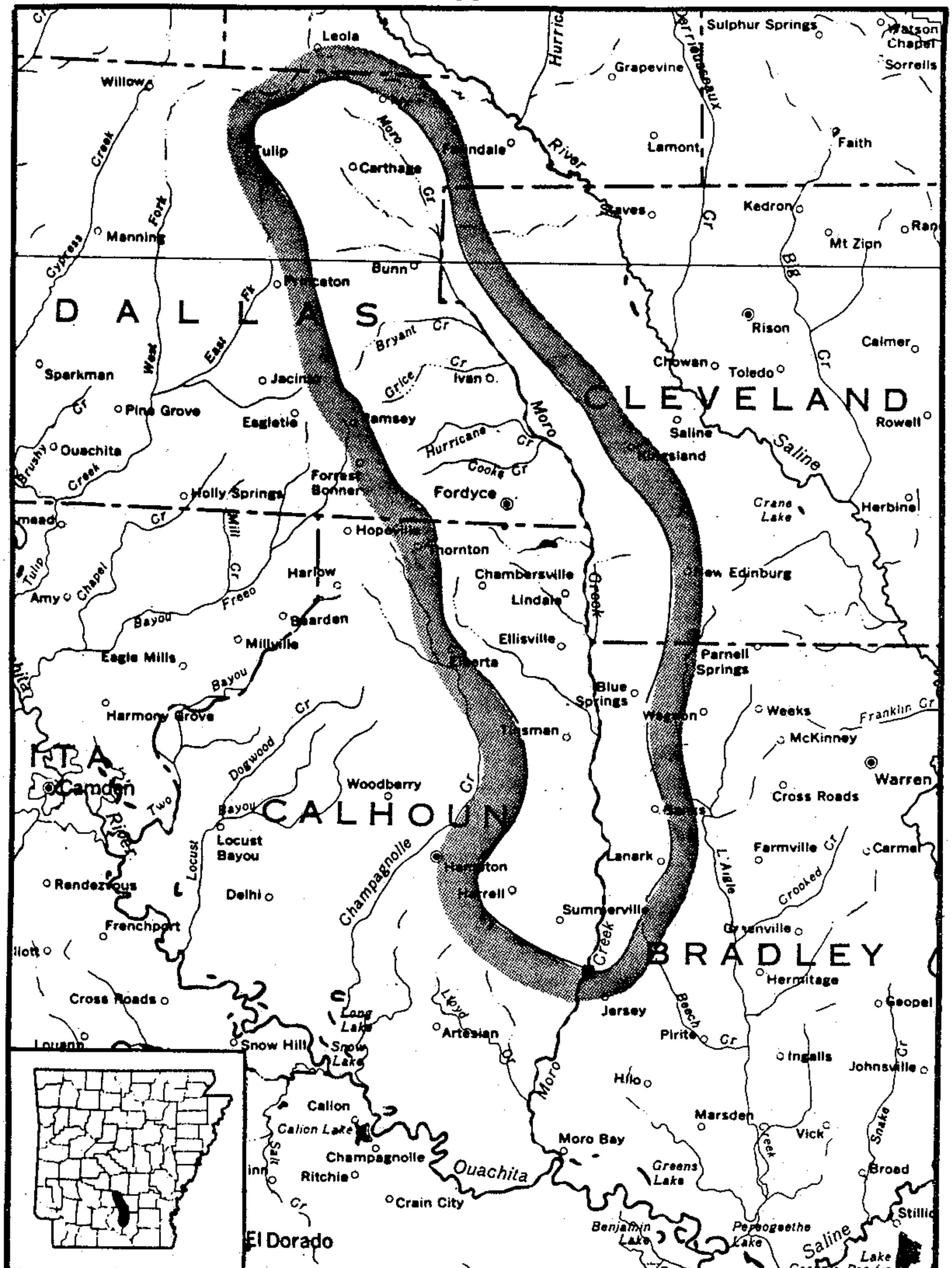
Soil Types - Soil types within the upper drainage of Moro Creek are predominantely the Amy-Smithton-Pheba association. This association is composed of poorly drained and somewhat poorly drained, level to nearly level, loamy soils on uplands. The immediate floodplain of Moro Creek consists of the Guyton association which are poorly drained, level, loamy soils on bottomlands. The lower portion of the Moro drainage continues to have sections of the Amy-Smithton-Pheba soil association as well as Sacul-Smithdale and Savannah-Ruston-Smithdale associations mixed throughout. The Sacul-Smithdale association is moderately well-drained and well-drained, nearly level to moderately steep, loamy soils on uplands. The Savannah-Ruston-Smithdale association consists of moderately well-drained and well-drained, nearly level to moderately sloping, loamy soils on uplands.

Flora - Loblolly pine and sweetgum trees dominate the forest in the upland areas of the basin. The lower overflow wetland areas are dominated by oak, hickory, beech and cypress.

Land Use - Land use within the watershed is 91% forest and 7% agriculture, according to the Soil Conservation Service. The predominant agricultural use is pastureland. The Moro Creek watershed has a very low level of man-induced disturbance and is, therefore, a good location to measure least-impaired conditions for the Gulf Coastal region.

Stream Characteristics - The 1983 USGS stream flow map shows Moro Creek to have a Q_{7-10} of zero. Typically, Gulf Coastal streams stop flowing in the late summer and a series of enduring pools develop. Conditions during the summer survey on Moro Creek followed this pattern. Significant physical

Figure GC-27



Scale 1:500,000
1 inch equals approximately 8 miles

10 0 10 20 30 40 Miles

10 0 10 20 30 40 50 Kilometers

MORO CREEK: Drainage area 451 square miles ■ Survey site ▒ Survey area characteristics include the deeply cut meandering stream channel, sandy substrate, low stream gradient, high percentage of instream cover (brush, logs and debris) and high percentage of stream canopy. Significant chemical characteristics include the low hardness, alkalinity and conductivity measurements. Very low concentrations of nutrients and minerals are characteristic of these waters. The BODs, both 5-day and 20-day, were slightly higher than expected in these streams and were suspected to contribute to the low dissolved oxygen measurements recorded at this site. The water had the typical dark coffee color, but the black scum was less prominent at this site and there seemed to be at least an equal amount of duckweed floating on the water's surface.

Methodology and Sampling Results

The summer stream survey was conducted during the week of August 1, 1985; the spring survey was conducted during the week of March 24, 1986.

Continuous Dissolved Oxygen

Summer - Two continuously recording meters were set up to monitor the dissolved oxygen and temperature during the week. One meter was set up approximately 300 yards upstream of the Highway 160 bridge. Site #2 was located downstream at the lower end of the large pool under the bridge. Both meters functioned properly for the survey period. The meters were checked and calibrated daily. Results obtained during the survey week are displayed in Figures GC-28 and GC-29. Each figure displays the D.O., temperature and percentage of D.O. saturation for each meter for the survey period.

The two figures are distinctly different. Site #1, located in the upstream section where the stream has an almost full canopy, is thought to be more representative. The recording is very stable or flat with only minor changes due to temperature changes. Site #2 downstream is atypical because the large pool at the cleared highway right-of-way allows full sunlight and increased wind action on this stream segment. The figure which displays data from #2 Site shows a classical diurnal fluctuation related to the photosynthetic process. The D.O. at Site #1 ranged from 1.9 to 2.4 mg/l and averaged 2.1 mg/l. The range of D.O. at Site #2 was from 2.8 to 5.9 mg/l and averaged 4.1 mg/l. D.O. saturations ranged from 20-30% at Site #1 and 40-70% at Site #2.

Spring - On March 24, 1986, two meters were set up to measure the dissolved oxygen and temperature in Moro Creek. Site #1 was located approximately 300 yards above the Highway 160 bridge and Site #2 was located approximately 300 yards downstream of the bridge. Unlike the pooled conditions of summer, Moro Creek was now estimated to be flowing at 350 cfs. The staff gauge which was set for this survey indicated that the creek was falling slowly during the week. Figures GC-30 and GC-31 display the dissolved oxygen, temperature and percent saturation for both sites during the survey period. No significant differences are found between the two sites. These spring conditions are distinctly different from those observed during the summer period. Dissolved oxygen

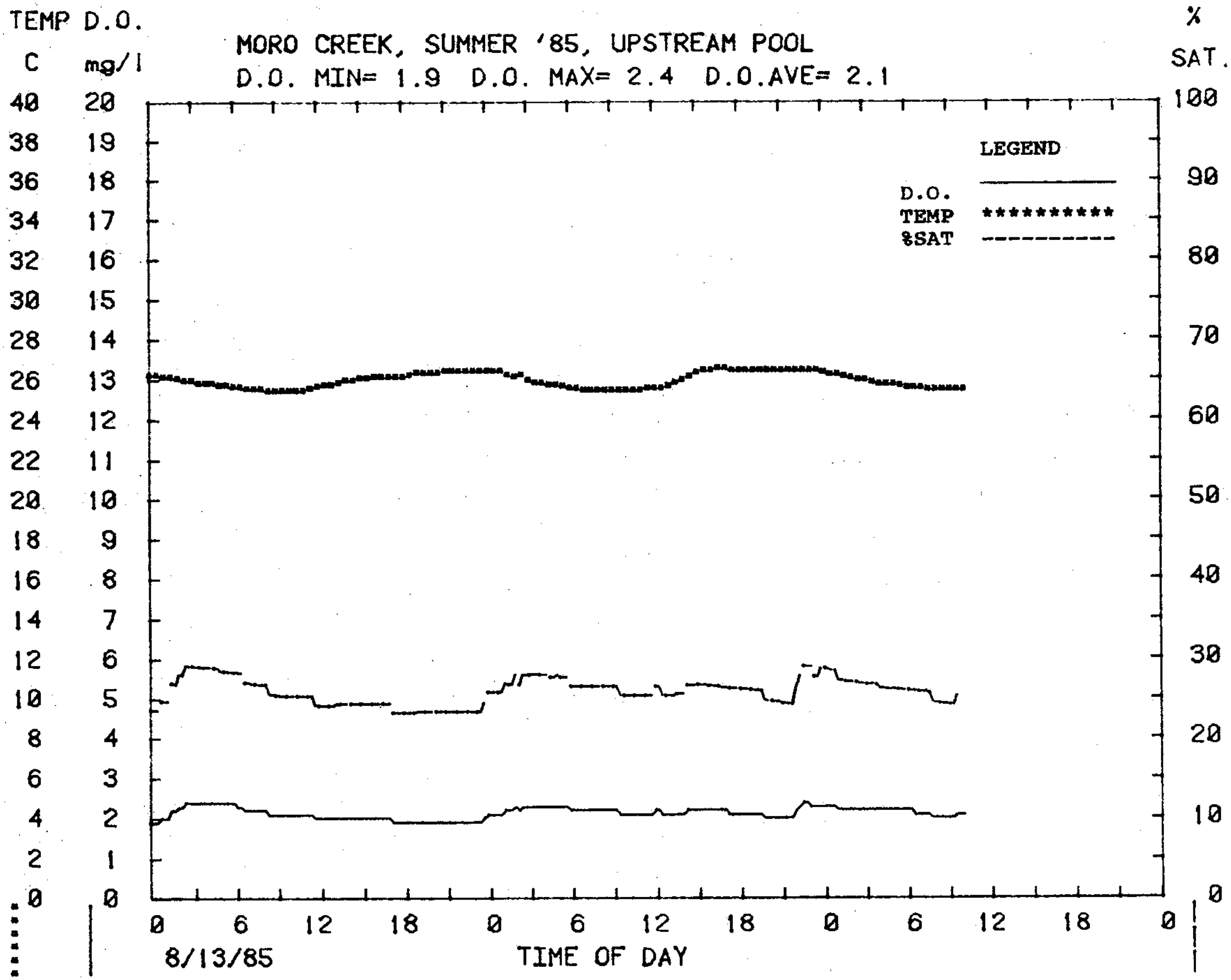


Fig. GC-28. Dissolved Oxygen Plot

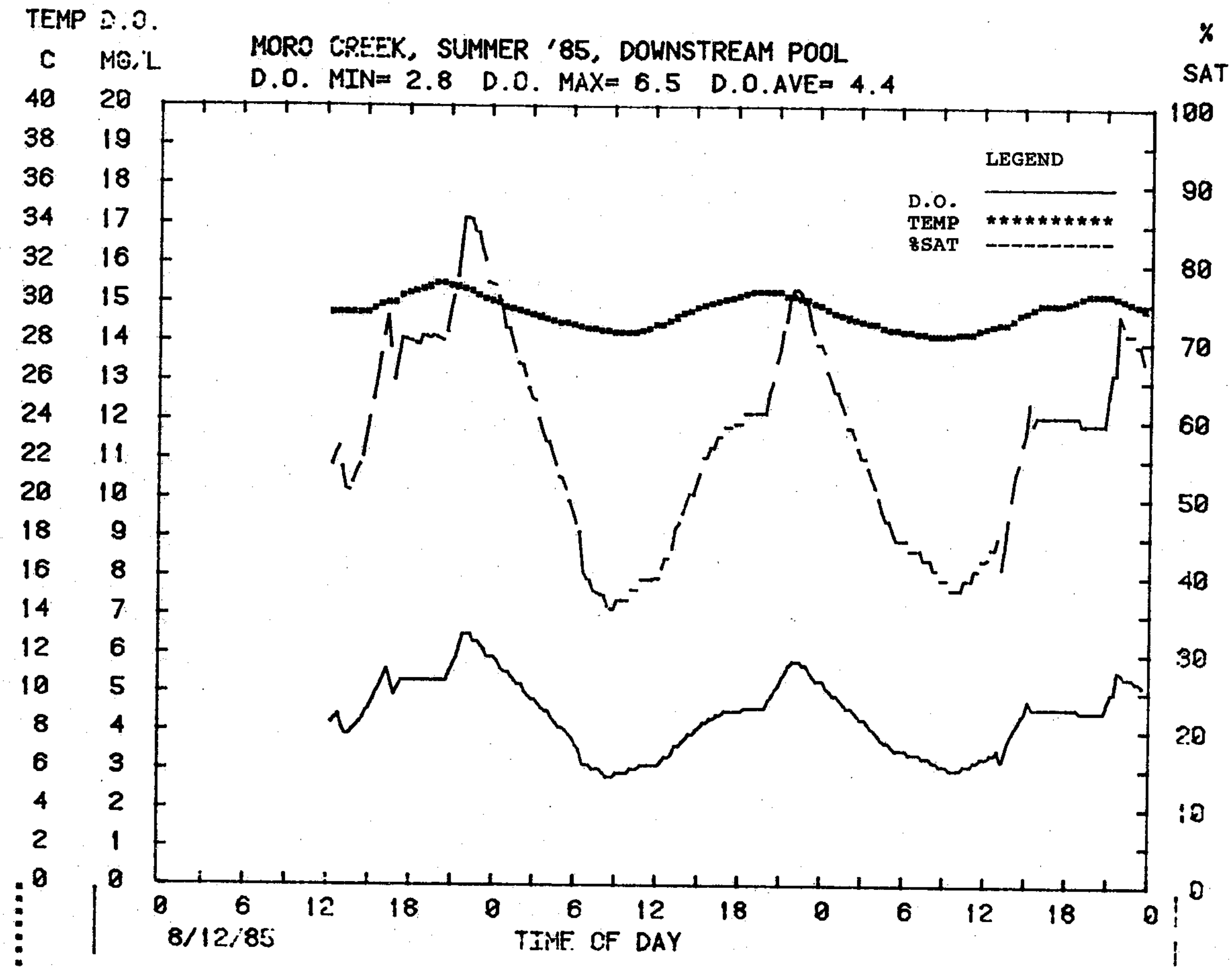


Fig. GC-29. Dissolved Oxygen Plot

These spring conditions are distinctly different from those observed during the summer period. Dissolved oxygen concentrations are much higher under these springtime conditions, mainly due to the additional flow. Average D.O. from both sites was approximately 9 mg/l. Dissolved oxygen percent saturation averaged 80-90%.

Chemical Parameters

Summer - Chemical data collected during the summer sampling period on August 13, 1985 are displayed in Table GC-37. The BOD_5 and BOD_{20} were 1.7 mg/l and 4.2 mg/l, respectively. The nutrient concentrations were very low. This site had a noticeable growth of duckweed floating on the water's surface. Mineral quality in Moro Creek reveals very low lelvels of sulfates (8 mg/l), chlorides (4.6 mg/l) and total dissolved solids (62 mg/l). Alkalinity and total hardness concentrations indicate that Moro Creek has very soft water with very little buffering capacity. The characteristic dark brown color, common throughout waters of the Gulf Coastal Region, was evident at this site. The test for fecal coliform bacteria indicated that the water was meeting the primary contact standard.

Spring - The spring samples were collected on March 25, 1986. Results are shown in Table GC-38. Water quality measured during the spring sampling period was only slightly different from the summer period. The most significant change in the stream was the volume of water now present. The stream was actually flowing as opposed to the series of enduring pools found during the summer. Chemical analyses from spring sampling revealed very little change from the summer analyses.

Physical Parameters

Physical evaluations were made during the week of August 12, 1985. Moro Creek had reached a routine critical condition for the annual cycle. The stream had essentially stopped flowing, forming standing water within the immediate streambed. Many of the secondary channels and sloughs off the main stream had already dried up. Table GC-39 displays the results of the physical evaluations on Moro Creek. Many of these physical parameters affect not only the use of the stream, but the chemical characteristics also. Characteristics which are common, not only to Moro Creek but also the region are: low stream gradient, high percentage of instream cover (brush, logs and debris) and moderate canopy covering the stream.

Macroinvertebrate Populations

Ninety-eight (98) taxa, representing 21 orders, were identified from the summer and spring samples of the benthic community (Table A-11, Appendix A). Numerically, the dominant orders of the combined samples, Coleoptera, Decapoda and Ephemeroptera comprised 31.8%, 18.4% and 13.2% of the sample, respectively. Taxonomically, Coleoptera was represented by

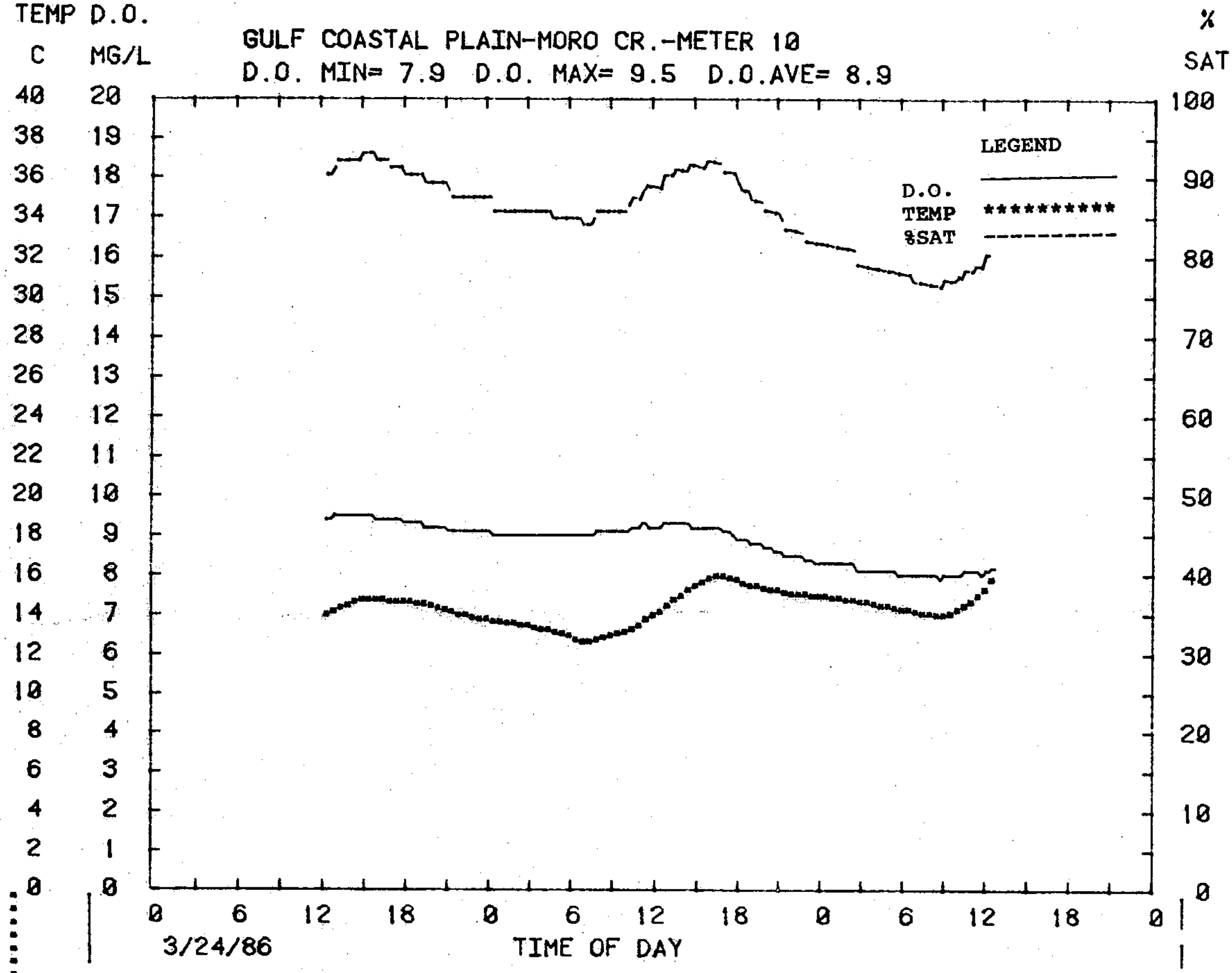


Fig. GC-30. Dissolved Oxygen Plot

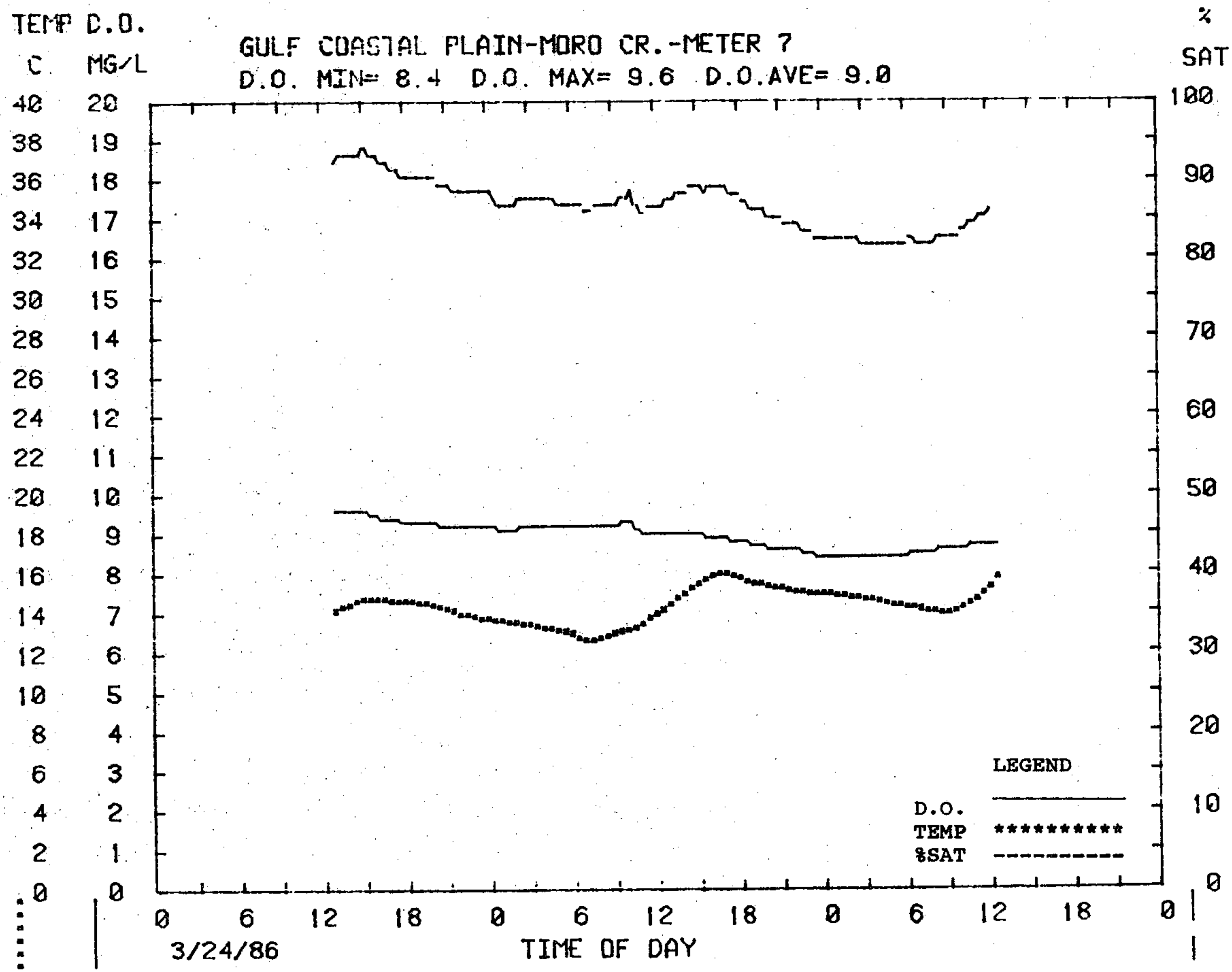


Fig. GC-31. Dissolved Oxygen Plot

Table GC-37

STREAM RECLASSIFICATION SURVEY

Chemical Results

Physiographic Region: Gulf Coastal Plain

Stream: Moro Creek

Drainage Area: 423 Square Miles

Station Description: Hwy. 160 bridge in Section 9, T 15 S, R 12 W, Bradley-Calhoun County line.

Date: August 13, 1985

PARAMETER	TIME COLLECTED 09:55	10:50	11:30	AVERAGE
Q, cfs	0	0	0	No Flow
Temperature, °C	25	26.5	26.5	26
pH	6.7	6.7	6.8	6.7
Turbidity, ntu	8	10	8	8
TSS, mg/l	8	8	6	7
TDS, mg/l	60	59	65	62
BOD-5, mg/l	1.8	1.6	1.8	1.7
BOD-20, mg/l	4.4	4.0	4.2	4.2
T.Phos., mg/l	0.12	0.11	0.11	0.11
PO4-P, mg/l	0.07	0.07	0.07	0.07
NO2+NO3-N, mg/l	0.05	0.05	0.05	0.05
NH3-N, mg/l	0.09	0.09	0.08	0.09
Cl -, mg/l	5	4.5	4.5	4.6
SO4 =, mg/l	8	8	8	8
Fe, mg/l	0.07	0.07	0.07	0.07
Conductivity, µmho	61	60	60	60
Alkalinity, mg/l	21	20	20	20
T. Hardness, mg/l	22	20	28	23
Chlorophyll a, µg/l	15.3	2.0	void	5.7
Fecal Coliform			64	64

Dissolved Oxygen Data for 13 Aug 1985	Upstream	Downstream
Average	2.1	4.2
Minimum	1.9	2.8
Maximum	2.4	5.9

Table GC-38

STREAM RECLASSIFICATION SURVEY

Chemical Results

Physiographic Region: Gulf Coastal Plain

Stream: Moro Creek

Drainage Area: 451 square miles

Station Description: Hwy 160 bridge, Section 9, T 15 S, R 12 W, Bradley-Calhoun County line

Date: March 25, 1986

PARAMETER	TIME COLLECTED 09:15	10:35	11:09	AVERAGE
Q, cfs	350 Est			350 Est
Temperature, °C	14	14	14	14
pH	6.44	6.44	6.49	6.5
Turbidity, ntu	17	17	17	17
TSS, mg/l	11	14	12	12
TDS, mg/l	78	67	72	72
BOD-5, mg/l	1.5	2.2	1.7	1.8
BOD-20, mg/l	3.4	4.2	3.9	3.8
T.Phos., mg/l	0.06	0.06	0.06	0.06
PO4-P, mg/l	0.01	0.02	0.01	0.01
NO2+NO3-N, mg/l	0.04	0.05	0.04	0.04
NH3-N, mg/l	0.06	0.09	0.06	0.07
Cl -, mg/l	6.5	7.0	7.0	7.0
SO4 =, mg/l	11	12	11	11
Fe, mg/l	N/A	N/A	N/A	N/A
Conductivity,μmho	N/A	N/A	N/A	N/A
Alkalinity, mg/l	8	8	8	8
T. Hardness, mg/l	14	16	16	15
Chlorophyll a,μg/l	-	-	3.65	3.65
Fecal Coliform	-	-	40	40

Dissolved Oxygen Data for 25 Mar 1986		
	Meter 10	Meter 7
Average	9.0	9.0
Minimum	8.3	8.4
Maximum	9.3	9.3

Table GC-39

STREAM RECLASSIFICATION SURVEY

Physical Results

Stream:	Moro Creek
Date:	8/13/85
Drainage Area:	423 Square Miles
Watershed Land Use:	7% Agriculture 91% Forest
Stream Gradient:	1.6 fpm
Mean Channel Width:	96 feet
Mean Stream Width:	35 feet
Mean Stream Velocity:	NA
Observed Flow:	No Flow
Average Substrate Type:	26% Gravel 58% Sand 16% Mud/Silt
Mean Instream Cover:	61% Brush, Logs, Debris
Riffle/Pool Ratio of Transects:	20% Riffle 40% Moderate Pool 40% Shallow Pool
Mean Bank Overstory Cover:	95% Trees 12% Shrubs
Mean Bank Ground Cover:	30% Grass and Forbs 70% Dirt
Mean Bank Stability:	60% Stable 40% Moderate
Mean Stream Canopy:	71% Canopy
Comments:	

almost twice as many taxa as any other order. The dominant taxa common to both summer and spring were Uvarus (13.6%), Palaemonetes kadiakensis (13.1%) and Caenis (9.6%). Seasonal variation resulted in significant differences between the summer and spring benthic communities. Of the 99 taxa identified from the combined sample, 70 and 68 taxa were identified from the summer and spring samples, respectively. Of those, 40 taxa were present in both samples and comprised 84.8% of the organisms identified. The 30 and 28 taxa unique to the summer and spring benthos comprised 17.0% and 12.9% of their respective samples. However, the taxonomic distribution between summer and spring dominant orders remained almost identical. The dominant orders of the summer benthic community were Coleoptera (39.5%) and Ephemeroptera (19.9%). The dominant taxa of the summer sample were Uvarus (18.2%), Caenis (15.1%), Hydrovatus (8.0%) and Palaemonetes kadiakensis (7.7%). Other taxa, not numerically dominant but considered ecologically characteristic, includes Coptotomus, Hexagenia limbata, Peltodytes lengi and Sialis.

Spring - The dominant orders of the spring benthic sample were Decapoda (29.7%), Coleoptera (22.1%) and Amphipoda (12.0%). Only Palaemonetes kadiakensis comprised more than 10% of the spring sample. Other taxa considered ecologically characteristic included Gammarus minus, Peltodytes lengi, Sialis and Uvarus.

Analysis of the community parameters indicated a stable, balanced macroinvertebrate assemblage (Table GC-40). The diversity of all samples was at or above 4.5. The majority of the taxa have been shown to exhibit wide tolerance ranges for a variety of water quality parameters, but the diversity and uniform distribution within the ecological feeding groups are representative of the undisturbed nature of the watershed.

Table GC-40. Community Anaylsis of Benthic Samples from Moro Creek - 30 minute Qualitative Samples, 1985-1986

COMMUNITY PARAMETERS	Summer	Spring	Combined
Total # Organisms	1082	1720	2802
Total # Taxa	70	68	98
Diversity	4.4975	4.6438	4.9353
Index of Evenness	0.4687	0.4884	0.4479
Index of Dominance	0.7337	0.7628	0.7461
Index of Variety	6.8456	6.7831	8.8801
COMPARATIVE INDICES			
Dice Index (range 0-1)			0.58
Common taxa Index (range 0-1)			0.57
Qualitative Similarity Index (range 0-100)			39.0

Fish Populations

Summer - The sample area on Moro Creek was approximately 400 feet long, 30 feet wide and had an average depth of 2½ feet. It included a large pool connected to a small pool. There was a very slight flow out of the sample area. Approximately 6 pounds of 5% active rotenone were used to sample the population and approximately 15 man-hours were required to pick up the fish.

Forty-nine species were collected during this sample and one additional species was collected in the spring sample (Table GC-41). A total of 1260 specimens were taken on August 14, 1985, with a total relative abundance value of 283 and a diversity index of 5.38. This sample produced the largest species list, the highest relative abundance value and the highest diversity index of any sample of the project. Cyprinidae, Percidae and Centrarchidae provided similar proportions of the total population relative abundance (Table GC-42). Five species of primary feeders made up 8.5% of the population and five species of carnivores made up 11.8% of the population. The remainder of the population was macroinvertebrate feeders. Eight sensitive species were collected which comprised 11.8% of the total population.

Spring - Sampling was done at the site on March 24-25, 1986, using four trammel nets of 1½"(2), 2" and 3½" square mesh. Water temperature ranged from 13 to 16°C and the flow was 300 to 400 cfs.

Nets were set overnight and captured 31 specimens totalling 48.7 pounds and representing 7 species. White crappie were taken in this sample; this species had not been collected in the summer sample. Approximately one-half of the spotted suckers collected had completed spawning and the remainder were in the process of spawning. Chain pickerel and bowfin had completed spawning and the black and white crappie were in the advanced stages of gonad development.

Table GC-41. Fishes Collected from Moro Creek with Relative Abundance Values

Species		**R.A. VALUE**
Minytrema melanops	Spotted sucker	12.0
Notropis texanus	Weed shiner	12.0
Notropis fumeus	Ribbon shiner	12.0
**Etheostoma collettei*	Creole darter	11.0
Aphredoderus sayanus	Pirate perch	10.5
Lepomis gulosus	Warmouth	10.0
Hybognathus hayi	Cypress minnow	9.0
Hybognathus nuchalus	Silvery minnow	9.0
**Percina sciera*	Dusky darter	9.0
Lepomis macrochirus	Bluegill	9.0
Percina caprodes	Logperch	9.0
Ictalurus natalis	Yellow bullhead	9.0
Etheostoma chlorosomum	Bluntnose darter	9.0
Fundulus olivaceus	Blackspotted topminnow	8.0
Etheostoma whipplei	Redfin darter	7.5

Table GC-41, cont.

Gambusia affinis	Mosquitofish	7.5
Pomoxis nigromaculatus	Black crappie	7.0
Micropterus salmoides	Largemouth bass	7.0
Esox americanus	Grass pickerel	7.0
Notropis emiliae	Pugnose minnow	7.0
Lepomis megalotis	Longear	6.5
Amia calva	Bowfin	6.5
Fundulus notatus	Blackstripe topminnow	6.0
Esox niger	Chain pickerel	6.0
Centrarchus macropterus	Flier	5.0
Aplodinotus grunniens	Freshwater drum	5.0
Notropis chrysocephalus	Striped shiner	5.0
**Percina maculata*	Blackside darter	5.0
Lepomis punctatus	Spotted sunfish	4.5
Etheostoma gracile	Slough darter	4.0
Pimephales vigilax	Bullhead minnow	4.0
Lepomis cyanellus	Green sunfish	4.0
Etheostoma proeliare	Cypress darter	4.0
Labidesthes sicculus	Brook silversides	4.0
Notemigonus crysoleucas	Golden shiner	4.0
Elassoma zonatum	Banded pygmy sunfish	4.0
Noturus nocturnus	Freckled madtom	3.0
Erimyzon oblongus	Creek chubsucker	2.5
**Percina ouachitae*	Saddleback darter	2.5
Percina shumardi	River darter	2.0
**Moxostoma poecilurum*	Blacktail redhorse	2.0
Cyprinus carpio	Carp	2.0
**Ammocrypta vivax*	Scaly sand darter	2.0
Notropis umbratilis	Redfin shiner	2.0
Noturus gyrinus	Tadpole madtom	2.0
**Ammocrypta asprella*	Crystal darter	1.0
**Notropis amnis*	Pallid shiner	1.0
Notropis venustus	Blacktail shiner	1.0
Moxostoma erythrurum	Golden redhorse	1.0
Pomoxis annularis	White crappie	S

* - Sensitive species
S - Collected in spring sample only

Table 42. Summary of Fish Population Parameters from Moro Creek

Total Species Collected	50.0
Total Number Of Individuals	1260.0
Total Relative Abundance Value	283.0
Relative Abundance Diversity Index	5.38

Population Parameters	No. Sp.	% R.A.V.
CYPRINIDAE	12.0	24.0
CATOSTOMIDAE	4.0	6.2
ICTALURIDAE	3.0	4.9
CENTRARCHIDAE	10.0	20.1
PERCIDAE	12.0	23.3
Primary Feeders	5.0	8.5
Macroinvertebrate Feeders	40.0	79.7
Carnivores	5.0	11.8
Sensitive Species	8.0	11.8

GULF COASTAL STREAMS RECEIVING SIGNIFICANT GROUNDWATER FLOW

The East Fork of Tulip Creek and Cypress Creek are two streams within the Gulf Coastal Region which maintain a perennial flow. These streams represent a unique category of streams within the region because of their substantial, constant flows from groundwater contributions. The following data characterizes these two stream systems.

EAST FORK TULIP CREEK

The sample site on East Fork of Tulip Creek was in Dallas County in Section 19, R 15 W, T 9 S at the county road bridge (Figure GC-32). The creek begins in northern Dallas County and flows in a southerly direction, merging with watersheds from the east. It forms a confluence with West Tulip Creek 8 to 10 air miles below the sample site where the flow continues southward to the Ouachita River in the northern section of Ouachita County.

General Site Discussion

Watershed Size - The East Tulip watershed covers 46 square miles above the sample site location.

Geology - Surface geology in the Tulip Creek drainage basin is in the outcrop area of the Sparta Sand Formation of Eocene Age. This interbedded sand and clay deposit is considered lignitic. The creek bed and banks are covered with alluvial deposits of Quaternary Age.

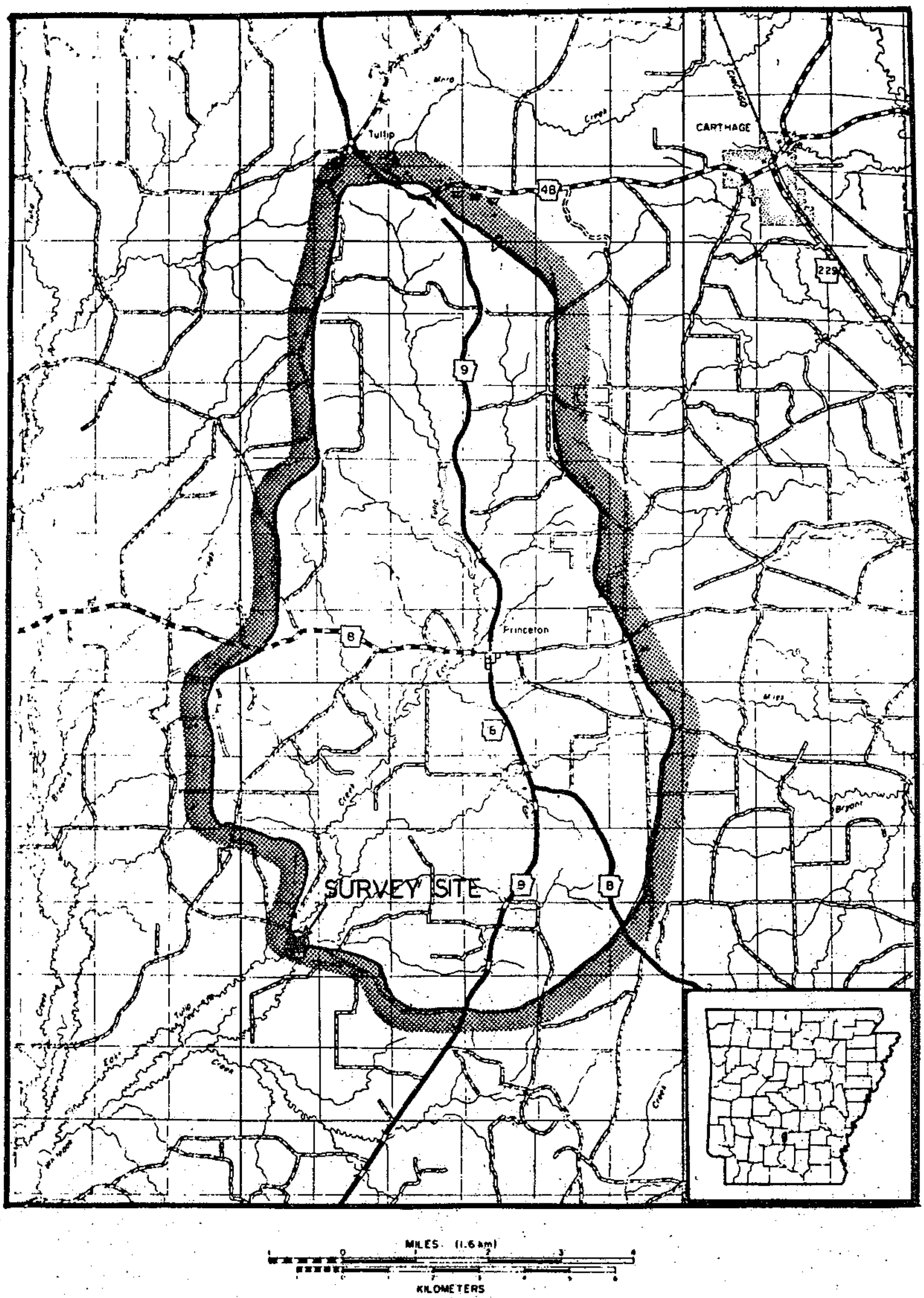
Topography - Land form topography is generally level to gently rolling sand and clay hills with broad streamside wetland areas directly adjacent to the creek.

Soil Types - Tulip Creek is in an area dominated by the Amy-Smithton-Pheba association of soils, a mixture of gravel, sand, silt and clay. These soils in upland areas are generally loamy, poorly drained to somewhat poorly drained and level to nearly level. The erosion factor is slight for these soils. The soils in this association range from strongly acidic to very strongly acidic (pH is in the range of 4.5 to 5.0).

Flora - Loblolly pine and sweetgum trees dominate the forest in the upland areas of the basin. Streamside overflow wetland areas are dominated by beech, oak, and hickory trees.

Land Use - Land use in the basin, according to S.C.S. data, is 96% silviculture and 4% agriculture. Agricultural uses are predominantly pastureland. Overall, the basin has a low level of man-induced disturbances and represents a least-impaired

Figure GC-32



EAST FORK TULIP CREEK: Drainage area 46 square miles ■ Survey site ▒ Survey area stream in this region.

Stream Characteristics - Most drainage basins of this size in the Gulf Coastal Plain region would be dry or restricted to enduring pools during the dry period of the year. The Tulip Creek watershed, however, contains many springs and the stream has a steady groundwater discharge, causing the creek to flow year around. Both local citizens and the U.S.G.S. confirm that Tulip Creek has never gone dry at the sample site. Compared to the remainder of the Gulf Coastal Plain, this creek is considered part of a unique group and probably cannot be considered representative of the rest of the region. It will probably be considered aspart of a sub-region in the future.

Significant physical characteristics include the sandy stream banks, sandy substrate, low stream gradient, high percentage of instream cover (brush, logs, debris), low number of stream riffles and high percentage of stream canopy.

Of the chemical characteristics, the most unusual is the relatively acidic stream pH (ranging from pH 5.2 to 5.6), and a high degree of color. Both of these characteristics are directly related to soil types found in the basin and are generally characteristic of the entire Gulf Coastal Plain. Other chemical parameters of note are low water temperatures and low levels of nutrients. As would be expected from a least-disturbed stream, the water was very clean.

Methodology and Sampling Results

The summer stream survey was conducted during the week of August 8-12, 1983; the spring survey took place during the week of April 2-6, 1984.

Continuous Dissolved Oxygen

Summer - Dissolved oxygen observations during a high temperature, low flow, critical condition was the goal of the summer survey. In Tulip Creek, a fairly close approximation of critical conditions was observed. Flow in Tulip Creek was near its minimum, according to local residents. Instream temperatures did not approach what is considered the normal maximum of 30°C, partially due to the influence of groundwater and springs. A total stream canopy was also partially responsible for moderating temperatures by keeping the stream shaded.

Three continuous meters were set up in an area 100 to 300 feet upstream of the county road bridge on the afternoon of August 12, 1983, and were operated until the morning of August 12, 1983. All meters performed well and gave similar results.

Results obtained during the week are displayed in Figures GC-33, GC-34 and GC-35. Each graph displays the D.O., temperature and D.O. saturation for each meter for the entire survey period.

Over the survey period, there was surprisingly little variation in the dissolved oxygen concentration during any twenty-four hour period. Normally, the total diurnal fluctuation would be expected to be about 2 mg/l, but at Tulip Creek the diurnal fluctuation was only 0.9 mg/l. Minimum concentrations were also surprisingly high. The minimum over the 72-hour period was only 6.2 mg/l, which is comparable to the highest quality streams in the state.

An explanation of the small diurnal fluctuation in Tulip Creek is based on the physical and chemical characteristics of the stream. Low nutrient levels in the stream combined with very little sunlight penetrating to the stream has resulted in only a small amount of attached or floating algae. Without algae, there is nothing to generate excess oxygen in the stream during the daylight hours and, conversely, little to consume oxygen during the night by respiration. Minimum concentrations remain high because temperatures are kept low by groundwater influence. D.O. saturation varied from 75 to 85% over the survey period, which indicates that no organic loading is influencing D.O. concentrations.

Spring - Two meters were placed upstream of the bridge on April 2, 1984, one at the end of a riffle and one at a pool site. However, both meters malfunctioned and a meter was pulled from the Cypress Creek site and installed at the pool site on Tulip Creek on April 3rd (Tuesday) at about 1500. This meter performed satisfactorily for the remainder of the survey period. Plots of dissolved oxygen, temperature and percent saturation are shown in Figure GC-36.

A heavy rain occurred on April 2nd and caused the flow to increase substantially (the stream rose 8 feet), estimated to be in excess of 200 cfs. Because of the rainfall and increased flow, there was little variation in dissolved oxygen or temperature on April 4th. Flow had dropped on April 5 (to approximately 56 cfs) and instream temperature and D.O. variation were evident. Overall, there was little variation in dissolved oxygen, with a minimum of 8.9 mg/l occurring on April 4th and a maximum of 9.5 occurring on the 5th. Percent saturation values were about 85% and 90%, respectively.

Chemical Parameters

Summer - Chemical data collected during the summer observations of Tulip Creek are displayed in Table GC-43. Items of special interest are the low levels of nutrients,

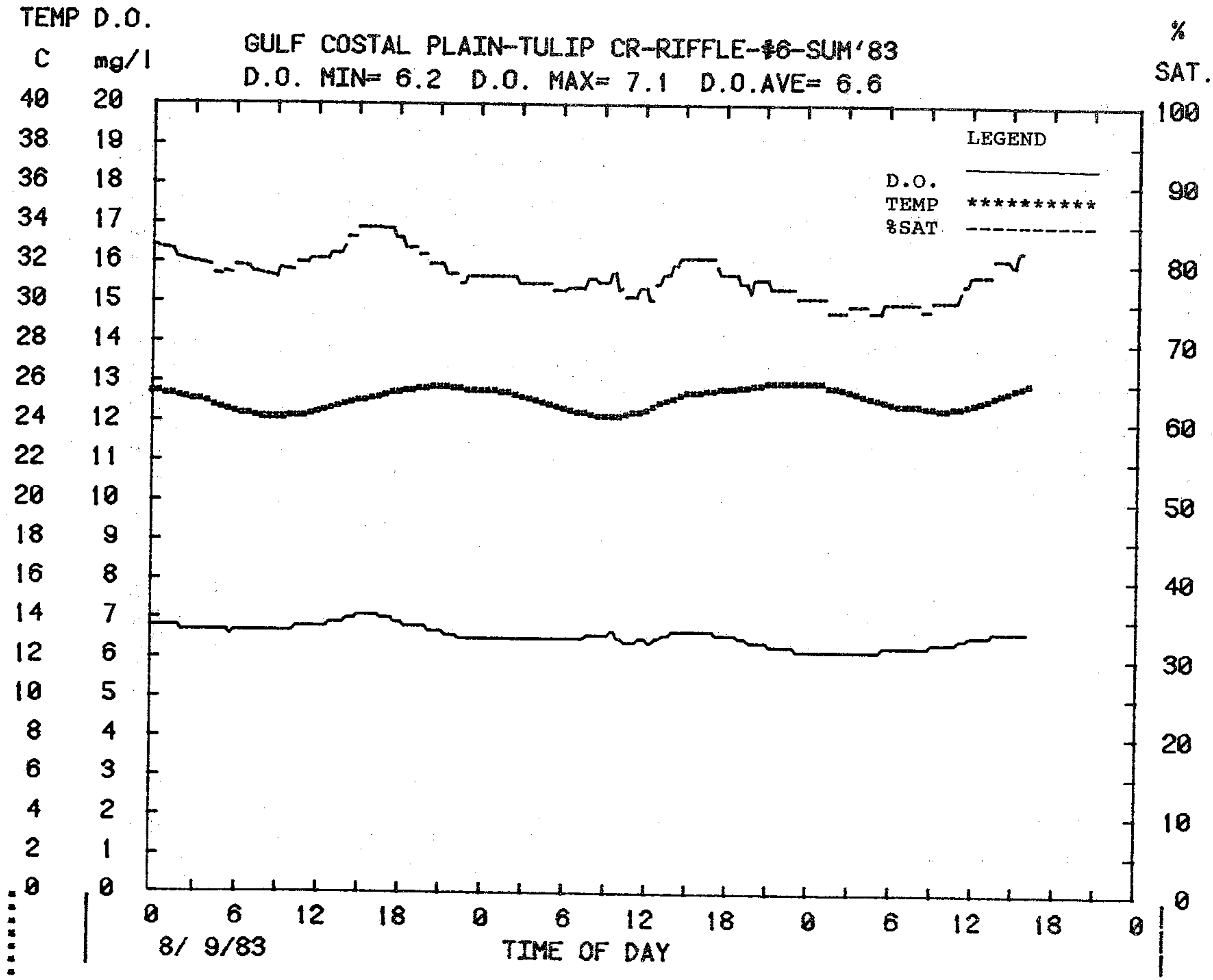


Fig. GC-33. Dissolved Oxygen Plot

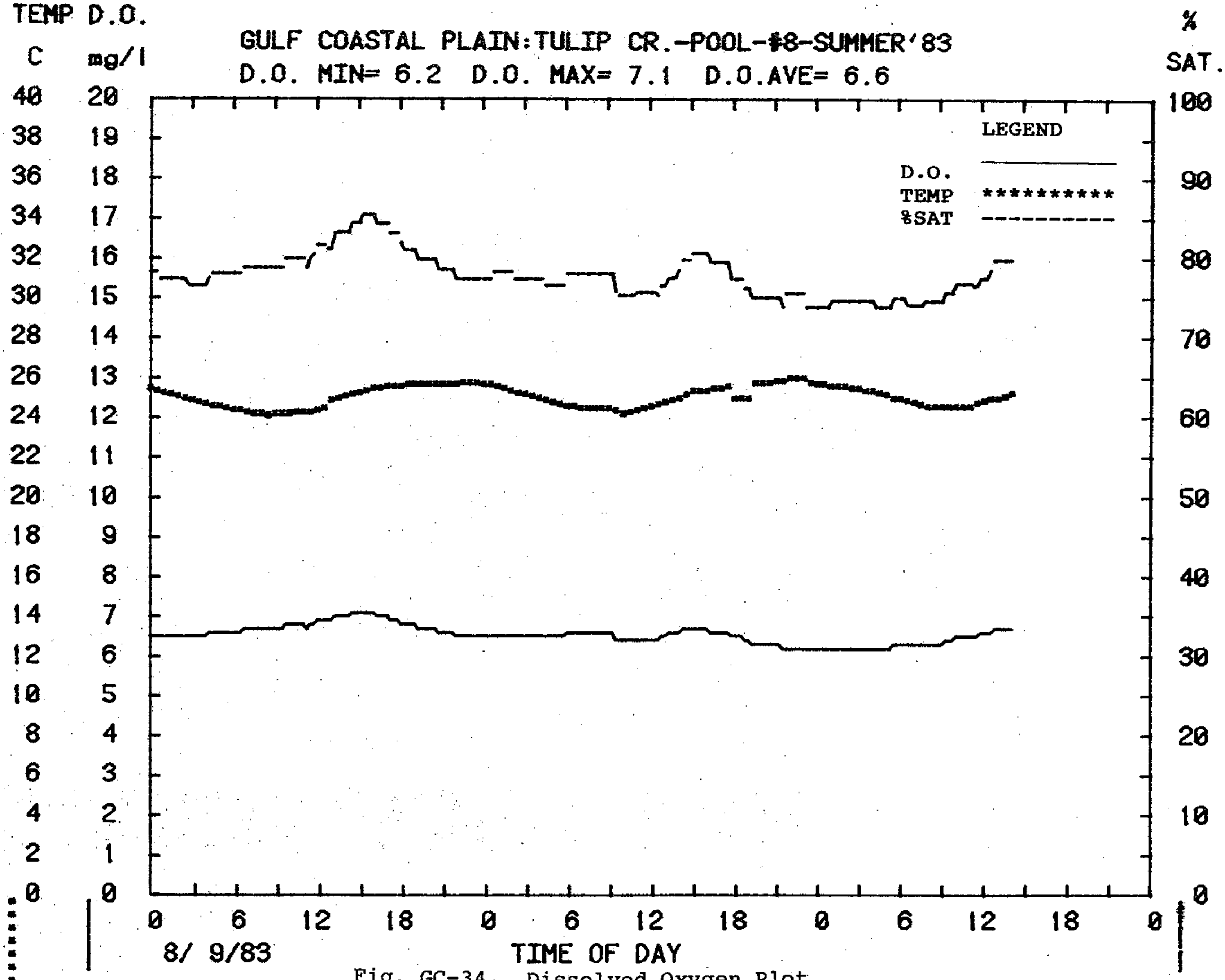


Fig. GC-34. Dissolved Oxygen Plot

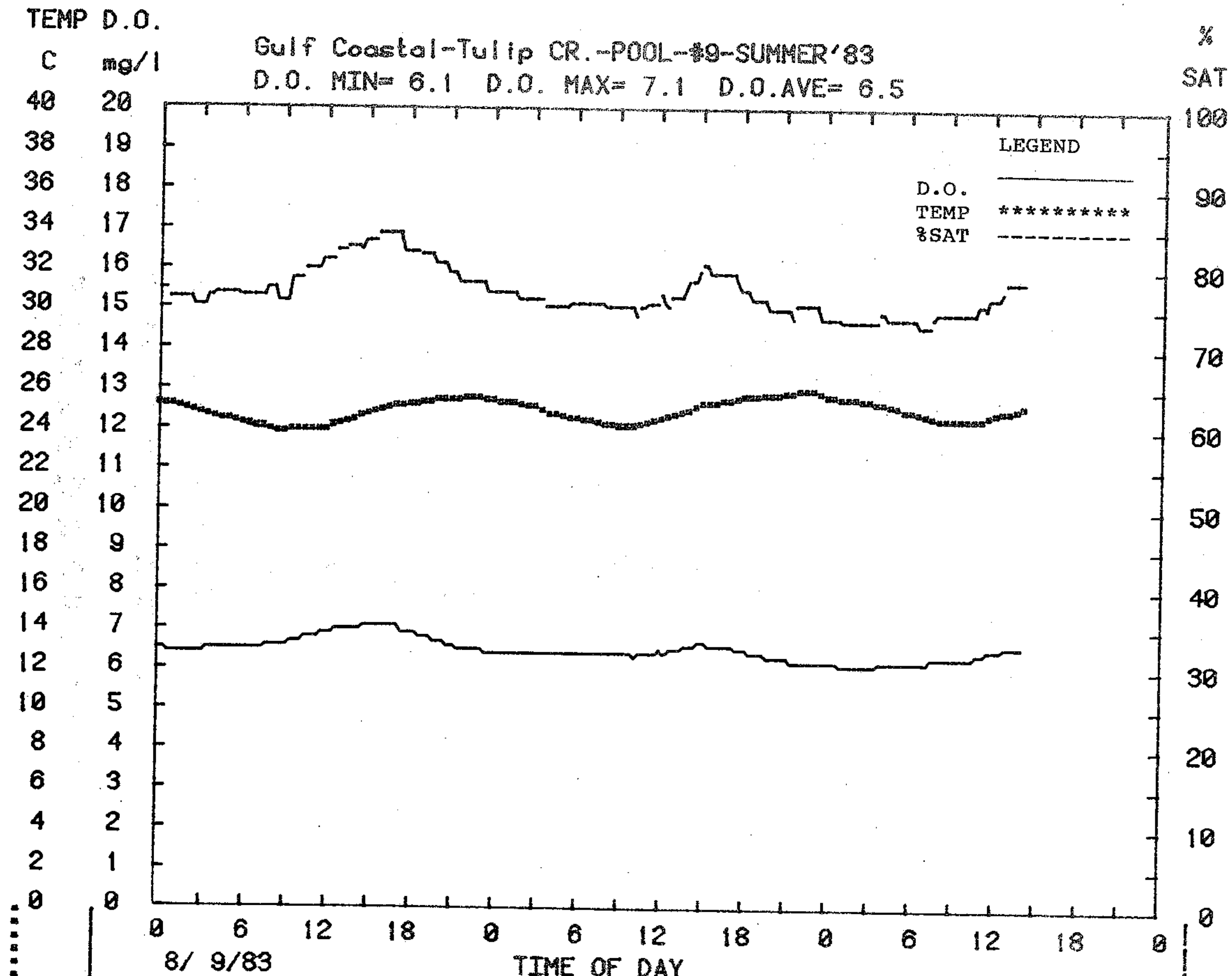


Fig. GC-35. Dissolved Oxygen Plot

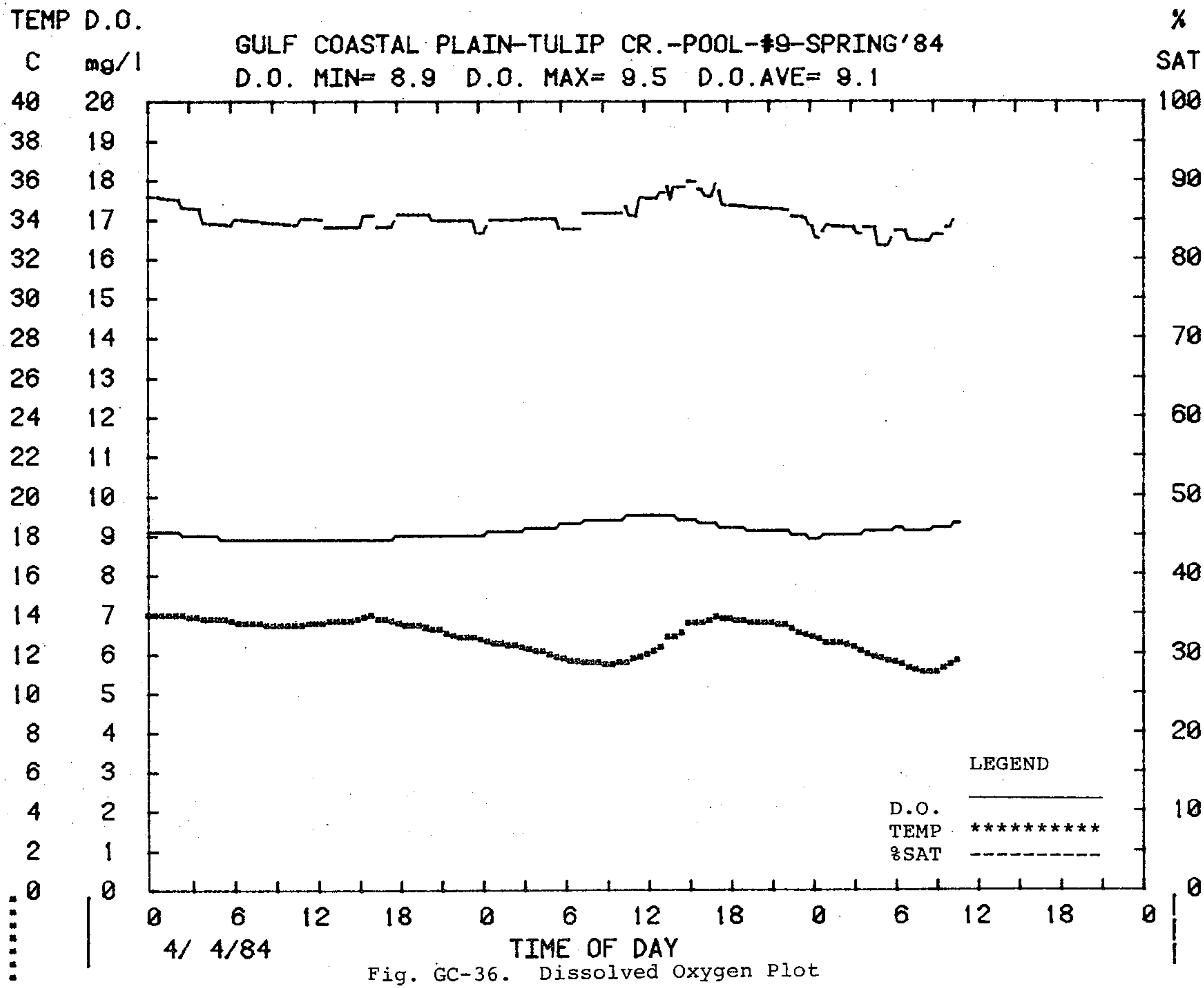


Fig. GC-36. Dissolved Oxygen Plot

Table GC-43

STREAM RECLASSIFICATION SURVEY

Chemical Results

Physiographic Region: Gulf Coastal Plain

Stream: East Fork Tulip Creek

Drainage Area: 46 Square Miles

Station Description: 300 feet upstream of bridge on county road in Section 19, T 9 S, R 15 W - Dallas County

Date: August 9, 1983

PARAMETER	TIME COLLECTED			AVERAGE
	10:35	12:51	14:16	
Q, cfs	5.2	5.2	5.2	5.2
Temperature, °C	24	24.5	25	24.5
pH	5.6	5.4	5.2	5.4
Turbidity, ntu	7.8	7.6	7.4	7.6
TSS, mg/l	6	4	4	5
TDS, mg/l	45	50	52	49
BOD-5, mg/l	0.4	0.4	0.3	0.4
BOD-20, mg/l	1.5	1.3	1.4	1.4
T.Phos., mg/l	0.03	0.03	0.02	0.03
PO4-P, mg/l	0.01	<0.01	<0.01	<0.01
NO2+NO3-N, mg/l	0.08	0.08	0.09	0.08
NH3-N, mg/l	0.04	0.04	0.05	0.04
Cl -, mg/l	5	5	5	5
SO4 =, mg/l	2	8	3	4
Fe, mg/l	0.42	0.39	0.43	0.41
Conductivity, μmho	37	38	37	37
Alkalinity, mg/l	8	9	8	8
T. Hardness, mg/l	10	10	12	11
Chlorophyll a, μg/l	1.4	0.5	5.3	2.4
Fecal Coliform	-	-	112	112

Dissolved Oxygen Data for 9 Aug 1983		
	Pool	Riffle
Average	6.7	6.7
Minimum	6.5	6.4
Maximum	7.1	7.1

very low pH, and high iron concentrations.

These parameters may be explained by analyzing the physical characteristics of the stream. Low pH is directly related to the soil types found in the drainage basin. As previously noted, pH is very strongly acidic at all depths of the soil, ranging from 4.5 to 5.0. The pH in the stream is not much different, and ranges from 5.2 to 5.6.

Nutrient levels are low because of land use in the basin. Ninety-six percent of the basin is covered by forests and what little agriculture goes on in the basin is pastureland. All of this results in minimal disturbance of the soils in the basin, no application of commerical fertilizers and very little domestic animal waste which means there are no sources for man-induced nutrients to enter the stream.

The relatively high concentration of iron seems to correlate with color in the stream. Water in the Gulf Coastal Plain is uniform in its brown to black color. Iron is probably responsible for most of the brown color, while tannins and lignins leached from the soil are responsible for the black.

Spring - Spring samples were collected on Thursday instead of Tuesday because rain on Monday night caused the creek to flood on Tuesday. Flow had decreased almost to normal levels by Thursday. Results are shown in Table GC-44.

Water quality measured during the spring sampling was very similar to that of the summer samples. Flow was approximately ten times greater than the low flow measured during the summer and this higher flow resulted in only a slight increase in turbidity. The 20 NTU turbidity measurement is well below the 50 NTU standard for the stream. The pH reading of 5.8, even with the increased flow, shows that the acid condition of the water is related to the soils within the watershed. Nutrient and mineral values remained very low, showing little change from the summer sampling.

Physical Parameters

Physical evaluations were made on August 9, 1983. Flow, mean stream velocity and stream transects to assess width, depth, substrate, etc., were all conducted as outlined in the General Methodology section of this report.

Summer - Tulip Creek is typical of streams in the Gulf Coastal Plain in many ways (Table GC-45). In fact, the only variation from the norm at Tulip Creek was the higher than expected flow. Land use, topography, soil type, canopy, and geology have previously been mentioned as directly affecting many of the chemical characteristics of the stream.

Table GC-44

STREAM RECLASSIFICATION SURVEY

Chemical Results

Physiographic Region: Gulf Coastal Plain

Stream: East Fork Tulip Creek

Drainage Area: 46 Square Miles

Station Description: 300 feet above bridge on county road in Section 19, T 9 S, R 15 W - Dallas County

Date: April 5, 1984

PARAMETER	TIME COLLECTED 09:35	10:20	11:50	AVERAGE
Q, cfs *	56	56	56	56
Temperature, °C	12.0	12.0	12.0	12.0
pH	5.8	5.7	5.9	5.8
Turbidity, ntu	20	20	20	20
TSS, mg/l	–	–	–	–
TDS, mg/l	56	51	50	52
BOD-5, mg/l	1.4	1.5	1.2	1.4
BOD-20, mg/l	2.2	2.5	2.2	2.3
T.Phos., mg/l	0.04	0.04	0.04	0.04
PO4-P, mg/l	0.01	0.02	0.02	0.02
NO2+NO3-N, mg/l	0.03	0.03	0.03	0.03
NH3-N, mg/l	0.06	0.09	0.04	0.06
Cl -, mg/l	2.5	3	3	3
SO4 =, mg/l	5	4	5	5
Fe, mg/l	0.48	0.48	0.49	0.48
Conductivity, µmho	34	34	36	35
Alkalinity, mg/l	5	5	5	5
T. Hardness, mg/l	12	14	16	14
Chlorophyll a, µg/l	–	0.3	–	0.3
Fecal Coliform	–	–	30	30
MN mg/l	0.033	0.034	0.039	0.035
COD mg/l	16.0	17.3	14.7	16.0

Dissolved Oxygen Data for 5 Apr 1984		
	Riffle	
Average	9.2	
Minimum	8.9	
Maximum	9.5	

*Flow high due to rain on night of 4-2-84.

Table GC-45

STREAM RECLASSIFICATION SURVEY

Physical Results

Stream:	East Fork Tulip Creek
Date:	August 9, 1983
Drainage Area:	46 sq. miles
Watershed Land Use:	96% forest 4% agriculture
Stream Gradient:	3.5 ft./mile
Mean Channel Width:	41.4 ft.
Mean Stream Width:	25.8 ft.
Mean Stream Velocity:	.26 ft./sec.
Observed Flow:	5.2 cfs
Average Substrate Type:	100% sand
Mean Instream Cover:	1% undercut bank 51% brush,logs,debris 5% overhanging veg.
Riffle/Pool Ratio of Transects:	0% riffle 0% deep pool 80% moderate pool 20% shallow pool
Mean Bank Overstory Cover:	95% trees 67% shrubs
Mean Bank Ground Cover:	60% grasses forbs 40% dirt
Mean Bank Stability:	0% stable 65% moderate 35% unstable
Mean Stream Canopy:	94.5%

Comments: Substrate type is listed as 100% sand but is more likely to be a mixture of sand/silt/mud; there is a problem in making this distinction.

Other characteristics that stood out at Tulip Creek were banks and substrate consisting entirely of sand, a low stream gradient and a high percentage of instream cover (brush, logs and debris). All of these characteristics are typical of small streams throughout the Gulf Coastal Plain.

Spring - No additional physical evaluations were made during the spring survey other than flow.

Macroinvertebrate Populations

A total of 41 taxa representing 14 orders were identified from samples collected from East Fork Tulip Creek. Fifteen and 33 taxa were identified from the summer and spring samples, respectively. The total number of organisms collected in the spring was almost three times that collected in the summer (Table A-12, Appendix A). These increases were probably a result of the increased sampling effort during the spring survey. It should be noted that spring sampling was hampered by the high water conditions which existed during the survey, thus making it difficult to sample all habitats completely.

The qualitative comparative indices indicated almost a complete lack of uniformity between the summer and spring sample (Table GC-46). These indices are lower than expected due to the two-fold increase in taxa collected during the spring. Seven of the 15 taxa (47%) identified from the summer collection were also present in the spring. Numerically, these seven taxa comprised 69% of the summer sample, but only 20% of the spring sample. The summer sample was dominated by *Viviparus* (a snail), and Cambarinae (female and immature crayfish). The spring sample was dominated by *Stylobromus* (an amphipod), *Isonychia* (a mayfly) and Cambarinae.

The community parameters calculated from the two collections indicated a sharp increase in community diversity from summer to spring (Table GC-46). The diversity index increased by a magnitude of one. This increase was in response to the greater number of taxa collected, as indicated by the fact that the index of variety increased while the index of evenness remained almost identical to summer values. These differences are thought to be associated with the increased sampling effort and not an increase in community quality. The spring sample is probably more indicative of the benthic community and is representative of a diverse, stable ecosystem which can be characterized as having "good" water quality.

Table GC-46. Community Analysis of Benthic Samples from East Fork Tulip Creek - Qualitative Sample, 1983-84

COMMUNITY PARAMETERS	Summer	Spring	Combined
Total # Organisms	45	130	175
Total # Taxa	15	33	42
Diversity	3.3309	4.3104	4.6002
Index of Evenness	0.2721	0.3151	0.2777
Index of Dominance	0.8524	0.8545	0.8586
Index of Variety	2.5492	4.5557	5.3683
COMPARATIVE INDICES			
Dice Index (range 0-1)		0.29	
Common Taxa Index (range 0-1)		0.32	
Qualitative Similarity Index (range 0-100)		17.0	

Fish Populations

Summer - A combination of collecting methods was used at this site. The 3500-watt, 220-volt, a.c. electroshocker transported in a flat-bottomed boat was used to collect fish from the county road bridge upstream for about 200 yards. Also, about one-third of an acre below the bridge was treated with 4 pounds of 7.2% powdered rotenone.

Fishes collected by both methods were lumped together for determination of species relative abundance. A list of all species collected in order of their relative abundance is given in Table GC-47. A total of 703 individuals from 36 species were collected with a total relative abundance value of 238.5, a diversity index of 5.00, and an index of evenness of 0.97 (Table GC-48). Family groupings of species produced seven species of Percidae totaling 19.1% of the population's relative abundance; nine species of Centrarchidae, 25.8%; six species of Cyprinidae, 15.5%; three species of Ictaluridae, 11.3%; and four species of Catostomidae comprised 9.4% of the total. Four species of primary feeding fishes made up 5.5% of the population's relative abundance; 28 species of secondary feeders, 83.8%; and four species of top carnivores comprised 10.7% of the total fish. Six sensitive species made up 18.5% of the population.

Table GC-47 - Fishes Collected from East Fork Tulip Creek with Relative Abundance Values

Species		R.A. VALUE
Notropis umbratilis	Redfin Shiner	12
**Moxostoma poecilurum*	Blacktail redhorse	12
Lepomis megalotis	Longear	12
Noturus miurus	Brindled madtom	10.5
Noturus nocturnus	Freckled madtom	10.5
Esox americanus	Grass pickerel	9
Notropis chrysocephalus	Striped shiner	9
Fundulus notatus	Blackstripe topminnow	9
Aphredoderus sayanus	Pirate perch	9
Elassoma zonatum	Banded pygmy sunfish	9
**Ammocrypta vivax*	Scaly sand darter	9
**Etheostoma collettei*	Creole darter	9
Pimephales notatus	Bluntnose minnow	7.5
Fundulus olivaceus	Blackspotted topminnow	7.5
Micropterus salmoides	Largemouth bass	7.5
Etheostoma gracile	Slough darter	7.5
Moxostoma erythrurum	Golden redhorse	6.5
Lepomis cyanellus	Green sunfish	6.5
Lepomis gulosus	Warmouth	6.5
**Percina sciera*	Dusky darter	6.5
Notropis emiliae	Pugnose minnow	6
Ictalurus natalis	Yellow bullhead	6
Micropterus punctulatus	Spotted bass	6
Etheostoma whipplei	Redfin darter	6
**Percina maculata*	Blackside darter	6
Lepomis punctatus	Spotted sunfish	5
Gambusia affinis	Mosquitofish	4.5
Centrarchus macropterus	Flier	4.5
Lepomis macrochirus	Bluegill	4.5
Lamprey larvae	Lamprey	3
Amia calva	Bowfin	3
Erimyzon oblongus	Creek chubsucker	2
Minytrema melanops	Spotted sucker	2
Hybognathus nuchalis	Silvery minnow	1.5
**Etheostoma stigmaeum*	Speckled darter	1.5
Campostoma anomalum	Stoneroller	1
	Total	238.5

*Sensitive Species

Table GC-48. Summary of Fish Population Parameters from East Fork of Tulip Creek

Total Species Collected	36.0
Total Number Of Individuals	703.0
Total Relative Abundance Value	238.5
Relative Abundance Diversity Index	5.00

Population Parameters	No. Sp.	% R.A.V.
CYPRINIDAE	6.0	15.5
CATOSTOMIDAE	4.0	9.4
ICTALURIDAE	3.0	11.3
CENTRARCHIDAE	9.0	25.8
PERCIDAE	7.0	19.1
Primary Feeders	4.0	5.5
Macroinvertebrate Feeders	28.0	83.8
Carnivores	4.0	10.7
Sensitive Species	6.0	18.5

Spring - On April 2, 1984, one 3½" and one 1½" mesh monofilament trammel nets were set below the bridge at the sample site. Also, three hoop nets (one below and two above the bridge) were set. Rain and high water levels reduced efficiency of sampling. Nets could not be checked until the second and third days after they were set.

Nets were filled with leaves and other debris. The only fishes taken were spotted suckers, golden redhorse, and blacktail redhorse, some of which were in breeding condition.

CYPRESS CREEK

Cypress Creek begins in the southern part of Hot Spring County, flows in a southwesterly direction through the western part of Dallas County and enters the Ouachita River about 10-12 air miles below the sample site. The sample site for Cypress Creek was located in Section 3, R 17 W, T 9 S (Figure GC-37).

General Site Discussion

Watershed Size - The watershed size of Cypress Creek above the county road bridge is 73 mi^2. This size of watershed was expected to have zero flow during the summer months. However, in this case, Cypress Creek drains an area with steady groundwater recharge causing year-round flow.

USGS and the Soil Conservation Service list Cypress Creek as a perennial stream approximately 15 miles upstream of the sample site location. At that point the drainage area is 17 mi^2. A perennial stream with a watershed of less than 17 mi^2 is atypical for the Gulf Coastal region. Therefore, the information gathered from this stream should not be extrapolated to the rest of the region, but should be considered a sub-region in the future.

Geology - As with Tulip Creek, Cypress Creek drains an area that is underlain by the Sparta Sand Formation with alluvial deposits underlying the creek bed and surrounding banks.

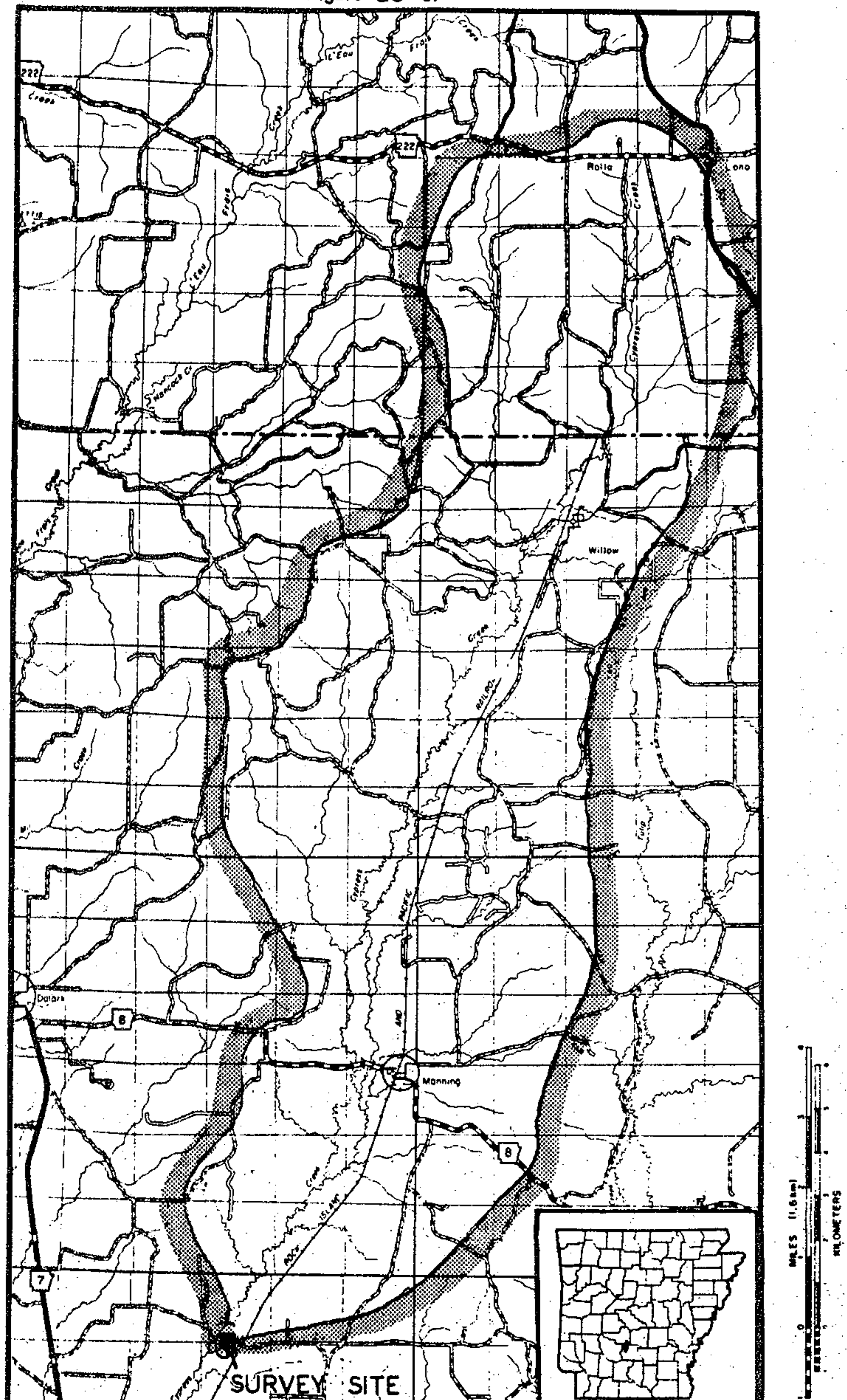
Topography - Topography within the watershed is generally level to gently rolling sand hills with broad streamside wetland areas directly adjacent to the creek.

Soil Types - Cypress Creek is in an area that is dominated by the Amy-Smithton-Pheba and Pikeville-Savannah-Smithdale associations. The predominant soil association is the Amy-Smithton-Pheba. This association consists of poorly drained to somewhat poorly drained, level to nearly level, loamy soils found on upland areas. The soils of the Pikeville-Savannah-Smithdale association are well drained to moderately well drained, nearly level to moderately sloping, loamy soils found on upland areas.

Soils in both associations are strongly acidic to very strongly acidic (pH values are in the range of 4.5 to 5.5). Erosional potential is slight.

Flora - Loblolly pine and sweetgum trees dominate the forest in the upland areas of the basin. Low overflow wetland areas are dominated by beech, oak and hickory trees.

Figure GC-37



CYPRESS CREEK: Drainage area 73 square miles

■ Survey site ░ Survey area

Land Use - Land use within the watershed is 73% forest and 27% agriculture, according to the Soil Conservation Service. Based on site observations, the percentage of agriculture appears to be high. Nonetheless, the predominant agricultural use is pastureland. Overall, the watershed has a very low level of man-induced disturbances and qualifies as least-impaired for this region.

Stream Characteristics - Cypress Creek should be considered atypical for this watershed size in the Gulf Coastal Plain due to its continuous flow. The dominant physical characteristics of Cypress Creek consist of moderate bank stability with predominant tree cover, deep pools with few or no riffles and a substrate that consists mostly of sand. The creek has a mean width, depth and velocity of 32 ft., 2.5 ft. and 0.36 fps, respectively, during the critical summer low flow period. Cypress Creek has an almost complete canopy provided by trees.

Methodology and Sampling Results

The summer survey was conducted from August 8, 1983, to August 12, 1983. Weather during this period was sunny to partly cloudy and hot. Rain during the week prior to the survey caused high flows which fell gradually during the survey.

The spring survey was conducted from April 2, 1984, to April 6, 1984. Weather during this period was cloudy to partly cloudy. The weather was rainy prior to the survey period and rain fell again on the night of April 2, 1984. Flows were high but falling during the latter part of the survey.

Continuous Dissolved Oxygen

Summer - Three continuous D.O. meters were set up 500 to 800 feet upstream of the county road bridge on the afternoon of August 8, 1983; they operated until the morning of August 12, 1983. The riffle location was on the downstream side of a man-made, rock dam. All meters performed well and gave nearly identical results.

The continuous D.O. data collected on Cypress Creek during the summer survey showed a slight but consistent decline (6.1 to 5.0) in D.O. over the 72-hour period (Figures GC-38 through GC-40). This decline is probably due to the decrease in flow. The D.O. and percent saturation data indicate little or no diurnal fluctuation. The average temperature in Cypress Creek for this period was 26°C. This temperature is lower than expected and was probably due to the shade provided by the stream canopy and groundwater influences.

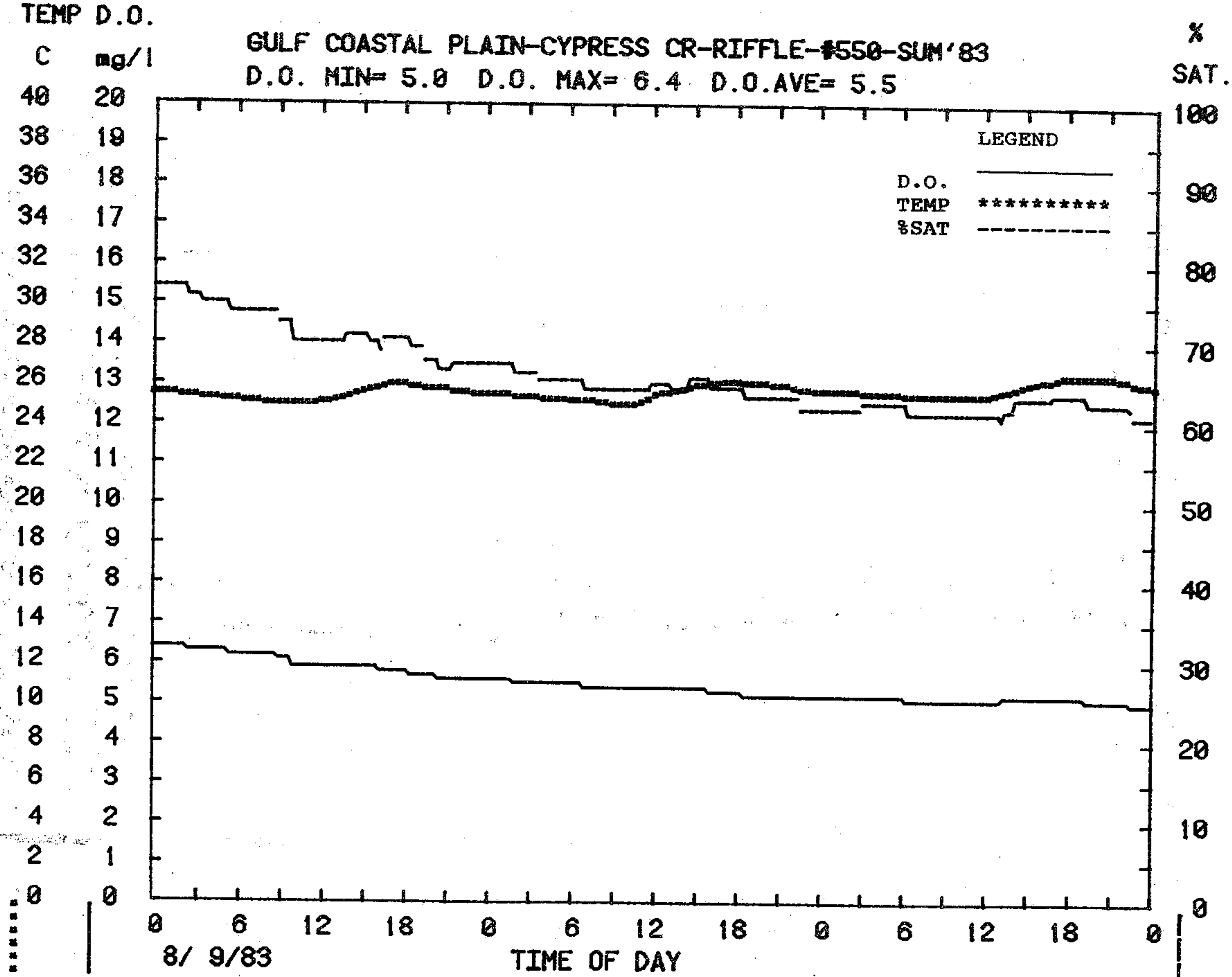


Fig. GC-38. Dissolved Oxygen Plot

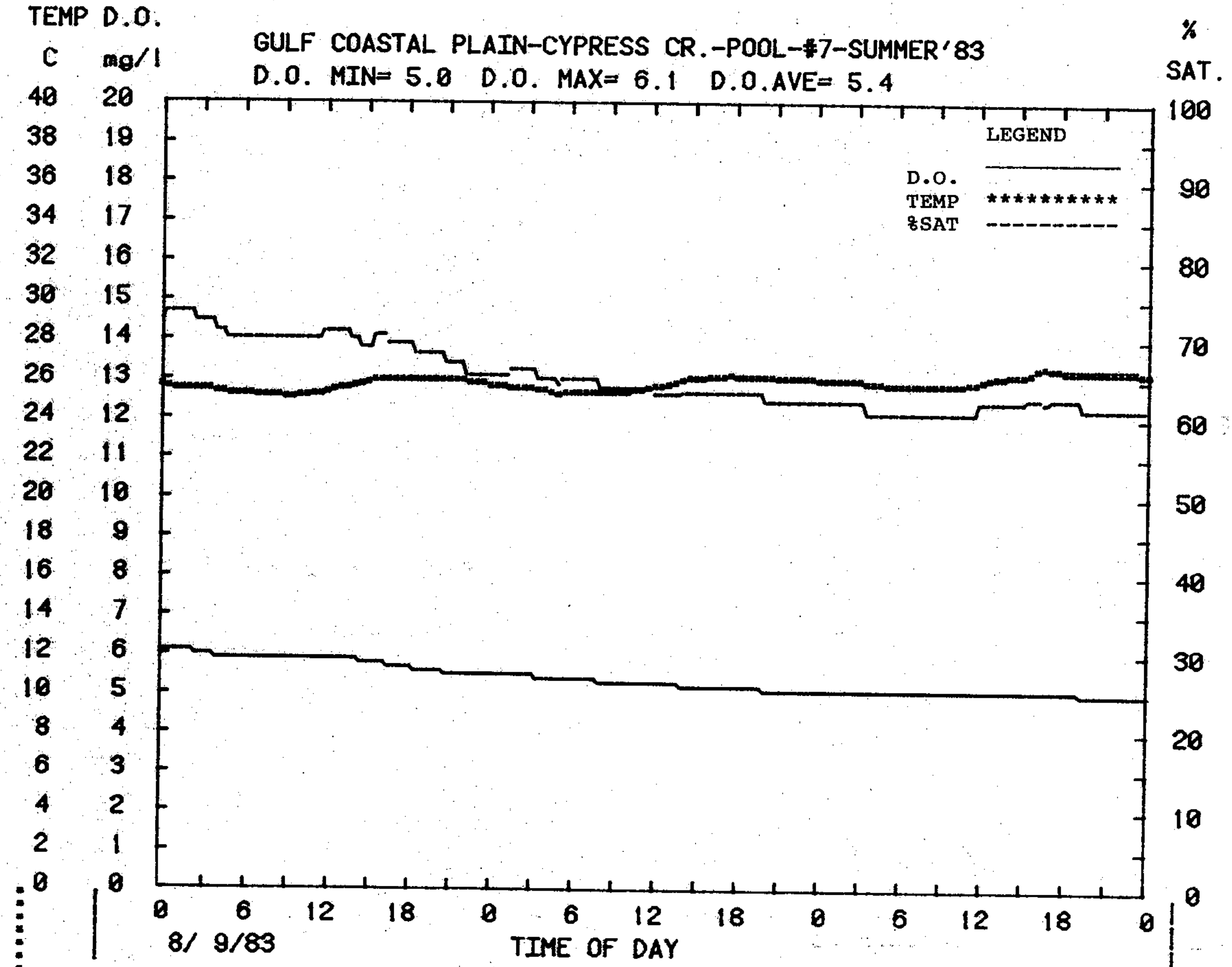


Fig. GC-39. Dissolved Oxygen Plot

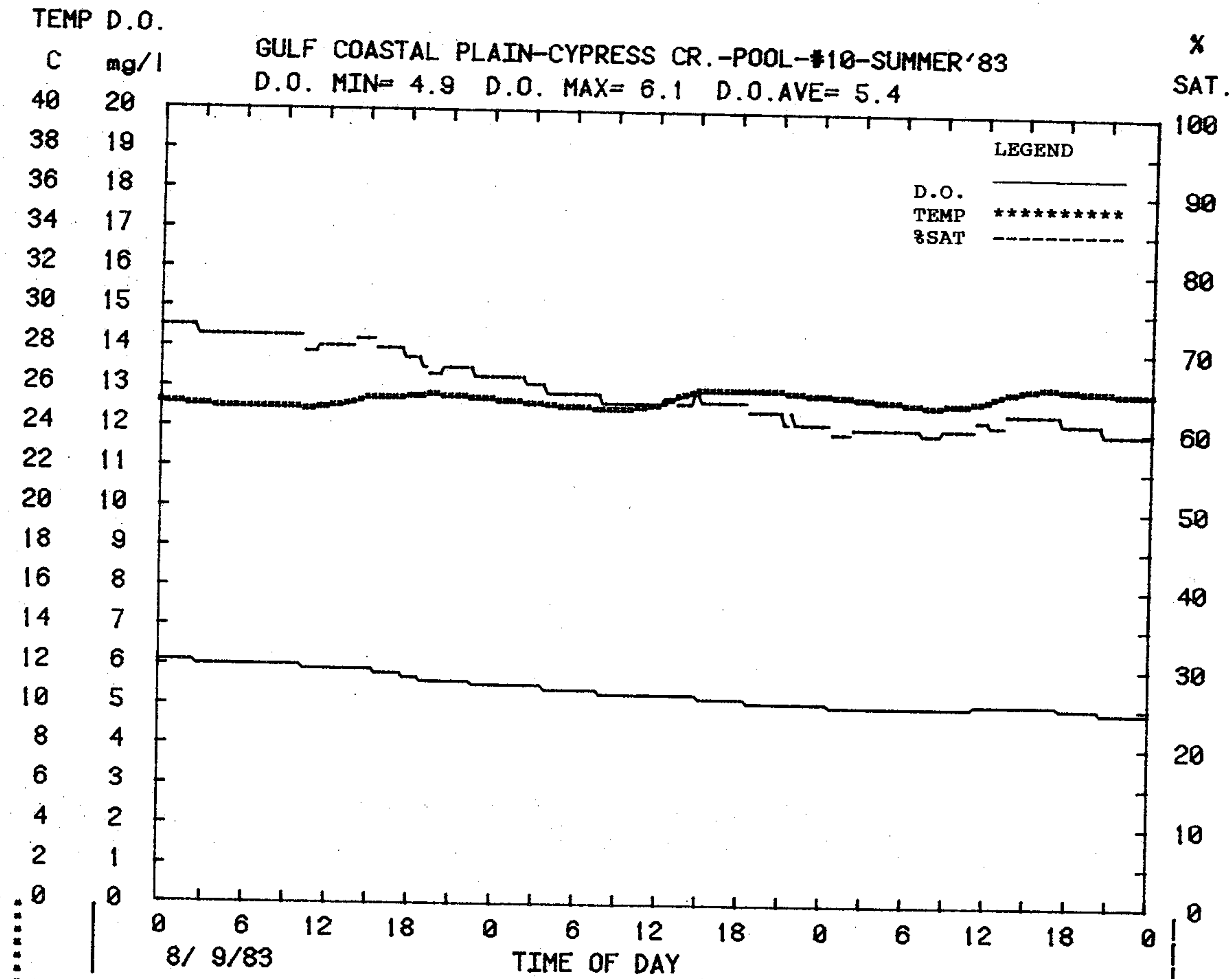


Fig. GC-40. Dissolved Oxygen Plot

Spring - Two continuous D.O. meters were placed upstream of the bridge. However, due to problems at the East Tulip Creek site, one of these had to be transferred after one day. The one meter that was left performed well.

The dissolved oxygen data collected during the spring survey showed a slight diurnal fluctuation of 0.6 mg/l. The weather during this period consisted of extremely heavy rainfall during the first day, which raised the flow in the stream significantly that day. This was followed by sunny days for the rest of the survey. However, the D.O. remained almost constant throughout the survey period (Figures GC-41 and GC-42).

Chemical Parameters

Summer - Grab samples were taken during the summer survey about 200 yards upstream of the county road bridge. These samples were collected on August 9, 1983, at 0940, 1200 and 1420.

Spring - During the spring survey the sampling date was changed from April 3 to April 5, 1984. This change was due to a heavy rainfall which occurred on the night of April 2. The three samples were collected at 0900, 1000 and 1100.

The results of the chemical analyses for summer and spring are given in Tables GC-49 and GC-50, respectively. The nutrient levels in Cypress Creek for both the summer and spring surveys were low. This is probably due to the limited agriculture in the drainage area, most of which was pastureland. The only unusual parameters are the low pH and high total iron. The pH values ranged from 5.6 in the spring to 6.1 in the summer. These values are low but are attributable to the soil types in this watershed. The soil pH varies from 4.5 to 5.5.

The total iron values were high and appear to be directly related to the turbidity. This tends to indicate that the iron is not dissolved but rather suspended in the water column. The summer iron values were higher than in spring and may have been associated with the groundwater flows which dominate during the dry season.

Physical Parameters

The majority of the physical evaluations were made during the summer survey on August 9, 1983. The evaluations were conducted as outlined in the General Methodology of this report. Flow during the summer survey was falling slightly throughout the survey period. Mean stream velocity was 0.36 fps which was somewhat faster than expected. The results are summarized in Table GC-51.

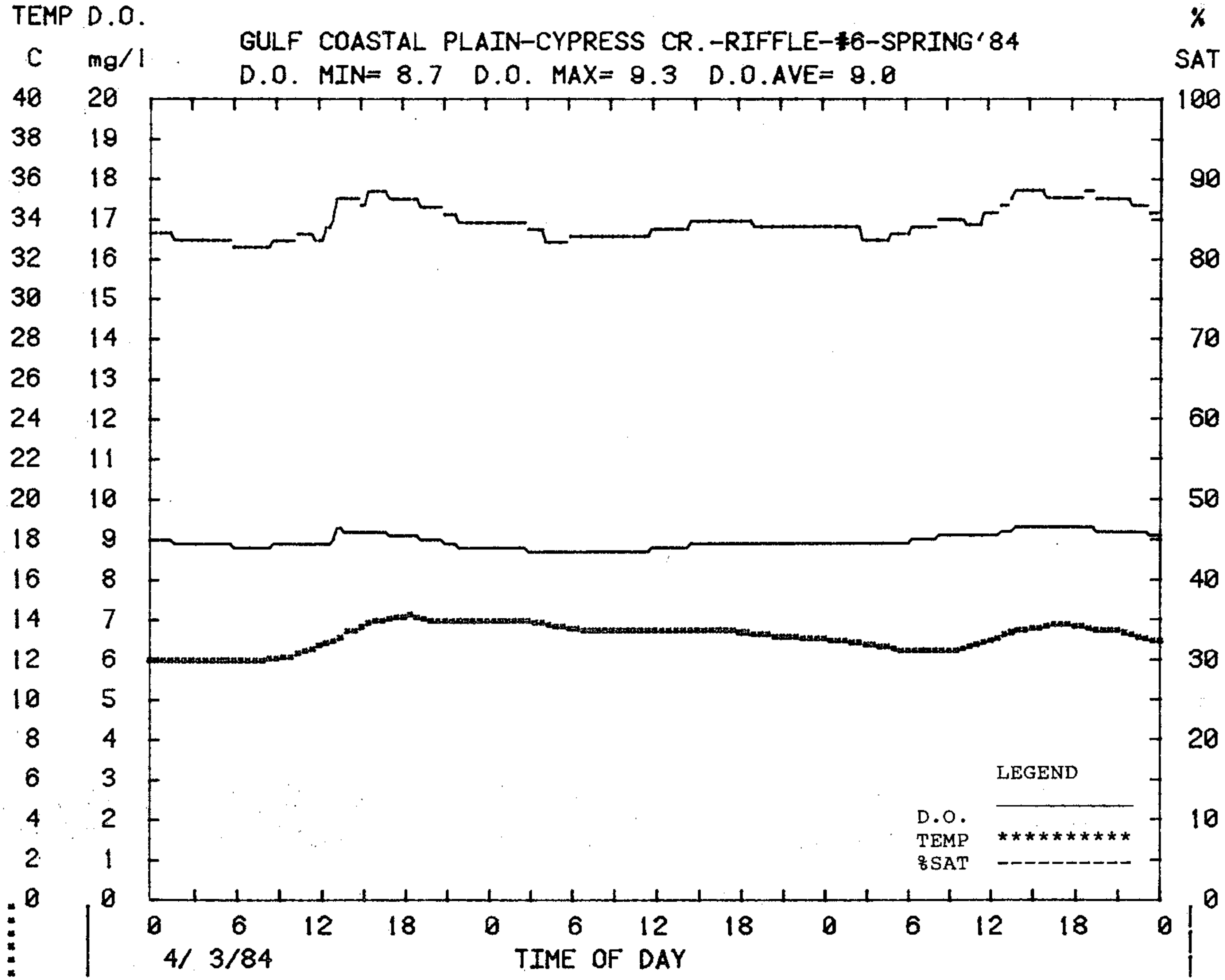


Fig. GC-41. Dissolved Oxygen Plot

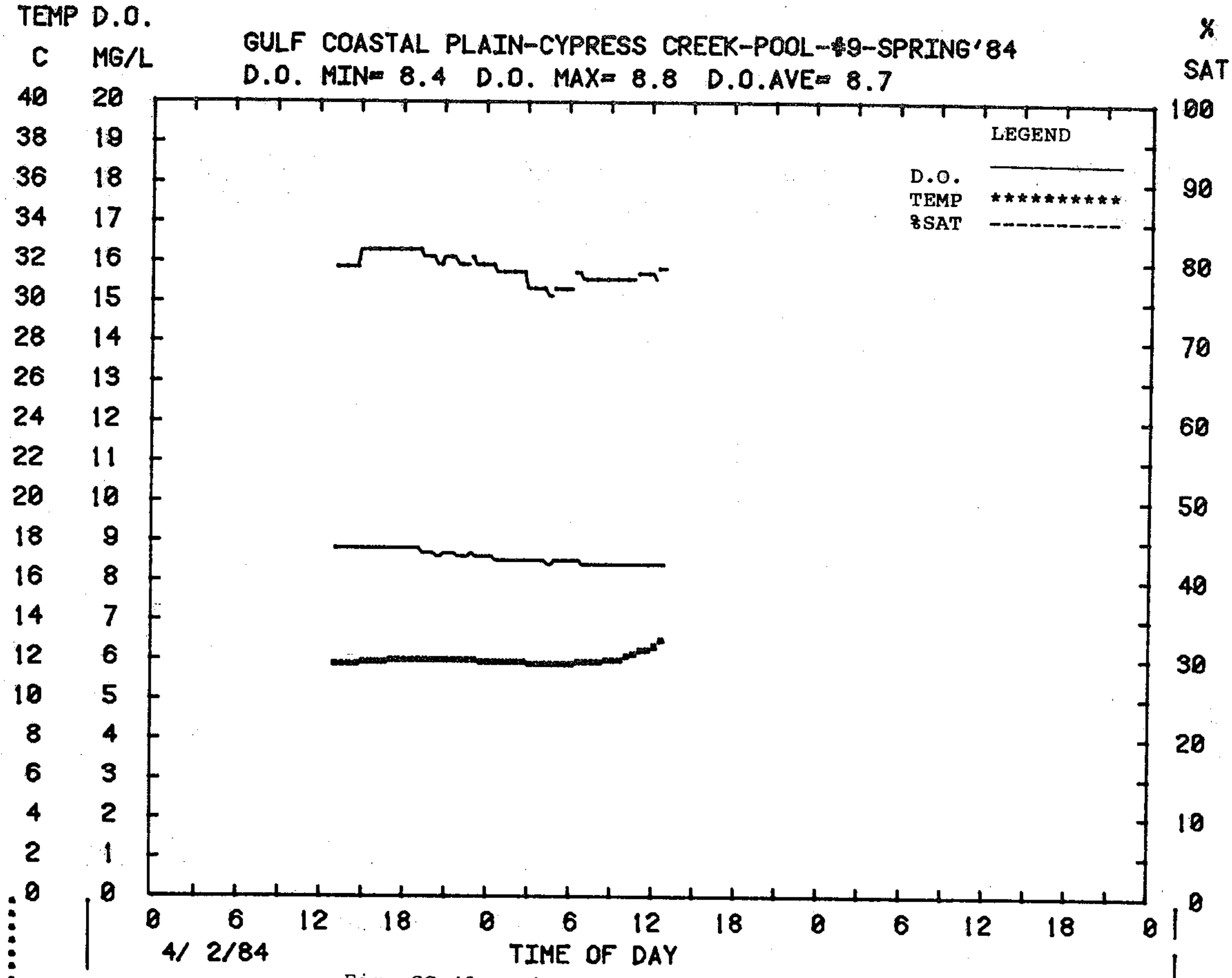


Fig. GC-42. Dissolved Oxygen Plot

Table GC-49

STREAM RECLASSIFICATION SURVEY

Chemical Results

Physiographic Region: Gulf Coastal Plain

Stream: Cypress Creek

Drainage Area: 73 Square Miles

Station Description: Above riffle (small rock dam) 600 feet above bridge on county road located in Section 3, T 9 S, R17 W - Dallas County

Date: August 9, 1983

PARAMETER	TIME COLLECTED 09:40	12:00	14:20	AVERAGE
Q, cfs	10.8	10.8	10.8	10.8
Temperature, °C	25	25	25.5	25
pH	5.9	6.1	6.3	6.1
Turbidity, ntu	22	21	21	21
TSS, mg/l	8	6	8	7
TDS, mg/l	45	44	45	45
BOD-5, mg/l	0.9	0.7	0.6	0.7
BOD-20, mg/l	2.5	2.1	1.7	2.1
T.Phos., mg/l	0.05	0.05	0.04	0.05
PO4-P, mg/l	0.01	0.01	0.03	0.02
NO2+NO3-N, mg/l	0.14	0.14	0.15	0.14
NH3-N, mg/l	0.06	0.06	0.08	0.07
Cl -, mg/l	5	4.5	5	5
SO4 =, mg/l	1	1	<1	<1
Fe, mg/l	1.04	0.91	0.86	0.94
Conductivity, μmho	25	23	25	24
Alkalinity, mg/l	5	5	5	5
T. Hardness, mg/l	10	10	10	10
Chlorophyll a, μg/l	6.2	1.7	1.1	3.0
Fecal Coliform	-	-	172	172

Dissolved Oxygen Data for 9 Aug 1983		
	Pool	Riffle
Average	5.9	6.0
Minimum	5.5	5.6
Maximum	6.1	6.3

Table GC-50

STREAM RECLASSIFICATION SURVEY

Chemical Results

Physiographic Region: Gulf Coastal Plain

Stream: Cypress Creek

Drainage Area: 73 Square Miles

Station Description: 600 feet above bridge on county road in Section 3, T 9 S, R 17 W - Dallas County

Date: April 5, 1984

PARAMETER	TIME COLLECTED 09:00	10:00	11:00	AVERAGE
Q, cfs *	~ 150	~ 150	~ 150	~ 150
Temperature, °C	13	13	13	13
pH	5.6	5.6	5.6	5.6
Turbidity, ntu	9.8	9.6	10.0	9.8
TSS, mg/l	-	-	-	-
TDS, mg/l	38	40	40	39
BOD-5, mg/l	1.5	1.4	1.3	1.4
BOD-20, mg/l	2.6	2.4	2.4	2.5
T.Phos., mg/l	0.02	0.06	0.03	0.04
PO4-P, mg/l	0.02	0.02	<0.01	<0.02
NO2+NO3-N, mg/l	0.04	0.04	0.04	0.04
NH3-N, mg/l	0.05	0.03	0.06	0.05
Cl -, mg/l	2	2	2	2
SO4 =, mg/l	3	3	3	3
Fe, mg/l	0.39	0.42	0.36	0.39
Conductivity, μmho	22	22	21	22
Alkalinity, mg/l	2	2	2	2
T. Hardness, mg/l	12	12	8	11
Chlorophyll a, μg/l	-	0.3	0.3	0.3
Fecal Coliform	-	-	10	10
MN mg/l	0.038	0.043	0.040	0.040
COD mg/l	14.0	16.7	12.0	14.2

Dissolved Oxygen Data for 5 Apr 1984		
	Riffle	
Average	9.1	
Minimum	8.9	
Maximum	9.3	

*Flow high due to rain on night of 4-2-84.

Table GC-51

STREAM RECLASSIFICATION SURVEY

Physical Results

Stream:	Cypress Creek
Date:	August 9, 1983
Drainage Area:	73 Sq. miles
Watershed Land Use:	73% forest 27% agriculture
Stream Gradient:	4.2 ft./mile
Mean Channel Width:	44.8 ft.
Mean Stream Width:	32.0 ft.
Mean Stream Velocity:	.36 ft./sec.
Observed Flow:	10.8 cfs
Average Substrate Type:	1% boulder 61% sand 2% rubble 28% mud/silt 8% gravel
Mean Instream Cover:	.6% undercut bank 13% brush,logs,debris 2% overhanging veg. .6% inundated veg.
Riffle/Pool Ratio of Transects:	0% riffle 60% deep pool 20% mod. pool 20% shallow pool
Mean Bank Overstory Cover:	91% trees 18% shrubs
Mean Bank Ground Cover:	21% grasses forbes 79% dirt
Mean Bank Stability:	10% stable 80% moderate 10% unstable
Mean Stream Canopy:	90%

Comments: Substrate type is variable due to the 1st transect being untypical. An old rock dam was located just above that transect.

Cypress Creek is a meandering stream that consists mostly of deep pools with steep, moderately stable banks. The stream substrate consists largely of sand with a moderate amount of instream cover.

Macroinvertebrate Populations

A total of 57 taxa representing 13 orders were identified from summer and spring benthic samples collected within the study area (Table A-13, Appendix A). Twenty-six (26) and 44 taxa were identified from the summer and spring collections, respectively. The total number of organisms collected in the spring was almost twice that collected in the summer. The increases in taxonomic diversity and numerical abundance from summer to spring samples were due, at least in part, to increased sampling effort despite the high volume flows during the spring survey which hindered collection of the deeper water microhabitats.

Numerically, the dominant orders of the summer sample were decapods, coleopterans, and tricopterans, comprising 20.5, 16.2 and 14.5% of the sample, respectively. Taxonomically, the dominant groups were coleopterans, ephemeropterans, and odonates. The dominant orders of the spring sample were the ephemeropterans and coleopterans comprising 39.4 and 16.7% of the numerical total and almost 50% of the taxa.

The qualitative similarity indices indicated only slight uniformity between the summer and spring samples (Table GC-52). However, 14 of the 26 taxa identified from the summer sample were also collected in the spring. Also, four of the five dominant taxa of the summer sample were collected in the spring. The reduced values calculated for the qualitative similarity indices were a result of the large increases in taxa collected during the spring survey and the seasonal progression of insect taxa characteristic of natural communities.

The community parameters calculated for the spring and summer collections indicated a very diverse stable macroinvertebrate community (Table GC-52). There was a slight increase in the diversity indices from summer to spring. This increase was a result of the additional number of taxa collected as evidenced by the increase in index of variety. The decrease in index of evenness and increase in index of dominance were generated by the two fold increase in total number of organisms collected. This increase was due to the increased sampling effort and not a reduction in water quality.

Table GC-52. Community Analysis of Benthic Samples from Cypress Creek - Qualitative Sample, 1983-84

COMMUNITY PARAMETERS	Summer	Spring	Combined
Total # Organisms	117	204	321
Total # Taxa	26	45	57
Diversity	4.2564	4.6433	5.1914
Index of Evenness	0.8952	0.8557	0.8862
Index of Dominance	0.4169	0.5978	0.5216
Index of Variety	3.7843	5.4741	6.8456
COMPARATIVE INDICES			
Dice Index (range 0-1)		0.37	
Common Taxa Index (range 0-1)		0.23	
Qualitative Similarity Index (range 0-100)		38.0	

Fish Populations

Summer - Approximately one-half acre of the stream was treated with 5 pounds of 7.2% powdered rotenone. A total of 950 fishes were collected. Table GC-53 lists all species collected and their relative abundance. There were 42 species collected, with a total relative abundance value of 247, a diversity index of 5.07 and an index of evenness of 0.94 (Table GC-54). Centrarchidae was the dominant family of fishes. Nine species of Centrarchidae made up 24.9% of the total relative abundance; ten species of Percidae, 16.2%; three species of Ictaluridae, 12.1%; five species of Cyprinidae, 11.9% and four species of Catostomidae comprised 8.7% of the total. Primary feeding fishes from three species made up only 2% of the total relative abundance value, 32 species of secondary feeders made up 80.1% and seven top carnivore species comprised 16.2% of the total population. There were nine sensitive species present, totaling 13.8% of the population relative abundance.

Spring - Two trammel nets and three hoop nets were used in an attempt to collect fishes from Cypress Creek. A 3.5-inch mesh and a 1.5-inch monofilament trammel net and three hoop nets were set on April 2, 1984. Increased flows, high water and debris reduced netting efficiency. Two different types of electrofishing gear were also used. They also were inefficient.

Netting produced only one spotted bass, one spotted sucker and a yellow bullhead. All were sexually mature and near or in spawning condition. Electrofishing with the boat-mounted shocker was limited due to navigation difficulties but it produced numerous adult and larvae lamprey and an adult bowfin. The adult lamprey, southern brook and chestnut were apparently in the process of spawning. Collection of the chestnut lamprey increased the total fish species collected to 43.

Table GC-53. Fishes Collected from Cypress Creek on August 11, 1983, with Relative Abundance Values

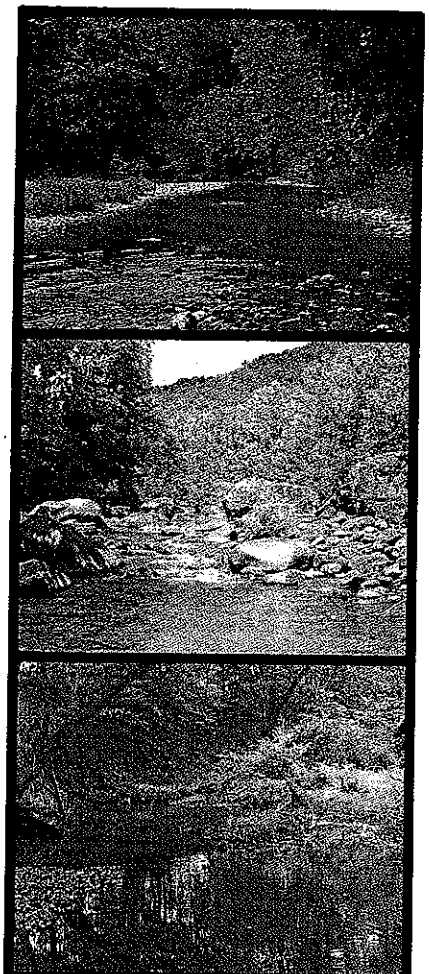
Species		R.A. VALUE
Noturus nocturnus	Freckled madtom	12.0
Lepomis megalotis	Longear	12.0
Notropis umbratilis	Redfin shiner	12.0
Ictalurus natalis	Yellow bullhead	12.0
Aphredoderus sayanus	Pirate perch	10.5
Esox niger	Chain pickerel	10.5
Centrarchus macropterus	Flier	9.0
Lepomis cyanellus	Green sunfish	9.0
Lepomis gulosus	Warmouth	9.0
Fundulus olivaceus	Blackspotted topminnow	9.0
Esox americanus	Grass pickerel	9.0
Etheostoma whipplei	Redfin darter	9.0
*Percina sciera	Dusky darter	8.0
*Etheostoma collettei	Creole darter	7.5
Micropterus punctulatus	Spotted bass	7.5
Fundulus notatus	Blackstripe topminnow	7.5
*Moxostoma poecilurum	Blacktail redhorse	7.5
Notropis chrysocephalus	Striped shiner	7.5
Minytrema melanops	Spotted sucker	7.0
Amia calva	Bowfin	7.0
Micropterus salmoides	Largemouth bass	6.0
Notropis emiliae	Pugnose minnow	6.0
Elassoma zonatum	Banded pygmy sunfish	6.0
*Percina maculata	Blackside darter	6.0
Lepomis punctatus	Spotted sunfish	6.0
Noturus gyrinus	Tadpole madtom	6.0
Moxostoma erythrurum	Golden redhorse	6.0
Gambusia affinis	Mosquitofish	4.5
Etheostoma gracile	Slough darter	4.5
Campostoma anomalum	Stoneroller	3.0
Anguilla rostrata	American eel	3.0
Labidesthes sicculus	Brook silversides	1.5
*Etheostoma parvipinne	Goldstripe darter	1.0
Etheostoma proeliare	Cypress darter	1.0
*Etheostoma stigmaeum	Speckled darter	1.0
Notemigonus crysoleucas	Golden shiner	1.0
Ichthyomyzon gagei	Southern brook lamprey	1.0
Pomoxis nigromaculatus	Black crappie	1.0
*Ammocrypta vivax	Scaly sand darter	1.0
Etheostoma chlorosomum	Bluntnose darter	1.0
*Fundulus catenatus	Northern studfish	1.0
*Hypentelium nigricans	Northern hogsucker	1.0
Ichthyomyzon castaneus	Chestnut lamprey	S
	Total	251.0

* Sensitive species
S - Collected during spring sampling only

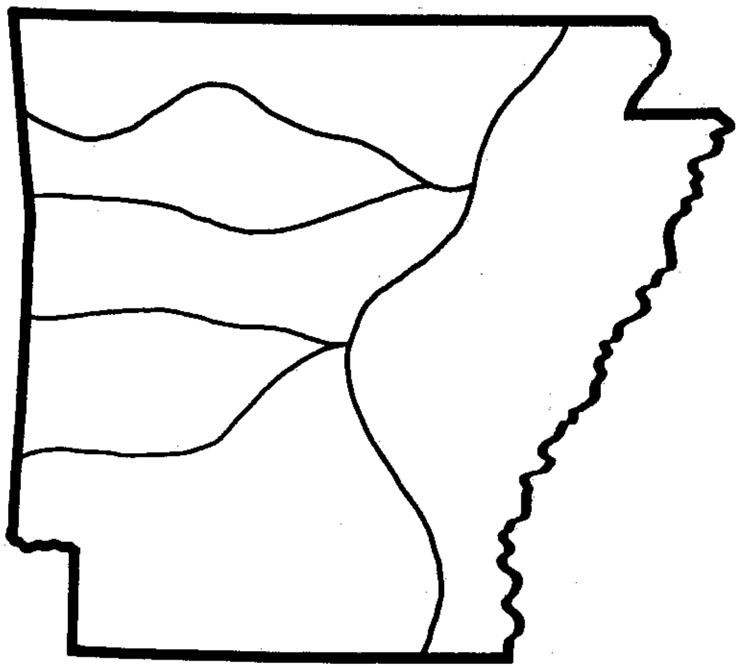
Table GC-54. Summary of Fish Population Parameters from Cypress Creek

Total Species Collected	43.0
Total Number Of Individuals	950.0
Total Relative Abundance Value	247.0
Relative Abundance Diversity Index	5.07

Population Parameters	No. Sp.	% R.A.V.
CYPRINIDAE	5.0	11.9
CATOSTOMIDAE	4.0	8.7
ICTALURIDAE	3.0	12.1
CENTRARCHIDAE	9.0	24.9
PERCIDAE	10.0	16.2
Primary Feeders	3.0	2.0
Macroinvertebrate Feeders	32.0	81.8
Carnivores	7.0	16.2
Sensitive Species	9.0	13.8



Physical, Chemical, and Biological Characteristics of Least-Disturbed Reference Streams in Arkansas' Ecoregions



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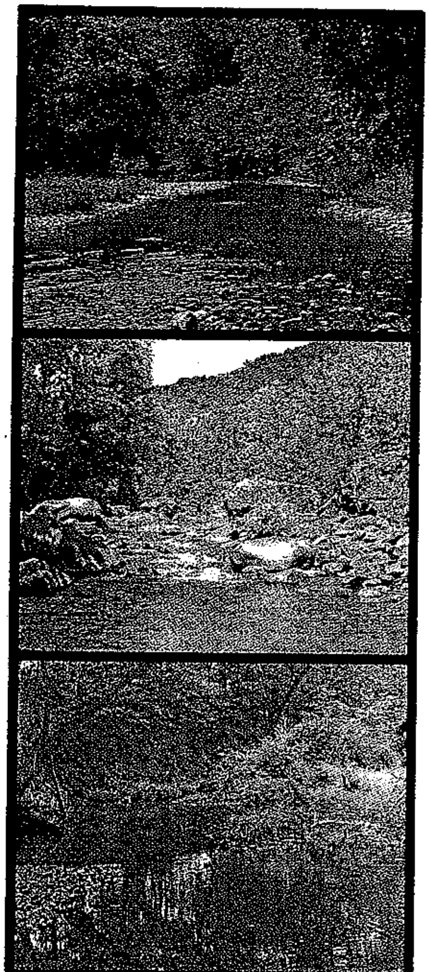
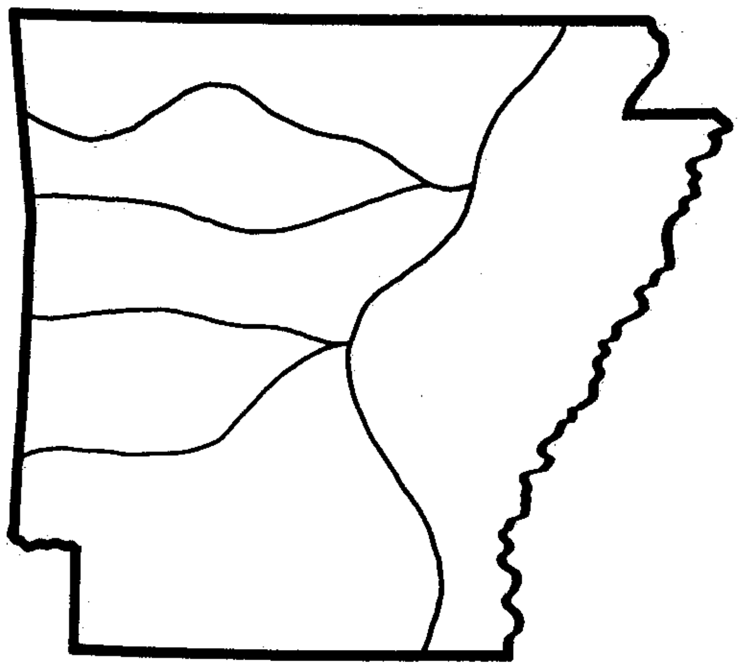


Physical, Chemical, and Biological Characteristics of Least-Disturbed Reference Streams in Arkansas' Ecoregions



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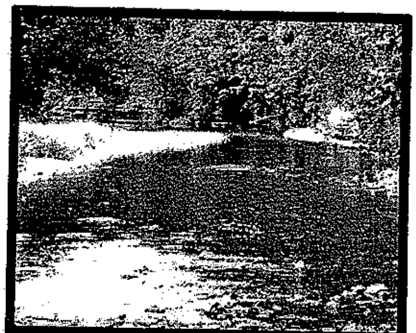
SIMPSON OWRB

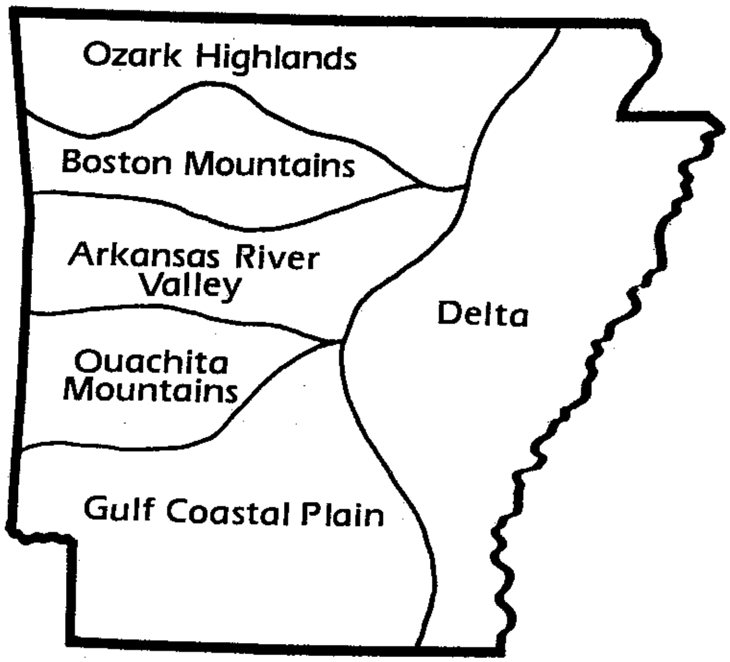
Physical, Chemical, and Biological Characteristics of Least-Disturbed Reference Streams in Arkansas' Ecoregions



Yocum Creek
Ozark Highlands

Archey Creek
Boston Mountains

Dutch Creek
Arkansas River Valley



Little Missouri River
Ouachita Mountains

Moro Creek
Gulf Coastal Plain

Bayou DeView
Delta

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PHYSICAL, CHEMICAL AND BIOLOGICAL CHARACTERISTICS OF LEAST-DISTURBED REFERENCE STREAMS IN ARKANSAS' ECOREGIONS

Volume II - Data Analysis

Funded by Section 205(j) of the Federal Clean Water Act

Arkansas Department of Pollution Control and Ecology

June, 1987

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PHYSICAL, CHEMICAL AND BIOLOGICAL CHARACTERISTICS OF LEAST-DISTURBED REFERENCE STREAMS IN ARKANSAS' ECOREGIONS

Volume II - Data Analysis

Introduction

The following discussion is an analysis of the salient data presented in the document "Physical, Chemical and Biological Characteristics of Least-Disturbed Reference Streams In Arkansas' Ecoregions, Volume I: Data Compilation." The data was obtained from intensive field investigations of 37 reference streams during both the low-flow, high-temperature season and the higher flows and cooler temperatures of spring. Among the immediately apparent and currently needed uses of this data are: (1) providing baseline data from waterbodies with the least amount of point source and nonpoint source disturbance; (2) a characterization of the streams within each ecoregion; (3) classification of streams based on their instream uses; (4) a reference gauge to evaluate monitoring data, abatement activities and perturbations; and (5) a sound basis for developing realistic water quality standards and beneficial uses within ecoregions.

Methodology

The delineation of ecoregions within Arkansas is based on the principles described by J.M. Omernik, M.A. Shirazi and R.M. Hughes in a "Synoptic Approach for Regionalizing Aquatic Ecosystems" (1981). The ecoregions were established as the areas of greatest homogeneity of land surface forms, potential natural vegetation, soil types and land uses. Areas within each ecoregion which contain similar characteristics of all four of the above-named features are established as the most typical area of the ecoregion. All other areas which are similar within three of the four features of the ecoregion are designated as generally typical.

Reference streams and sample sites were selected on the basis of the following criteria: (1) no (or very few) point source discharges and no substantial areas of nonpoint source disturbances; (2) the greatest possible amount of the drainage area within the most typical area of the ecoregion; and (3) a wide range of drainage areas above the sample sites.

Sampling activities at each site included measurements of numerous physical features of the stream. Some of these were flow, channel and stream width, substrate types, instream cover, composition of riparian area and amount of stream canopy. Approximately 20 water quality parameters were measured during both the spring and summer sampling and 48- to 72-hour continuous recordings of water temperature and dissolved oxygen were made. Macroinvertebrate populations were intensively sampled during both periods and a comprehensive fish population sample was taken during the summer period. Detailed descriptions of sampling and data collection methodology are given in the Data Compilation report.

Reference Streams and Sample Sites

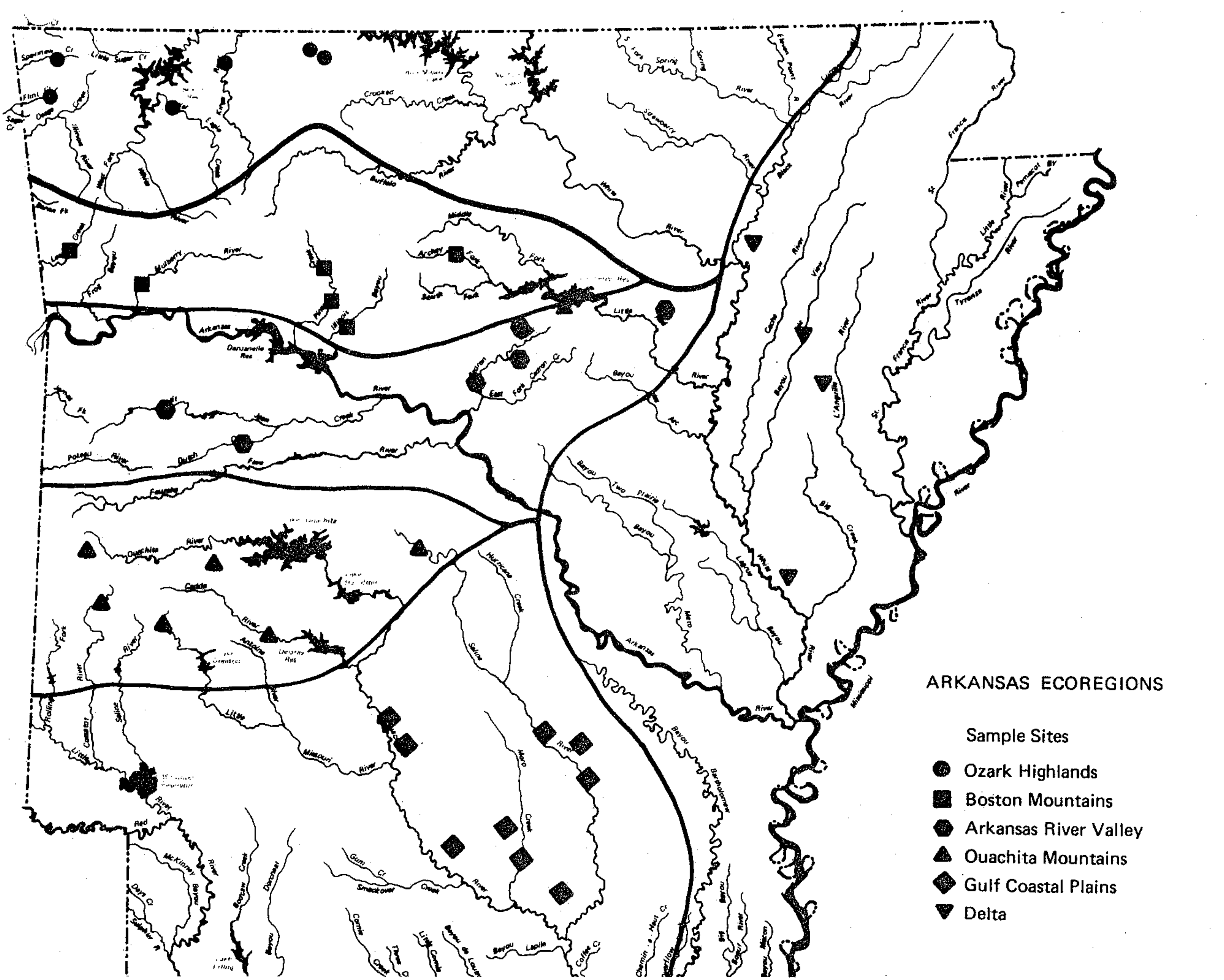
The following map shows the distribution of sample sites among the ecoregions; the corresponding table on page 4 lists all reference streams with their watershed size, stream gradient and seasonal flows at the sample site.

All reference streams chosen in the Ozark Highlands Ecoregion are located in the western half of the region. This is where the majority of the most typical areas of the ecoregion are located. All but the two smallest reference stream watersheds are located almost entirely within the most typical area of the ecoregion.

In the Boston Mountains Ecoregion, all sites except Lee Creek drained predominantly most typical areas of the ecoregion. The Archey Creek site was not in the most typical area, but much of the watershed above the site drained most typical areas.

Four of the sites within the Arkansas River Valley Ecoregion are located within the most typical area of this ecoregion. The Dutch Creek and Petit Jean River watersheds are located in a zone of disputed classification between the Ouachita Mountains and the Arkansas River Valley. According to Hughes and Omernik, both of these watersheds are within the Ouachita Mountains Ecoregion; however, Foti (1974) places this section of the state with the Arkansas River Valley subdivision. Physical, chemical and biological data collected at the Dutch Creek and Petit Jean River sample sites are more characteristic of the Arkansas River Valley and share very few similarities to Ouachita Mountains; therefore, these sites are included as part of the Arkansas River Valley Ecoregion.

Almost all of the reference stream sample sites in the Ouachita Mountains Ecoregion are located within the most typical areas. Only the Caddo River site has less than one-half of its watershed within the most typical area of the region. The South Fork Ouachita River site has one of the smaller watershed sizes selected for the region, but the stream gradient is only 7 ft/mi, which is relatively low for a small Ouachita Mountains stream. Conversely, the Cossatot River site has a watershed of 120 mi^2 and the steepest stream gradient of any sample site. These features substantially affected the biotic and abiotic features at both sites. Summertime flows encountered in the Ouachita Mountains streams are significant even in the smaller streams.


ARKANSAS ECOREGIONS
Sample Sites
Ozark Highlands
Boston Mountains
Arkansas River Valley
Ouachita Mountains
Gulf Coastal Plains
Delta

Watershed Size, Stream Gradient and Seasonal Flows of Ecoregion Reference Streams

Stream	Watershed Size (mi²)	Gradient (ft/mi)	Summer Flow (cfs)	Spring Flow (cfs)
Delta Ecoregion				
Boat Gunwale Slash	23	0.7	2.9	230.0
Second Creek	60	0.8	7.5	165.0
Village Creek	194	0.5	133.5	35.0
Bayou DeView	460	0.6	191.0	500*
Gulf Coastal Ecoregion				
E. Fork Tulip Cr.	46	3.5	5.2	56.0
Cypress Creek	73	4.2	10.8	150.0
Whitewater Creek	23	2.8	0.0	2.3
Big Creek	59	2.7	0.0	0.5
Derrieusseaux Cr.	148	3.4	0.0	200*
Bayou Freeo	156	3.0	0.0	16.1
Hudgin Creek	187	1.4	0.0	300*
L'Aigle Creek	232	2.6	0.0	188.7
Moro Creek	451	1.6	0.0	350.0
Arkansas River Valley Ecoregion				
Mill Creek	17	13.5	0	10
North Cadron Creek	21	10.0	0.1	10
Ten Mile Creek	49	8.1	0.2	105
Dutch Creek	110	3.8	0.5	70
Petit Jean River	241	3.9	0.3	300*
Cadron Creek	308	0.6	15.0	500*
Ouachita Mountains Ecoregion				
Board Camp Creek	19	27.8	2.7	19.7
Little Missouri R.	30	29.0	3.9	25.8
So. Fork Ouachita R.	46	7.0	6.7	33.7
Cossatot River	120	40.0	17.4	97.4
Caddo River	291	13.3	134.0	500*
Saline River	361	4.1	53.0	400*
Ozark Highlands Ecoregion				
South Fork Spavinaw Creek	18	25.5	1.4	17
Flint Creek	19	19.6	4.5	27
Yocum Creek	55	18.0	5.3	162
Long Creek	184	7.0	9.5	183
War Eagle Creek	263	4.0	25.1	102
Kings River	526	4.6	48.8	252
Boston Mountains Ecoregion				
Indian Creek	47	32	0.1	19
Hurricane Creek	50	33	0.1	30
Archey Creek	107	14	0.6	122
Illinois Bayou	125	12.5	1.0	147
Lee Creek	168	15.3	3.5	300*
Mulberry River	373	13.7	6.4	300*

*Estimated

Nine reference streams were ultimately selected within the Gulf Coastal Ecoregion. This larger number of reference streams resulted from the discovery of two major categories of streams within the ecoregion. Two streams with substantial springwater discharges, East Fork of Tulip Creek and Cypress Creek, were found to have significantly different physical, chemical and biological characteristics from the other seven typical Gulf Coastal Ecoregion streams. The most typical areas of this ecoregion are very scattered and small except for a large area located in the oil production section of southern Arkansas. Much of this area has substantial water quality impairment associated with the oil industry. As a result, only 30% to 50% of the watershed of most of the reference streams were within the most typical areas. None of the watersheds of Whitewater Creek and Freeo Bayou were within the most typical areas. Seventy (70) to 90% of the watersheds of Cypress and East Fork of Tulip Creek were in the most typical area, but these streams were considered atypical because of their springwater influence.

Only four reference streams were located in the highly agricultural Delta Ecoregion. Village Creek and Boat Gunwale Slash sites had drainage areas which were 80% to 100% within the most typical areas of the ecoregion. Bayou DeView and Second Creek drained only 20% to 30% of most typical areas. Although summertime flows in the Delta may be substantially influenced by withdrawals and discharges from irrigation activities, it is strongly suspected that the flows recorded at Village Creek and Bayou DeView during the summer period were atypically high from a previous summertime rain storm. Conversely, the spring flow recorded for Village Creek was atypically low due to the lack of springtime rainfall.

Physical Characteristics of Reference Streams

The geophysical components of each of the six physiographic regions in Arkansas are the major determinants of the overall water quantity and quality of each region. They are also generative forces in the composition of the aquatic community within the specific regions. Differing geologic formations influence various water quality conditions, e.g., the limestone geology of the Ozark Highlands increases the conductivity and hardness of its waters, while the turbid condition of some Arkansas River Valley waters result from the geology and soil types of this region. The soil types of the regions also determine the vegetation types. Water color in the Gulf Coastal Region is influenced by vegetation and soil types in the watershed. The geology of a region will determine the general characteristics of the groundwater and its relationship to surface water. Groundwater contribution to the base flow, therefore, will vary in quantity and duration within each region. The stream gradient influences water quality and also the composition of the aquatic community. Higher gradients generally produce higher stream velocities, which in turn affect the substrate by scouring, cutting channels and changing the features of the physical habitat. High stream velocities affect the benthic and fish community structure to the degree that only certain species adapt and thrive in this type of stream habitat. As gradient and stream velocities decline the aquatic community composition tends to reflect these changes. Instream dissolved oxygen is also influenced by stream velocity and turbulence which is a function of gradient and flow.

Although major physical features such as geologic formations serve to establish the different ecoregions, many other physical characteristics are unique to the streams within each ecoregion. These characteristics and their influence on the aquatic communities will be evaluated on a regional basis.

Delta Ecoregion

There are several physical features that are unique to Delta streams (Table P-1). The most obvious feature is the very low gradient. The average slope of all the streams surveyed was only 0.65 feet per mile drop in elevation. Many reaches of these streams have ill-defined streams channels, as evidenced by measured channel widths of almost one quarter mile wide. The substrates of these streams are composed predominantly of mud and silt, yet aquatic habitat is present in the form of brush, logs, debris and inundated vegetation. The land use in this ecoregion is 77% agricultural activities with the primary type being grain and fiber crop production. Irrigation practices in this type of agriculture have a definite impact on the stream flow in the late summer period. The smallest stream studied - Boat Gunwale Slash - with a watershed size of 23 mi^2 had almost a 3 cfs flow on August 2, 1983. The stream with the largest watershed - Bayou DeView - had a flow of 191 cfs on July 30, 1985. Both streams according to U.S.G.S. flow data, have a Q_{7-10} flow of 0 cfs. The influence of irrigation drainage is readily apparent in these and the other Delta streams surveyed. In the Delta streams influenced by these agricultural practices, the critical flow period and the critical temperature period do not generally coincide. The low flow months usually occur in the fall of the year after crop irrigation has ceased. By this time, the stream temperatures have usually declined by a few degrees. Despite the dominance of agricultural activities in the Delta, the stream canopy in the reference streams averaged 75%, which is the second highest value recorded in the ecoregion surveys. This is an atypically high value because least-disturbed streams were surveyed. Most of the drainage in the Delta has very limited wooded areas adjacent to the streams.

Gulf Coastal Ecoregion

The major streams in this region originate in the Ouachita Mountains Ecoregion. Another significant feature of this ecoregion is that some areas have perennially flowing streams of various watershed sizes while in other areas, streams with the largest watersheds have only intermittent flow during the summer and early fall months of the year. Table P-2 provides a summary of the physical characteristics evaluated during the

Table P-1

DELTA ECOREGION

PHYSICAL ATTRIBUTES

Stream Name	Watershed Size mi^2	Watershed Land Use	Stream Grad. ft/mi	Channel Width ft.	Stream Width ft.	Stream Vel. fps	Stream Flow cfs	Substrate Type percent	Instream Cover percent	Stream Canopy
Boat Gunwale Slash	23	72% agri. 28% forest	0.7	182	122	0.17	2.9	mud/silt	27% brush, logs, debris; 13% inundated veg.	94%
Second Creek	60	70% agri. 30% forest	0.75	62.5	42.2	0.28	7.5	mud/silt	35% brush, logs, debris; 6.4% overhanging veg; 1% inundated veg	55%
Village Creek	194	92% agri. 5% forest 3% urban	0.5	923	609	N/A	133.5	mud/silt	87% brush, logs, debris; 22% inundated veg.	85%
Bayou DeView	460	72% agri. 28% forest	0.6	1575	509	N/A	191	mud/silt	22% brush, logs, debris; 2% inundated veg.	60%

Physiographic Region Average

Delta Ecoregion Averages	183.25	77% agri. 23% forest	0.65	685	321	0.23	83.7	mud/silt	43% brush, logs, debris; 10% inundated veg; 2% overhanging veg.	73.5%

Table P-2
GULF COASTAL ECOREGION

PHYSICAL ATTRIBUTES

Stream Name	Watershed Size mi²	Watershed Land Use	Stream Grad. ft/mi	Channel Width ft.	Stream Width ft.	Stream Vel. fps	Stream Flow cfs	Substrate Type percent	Instream Cover percent	Stream Canopy
Whitewater Creek	23	91% forest 7% agri.	2.8	29	15	0	0	100% sand	32% brush, logs, debris; 1% overhanging veg.	96%
Big Creek	59	88% forest 12% agri.	2.7	40	6.4	0	0	100% sand	16% brush, logs, debris; 13% undercut bank	100%
Derrieusseaux Creek	148	93% forest 7% agri.	3.4	50	12	0	0	74% sand 22% mud/ silt; 4% gravel	41% brush, logs, debris; 2% undercut bank	88%
Bayou Freeo	156	91% forest 7% agri.	3	47	26	0	0	64% sand 36% gravel	74% brush, logs, debris	100%
Hudgin Creek	187	74% forest 26% agri.	1.4	69	32	0	0	100% mud/ silt	55% brush, logs, debris; 3% inundated veg; 1% overhanging veg.	68%
L'Aigle Creek	232	91% forest 7% agri.	2.6	89	34	0	0	66% mud 31% gravel	20% brush, logs, debris	47%
Moro Creek	423	91% forest 7% agri.	1.6	96	35	0	0	58% sand 26% gravel 16% mud/ silt	61% brush, logs, debris	71%
*East Fork Tulip Creek	46	96% forest 4% agri.	3.5	41.4	25.8	0.26	5.2	100% sand	51% brush, logs, debris; 5% overhanging veg. 1% undercut bank	95%
*Cypress Creek	73	73% forest 27% agri.	4.2	44.8	32	0.36	10.8	61% sand 28% mud/ silt 8% gravel	13% brush, logs, debris; 2% overhanging veg.	90%

*All physical parameters included in ecoregion averages except stream flows.

Physiographic Region Average:

Gulf Coastal Ecoregion Averages	150	88% forest 12% agri.	2.8	60	23	0	0	62% sand 26% mud/ silt 12% gravel	40% brush, logs, debris; 2% undercut bank; 1% overhanging vegetation	84%

stream surveys of this ecoregion.

Two of the reference streams in the Gulf Coastal Ecoregion, East Fork Tulip Creek and Cypress Creek, represent a unique group of streams in that they have a continuous year-round flow. Numerous springs in the headwaters of these streams produced flows of 5.2 and 10.8 cfs, respectively, during the summer surveys. This is a substantial flow for the 46 mi^2 watershed of East Fork Tulip and the 73 mi^2 watershed of Cypress Creek. The more typical Gulf Coastal Ecoregion streams are represented by the other seven reference streams. Of these streams, which range in watershed size from 23 to 451 mi^2, the dominant characteristic is the absence of flow during the summer and early fall months. Another unique feature of this region is the low stream gradients in an area containing rolling hills. These streams meander back and forth through the broad sandy flats between these hills, with the stream channels being established by the high flows of winter and spring.

Land use in this region is dominated by forestry activities. Approximately 88% forestry cover existed in the watersheds of the streams surveyed while 12% was used for agricultural purposes - primarily pastureland. The forestry cover contributes to the high stream canopy which averaged 84% in the streams surveyed. The generally forested watersheds also contribute to instream cover by deposition of logs, brush and debris into the stream through the natural growth and death processes and through streambank erosion and the subsequent falling of trees. The 40% composition of brush, logs, and debris as instream cover was one of the highest values encountered during the survey. Another unique feature of the Gulf Coastal region is the predominance of sand in the stream substrates. Three of the nine streams surveyed had substrates of 100% sand while the average sand content of all reference streams substrates was 62%. The permeability and porosity of the soils in this ecoregion may be a pertinent factor in the lack of summer flow in the more typical streams.

The high stream canopy plays an important role in regulation of water temperatures. In only one stream did the stream temperature reach 30°C during the surveys of this region. That stream had the least canopy cover of all streams survey. Most of the streams showed little or no diurnal variation in water temperature because of the large amount of stream canopy.

Arkansas River Valley

The Arkansas River Valley Ecoregion contains streams with characteristics similar to those of the Boston Mountains to the north and the Ouachita Mountains to the south. The general topography of this ecoregion reflects its transitional nature by being relatively flat in some areas while showing some of the greatest elevations in the state in other areas. Table P-3 summarizes the physical characteristics of the streams surveyed.

Table P-3

ARKANSAS RIVER VALLEY ECOREGION

PHYSICAL ATTRIBUTES

Stream Name	Watershed Size mi^2	Watershed Land Use	Stream Grad. ft/mi	Channel Width ft.	Stream Width ft.	Stream Vel. fps	Stream Flow cfs	Substrate Type percent	Instream Cover percent	Stream Canopy
Mill Creek	17	57% agri. 43% forest	13.5	39.2	32	0	0	76% bedrock 24% mud/silt	1% undercut bank 2% brush, logs, debris	56%
North Fork Cadron	21	61% agri. 39% forest	10	42.3	20.3	0.05	0.07	57% bedrock 25% rubble 6% gravel	1% undercut bank 3% brush, logs, debris; 3% inundated veg.	33%
Ten Mile Creek	49	43% agri. 55% forest	8.1	61.3	41.5	0.1	0.2	49% boulder 26% rubble 19% gravel	17% inundated vegetation	88%
Dutch Creek	110	35% agri. 65% forest	3.8	62.2	37.3	0.05	0.5	43% gravel 43% mud/silt 13% rubble	44% brush, logs, debris; 2% undercut bank	98%
Petit Jean River	241	45% agri. 52% forest	3.9	65	48	0.03	0.3	29% boulder 33% rubble 23% gravel	3% brush, logs, debris; 1% under cut bank; 5% inundated veg.	64%
Cadron Creek	308	62% agri. 38% forest	0.6	115	93	0	0	100% mud/silt	6% brush, logs, debris	22%

Physiographic Region Average

Stream Name	Watershed Size mi^2	Watershed Land Use	Stream Grad. ft/mi	Channel Width ft.	Stream Width ft.	Stream Vel. fps	Stream Flow cfs	Substrate Type percent	Instream Cover percent	Stream Canopy
Arkansas River Valley Ecoregion Averages	124	51% agri. 49% forest	6.7	64.2	45.4	0.04	0.18	22% bedrock 16% rubble 15% gravel 15% boulder 31% mud/silt	1% undercut bank 10% brush, logs, debris; 4% inundated veg.	55%

The Arkansas River Valley streams with small watersheds that were studied are similar to some of the larger Boston Mountains streams in regard to stream gradient and substrate type. These small streams' substrates are dominated by bedrock, which is also the case for Lee Creek and the Mulberry River, located in the southern portion of the Boston Mountains Ecoregion. The stream gradients of Mill Creek and North Fork Cadron are the highest of all the Arkansas River Valley streams surveyed and are similar to the largest watershed Boston Mountains streams studied.

The land use patterns in this ecoregion consist of about 31% agriculture and 49% forestry. Generally, the agricultural uses are dominated by the production of beef cattle, dairy cattle and poultry. These agricultural activities in the Arkansas River Valley result in high water usage during the hot, dry period.

Flow in the Arkansas River Valley streams is generally very low or nonexistent during the summer and early fall months. Many of the streams studied were pooled, while the remainder had only a trickle of flow between pooled areas. Some of the larger Arkansas River Valley streams are similar to Delta streams in terms of gradient and substrate type. Cadron Creek has a 308 mi^2 watershed at the study site. The stream gradient at this site is only 0.6 feet per mile and the substrate consists of mud and silt. This stream had no measurable flow during the late August survey. Streams of a similar size surveyed in the Delta had flows of 133 and 191 cubic feet per second.

Instream cover in the Arkansas River Valley streams is generally dominated by brush, logs and debris; however, there is considerable variation among these streams and many have only limited amounts of this type of instream cover. Only Dutch Creek, which had the greatest canopy cover at 98%, had substantial brush, logs and debris instream cover (44%). Ten Mile Creek, with a watershed size of 49 mi^2 and an 88% canopy cover, had instream cover consisting solely of 17% inundated vegetation. The substrate types in these streams contribute substantially to the habitat of many species of aquatic inhabitants. Although not specifically designated as instream cover in this study, boulders and rubble serve as attachment sites for many macroinvertebrate species and as refuge areas for fish species. A combination of boulders and rubble dominated the substrates in Ten Mile Creek and Petit Jean River.

Ouachita Mountains Ecoregion

The steep topography of the Ouachita Mountains Ecoregion influences the physical characteristics of the streams in this region and the recreational uses of these waterways. The steep slopes promote rapid stormwater runoff, which generates high velocity streams with many rapids and chutes. These streams attract "white water" boating enthusiasts from Arkansas and several adjacent states during the high flow periods. The physical characteristics of the six least-disturbed streams studied in this ecoregion are summarized in Table P-4.

The Ouachita Mountains streams surveyed had the second highest average summer flow of all the ecoregions studied. The geology of the Ouachita Mountains Ecoregion generates perennial stream flow in many very small watersheds. Board Camp Creek had the smallest watershed size of the reference streams in this ecoregion, yet a summer flow of 2.9 cfs was measured. Springs and seeps in this ecoregion not only serve to provide stream flow, but also aid in keeping the water temperatures cool. This is important because the Ouachita Mountains streams, although having watersheds dominated by forests, generally have a low percentage of stream canopy. This lack of canopy exposes more of the stream surface to the sun, resulting in warmer stream temperatures. An example of this is the Cossatot River, which had no canopy in the reach studied. This stream had the highest temperature of any of the Ouachita Mountains streams surveyed. The paucity of canopy in this ecoregion is due in part to the very rocky stream banks which do not promote tree growth and also a result of the erosive action of spring flooding.

A high stream gradient exists in many of the headwater streams in this ecoregion, which creates very high stream velocities of stormwater runoff. Streams in the Ouachita Mountains have been known to rise several feet in only a few hours during a storm event. The scouring action of this water as it flows downstream cuts a stream channel much wider than the normal stream width and in the process removes streamside vegetation. In most instances the channel width is more than twice the stream width in the Ouachita Mountains streams surveyed. Stream gradients ranged from a high of 40 ft/mi for the Cossatot River to a low of 4.1 ft/mi for the Saline River.

In some instances, the gradient affects the presence of instream cover. The high velocities of flood events tend to scour the higher gradient streams of any accumulated debris, brush and logs, while the lower stream gradients tend to have a greater percentage of this kind of instream cover. The Saline River appears to be an exception. It has a slope of 4.1 ft/mi and only 2% of the stream channel contained brush, logs and debris at the sample site. The large volume of water that accumulates in the 361 mi^2 watershed during storm events may be sufficient to effectively scour this stream as well. The South Fork of the Ouachita River has a much smaller watershed but a similar stream gradient. However, due to the larger stream width in relation to channel width in the South Fork Ouachita compared to the Saline River, a greater percentage of canopy and brush, logs and debris exist in South Fork.

The substrate components of the Ouachita Mountains streams are comprised of gravel (36%), rubble (31%), boulders (14%) and bedrock (13%). The remainder consists of mud/silt, sand and detritus. In many streams in this ecoregion, boulders and

Table P-4

OUACHITA MOUNTAINS ECOREGION

PHYSICAL ATTRIBUTES

Stream Name	Watershed Size mi^2	Watershed Land Use	Stream Grad. ft/mi	Channel Width ft.	Stream Width ft.	Stream Vel. fps	Stream Flow cfs	Substrate Type percent	Instream Cover percent	Stream Canopy
Board Camp Creek	19	90% forest 10% agri.	27.8	61.3	28.5	0.36	2.7	62% gravel 18% rubble 15% bedrock	12% inundated veg; 6% overhanging veg.	72%
Little Missouri River	30	90% forest 10% agri.	29.4	47.1	31	0.44	3.9	50% rubble 19% gravel 24% boulder	2% inundated veg; 4% overhanging veg.	24%
South Fork Ouachita River	46	90% forest 10% agri.	7.3	47.3	37	0.35	6.7	91% gravel 9% mud/silt	16% brush, logs, debris; 3% under cut bank; 1% overhanging veg.	48%
Cossatot River	120	85% forest* 15% agri.	40	187	74.1	0.47	17.2	37% bedrock 42% boulder 18% rubble	<1% inundated vegetation	0%
Caddo River	291	60% forest 40% agri.	13.3	315	127	N/A	133.8	63% rubble 16% boulder 12% gravel	7% inundated veg 4% brush, logs, debris; 3% overhanging veg.	26%
Alum Fork Saline River	361	95% forest 5% agri.	4.1	126	64	N/A	33.4	34% rubble 29% gravel 26% bedrock	2% brush, logs, debris; 3% inundated veg.	11%

*Estimate based on visual observation of watershed.

Physiographic Region Average

Ouachita Mountains Ecoregion Averages	144.5	85% forest 15% agri.	20.2	130.7	60.3	0.41	33	36% gravel 31% rubble 14% boulder 13% bedrock	4% inundated veg 2% overhanging veg; 4% brush, logs, debris	30%

rubble provide sanctuary to numerous aquatic species and thus serve as a source of instream cover.

Land use in the Ouachita Mountains is dominated by forestry activities. Most of the land is owned by private timber companies and the Ouachita National Forest. Timber cutting activities in many areas disturb the soil and increase erosion. This can subsequently alter the substrate composition of the streams.

Ozark Highlands Ecoregion

Probably the single most important factor affecting the water quality of the streams in the Ozark Highlands Ecoregion is the land use patterns that exist in the watersheds of these streams. There are many streams and lakes in this ecoregion that serve large numbers of recreation seekers each year. The popularity of the Buffalo River is an excellent example of the recreational potential that exists. The streams selected for study are presently being affected by the land uses in the watershed. These effects are more evident in the chemical analyses than in the physical analyses. The physical characteristics of the six streams selected in this ecoregion are summarized in Table P-5.

The Ozark Highlands Ecoregion is unique because of its rugged mountains with steep ridges and many "plateau" areas which have been developed for agricultural activities. There are numerous grape vineyards, apple orchards and other types of fruit crop production in this region. Much of the area is also used for beef cattle and dairy cattle farming. The agricultural activities that appear to have the greatest impact on the streams of this ecoregion are the increasing numbers of poultry and hog farming operations. The waste products from these operations are commonly used as fertilizer on the pasturelands. The average watershed land use for the six streams surveyed indicates that 62% of the watersheds are being used for agricultural activities. The majority of this consists of pasturelands. Although there are areas of natural prairie in the Ozark Highlands, many other areas have been cleared of forestry cover in order to develop the land for agricultural purposes. A reduction in stream canopy is one result of this land clearing activity. The low percent of stream canopy in the Ozark Highlands allows a greater length of time for sunlight to reach the streams, which promotes both increasing stream temperatures and growth of aquatic vegetation.

The geology of the Ozark Highlands Ecoregion is dominated by large amounts of of limestone, dolomite and chert. The presence of limestone as surface rocks influences both water quality and quantity. The solubility of these surface rocks and the many subsurface fractures produce springs and seeps that feed the streams in this ecoregion. The nature of the geology not only produces stream flow but also can eliminate stream flow due to the presence of solution channels. The "losing stream" phenomenon is present in this ecoregion

Table P-5

OZARK HIGHLANDS ECOREGION

PHYSICAL ATTRIBUTES

Stream Name	Watershed Size mi^2	Watershed Land Use	Stream Grad. ft/mi	Channel Width ft.	Stream Width ft.	Stream Vel. fps	Stream Flow cfs	Substrate Type percent	Instream Cover percent	Stream Canopy
South Fork Spavanaw Creek	18	70% agri. 30% forest	25.5	78.5	27.6	0.55	1.4	87% gravel 13% rubble	5% brush, logs, debris; 5% over-hanging veg; 23% inundated veg.	19%
Flint Creek	19	82% agri. 18% forest	19.6	34.8	28.9	0.71	4.5	66% gravel 28% rubble	2% brush, logs, debris; 11% over hanging veg; 15% inundated veg.	11%
Yocum Creek	55	70% agri. 30% forest	18.2	72.2	26.2	1	5.3	69% gravel 27% rubble 5% bedrock	3% brush, logs, debris; 2% over-hanging veg.	21%
Long Creek	184	70% agri. 30% forest	6.8	54.8	39.8	0.57	9.5	51% gravel 25% sand 12% bedrock 5% rubble	3% brush, logs, debris; 2% under cut bank; 4% overhanging veg; 3% inundated veg	36%
War Eagle Creek	263	47% agri. 52% forest	4	109	57	0.77	25	54% gravel 35% rubble 7% sand	3% brush, logs, debris; 2% over-hanging veg; 3% inundated veg.	37%
Kings River	526	35% agri. 63% forest	4.6	146	112	N/A	48.8	52% gravel 23% bedrock 7% rubble 7% sand	1% undercut bank 1% inundated veg	29%

Physiographic Region Average

Ozark Higlands Ecoregion Averages	178	62% agri. 37% forest	13.1	82.6	48.6	0.72	15.8	63% gravel 19% rubble 7% bedrock 7% sand	3% brush, logs, debris; 4% over-hanging veg; 8% inundated veg; 1% undercut bank	26%

largely due to the limestone geologic formations. South Fork Spavinaw Creek and Flint Creek, with 18 and 19 mi^2 watersheds, respectively, are influenced by springs and seeps and had flows of 1.4 and 4.5 cfs during the summer sample. Summer flow measurements ranged from the 1.4 cfs in South Fork Spavinaw Creek to 48.8 cfs in the 526 mi^2 watershed of the Kings River. The average flow for the reference streams was 15.8 cfs with an average watershed size of 178 mi^2. Only the Delta and the Ouachita Mountains had greater average flows. Land use patterns may reduce the water volume in the Ozark Highlands due to consumption by livestock and use for irrigation of some types of crops.

The substrates of the streams in this ecoregion are dominated by gravel. The average gravel content of the six streams surveyed was 63%. Nineteen percent of the substrate consisted of rubble while sand and bedrock totalled 7% each. The majority of the instream cover consisted of inundated vegetation. This is not surprising considering the impact of nutrient contributions from the watershed and the low percentage of canopy cover. These two factors also contribute to periphyton and algae production. Other instream cover included 4% overhanging vegetation and 1% undercut bank.

Stream gradients ranged from 25.5 ft/mi to 4 ft/mi in reference streams of this ecoregion. Although the gradient average was substantially lower than that of the Ouachita Mountains and the Boston Mountains, the average stream velocity was much higher in the Ozark Highlands. The velocity difference appears to be a result of the geologic formations of the ecoregions. The Ouachita Mountains, while having greater slopes, have streams consisting of varying lengths of relatively flat areas interspersed with sharp drop or fall areas. The surface geology consists of novaculite, shales and sandstones which are relatively impermeable to the eroding action of high stream flows. Although having a lower gradient, the Ozark Highlands streams flow over a surface geology consisting primarily of limestone deposits. The porous nature of this substrate allows a more linear decline in stream gradient due to the "cutting" action into the substrate by high stream flows. As a result a more steady, uniform stream flow is achieved, resulting in faster stream velocities.

Boston Mountains Ecoregion

The Boston Mountains Ecoregion is the most rugged of the ecoregions, containing the highest reliefs. Its rugged nature produces streams with very high gradients. The stream slopes of the larger Boston Mountains streams which drain southward are similar to the smaller Arkansas River Valley streams located along the northern edge of the Arkansas River Valley Ecoregion. The high stream gradients promote rapid runoff during storm events which not only widens the stream channels but also removes accumulated debris by scouring the stream substrate. The majority of the Boston Mountains Ecoregion is within the Ozark National Forest and has a high recreational value. The physical characteristics of the six least-disturbed streams surveyed in this ecoregion are summarized in Table P-6.

One interesting relationship is the amount of the forestry cover as compared to stream canopy. This ecoregion has the highest average percentage of forestry cover of any ecoregion surveyed, and it has the lowest percentage of stream canopy. A very similar situation was evident in the Ouachita Mountains Ecoregion. In both ecoregions, the stream gradients and the ratio of stream widths to channel widths were similar and both had low total instream cover. There appears to be a definite inverse relationship between high stream gradients and low instream cover and canopy. The scouring action of floodwaters in high gradient streams removes the brush, logs and debris type of instream cover and reduces riparian canopy which protects the waters from prolonged exposure to the sun. In streams having substrates dominated by rock, these exposed rocks are heated by the sun and this heat is transferred to the water. The high stream temperatures of the Boston Mountains reference streams resulted from these conditions. The water temperature in Hurricane Creek was the coolest recorded from reference streams of the ecoregion and it also had the largest percentage of canopy.

Summer stream flows in the Boston Mountains Ecoregion are very low. The average summer flow of all reference streams with watersheds from 47 to 373 mi^2 was 1.9 cfs. These flow patterns are similar to the streams in the Arkansas River Valley. The substrate components of the Boston Mountains streams consist of 34% bedrock, 30% rubble, 13% boulders, 11% gravel and 9% sand. As was previously noted, the instream cover in these streams is minimal. Inundated vegetation averaged 5%. The remaining instream cover consisted of 1% brush, logs and debris, 1% undercut banks and 1% overhanging vegetation. However, many species of aquatic inhabitants utilize the abundant substrate components such as rubble and boulders.

Water Quality Data from Ecoregion Reference Streams

Both biochemical and chemical water quality parameters were measured at each reference stream sample site during the summer and spring sample period. Triplicate samples were taken for all parameters except fecal coliform. For discussion purposes, the 18 parameters measured are grouped as either biochemical, mineral or nutrient constituents. Biochemical constituents include BOD_5, BOD_{20}, chlorophyll $\bar{a}$ and fecal coliform. Mineral constituents are hardness, conductivity, alkalinity, total dissolved solids, total suspended solids, turbidity, pH, chlorides, sulfates and total iron. Nutrients include: ammonia nitrogen, nitrite-nitrate nitrogen, ortho-phosphorus and total phosphorus.

Table P-6

BOSTON MOUNTAINS ECOREGION

PHYSICAL ATTRIBUTES

Stream Name	Watershed Size mi^2	Watershed Land Use	Stream Grad. ft/mi	Channel Width ft.	Stream Width ft.	Stream Vel. fps	Stream Flow cfs	Substrate Type percent	Instream Cover percent	Stream Canopy
Indian Creek	47	95% forest 5% agri.	32	53	40	0	0	43% bedrock 21% rubble 21% sand 11% gravel	No instream cover observed	5%
Hurricane Creek	50	95% forest 5% agri.	33	62	60	0	0	35% rubble 31% sand 23% gravel 6% mud/silt	2% undercut bank 1% brush, logs, debris	59%
Archey Fork Creek	107	85% forest 15% agri.	14	84.2	51.1	0.11	0.6	44% rubble 35% boulder 11% bedrock 8% gravel	13% inundated veg; 5% over-hanging veg; 1% undercut bank	7%
Illinois Bayou	125	82% forest 18% agri.	12.5	83.5	42.5	0.1	1	41% bedrock 25% rubble 15% boulder 14% gravel	3% inundated veg 2% overhanging veg; 2% brush, logs, debris	8%
Lee Creek	168	83% forest 17% agri.	15.3	132	63	0.11	3.5	54% bedrock 34% rubble 12% boulder	15% inundated vegetation	0%
Mulberry River	389	90% forest 10% agri.	13.7	259	141	N/A	6.4	56% bedrock 19% rubble 18% boulder 7% gravel	2% brush, logs, debris; 1% under cut bank	15%

Physiographic Region Average

Boston Mountains Ecoregion Averages	145	88% forest 12% agri.	20.1	112.3	66.3	0.1	1.9	34% bedrock 30% rubble 13% boulder 11% gravel 9% sand	5% inundated veg 1% overhanging veg; 1% under-cut bank; 1% brush, logs, debris	16%

Data from each ecoregion is discussed separately and a comparison among the ecoregions is in the concluding segment. Appendix A contains all water quality data collected.

Delta Ecoregion

Almost all mineral constituents, particularly those which can be associated with agricultural activities in the watershed, show notably higher values in the Delta Ecoregion. Specifically, these include turbidity, total dissolved solids, total suspended solids, sulfates and total iron (Figures C-1, C-2). Values for these parameters are also considerably elevated during the springtime, high flow season. Boat Gunwale Slash, which has the smallest watershed of the Delta reference streams and the largest proportion of undisturbed riparian area, has the lowest values for the agriculturally related mineral constituents. Second Creek has relatively elevated values for chlorides, conductivity, hardness and alkalinity during the summer period (Figures C-2, C-3). Initially this was believed to be caused by irrigation water from wells being drained from crops; however, there are areas within the Delta where isolated segments of saline soils occur.

The biochemical constituents are also noticeably higher in the Delta Ecoregion, particularly BOD_{20} and chlorophyll $\bar{a}$ (Figures C-4, C-5). These values seem to be directly related to size of watershed and/or flows. Fecal coliform values are very high but also appear related to nonpoint watershed contributions.

Both total and ortho-phosphorus values are highest in this region. A distinct, direct relationship of higher values to the larger watershed sizes and the higher flow season exists. However, Boat Gunwale Slash (the smallest watershed) appeared to have slightly higher than anticipated spring phosphorus values and notably higher total and ortho-phosphorus values during the summer period. Therefore, in this stream, the phosphorus values seem to be associated with instream activities rather than watershed runoff. The ammonia nitrogen values in Boat Gunwale Slash exhibit a pattern similar to that of phosphorus; however, the nitrite-nitrate value was very similar to the other reference streams of the region (Figures C-4, C-5).

It is apparent that the Delta Ecoregion reference streams show increasing impairment from agricultural activity as watershed size increases. This feature was magnified by the atypically high summertime flows in the larger reference streams.

Gulf Coastal Ecoregion

The reference streams of the Gulf Coastal Ecoregion fall into two distinguishable groups. They are the typical streams and the streams with substantial springwater inflow (East Fork Tulip and Cypress Creeks). The most obvious difference in these two groups is the summer flow (Figure C-6). Typical

Figure C-1. Water Quality Data for
Delta Ecoregion Reference Streams

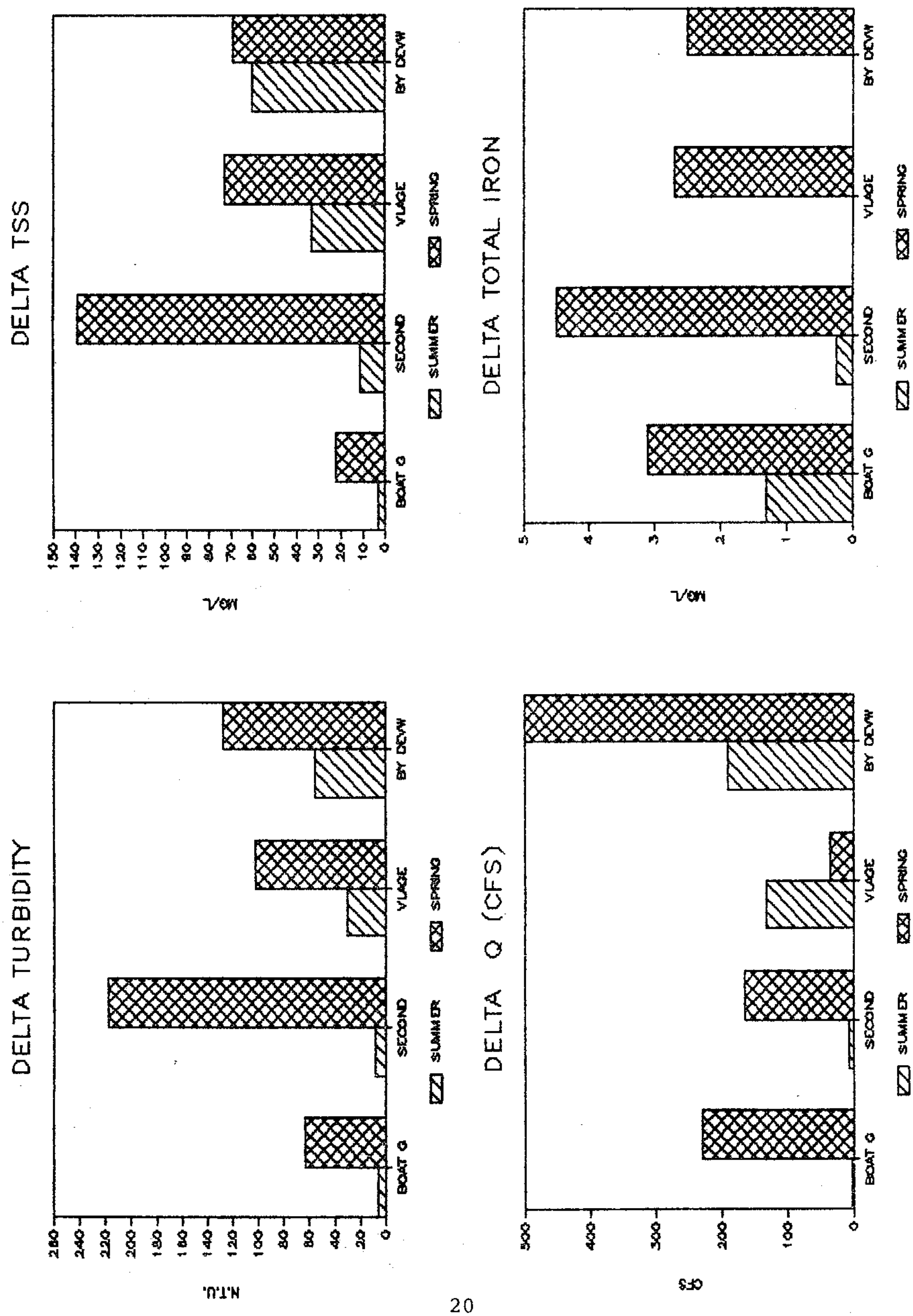


Figure C-2. Water Quality Data for
Delta Ecoregion Reference Streams

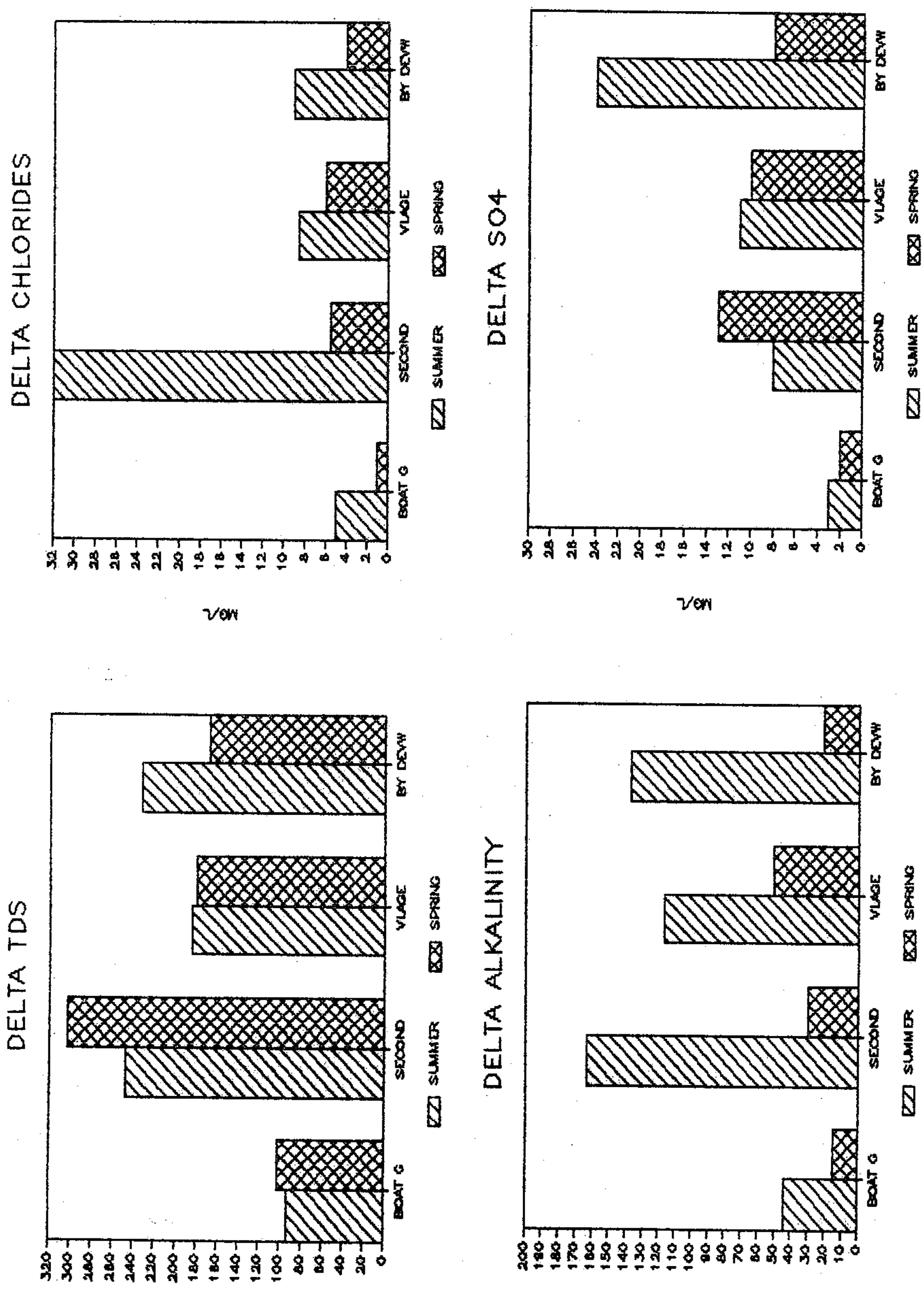
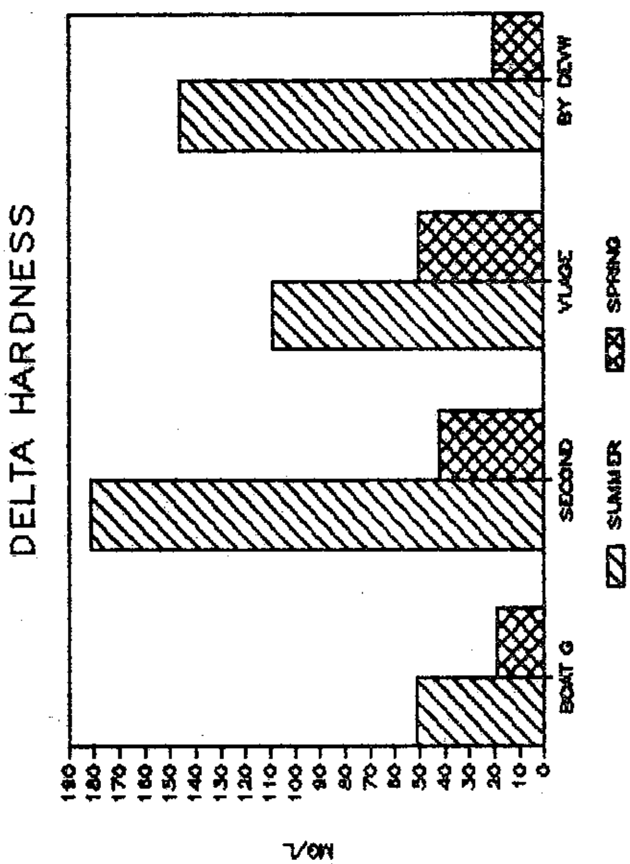
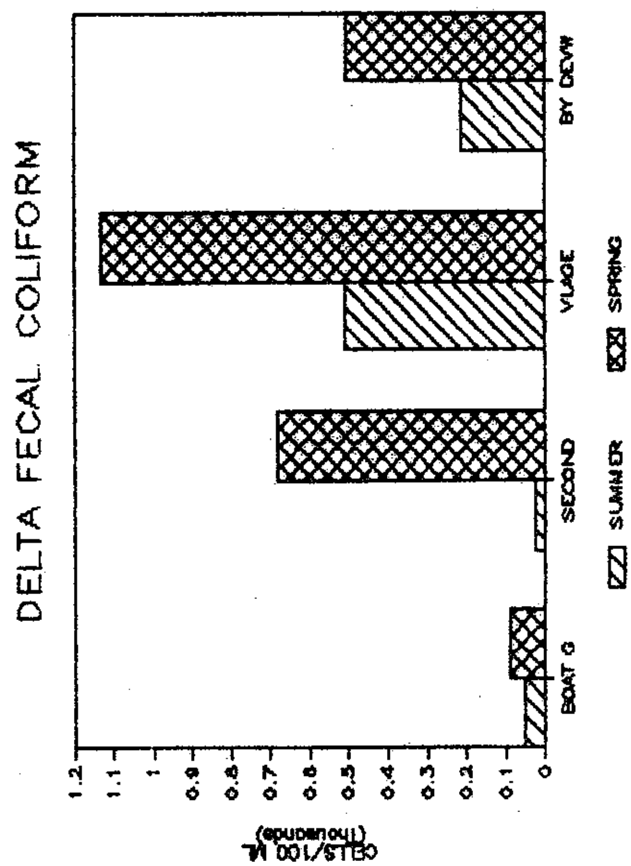


Figure C-3. Water Quality Data for Delta Ecoregion Reference Streams





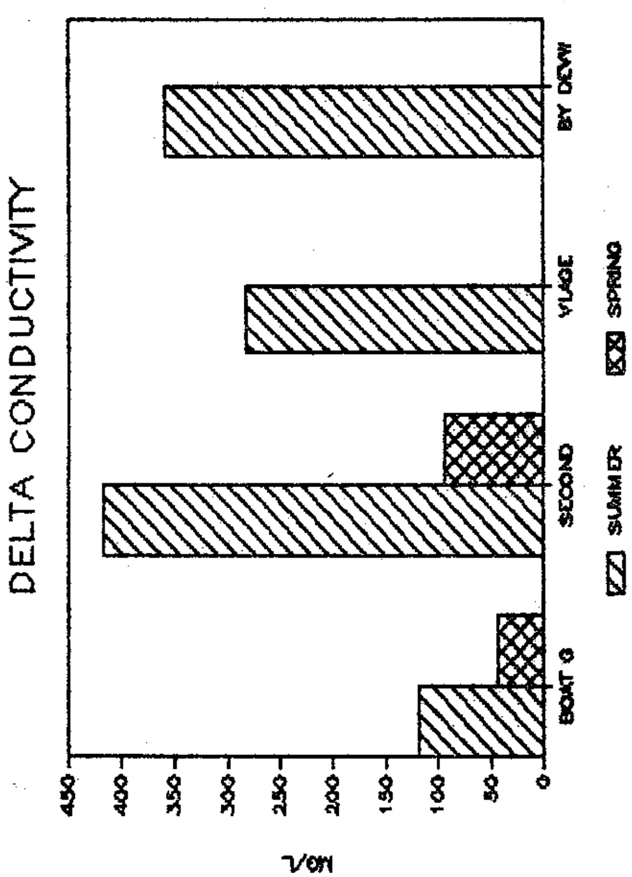


Figure C-4. Water Quality Data for Delta Ecoregion Reference Streams

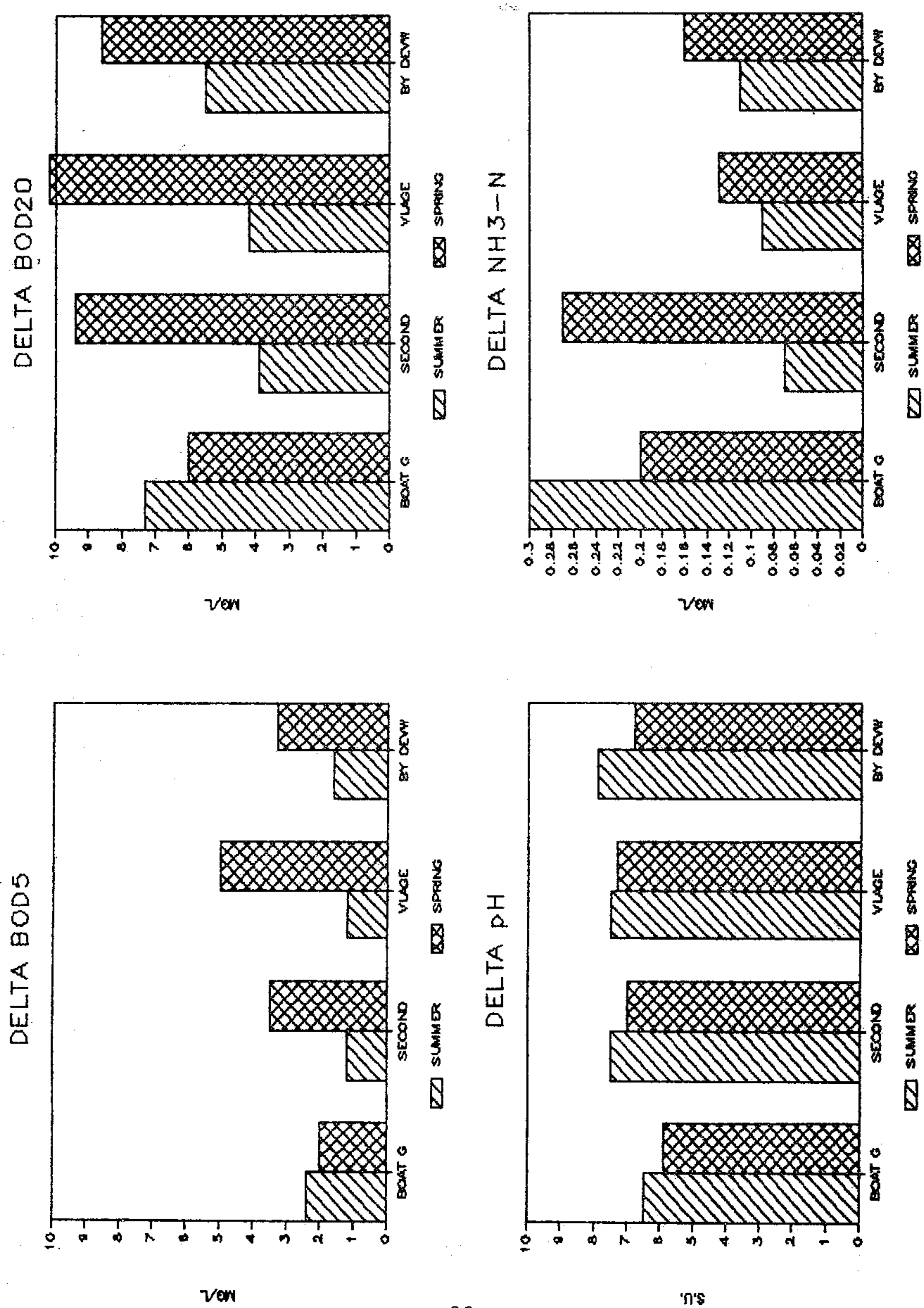


Figure C-5. Water Quality Data for
Delta Ecoregion Reference Streams

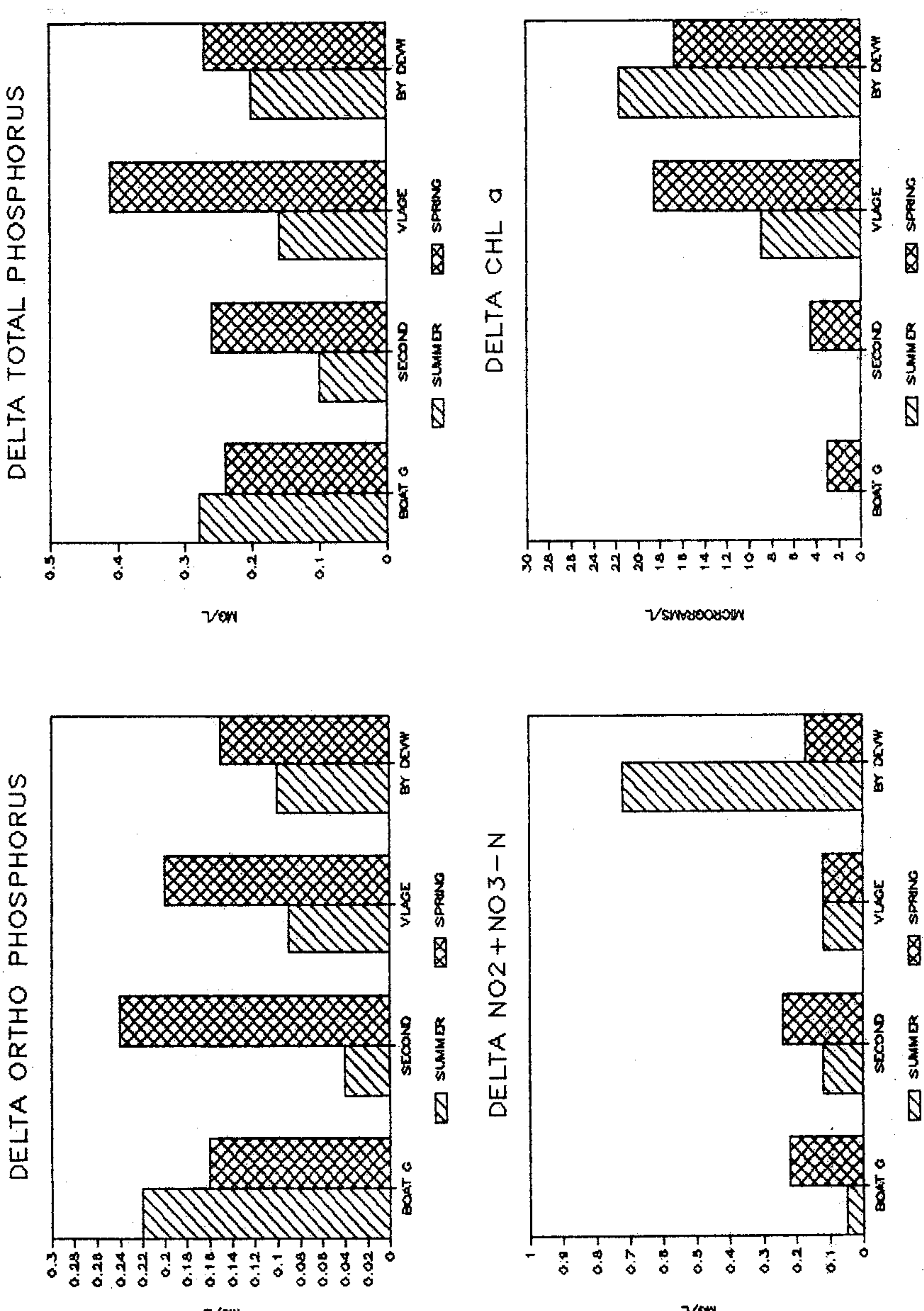
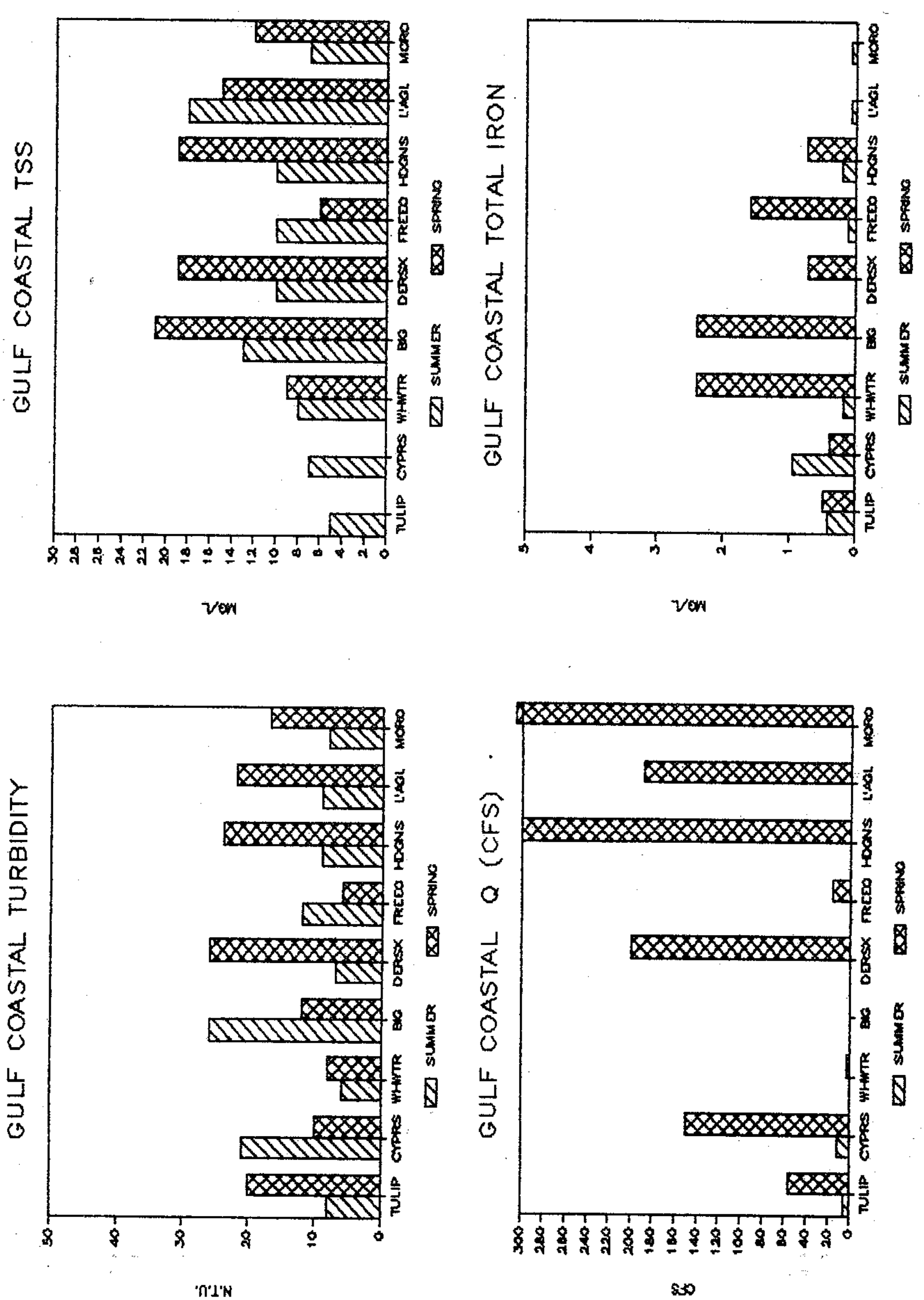


Figure C-6. Water Quality Data for
Gulf Coastal Ecoregion Reference Streams



Gulf Coastal streams with watershed sizes up to nearly 500 mi^2 cease to flow during the critical summer period. However, most of these streams maintain enduring pools of water of sufficient size to support a diverse fish population. The springwater-influenced streams maintain substantial flows during the critical summer period. Notable differences in the water quality also exist between these two types of Gulf Coastal streams.

Total dissolved solids, total suspended solids, alkalinity, hardness and conductivity are notably lower in the spingwater-influenced streams and fairly consistent in all of the typical streams (Figures C-6, C-7 and C-8). Summertime values of total iron are higher in the springwater streams although springtime values in some of the typical streams are elevated (Figure C-6). Very little difference is noted in the turbidity values of all Gulf Coastal reference streams. All values are low and generally show modest increases during increased spring flows (Figure C-6). Summer chloride values are very low in all streams but show slight elevations in the typical streams during the spring season. In contrast, spring chloride values decline in the springwater influenced streams (Figure C-7). Sulfates are notably lower in the springwater streams and unusually high in Big Creek and Hudgin Creek. These streams have adjacent watersheds and may share the same source of sulfates (Figure C-7). The pH values in all streams remained below 7.0 and the springwater-influenced streams generally remain below 6.0 (Figure C-9).

BOD patterns within the Gulf Coastal reference streams are interesting. Both BOD_5 and BOD_{20} are noticeably lower in the springwater-influenced streams during the summer. The spring values increase over the summer values in these two streams, but in the typical streams, the summer values are higher than the spring values (Figure C-9). All of the typical reference streams were restricted to enduring pools with no measurable flow during the summer sample period. This allows the biochemical reactions to take place in a confined area with little if any dilution. Chlorophyll a values were generally very low in all reference streams although notably high values of chlorophyll a and fecal coliform bacteria occurred in Big Creek (Figure C-8, C-10). With the exception of the spring value in Big Creek, all streams met the fecal coliform standard for primary contact use.

Nutrient parameters associated with nitrogen and phosphorus were very low in all reference streams, although summertime nitrite-nitrate nitrogen values were noticeably higher in the springwater-influenced streams (Figure C-10).

The water quality of the least-disturbed reference streams of the Gulf Coastal Ecoregion can generally be described as mildly acidic and low in mineral and nutrient quantities. However, in most of these streams, the intermittent summertime flows and pooled conditions allow the maximum extent of biochemical, oxygen-demanding activities to occur. In the absence of dilution and reaeration flows, dissolved oxygen

Figure C-7. Water Quality Data for
Gulf Coastal Ecoregion Reference Streams

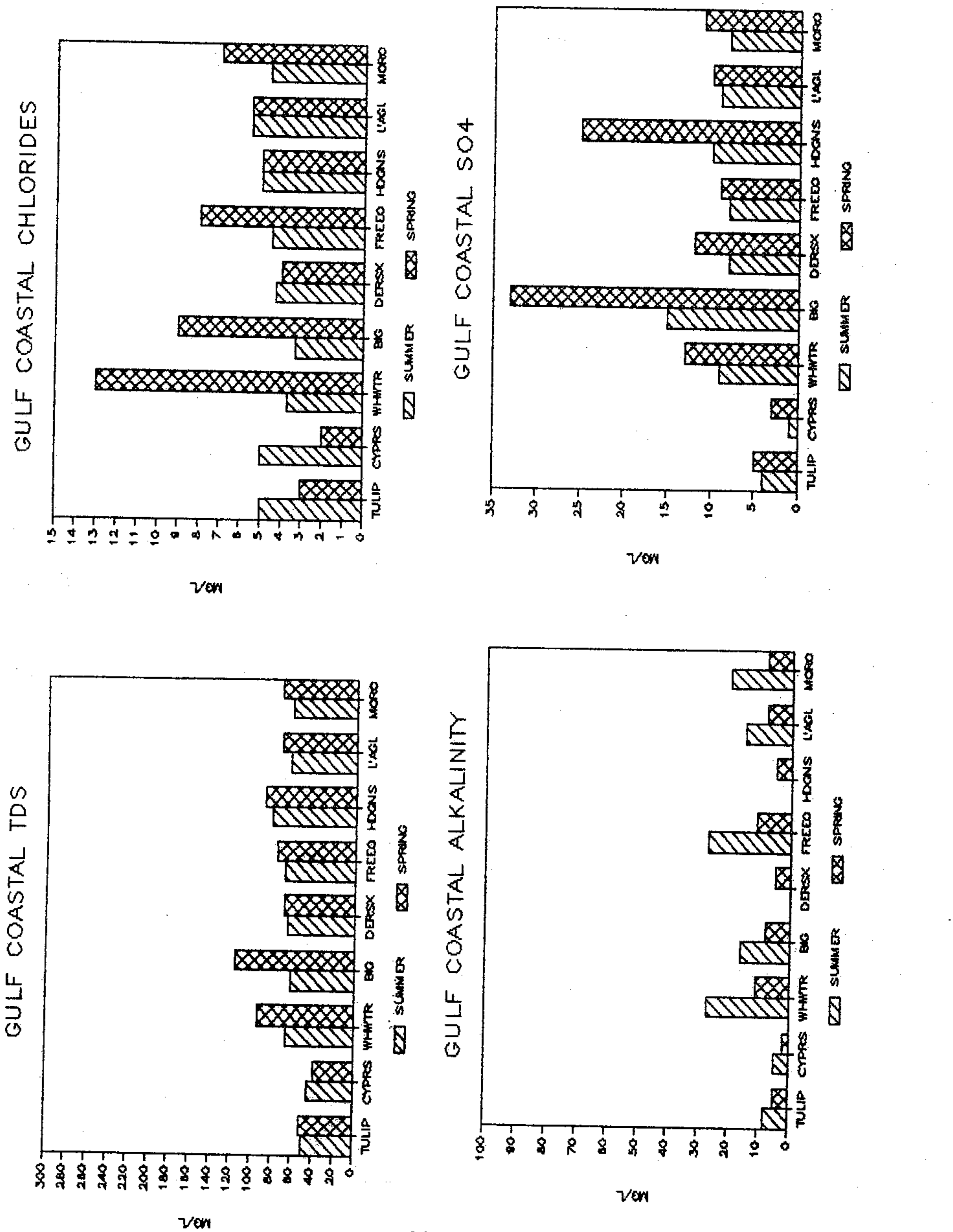
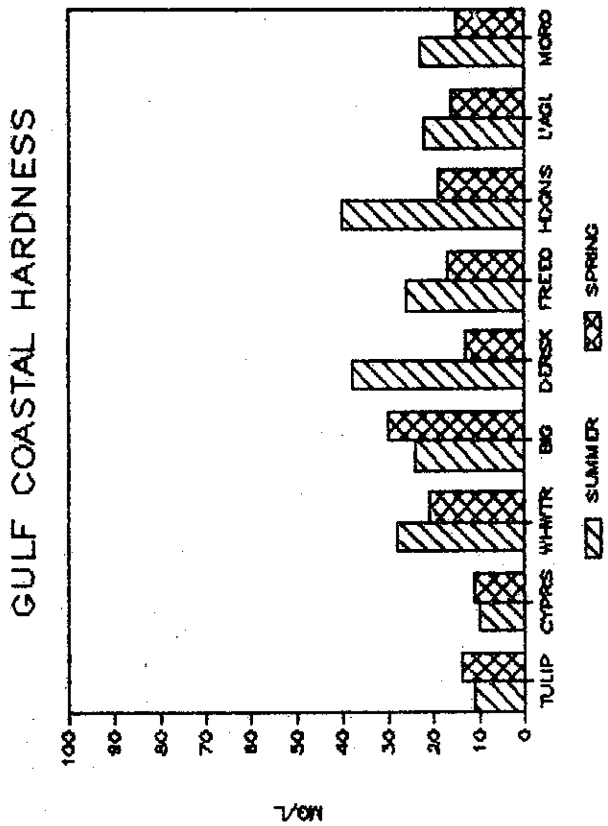
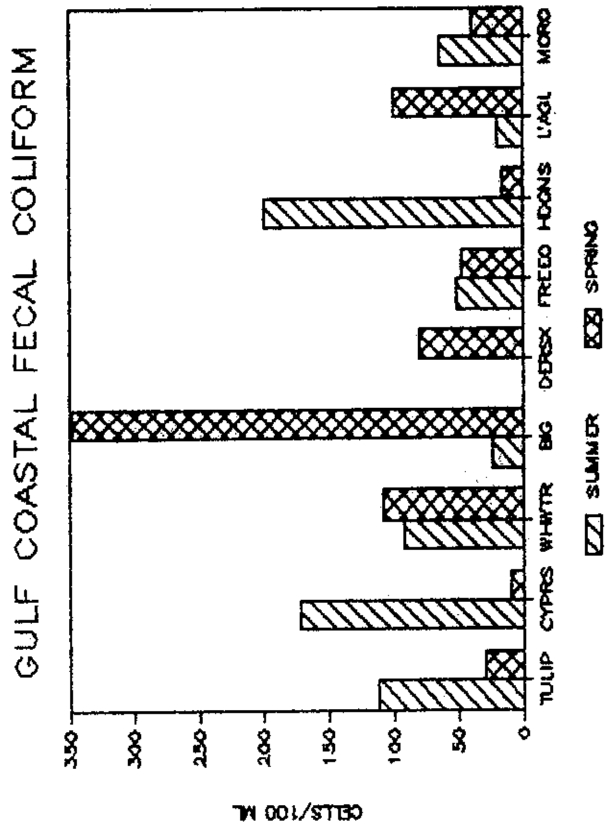


Figure C-8. Water Quality Data for
Gulf Coastal Ecoregion Reference Streams





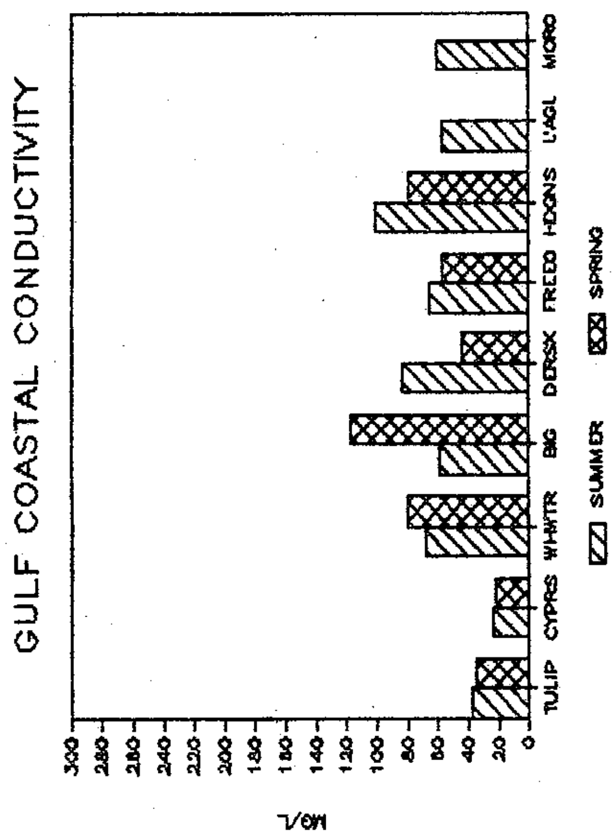


Figure C-9. Water Quality Data for Gulf Coastal Ecoregion Reference Streams

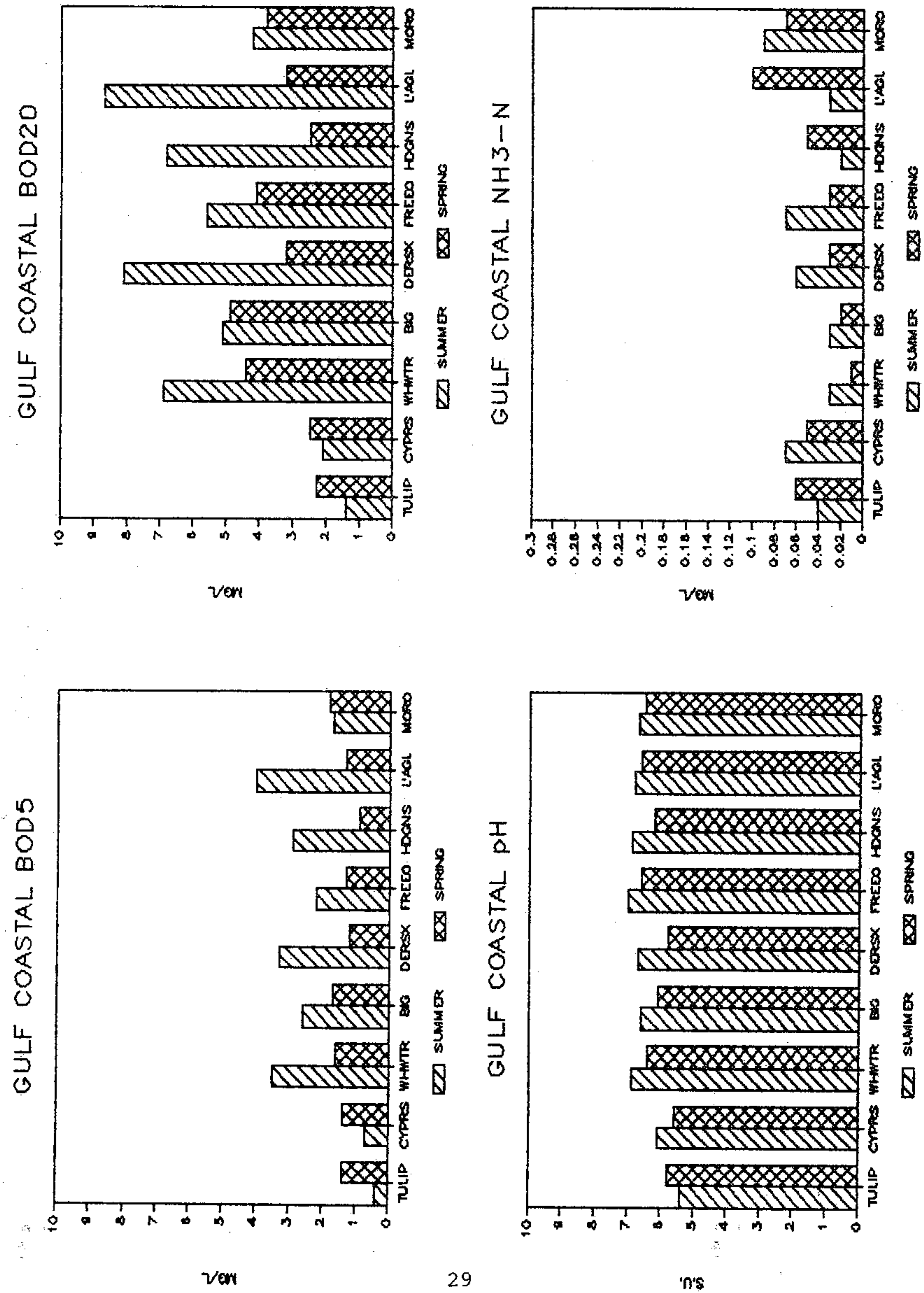
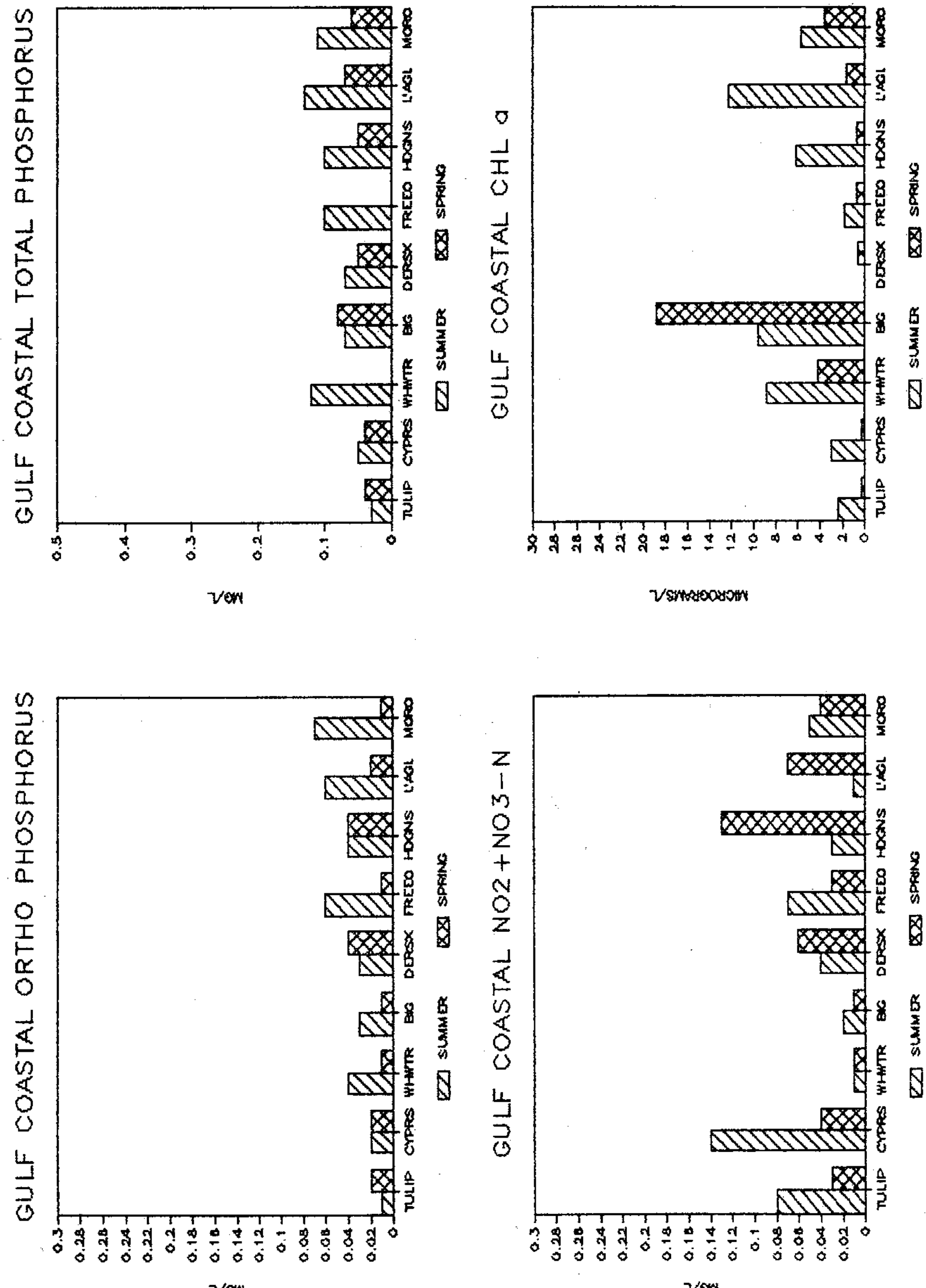


Figure C-10. Water Quality Data for
Gulf Coastal Ecoregion Reference Streams



becomes the critical water quality component. In a few of the Gulf Coastal streams which maintain summer flows through springwater inflow, these conditions do not occur and dissolved oxygen values remain high. Both types of streams have very little buffering capacity, either chemically or flow related, and their water quality characteristics are therefore rather sensitive and potentially unstable.

Arkansas River Valley Ecoregion

Most of the mineral constituents in the waters of the Arkansas River Valley Ecoregion reference streams are present in relatively low amounts. Values for total dissolved solids, total suspended solids, sulfates, turbidity, alkalinity and hardness indicate a possible positive correlation to stream watershed size (Figure C-11, C-12, C-13). In most cases, the seasonal variation of these parameters is distinctive. However, chlorides seem to be very uniform among all of the reference streams during both the spring and summer season (Figure C-12). During the summer period, these and other water quality parameters were not flow-related since the summer flows were near zero at all sites (Figure C-11). The high summer flow in Cadron Creek was estimated at the fish sample site, which was over a mile upstream of the water quality collection site. Upstream, a very slight water movement was noticed, and the wide, deep, continuous pool at this site produced an estimated flow of about 15 cfs. Almost no water movement, or even possibly backflow, was noted at the water sampling site. This condition was caused by the nearness of this site to the Arkansas River and its navigation pools, which retard flows from the tributaries to the river.

Consistency of the values of the biochemical parameters among the reference streams is apparent. Noticeable exceptions are the higher summer BOD and chlorophyll a values in Mill Creek and Cadron Creek (Figure C-14, C-15). These values are caused by the isolated pool conditions of Mill Creek and the large, deep pool in Cadron Creek, creating an almost lentic situation. Also, the stream is exposed to nearly total sunlight due to the limited stream canopy. Summer fecal coliform values exceed the primary contact use standard in Mill Creek, North Fork Cadron Creek and Ten Mile Creek. The extremely high value in North Fork Cadron Creek was probably caused by the high density of cattle grazing in pastures adjacent to the sample site and the use of the stream for cattle watering (Figure C-13).

Phosphorus and ammonia nitrogen values are generally low in the reference streams of the ecoregion. However, Ten Mile Creek has unexplained higher values for total phosphorus with almost all of it in the available (ortho-phosphorus) form. Also, nitrate-nitrate nitrogen values are notably elevated in most of the reference streams during the spring-flow season (Figure C-15). This is probably a reflection of cattle grazing as a major watershed use in much of the Arkansas River Valley.

Figure C-11. Water Quality Data for
Arkansas River Valley Ecoregion Reference Streams

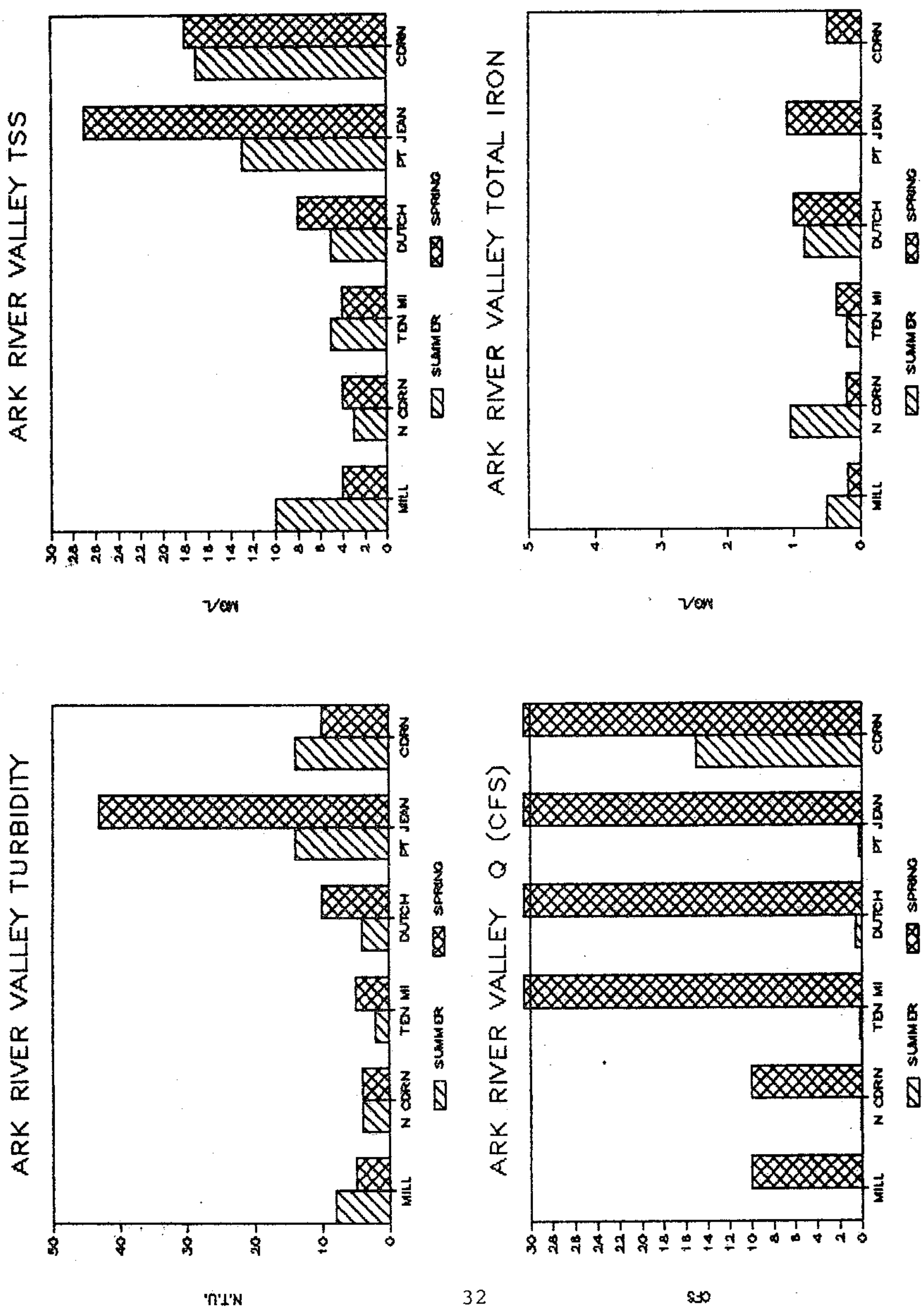


Figure C-12. Water Quality Data for
Arkansas River Valley Ecoregion Reference Streams

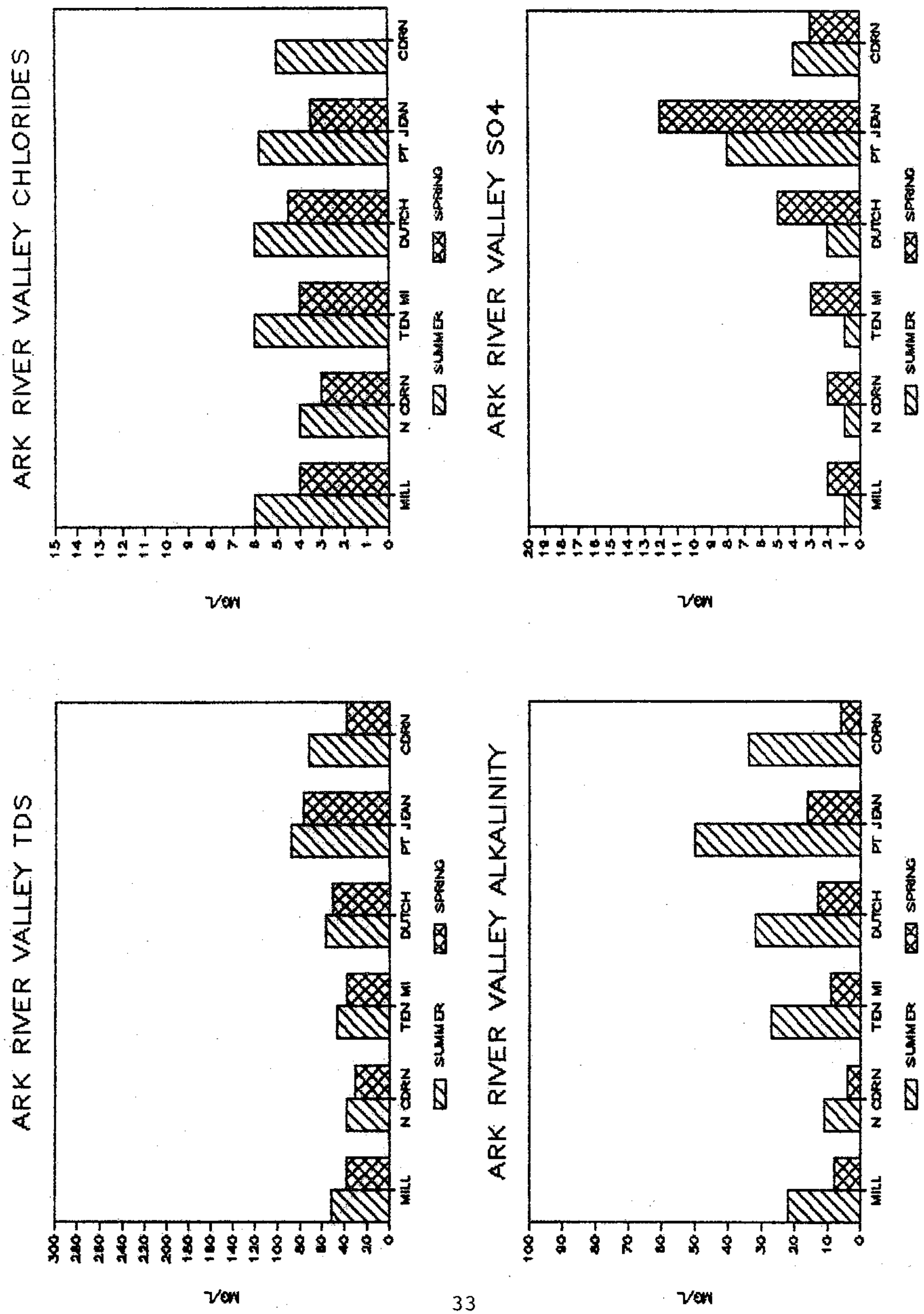
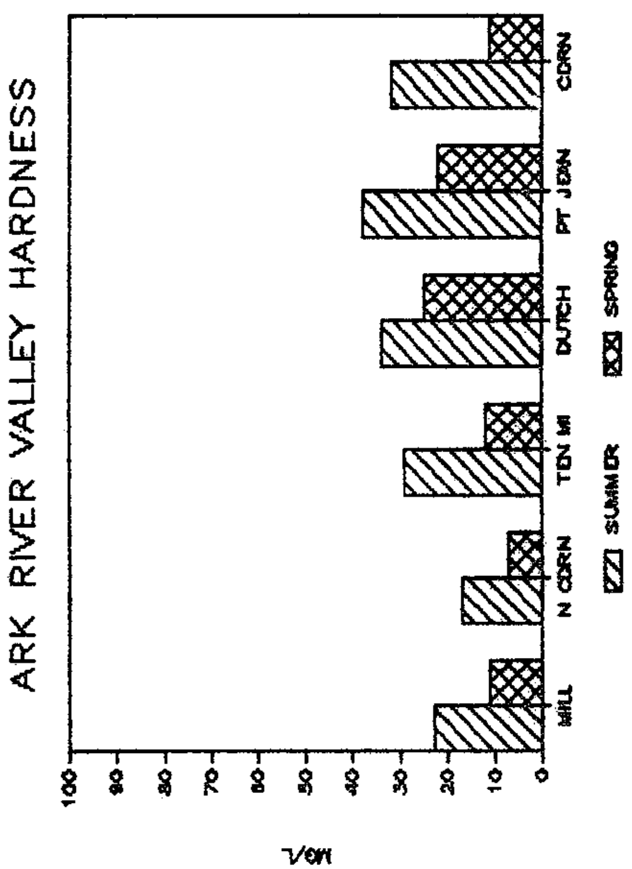
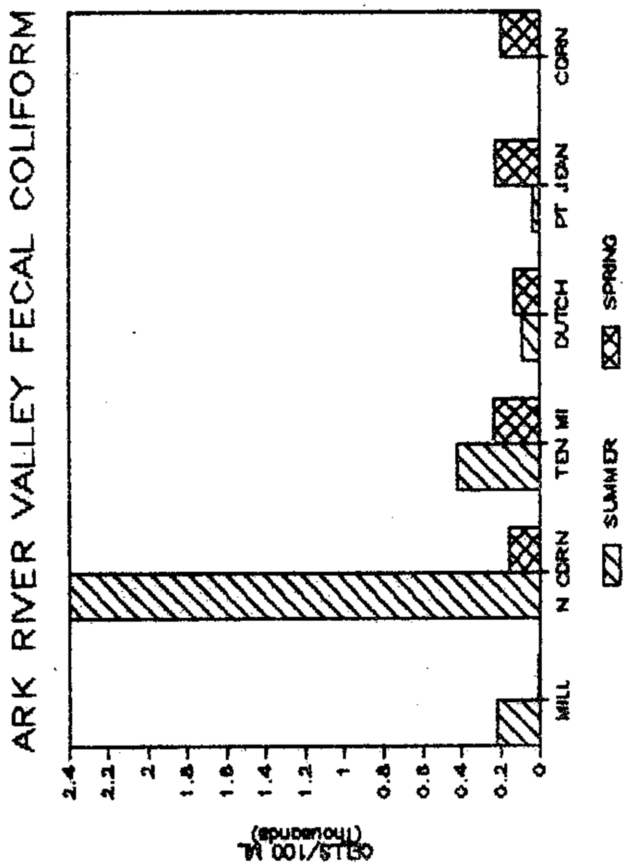


Figure C-13. Water Quality Data for
Arkansas River Valley Ecoregion Reference Streams





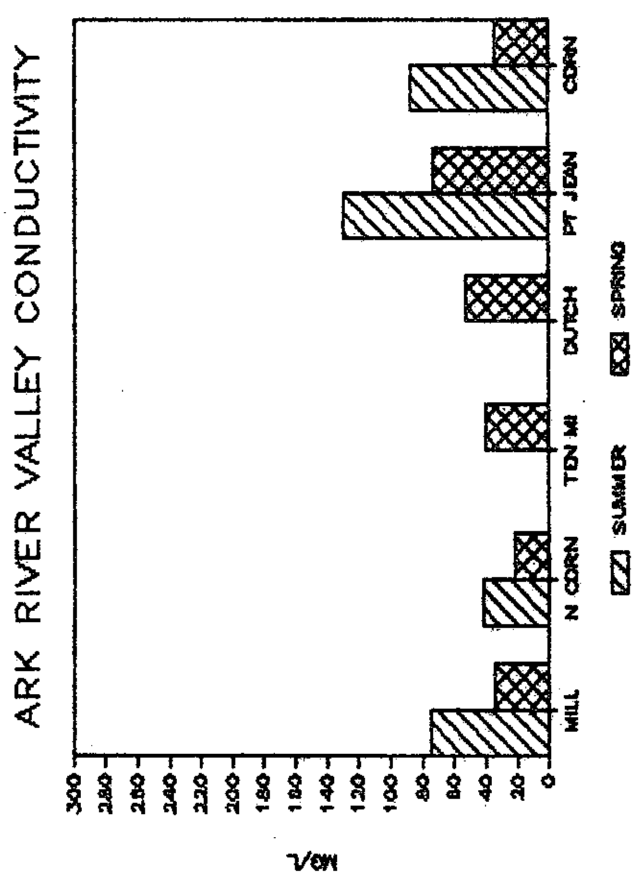


Figure C-14. Water Quality Data for
Arkansas River Valley Ecoregion Reference Streams

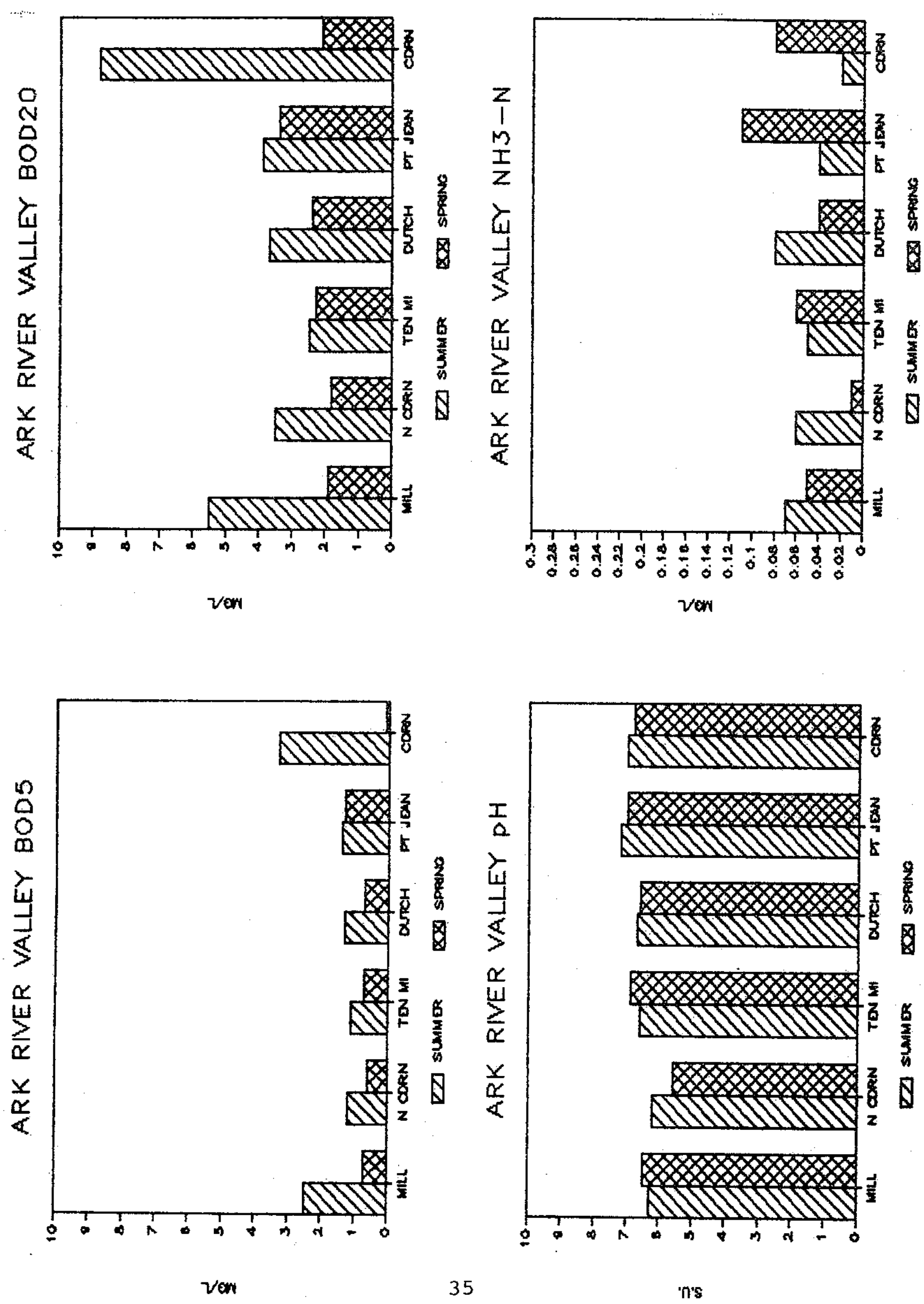
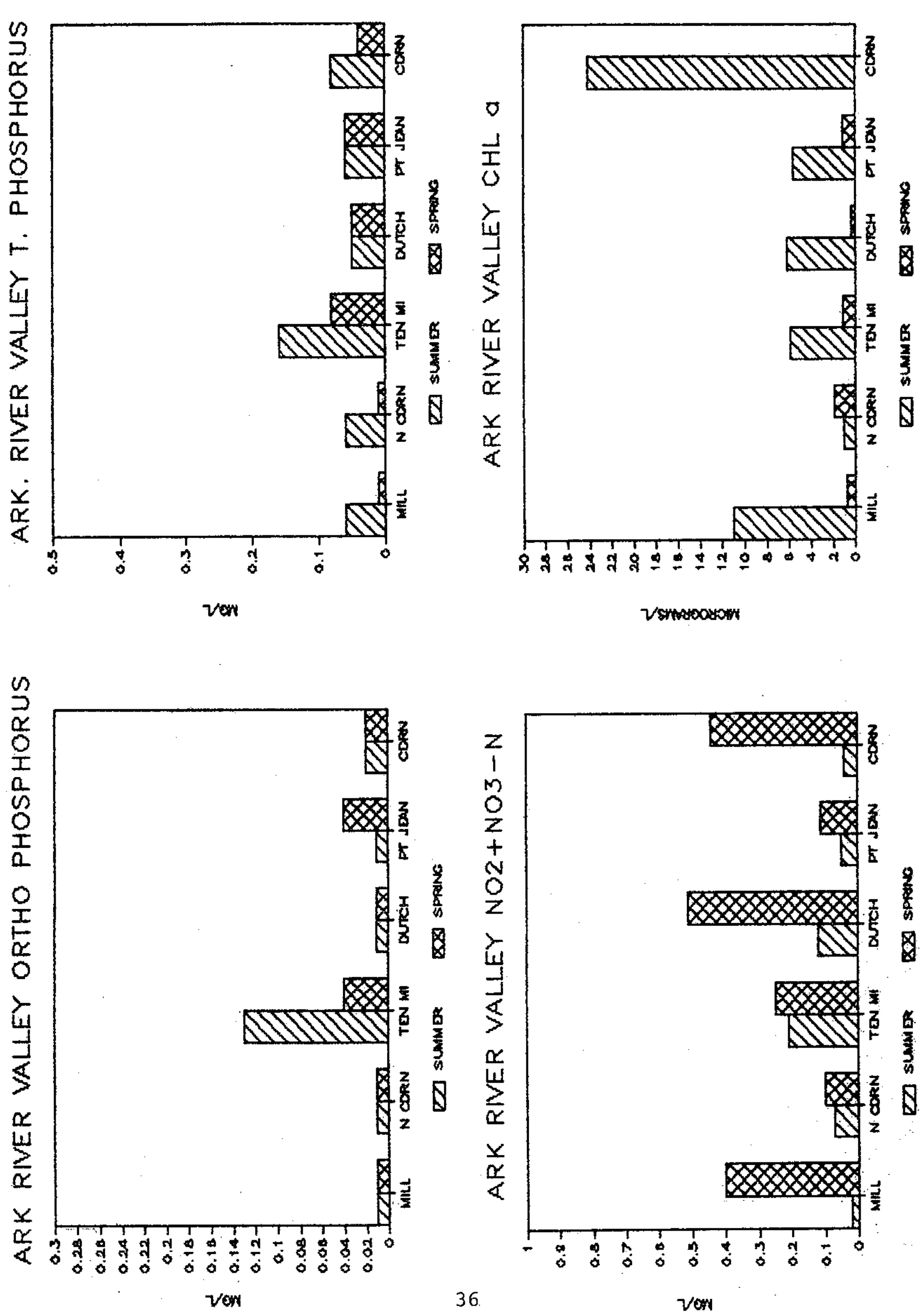


Figure C-15. Water Quality Data for
Arkansas River Valley Ecoregion Reference Streams



In general, the reference streams in this ecoregion have good water quality although perturbations in the watershed are distinctly reflected in the waters. The easily erodible soils found in much of this ecoregion increase the impact of land uses in the watershed in determining the quality of water in Arkansas River Valley streams.

Ouachita Mountain Ecoregion

In the Ouachita Mountains Ecoregion, almost all mineral, biochemical and nutrient water quality parameters measured are consistently low which indicates very high quality water. The mineral water quality values show the only substantial variation. This occurs at the site on the South Fork of the Ouachita River and reflects isolated limestone outcropping in the watershed. Alkalinity, hardness, conductivity and total dissolved solids are noticeably higher at this site (Figure C-16). Also, there is a general increase in the values for these parameters from the two reference streams with the largest watersheds, while the two smallest streams have the lowest values. Although representing a relatively low value, total iron is present in a substantially higher concentration in the spring sample on the Saline River (Figure C-18). This sampling followed a major rise and fall of the water level in this stream from heavy rains. In-wash from the watershed was probably the cause of this elevated iron concentration. Turbidity values in all reference streams during both seasons were very low even though substantial flows existed at all sites and spring flows were very high in the larger watersheds (Figure C-18).

Of the biochemical parameters, the BOD values are consistently very low in all reference streams, indicating very little water column demand on the dissolved oxygen in these waters (Figure C-19). The summer fecal coliform value in South Fork Ouachita River is high and probably reflects cattle grazing activities in small pastures along the streambed (Figure C-17). Also, slightly higher chlorophyll a values are noted in the Caddo River samples (Figure C-20). This sample site is in a very large, deep pool which slows water velocity and allows a slight increase in plankton production. The nutrient parameters associated with nitrogen and phosphorus are similarly very low in these reference streams and they are limiting factors in biotic production (Figure C-20).

Reference streams of the Ouachita Mountains Ecoregion demonstrate that waters of this region are naturally low in mineral quantities, except in areas of limestone outcroppings, and low in nutrient quantities. This results in a very low biotic production potential.

Ozark Highland Ecoregion

The water quality in the Ozark Highlands is substantially different from that of the other ecoregions. The differences are caused by natural geologic conditions and by man-induced conditions related to land uses. Minerals, some nutrients and

Figure C-16. Water Quality Data for
Ouachita Mountains Ecoregion Reference Streams

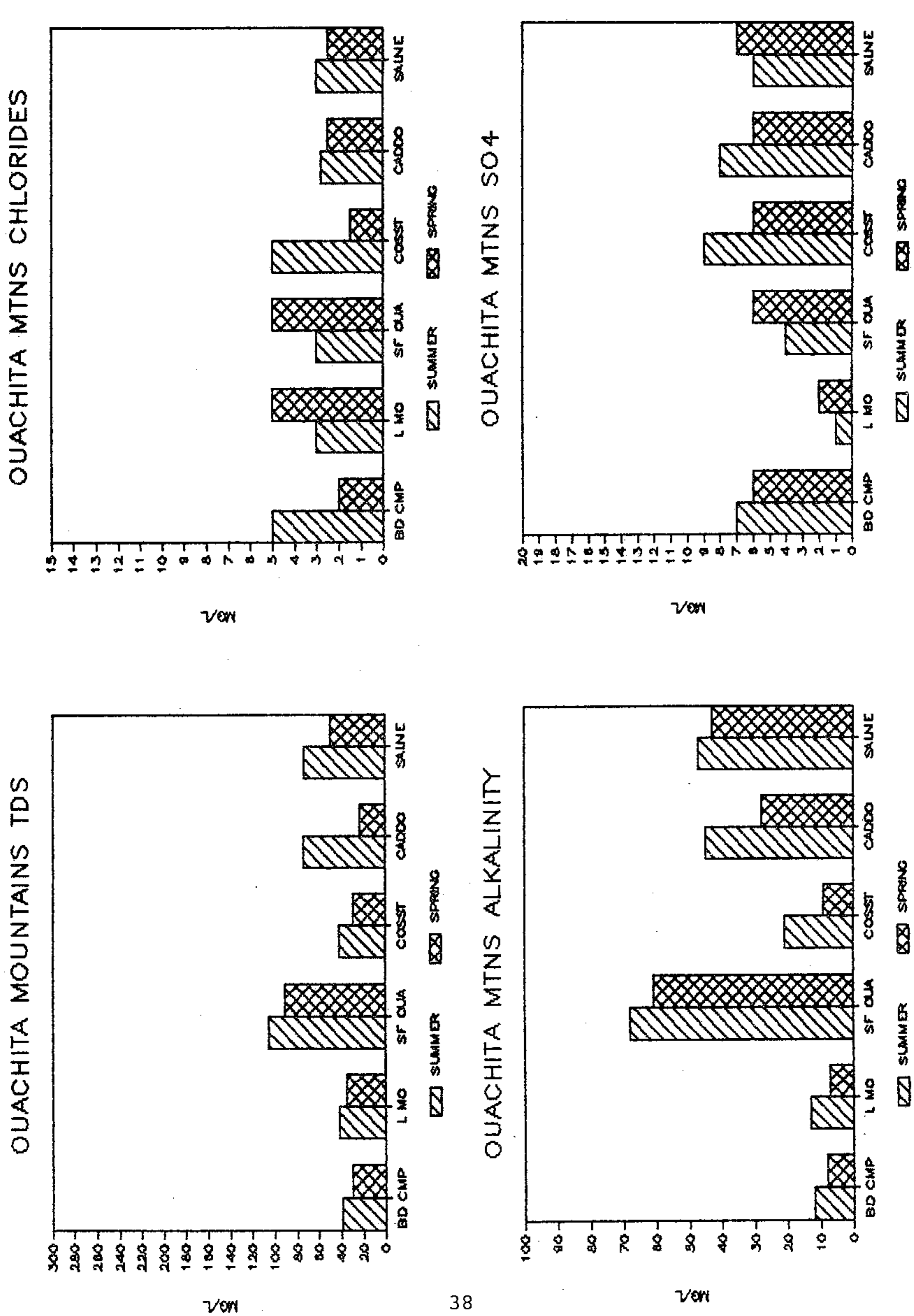
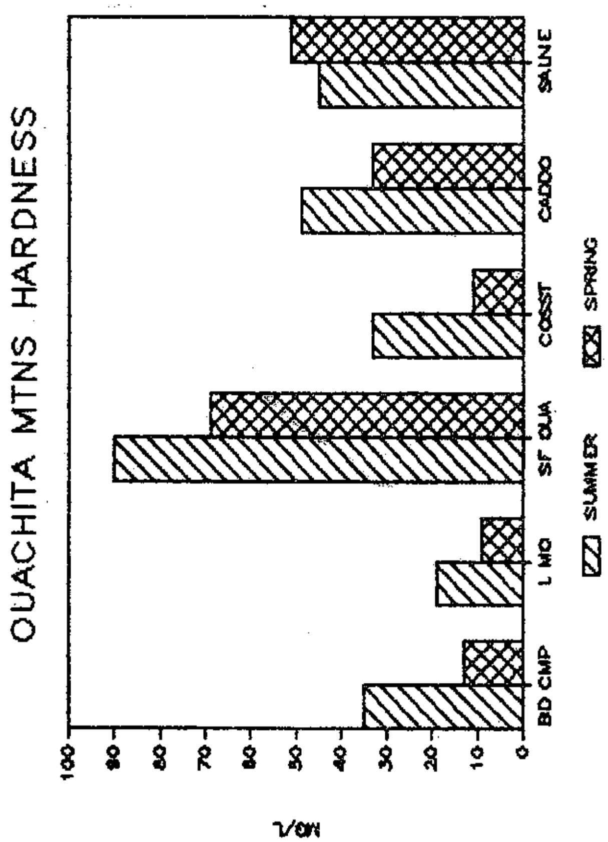
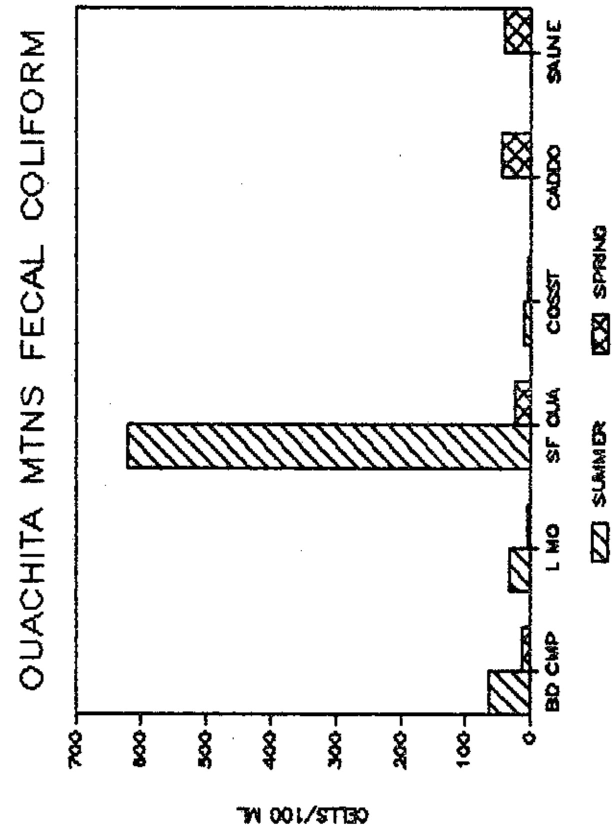


Figure C-17. Water Quality Data for
Ouachita Mountains Ecoregion Reference Streams





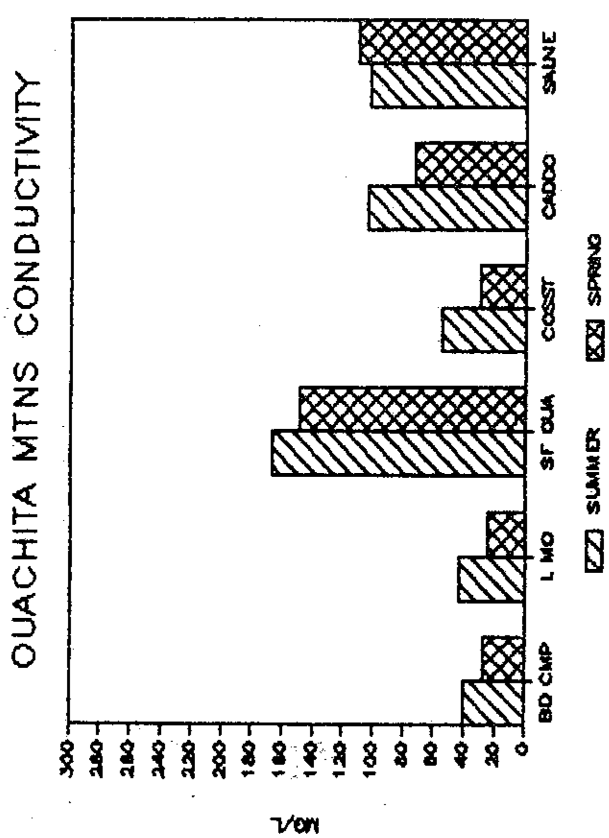


Figure C-18. Water Quality Data for
Ouachita Mountains Ecoregion Reference Streams

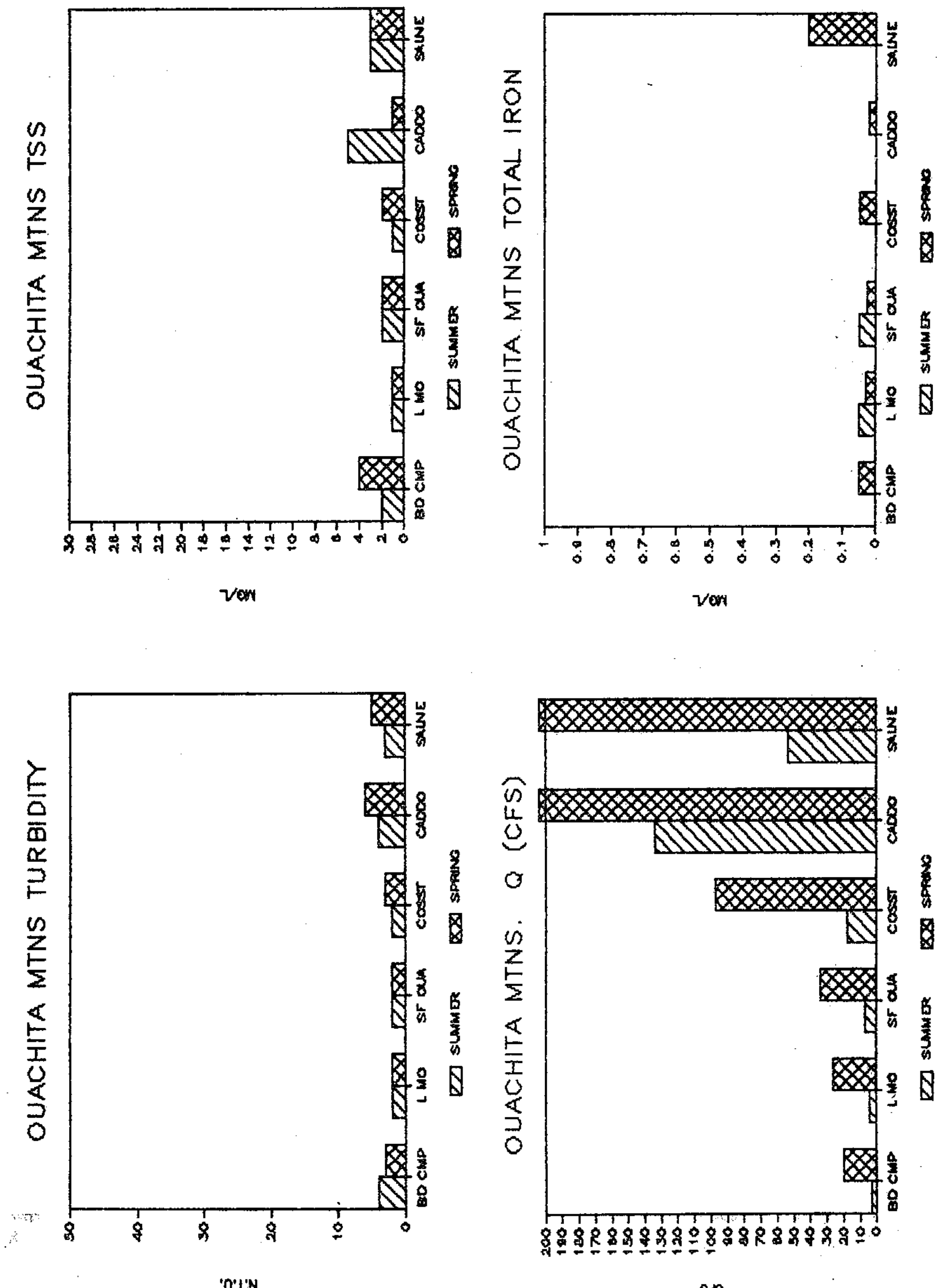


Figure C-19. Water Quality Data for
Ouachita Mountains Ecoregion Reference Streams

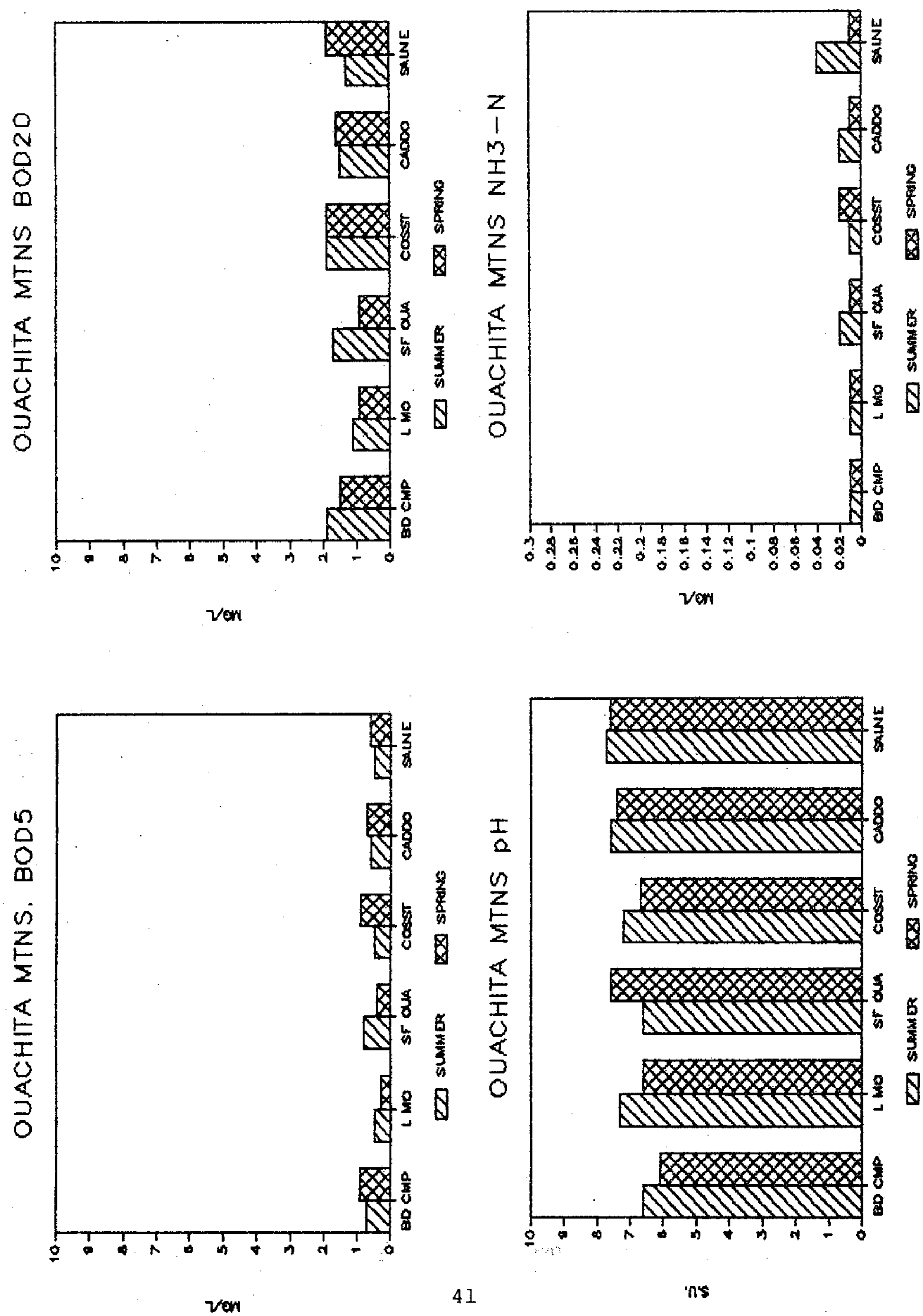
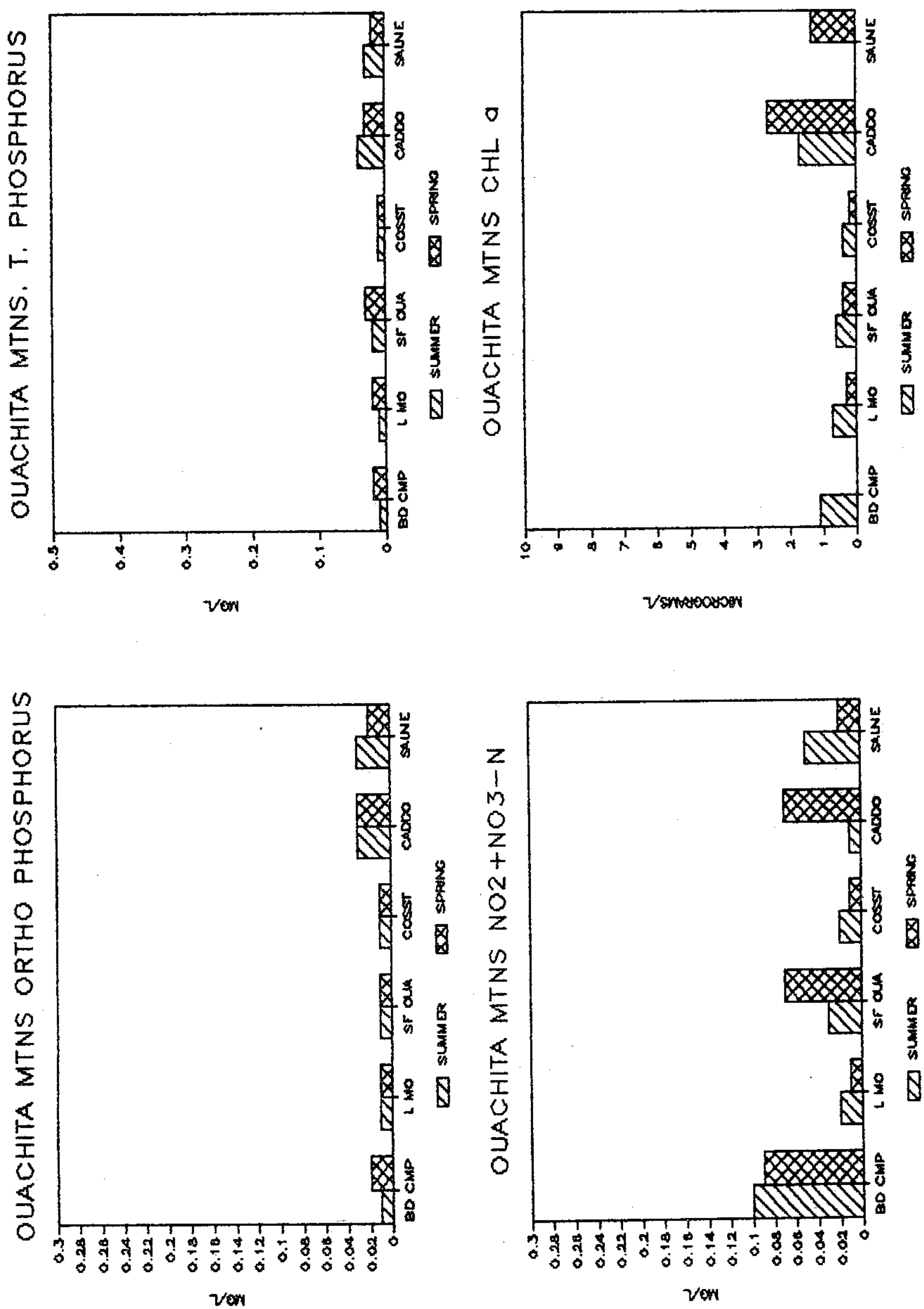


Figure C-20. Water Quality Data for
Ouachita Mountains Ecoregion Reference Streams



most biochemical parameters are notably high in this ecoregion when compared to other regions.

Stream flows within the region are normally present the entire year, even in relatively small watersheds. Flows include frequent groundwater contributions and sections of under-gravel flow within the streambed. Base flows as well as runoff flows are generally related to watershed size (Figure C-21). Although flows are substantial at times, water turbidity normally remains below 10 NTU (Figure C-21). Surface rocks in this ecoregion contain large amounts of limestone and dolomite and therefore produce high alkalinity, total hardness, conductivity and total dissolved solids in the surface waters (Figure C-22 and C-23). These values are consistently high in all reference streams and the variation that occurs is most likely related to the amount of limestone in the watershed. Sulfate values are similar to those in other ecoregions and appear to be directly related to watershed size (Figure C-22).

The biochemical water quality constituents appear to be similar to the other regions. However, there are definite indications in these waters of the practice of land application of waste from confined animal production facilities such as poultry and hogs. Also, many areas of improved pasture with intensive cattle grazing exist in this region. Exceptionally high fecal coliform values (2300 to 8800 cells per 100 ml) were found during spring sampling in South Fork Spavinaw, Flint and Yocum Creeks (Figure C-23). Since there are no major point source discharges in these streams and because these values are associated with springtime surface runoff, it is apparent that the source is from animal waste in the watershed. Although there is apparent heavy organic loading to the watershed of many of these streams, BOD values are not considered to be high (Figure C-24). Stream flows, substrate types and high stream gradients apparently result in reaeration rates which satisfy the oxygen demand from much of the watershed. Chlorophyll a values are similarly lower than might be expected with the known nonpoint source contribution to these streams (Figure C-25). However, stream flow velocities prevent excessive phytoplankton development. Periphyton production was not measured but general observations indicate that the primary production in these streams is periphyton.

Nutrient water quality values, particularly nitrite-nitrate nitrogen, also indicate substantial contributions from land uses. These values are much higher in the Ozark Highlands than any other region, and the highest values are found in the three reference streams which contained the highest fecal coliform values. These are also the streams with the smallest watersheds (Figure C-25). The two reference streams with the largest watersheds have relatively low nitrate-nitrite values. These were lower during the spring period than during the summer. This indicates watershed-specific problems related to location and magnitude of activity rather than size of watershed and magnitude of surface runoff. All phosphorus

Figure C-21. Water Quality Data for Ozark Highlands Ecoregion Reference Streams

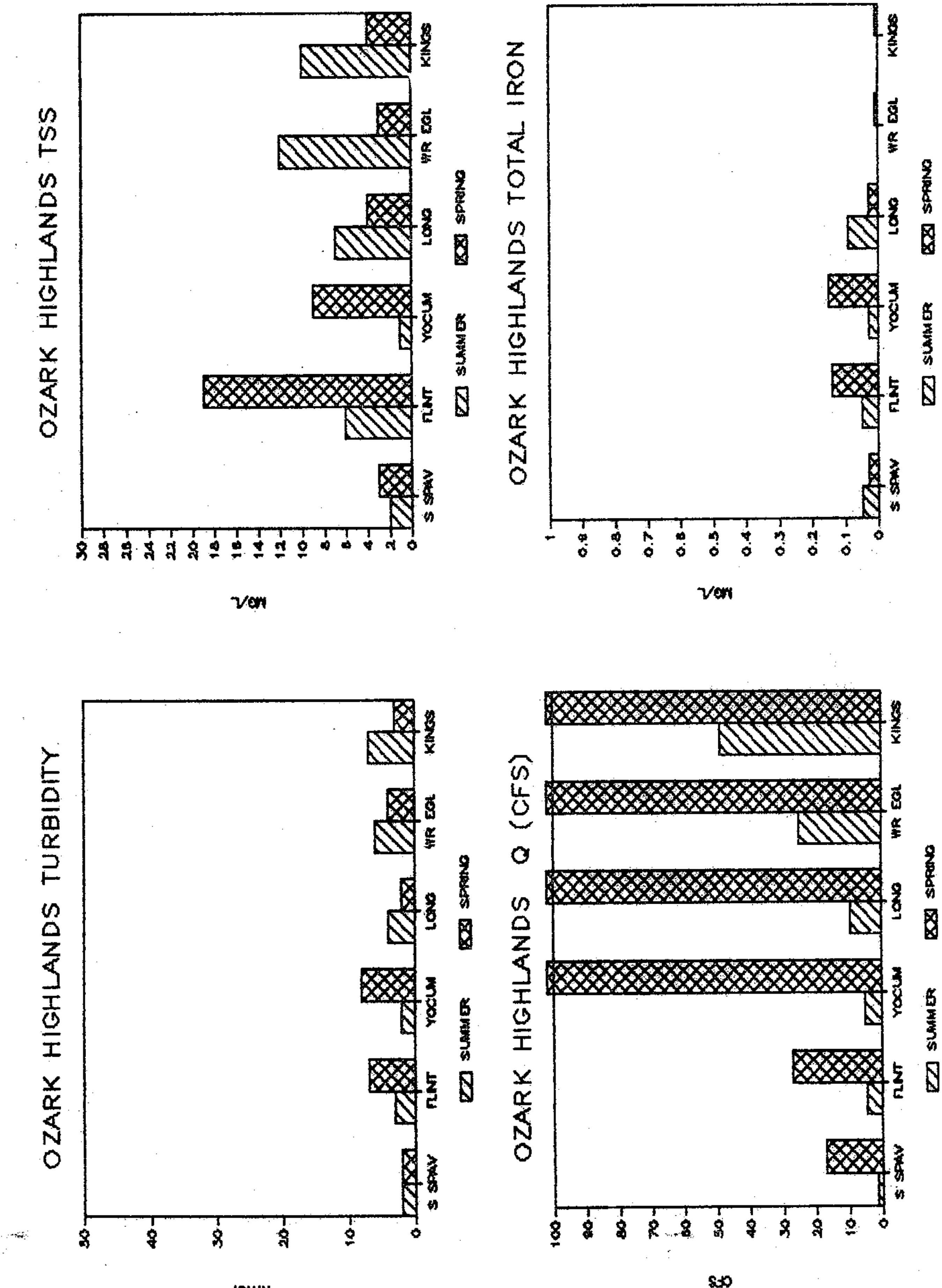


Figure C-22. Water Quality Data for
Ozark Highlands Ecoregion Reference Streams

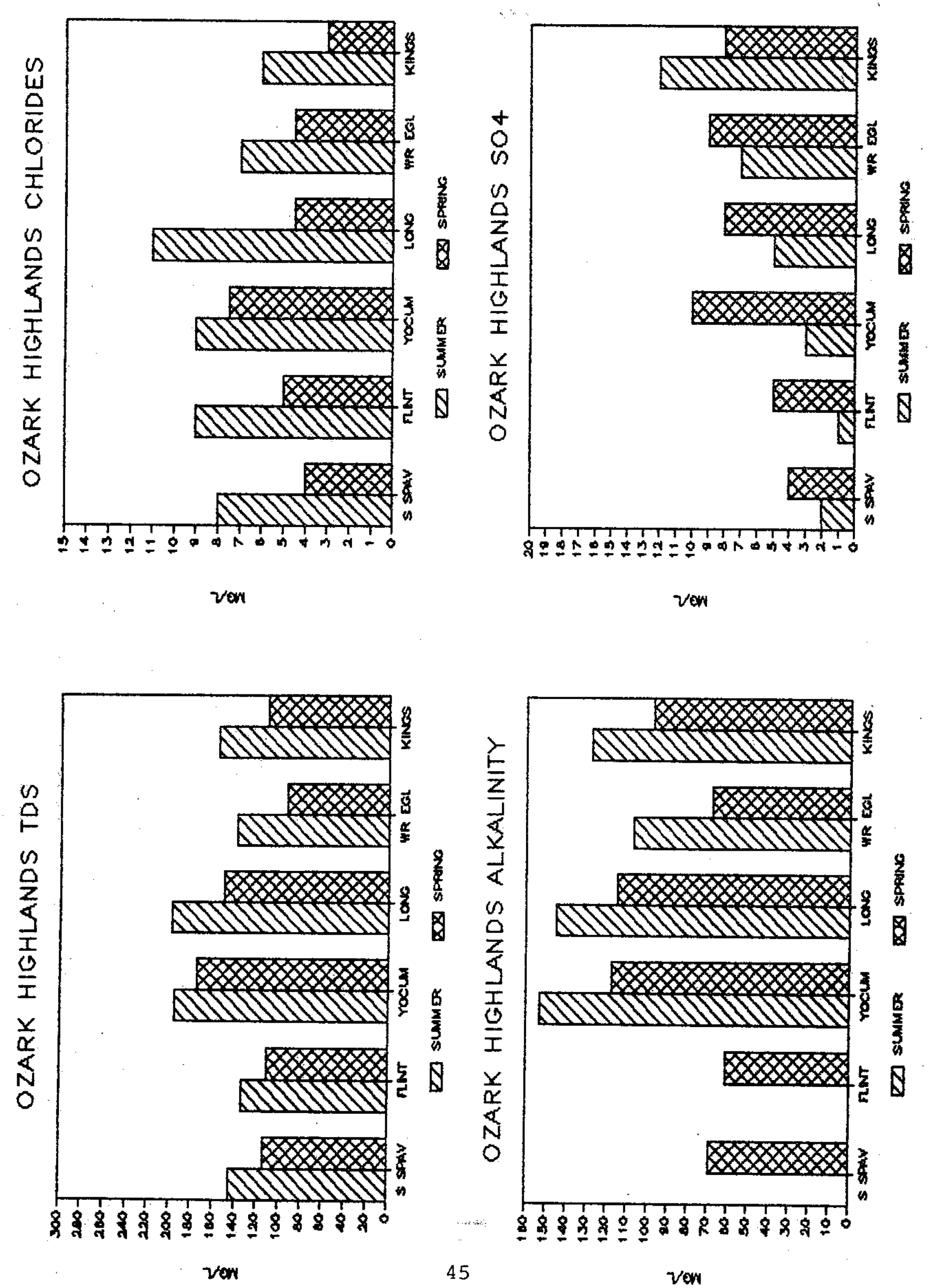
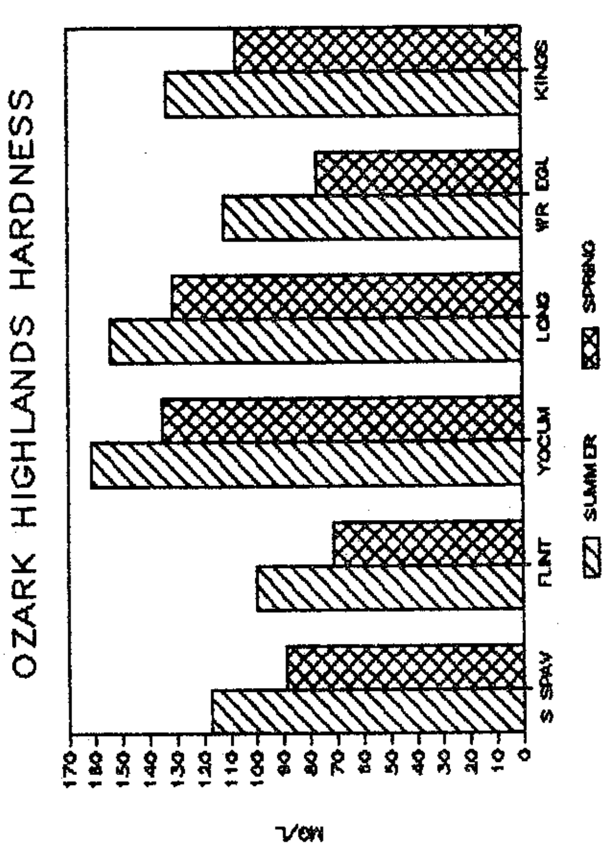
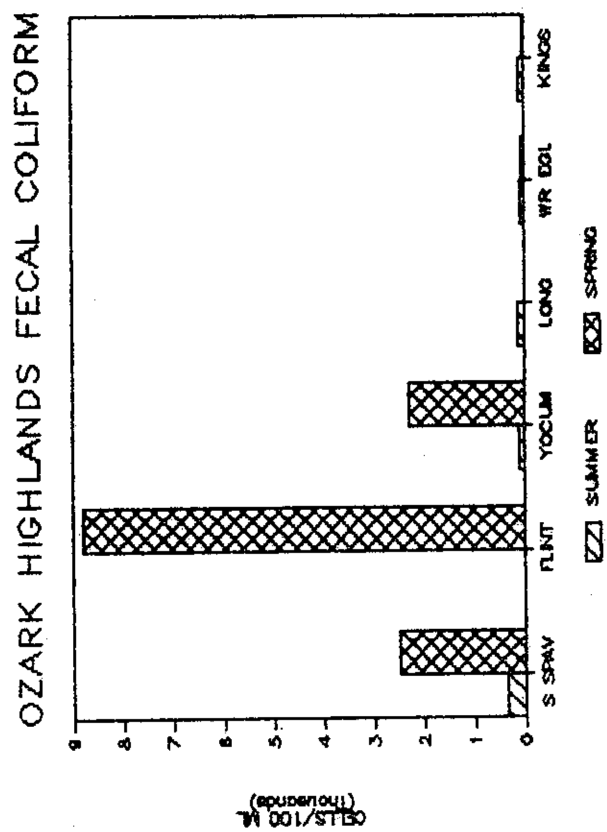


Figure C-23. Water Quality Data for
Ozark Highlands Ecoregion Reference Streams





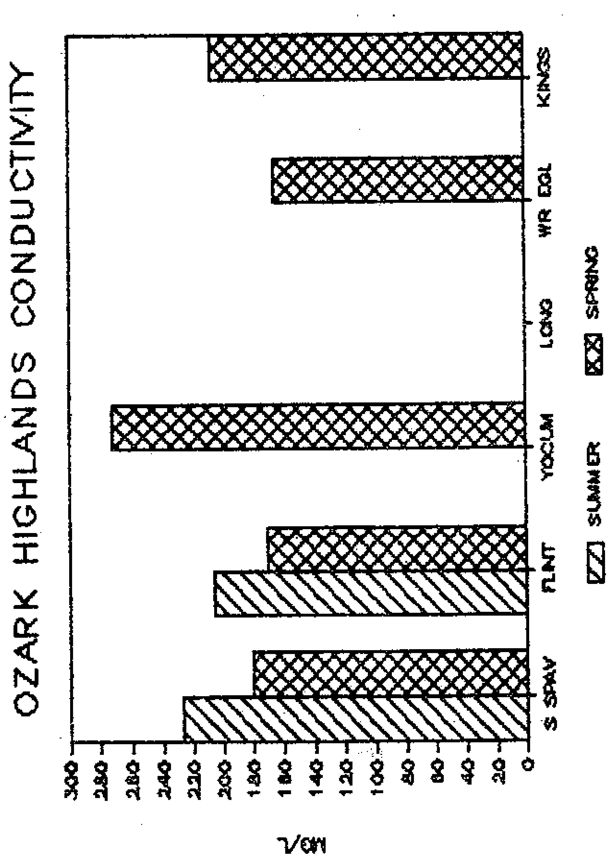


Figure C-24. Water Quality Data for
Ozark Highlands Ecoregion Reference Streams

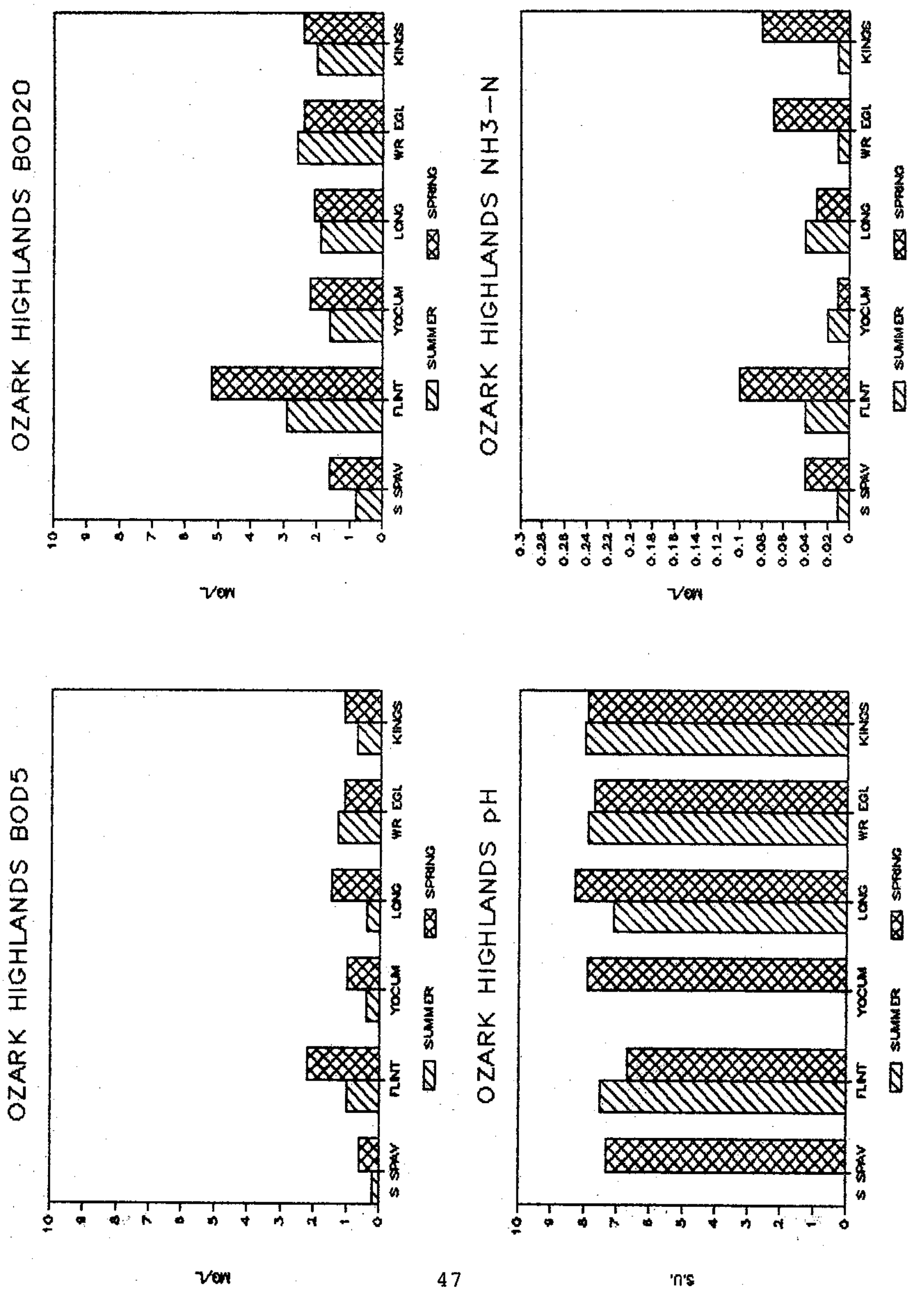
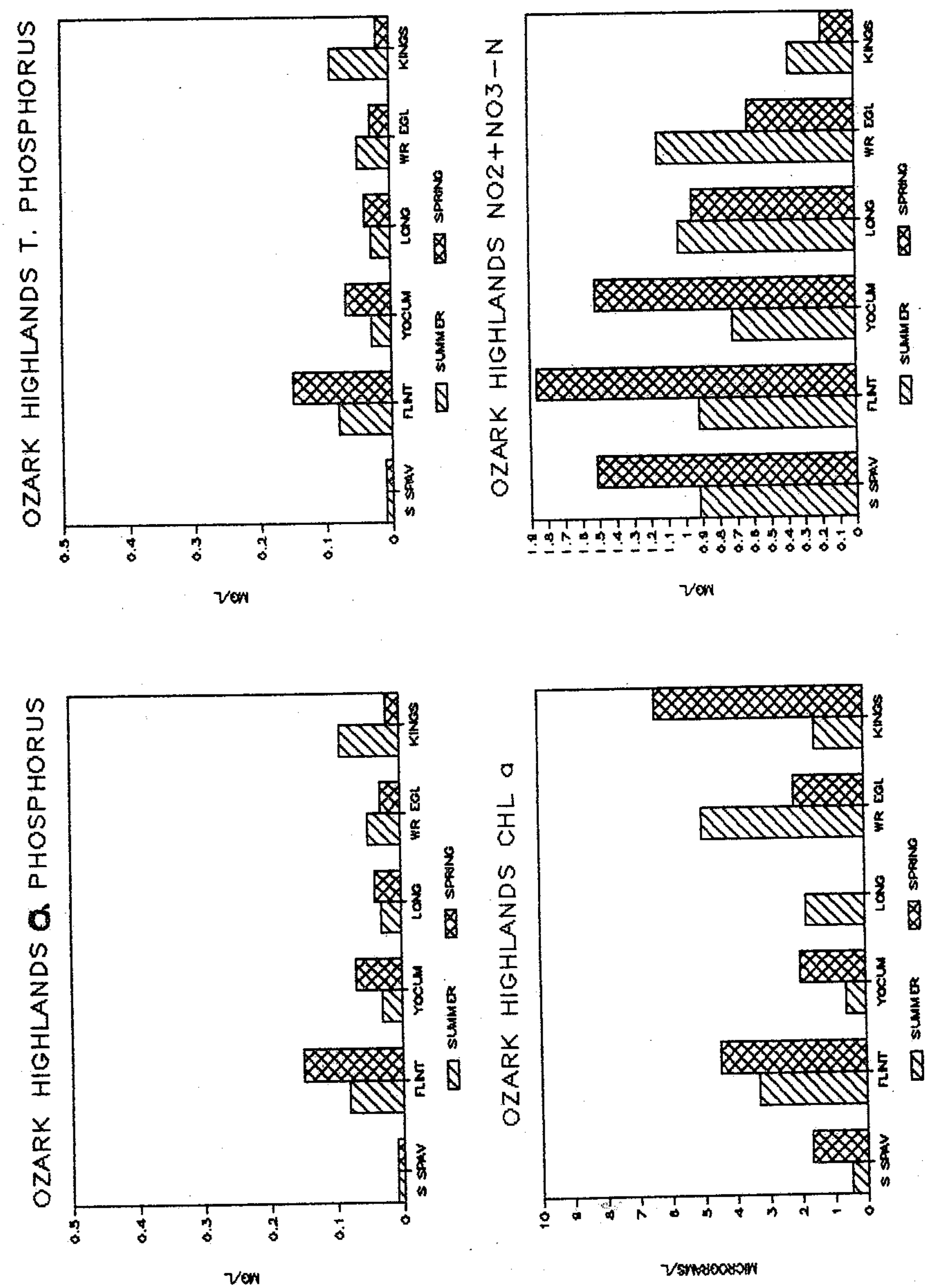


Figure C-25. Water Quality Data for
Ozark Highlands Ecoregion Reference Streams



values are relatively low, except the spring value in Flint Creek, which shows a higher value for total phosphorus and ortho-phosphorus (Figure C-25). Moderate increases in available phosphorus combined with the high nonpoint source nitrogen contributions may cause substantial changes in the environment of these streams.

The water quality of the Ozark Highlands reference streams reflects the natural geologic characteristics of the ecoregion, which produce relatively high mineral constituents. It also reflects the land application of animal waste from concentrated poultry and livestock production facilities to the watersheds. High fecal coliform and nitrite-nitrate nitrogen values result from this practice. High phosphorus values are not apparent and either do not occur in high levels in the nonpoint contributions or are being adsorbed by soil particles and utilized in terrestrial plant production. Biological production in these streams was measured only by chlorophyll a in the water column. These values were low due to water flow velocities; however, observations indicate that periphyton, macroinvertebrate and fish production is high.

Boston Mountains Ecoregion

Reference streams in the Boston Mountains Ecoregion contain very low concentrations of minerals, similar to those of the Ouachita Mountains. In contrast, summer flows in Boston Mountains Ecoregion streams are very low and surface flows in many of the smaller streams (less than 50 mi^2 watershed) cease during every summer. Streams with watershed sizes up to about 400 mi^2 have Q_{7-10} flows of zero and annual summer flows decline as low as 5 cfs (Figure C-26). Only the summer values of chlorides in Lee Creek appear to vary noticeably from the other reference streams. Summer values of sulfates, alkalinity, and hardness also show some increase in Lee Creek (Figure C-27, C-28). These values are not alarmingly high but are relatively high for this ecoregion. The source is unknown although one or more oil wells operated in this watershed in the past.

Biochemical parameters are also very low in reference streams of this ecoregion. Twenty-day BOD values are generally less than 2 mg/l and summer values are slightly higher than spring values because of the "pooled" conditions of most of these streams during the summertime (Figure C-29). A relatively high quantity of fecal coliform bacteria was found in Illinois Bayou in the summer sample (Figure C-28). Homes are occasionally found along the stream bank in this segment and some small pastures for cattle grazing are located in the isolated land tracts that are not in National Forest ownership.

Nutrient values are lowest in reference streams of this ecoregion when compared to all other ecoregions. Nitrite-nitrate nitrogen values are generally less than 0.04 mg/l and may show a slight direct correlation with

Figure C-26. Water Quality Data for
Boston Mountains Ecoregion Reference Streams

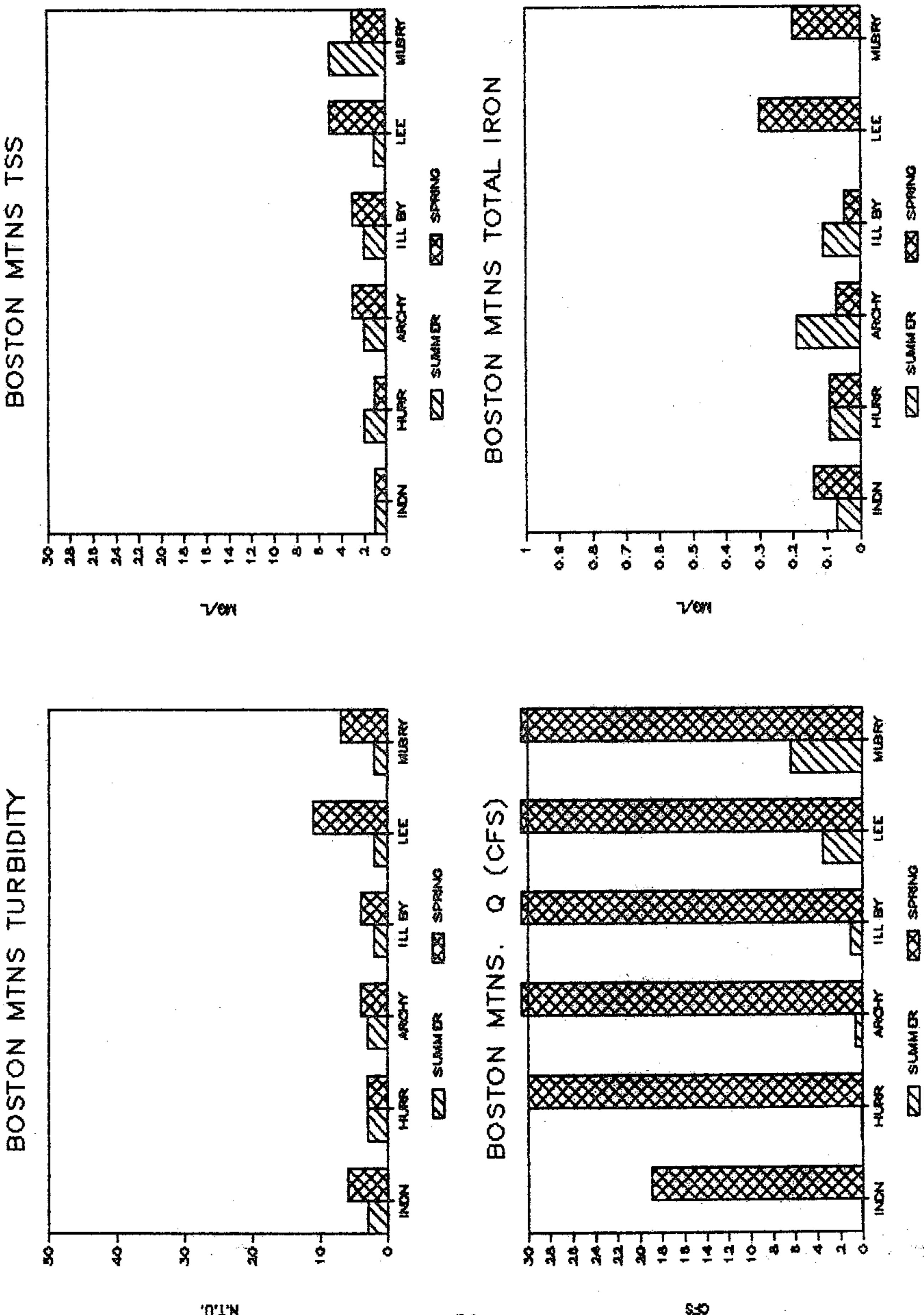
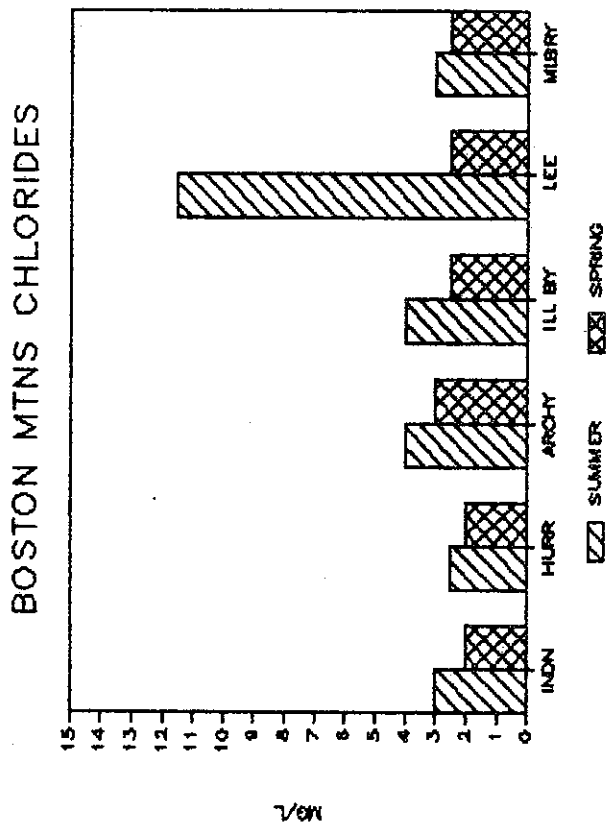
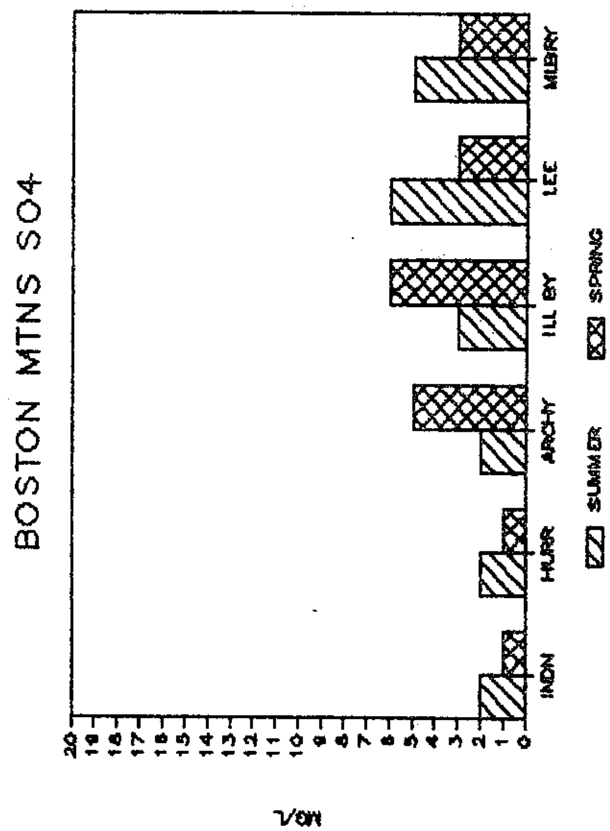
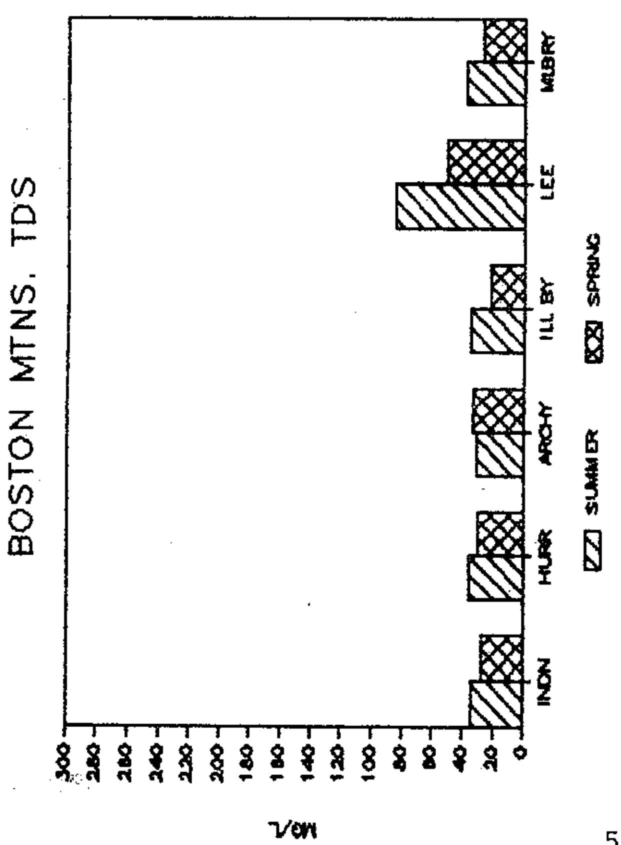


Figure C-27. Water Quality Data for
Boston Mountains Ecoregion Reference Streams







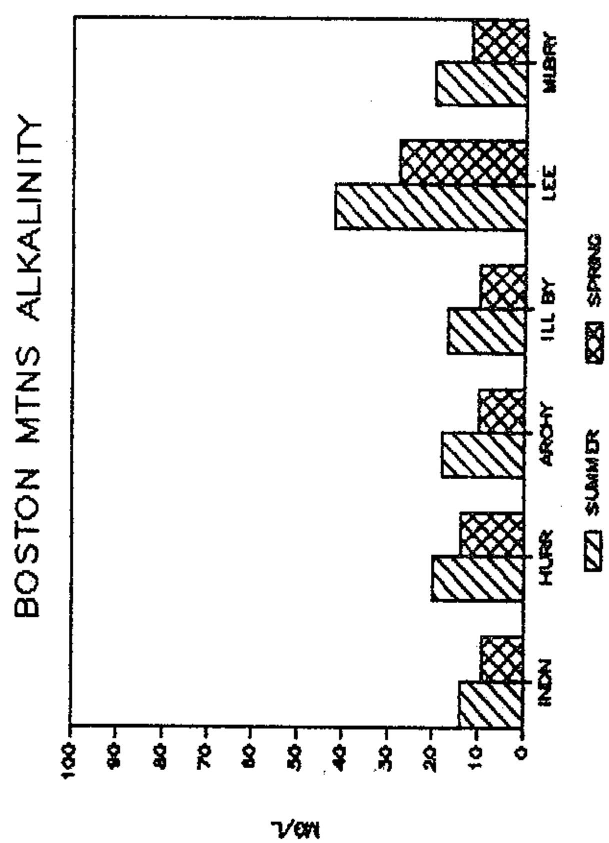
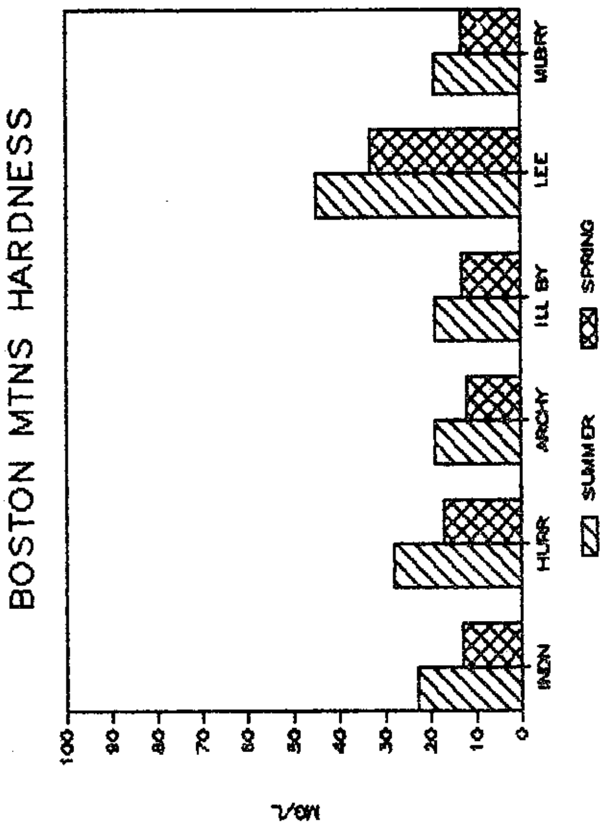
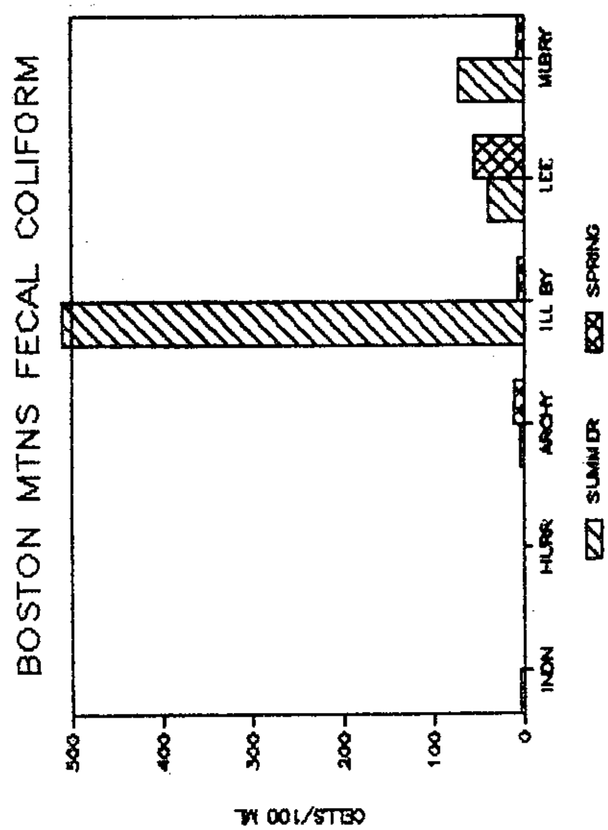


Figure C-28. Water Quality Data for
Boston Mountains Ecoregion Reference Streams





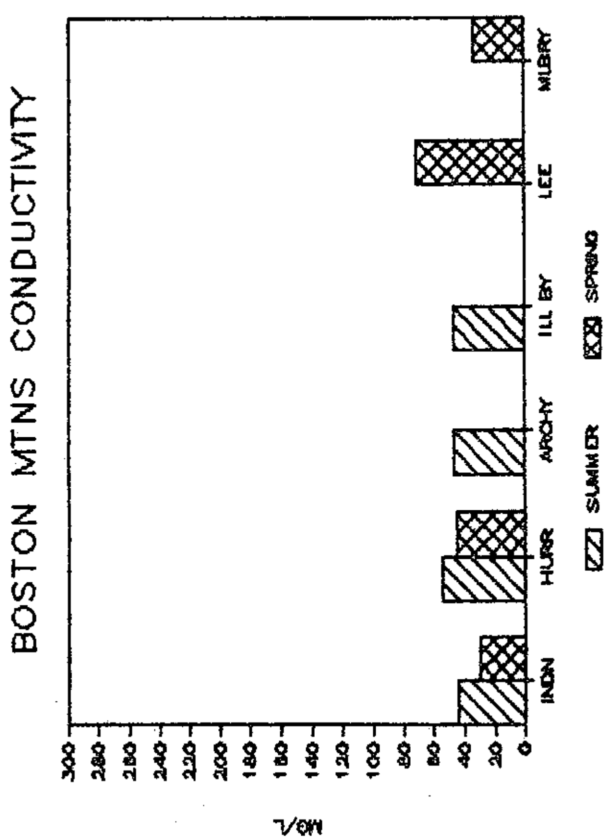
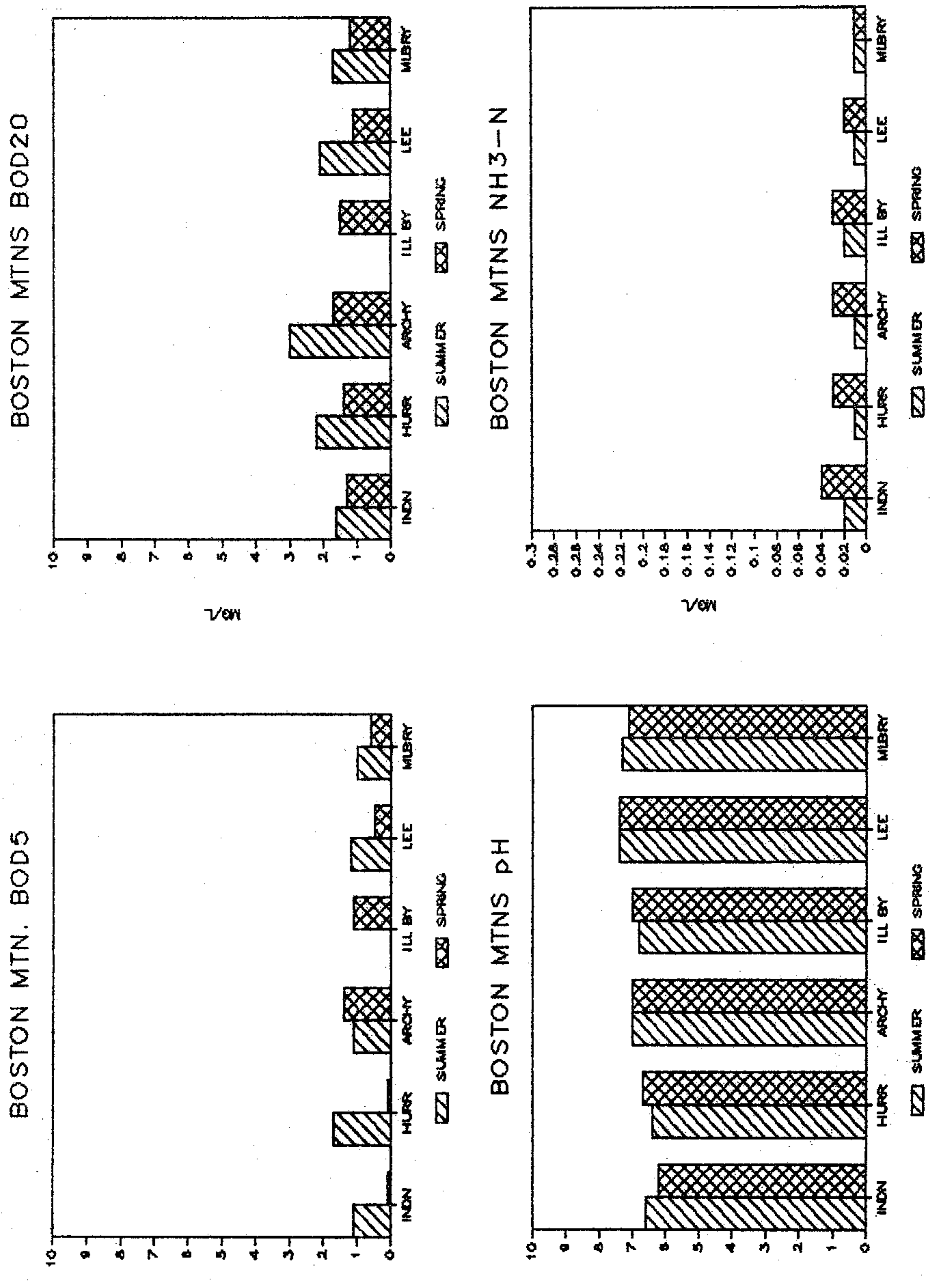


Figure C-29. Water Quality Data for
Boston Mountains Ecoregion Reference Streams



watershed size, particularly during the spring season (Figure C-30). Conversely, ammonia nitrogen values, which are also extremely low, show a slight inverse relationship with watershed size (Figure C-29). Phosphorus also appears to increase with increased flows from the larger watershed streams (Figure C-30).

The streams within the Boston Mountains Ecoregion are probably the most sensitive in the state because of their low flow regime which provides only limited flows during the dry season and a near absence of a mineral buffering capacity. Slight increases in nutrient values could cause significant changes in the chemical and biotic features of these streams. The flow regime of these streams, the physical features which allow maximum exposure to sunlight due to limited stream canopy and the sensitive biota add to the precarious balance of these ecosystems.

Comparison of Ecoregions

The mineral water quality of all ecoregions reflects the geologic characteristics of the region and man's activities within the watersheds. Since the reference streams were chosen for their limited point source discharges, such discharges are not evident in the data, but the potential effects of future discharges can be anticipated from the data collected. The natural geologic contributions reflected in mineral water quality of these reference streams is minimal except in the limestone and dolomite areas, located for the most part in the Ozark Highlands. However, man-induced, nonpoint sources are distinctly apparent in the Ozark Highlands and the Delta Ecoregions.

Alkalinity, hardness, total dissolved solids and conductivity are both spatially and temporally consistent in the Ozark Highland reference streams (Figure C-31). This demonstrates the persistent contribution from the watershed geology. In contrast, turbidity, total suspended solids (most of which is clay particles) and total iron are substantially higher in the Delta Ecoregion during the high flow periods which reflects disruptions in the watershed caused by agricultural activities and drainage projects (Figure C-32). Chloride and sulfate values are generally reflecting only watershed geology in all ecoregions; however, it has been speculated that the use of groundwater for irrigation of crops causes some increase in these minerals in surface waters which receive such discharges. The high sulfate values in the spring data from the Gulf Coastal Ecoregion was caused by high values in only two streams with adjacent watersheds. The cause is unknown (Figure C-33).

BOD values are highest in the three lowland ecoregions (Delta, Gulf Coastal and Arkansas River Valley - Figure C-34). These values are highest during the spring in the Delta which is another indication of disturbed watershed contributions. However, in the Gulf Coastal and Arkansas River Valley, BOD values are highest during the summer as a result of the

Figure C-30. Water Quality Data for
Boston Mountains Ecoregion Reference Streams

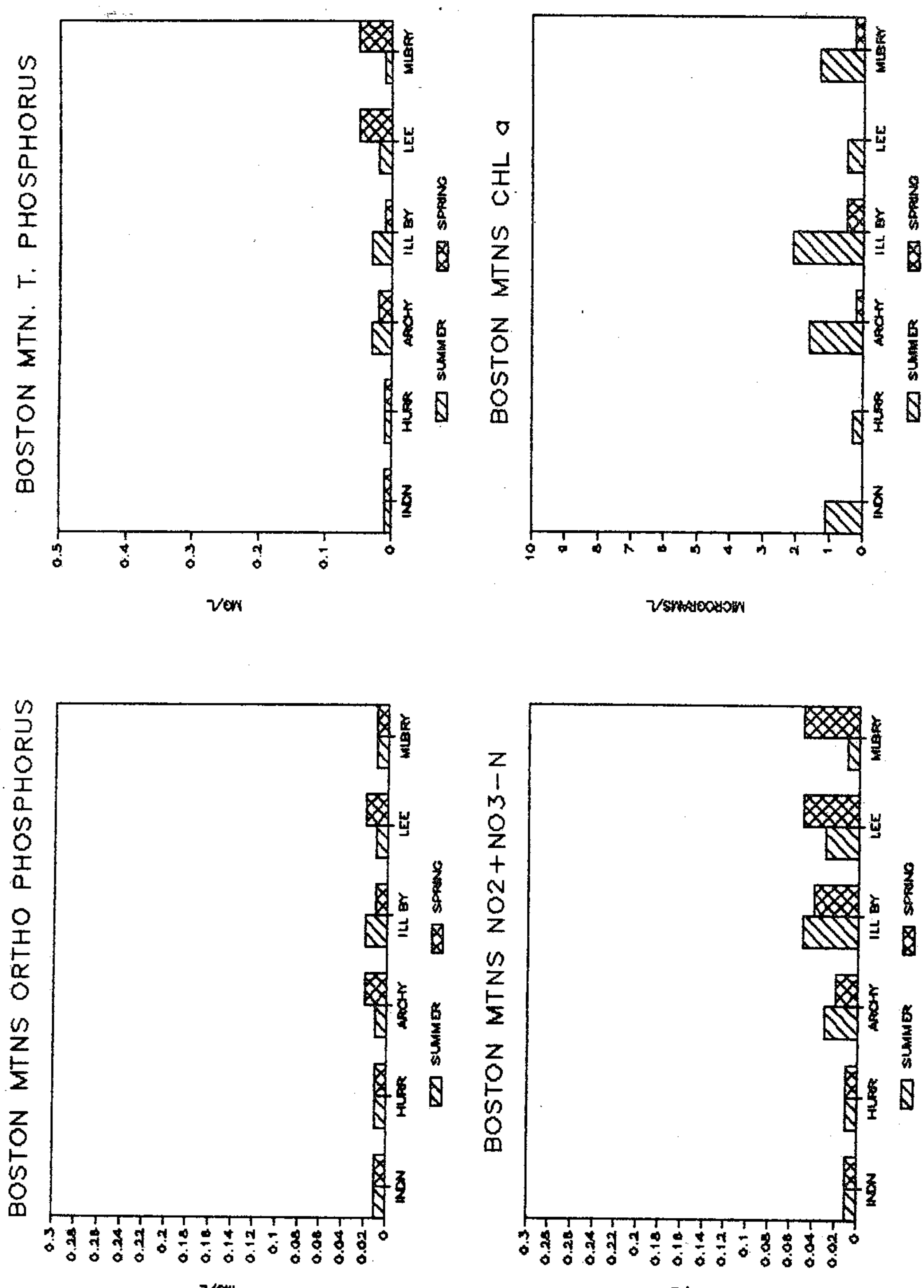
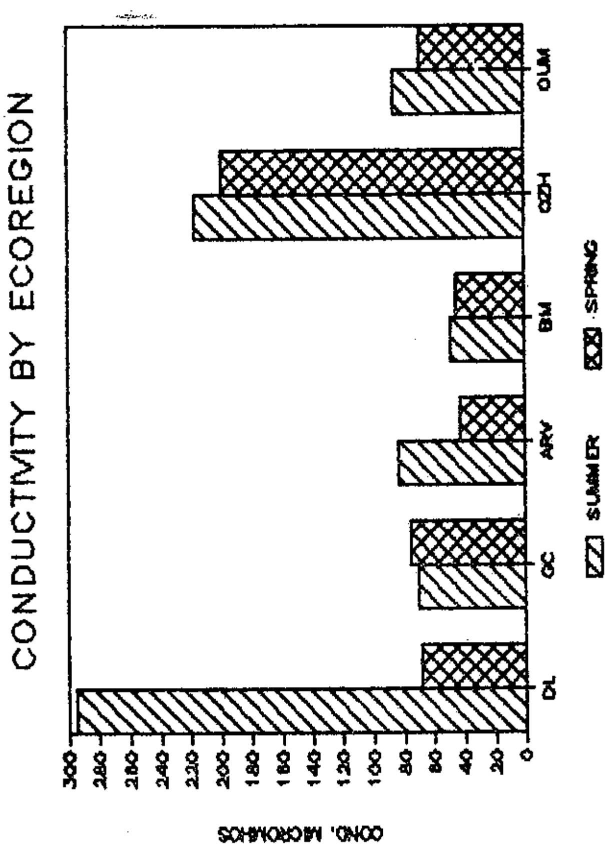
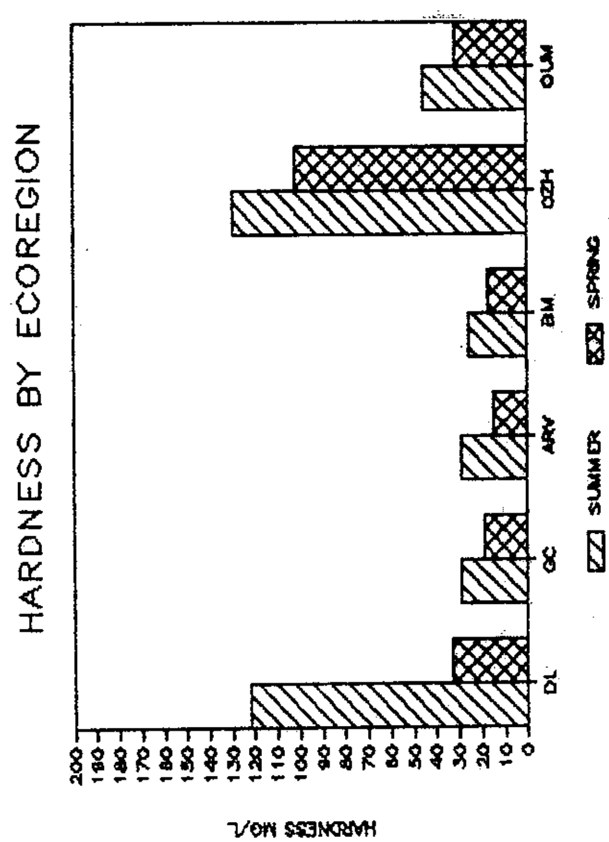
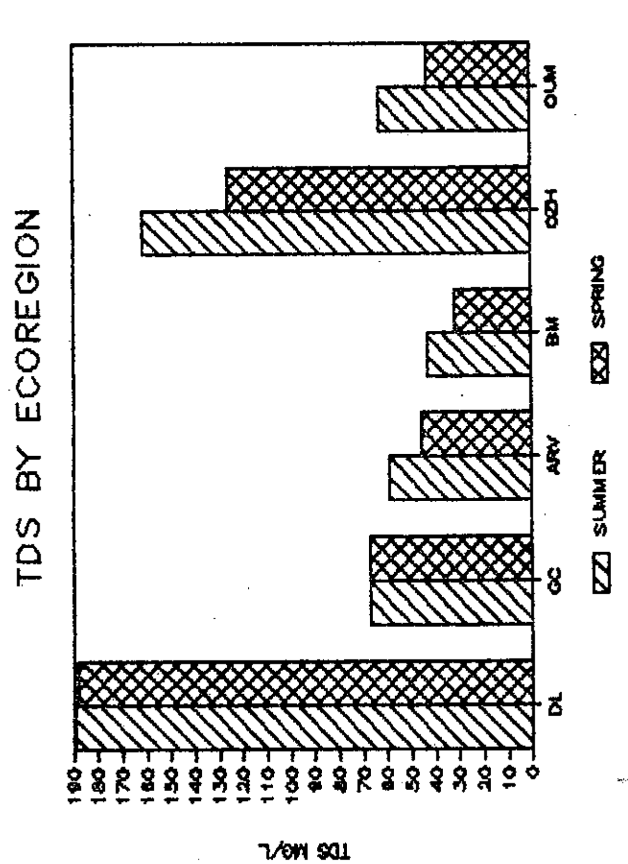


Figure C-31. Comparison of Water Quality
from all Ecoregions







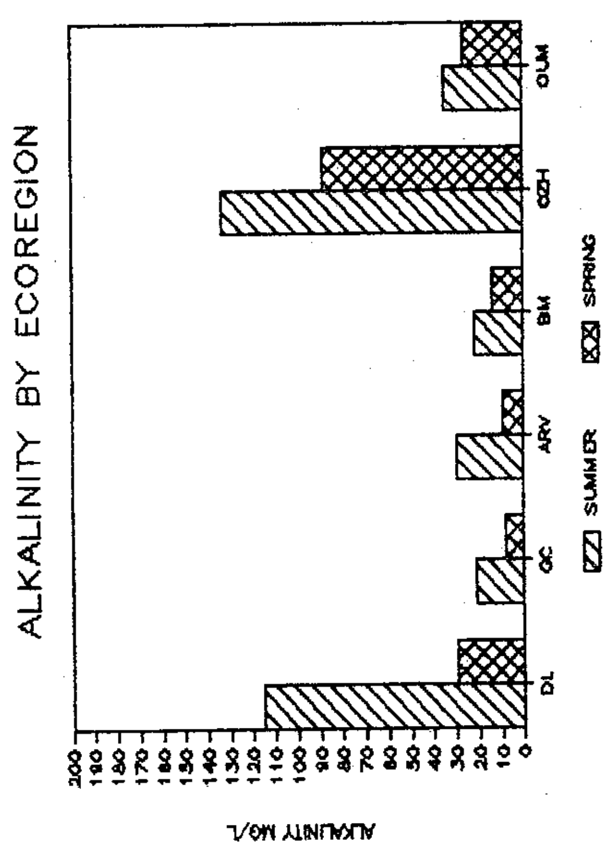


Figure C-32. Comparison of Water Quality Data from all Ecoregions

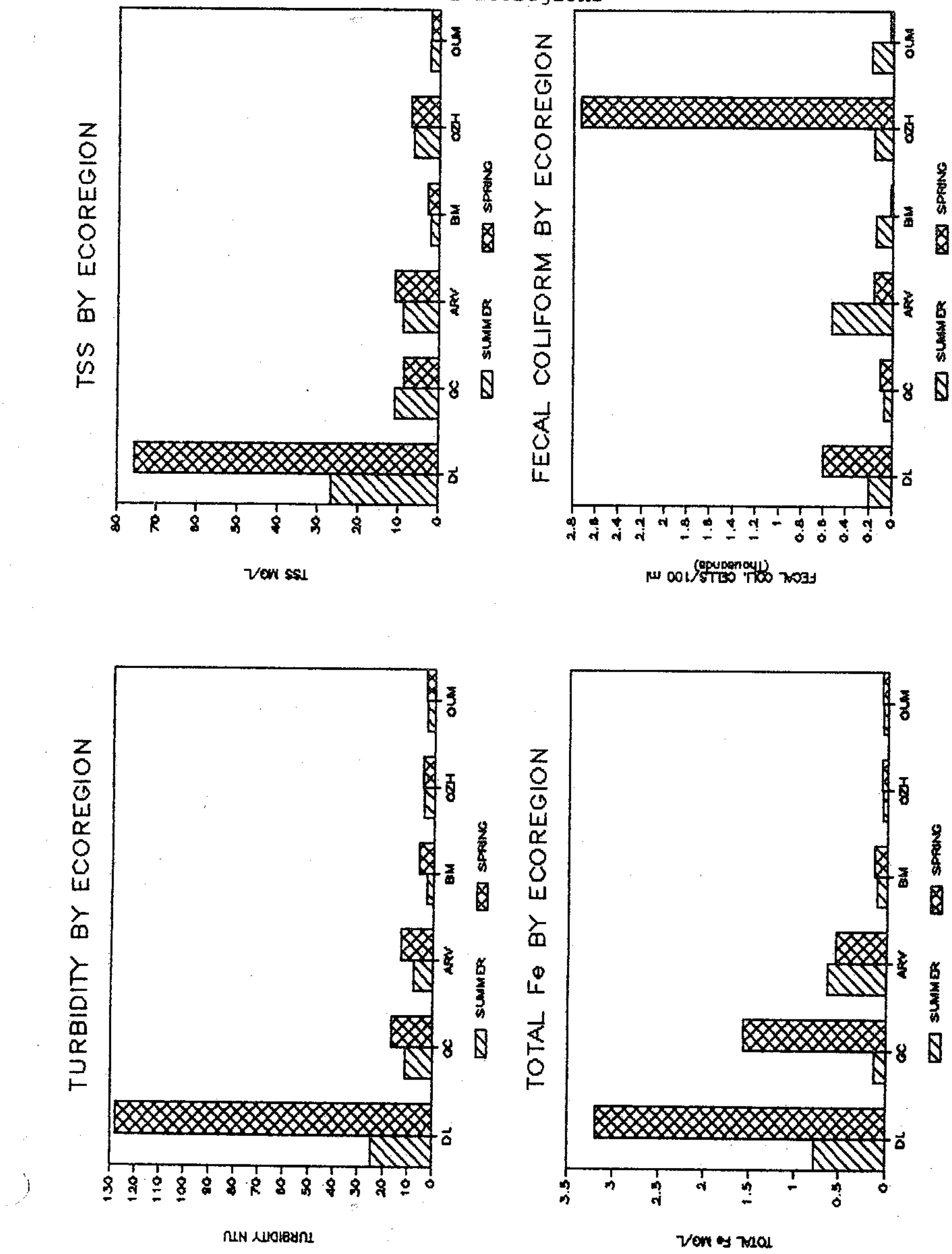
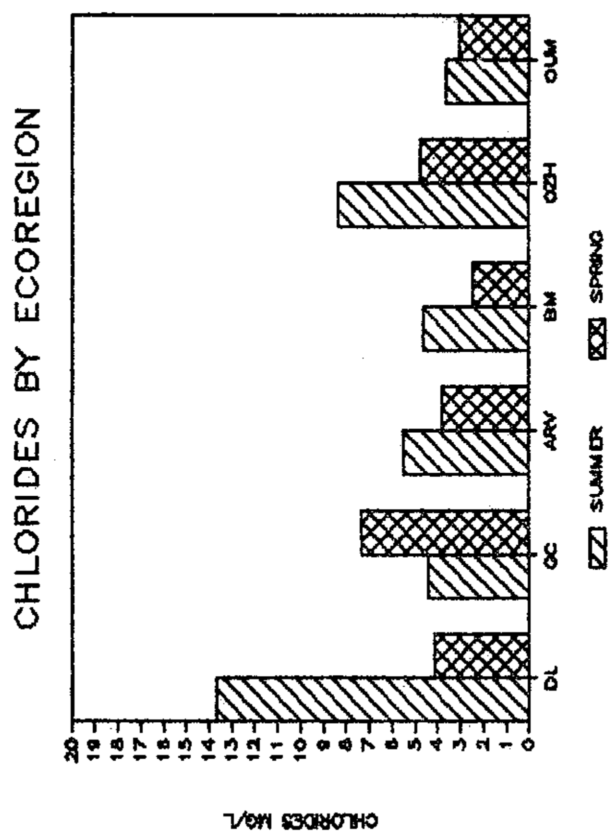


Figure C-33. Comparison of Water Quality Data from all Ecoregions



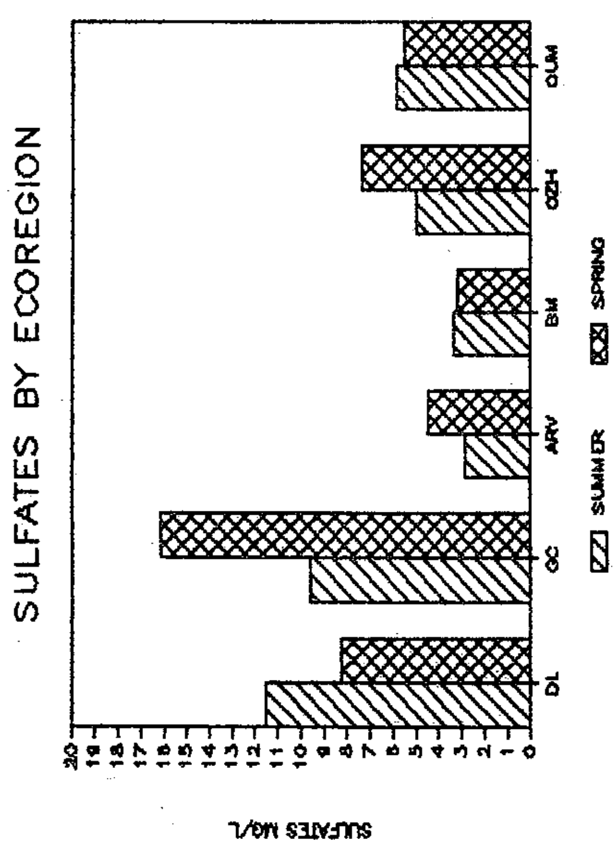
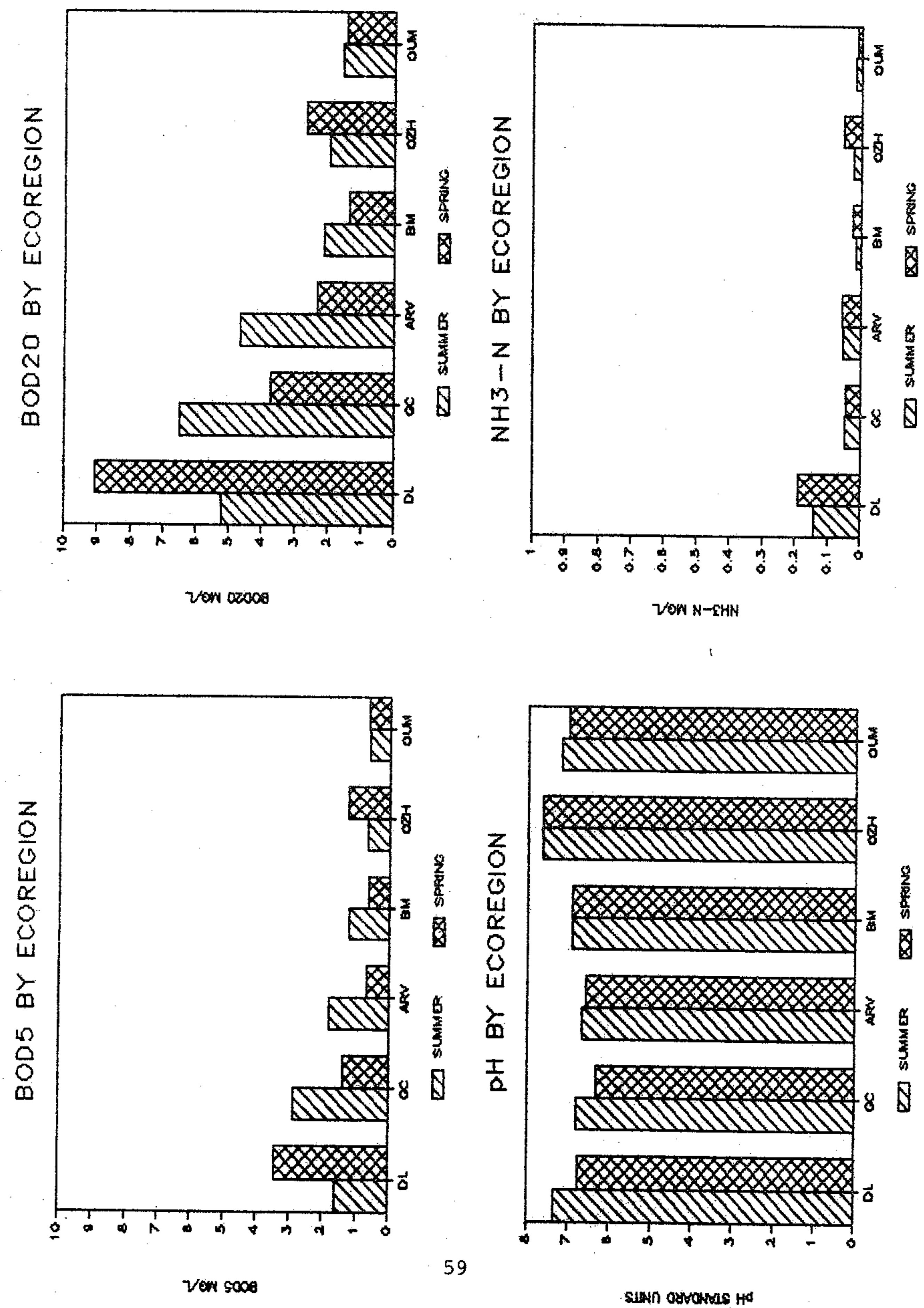


Figure C-34. Comparison of Water Quality Data from all Ecoregions



extremely low flows and/or pooled conditions. In the three remaining ecoregions, the BOD values are very low although the Boston Mountains streams also exhibit the "pooled," summertime, low flow conditions. Chlorophyll $\underline{a}$ values are similarly much higher in the lowland ecoregions than in the upland regions (Figure C-35). Fecal coliform values are exceptionally high in the Ozark Highlands during the spring (Figure C-32). This is caused by land use activities which are apparently very intensive in the watersheds of three of the six reference streams in this region. These activities include confined animal production facilities and the distribution of waste from these facilities to pastureland.

Phosphorus nutrients are noticeably higher in the Delta Ecoregion and relatively low in the other regions including the Ozark Highlands (Figure C-35). This apparently demonstrates the difference in phosphorus contributions from row-crop agriculture activities in the Delta and the confined animal production activities in the Ozark Highlands. In contrast, nitrite-nitrate nitrogen values are exceptionally high in the Ozark Highlands but are more typical in the Delta and in other ecoregions (Figure C-35).

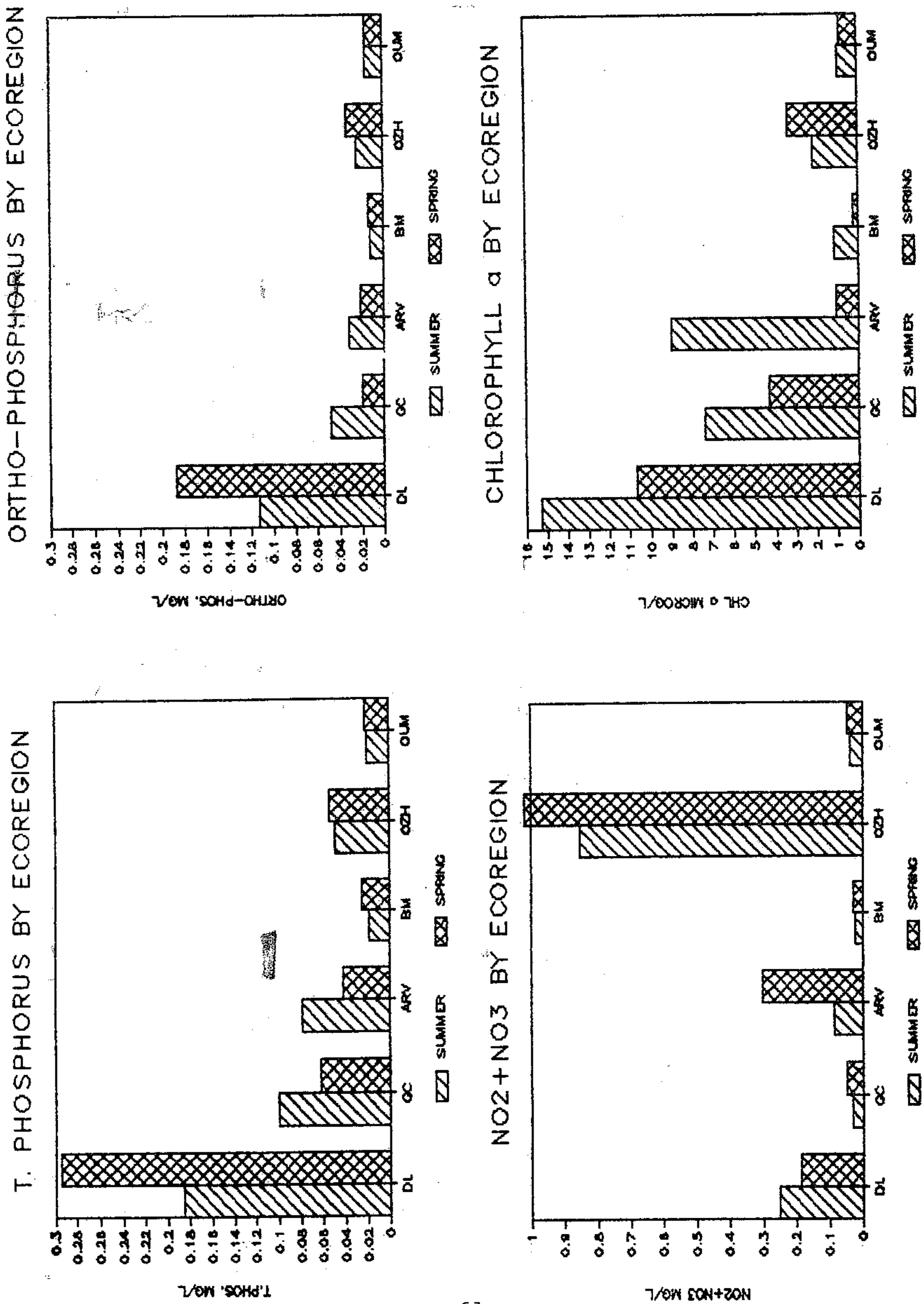
In using water quality data from this project to establish baseline data for ecoregion water quality criteria, it should be recognized that these values reflect measurable impacts of man's activities in the waters of at least two of the ecoregions. It is not likely that these impacts can be eliminated, but the progression of such activities should be abated.

Water Temperatures of Ecoregion Reference Streams

Water temperature at all sample sites was monitored with the continuous DO-temperature meters which also provided the dissolved oxygen data. Temperature calibration of these instruments was not possible in the field; however, the water temperature was checked against the portable, DO-temperature meters each time DO was calibrated. Temperature variations between the meters was within ± 1°C and the range of accuracy specified for the portable meters is ± 0.7°C.

Data from the statewide ambient monitoring program indicates that maximum water temperatures normally occur in late June or July. Since summertime sampling for this project extended to early September for some sites, the water temperature data presented may not reflect maximum temperatures. Springtime sampling occurred from late March to late May, and water temperatures varied considerably over short time periods and from the southern to the northern part of the state. Although attempts were made to sample southern waters first and move northward as temperatures rose, substantial variations in water temperatures were encountered. For this reason, the spring temperature data was useful only to relate to fish

Figure C-35. Comparison of Water Quality Data from all Ecoregions



spawning activities and to determine oxygen saturation values. Appendix B provides both spring and summer water temperature data for all reference streams.

Delta Ecoregion

The highest daily summertime values for all Delta Ecoregion reference streams occurred in Bayou DeView and were as follows: maximum 28.5°C, average 27.9°C and 26.6°C (Figure T-1). Atypically high flows existed during the summer sampling at this site and at the other large watershed site. This may have caused slightly cooler water temperatures. The small variation between the maximum and minimum values at Bayou DeView is also a result of the above normal flows. In contrast, the greatest variation in water temperatures was seen in Second Creek which had relatively low flows. The average springtime water temperature in the Delta reference streams ranged from 14.3°C to 21.5°C during the sample periods. These occurred on April 2, 1985, and April 8, 1986, in Second Creek and Bayou DeView, respectively.

Gulf Coastal Ecoregion

The highest maximum summertime water temperature recorded in Gulf Coastal reference streams was 28.0°C. The highest minimum was 25.6°C and the average was 26.7°C; all of these values occurred in L'Aigle Creek (Figure T-1). Although the maximum values ranged from 23.6°C to 28.0°C among all streams, there seemed to be no correlation to stream size or to springwater influences. The apparent controlling factor was stream canopy which is characteristically high in the Gulf Coastal Ecoregion. A further indication of canopy impact on stream water temperatures is the very small variation in daily maximum and minimum temperatures in this region. Springtime water temperatures encountered in this ecoregion averaged from 13.0°C to 17.1°C and occurred on April 5, 1984, and April 1, 1986, in East Fork Tulip Creek and Freeo Creek, respectively. These differences reflect the annual variations within the spring season.

Arkansas River Valley Ecoregion

The highest maximum daily water temperature recorded in this region was 30.5°C; the highest minimum and average values were 26°C and 28.1°C, respectively (Figure T-2). All of these high values occurred in Cadron Creek which is a large continuous pool at the sample site with very low, sluggish flow and limited stream canopy. Daily maximum temperatures ranged from 26.5°C to 30.5°C among all reference streams in this region and Cadron Creek values are noticeably higher than the other reference streams. Average springtime values ranged from 15.6°C in the Petit Jean River on April 15, 1986, to 16.3°C in Mill Creek on May 1, 1984.

TMDLs FOR CHLORIDE, SULFATE, AND TDS IN FLAT CREEK AND SALT CREEK, ARKANSAS

(Reaches 08040201-706 and -806)

October 8, 2003

TMDLs FOR CHLORIDE, SULFATE, AND TDS IN FLAT CREEK AND SALT CREEK, ARKANSAS

(Reaches 08040201-706 and -806)

Prepared for

EPA Region VI
Watershed Management Section
Dallas, TX 75202

Contract #68-C-99-249
Work Assignment #2-124

Prepared by

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October 8, 2003

EXECUTIVE SUMMARY

Section 303(d) of the Federal Clean Water Act requires states to identify waterbodies that are not meeting water quality standards and to develop total maximum daily pollutant loads for those waterbodies. A total maximum daily load (TMDL) is the amount of a pollutant that a waterbody can assimilate without exceeding the established water quality standard for that pollutant. Through a TMDL, pollutant loads can be allocated to point sources and nonpoint sources discharging to the waterbody.

The Flat Creek/Salt Creek basin, which is located in Planning Segment 2D, flows into Haynes Creek, which is a tributary of Smackover Creek in south central Arkansas in the Gulf Coastal Plain Ecoregion. The designated beneficial uses that have been established by the Arkansas Department of Environmental Quality (ADEQ) for all parts of the Flat Creek/Salt Creek basin are seasonal Gulf Coastal fishery; secondary contact recreation; and domestic, industrial and agricultural water supply. Where the drainage area is 10 mi^2 or more, the designated uses also include perennial Gulf Coastal fishery and primary contact recreation (ADEQ 2000).

The numeric standards that apply to the Flat Creek/Salt Creek basin for chlorides, sulfates, and total dissolved solids (TDS), are 19, 41, and 138 mg/L, respectively. ADEQ's historical water quality data for the Salt/Flat Creek basin show that the chloride, sulfates, and TDS standards are frequently exceeded. Because of this, Flat Creek and Salt Creek (reaches 08040201-706 and 08040201-806) were included on the Arkansas 1998 303(d) list for not supporting aquatic life and water supply uses due to nonpoint pollution from historical oil exploration activities in the watershed (ADEQ 2000). Both of these reaches were classified as medium priority on the 1998 303(d) list.

Historical water quality data from ADEQ monitoring stations OUA137A through I during two time periods in the basin were analyzed and plotted to examine relationships, seasonal patterns, and long-term trends.

TMDLs for dissolved minerals were developed for Flat Creek (chlorides, sulfates, and TDS) and Salt Creek (chlorides and TDS) based on mean annual conditions. A TMDL for sulfates was not needed for Salt Creek because the data showed that the standard for sulfates was being met in Salt Creek. Total allowable loads were calculated based on the water quality standards and estimates of average annual streamflow. Each of the dissolved mineral TMDLs for Flat and Salt Creeks included a background component, a load allocation for man-induced nonpoint sources from the watershed, and an explicit margin of safety of 10%. The percent reductions required to meet the water quality standards for dissolved minerals varied from 12% for sulfates in Flat Creek to 99% for chlorides in Salt Creek.

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1.0 INTRODUCTION

Flat Creek and Salt Creek, which are located in Planning Segment 2D, combine to form Haynes Creek, a tributary of Smackover Creek within the Ouachita River Basin in hydrologic unit code (HUC) 08040201. Additional RF-1 river reach numbers were created for Flat Creek as 706 and for Salt Creek as 806. The Flat Creek/Salt Creek basin is located in south central Arkansas in the Gulf Coastal Plain ecoregion. The Arkansas Department of Environmental Quality (ADEQ) has established numeric water quality standards for chlorides, sulfates, and total dissolved solids (TDS) to protect the designated use of domestic, industrial, and agricultural water supply. The standards for chlorides, sulfates, and TDS are 19, 41, and 138 mg/L, respectively. Because the chlorides, sulfates, and TDS standards are exceeded frequently in the watershed, Flat Creek and Salt Creek (reaches 706 and 806) were included on the Arkansas 1998 303(d) list for not supporting the aquatic life and water supply uses due to historical oil exploration activity (ADEQ 2000). Therefore, the development of TMDLs for chloride, sulfates, and TDS was required. These TMDLs were developed under Environmental Protection Agency (EPA) Contract #68-C-99-249, Work Assignment #2-124.

2.0 BACKGROUND INFORMATION

2.1 General Description

The Flat Creek/Salt Creek basin is located in south central Arkansas in the Gulf Coastal Plain Ecoregion (Figure 2.1). The Flat Creek/Salt Creek basin is in US Geological Survey (USGS) HUC 08040201 and ADEQ Planning Segment 2D. Salt Creek starts just north of Smithville and flows generally north to its confluence with Flat Creek. Flat Creek starts along the eastern edge of El Dorado and flows north as well. About 0.4 miles southeast of Norphlet, the unnamed tributary from El Dorado Chemical Company (ELCC) joins Flat Creek. Flat Creek and Salt Creek then come together to form Haynes Creek which then flows into Smackover Creek. The total drainage area of the basin at the confluence of Flat and Salt Creeks is approximately 56.1 mi^2 (USGS 1979), all of which is in Union County.

The Flat Creek/Salt Creek watershed consists of a coastal plain of rolling terrain broken by stream valleys. Streams meander and are of moderate to low gradient (all less than 10 ft/mi). Substrate types are dominated by sand mixed with mud and silt, and rounded small sized gravel.

The soils in the basin are broadly classified as ultisols (SCS 1982) which are usually associated with forest vegetation and which have moderate to high permeability, argillic horizons, and low base saturations. The upland area soils are represented by the Briley, Darden, Harleston, Rosalie, Warnock, and Smithdale map units. Bibb and Guyton loams soils are found predominantly in the flood plains.

Of particular interest for this study is the Oil Wasteland-Fluvaquent complex, found on flood plains of local drainages and major streams. Mapped areas range from 20 to 1,000 acres in size. Sixty percent of the mapped areas consist of oil and wasteland soils that have been impacted by oil and saltwater, typically lack plant cover, and are severely eroded. Even though these soils have been affected by oil waste and salt water runoff, they support salt water grasses and cattails.

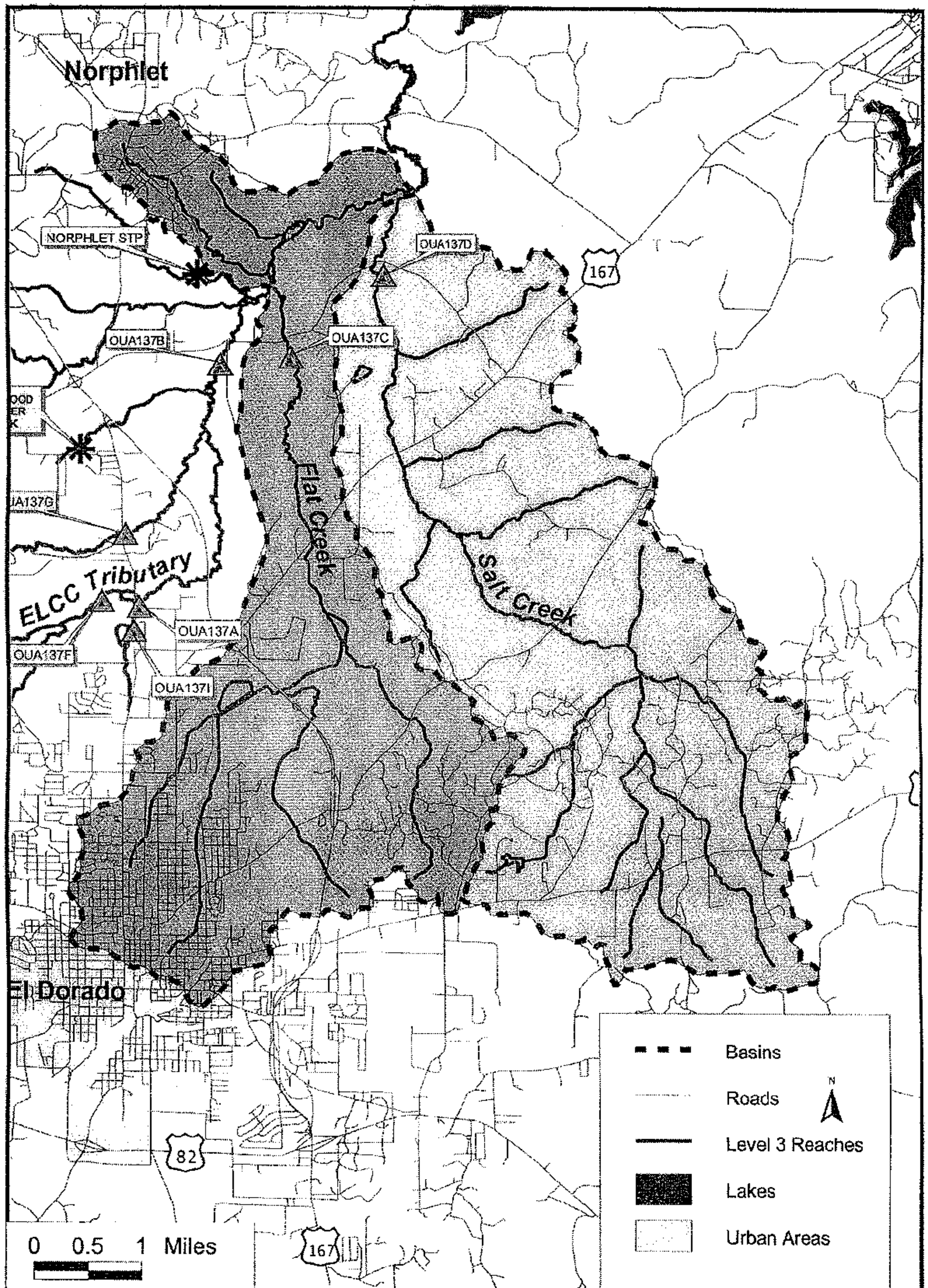

Figure 2.1. Flat Creek and Salt Creek (reaches -706 and -806).

2.2 Land Use

Land use in the Flat Creek/Salt Creek basin is predominantly forest and pasture with some urban development. Historically, oil and gas development has occurred in the basin in the forest and wetland areas (Figure 2.2). The USGS topographic maps of the area identify the headwaters of Flat and Salt Creeks as being located in the East El Dorado Oil Field. Approximate percentages of each land use by basin are shown in Table 2.1.

Table 2.1. Land uses in the Flat Creek/Salt Creek basin.

	Flat Creek (Reach 706)	Salt Creek (Reach 806)
Alluvial/Wetland Forest	17.3%	22.7%
Forest	50.0%	67.0%
Bare	16.8%	9.0%
Water	1.1%	1.3%
Urban Residential	11.9%	0.0%
Urban Commercial	2.9%	0.0%
Total	100.0%	100.0%

Prior to development, the Flat Creek/Salt Creek basin was predominantly bottomland hardwood forest.

2.3 Hydrology

A search for USGS flow monitoring gages within the Flat Creek/Salt Creek basin indicated that there were no active or inactive flow gages. The nearest, most relevant USGS flow gage appears to be USGS Gage No. 07362100 (Smackover Creek near Smackover, AR). It is located approximately 8 miles northwest of the study area in the Gulf Coastal Plain ecoregion and has a drainage area of 385 mi^2 (USGS 2000) compared to 56.1 mi^2 (USGS 1979) for the Flat Creek/Salt Creek basin. Based on this gage, the average annual runoff for the Flat Creek/Salt Creek basin is estimated to be approximately 15.0 inches (USGS 2000). The seasonal distribution of flow based on this gage is shown on Figure 2.3. Low flow months occur in late

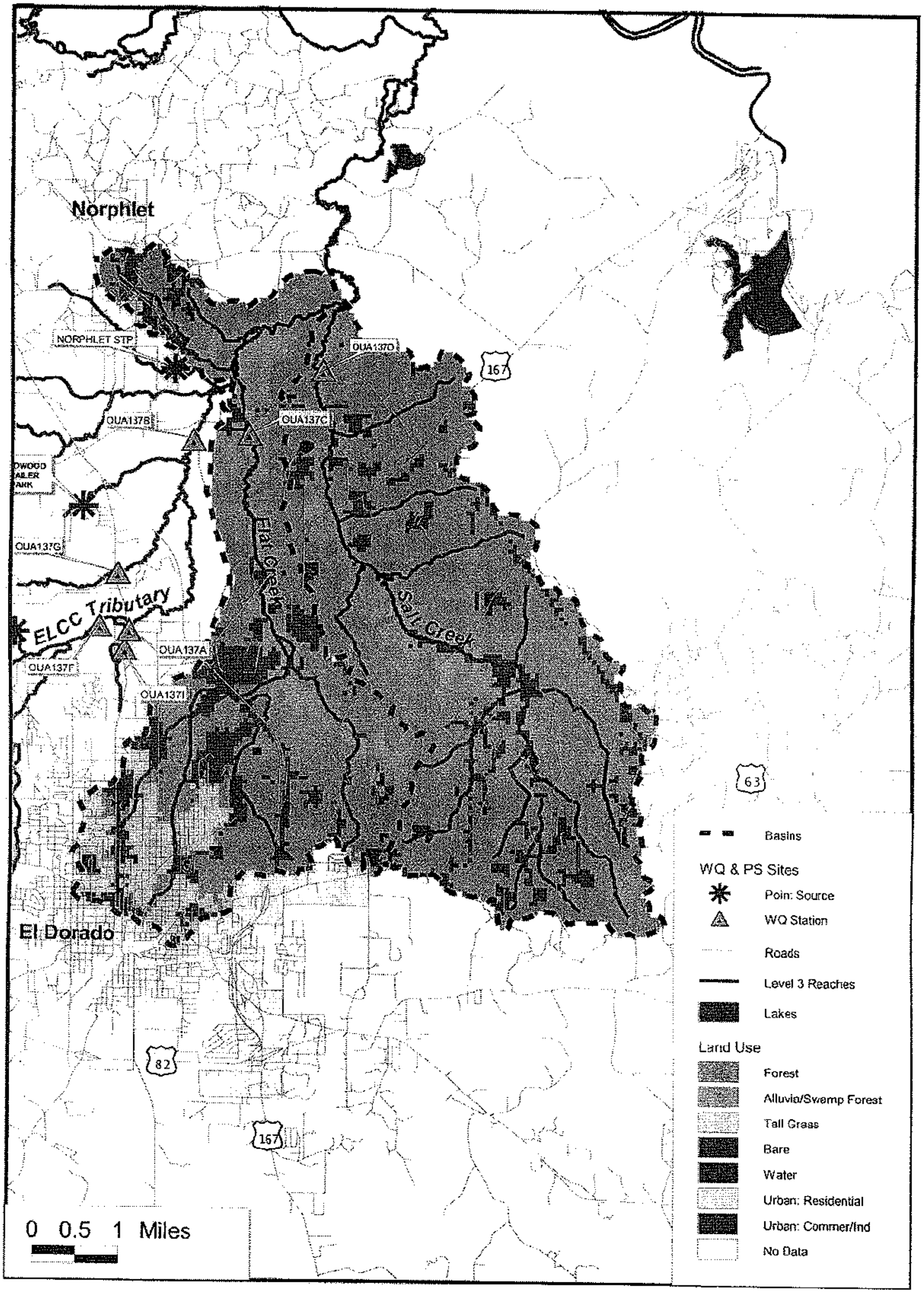

Figure 2.2. Land use in Flat Creek and Salt Creek (reaches -706 and -806).

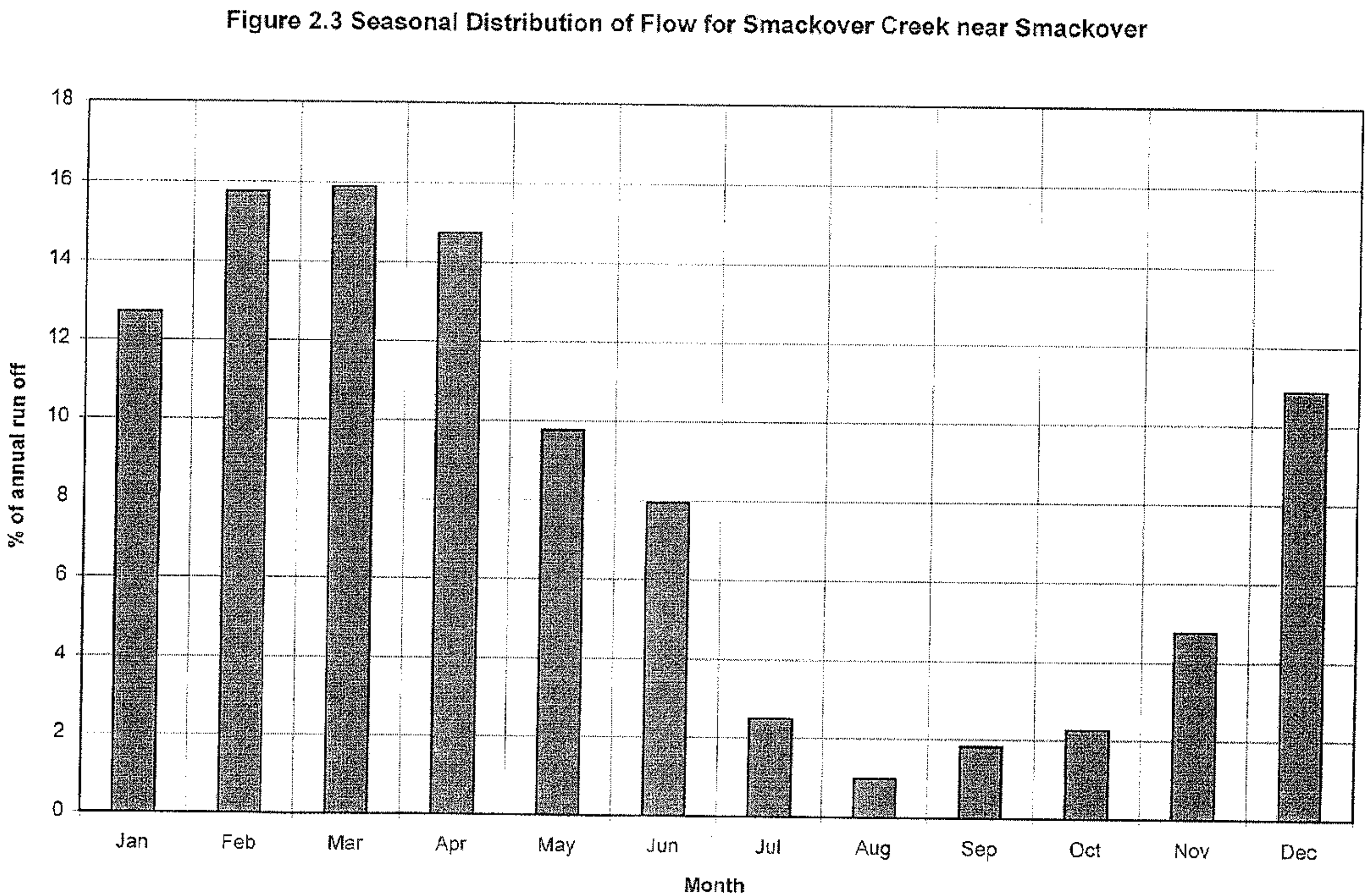

Figure 2.3. Seasonal distribution of flow for Smackover Creek near Smackover.

summer and high flow months occur in late winter to early spring. The 7Q10 critical low flows for Flat and Salt Creeks are 0 cubic feet per second (cfs) (USGS 1992).

Precipitation data were obtained from the NWS station in El Dorado, which had a long period of record (1930 to 2000). Average annual precipitation for the Flat Creek/Salt Creek basin is approximately 51.8 inches (Hydrosphere 2001) of which approximately 29% is runoff. Mean monthly precipitation totals for the El Dorado station are shown on Figure 2.4. The mean monthly precipitation values are highest from December through May and lowest for August and September.

2.4 Designated Uses and Water Quality Standards

The State of Arkansas has developed water quality standards for waters of the state (ADEQ 2001). The standards are defined according to ecoregions and designated uses of the waterbodies. The Flat Creek/Salt Creek basin lies entirely within the Gulf Coastal Plain ecoregion. Designated beneficial uses for all parts of the Flat Creek/Salt Creek basin include seasonal Gulf Coastal fishery; secondary contact recreation; and domestic, industrial, and agricultural water supply. Where the drainage area is 10 mi^2 or more, the designated uses also include perennial Gulf Coastal fishery and primary contact recreation.

Dissolved mineral standards (i.e., chlorides, sulfates, and TDS) are addressed in Section 2.511 of the Arkansas Water Quality Standards (ADEQ 2001). The specific standards for the Flat Creek/Salt Creek basin are:

CL – 19 mg/L
SO4 – 41 mg/L
TDS – 138 mg/L

The DO standards for the Flat Creek/ Salt Creek basin during the critical season are 2 mg/L for watersheds less than 10 mi^2 and 3 mg/L for watersheds greater than 10 mi^2 and less than 500 mi^2. For the primary season, the DO standard is 5 mg/L (regardless of watershed size).

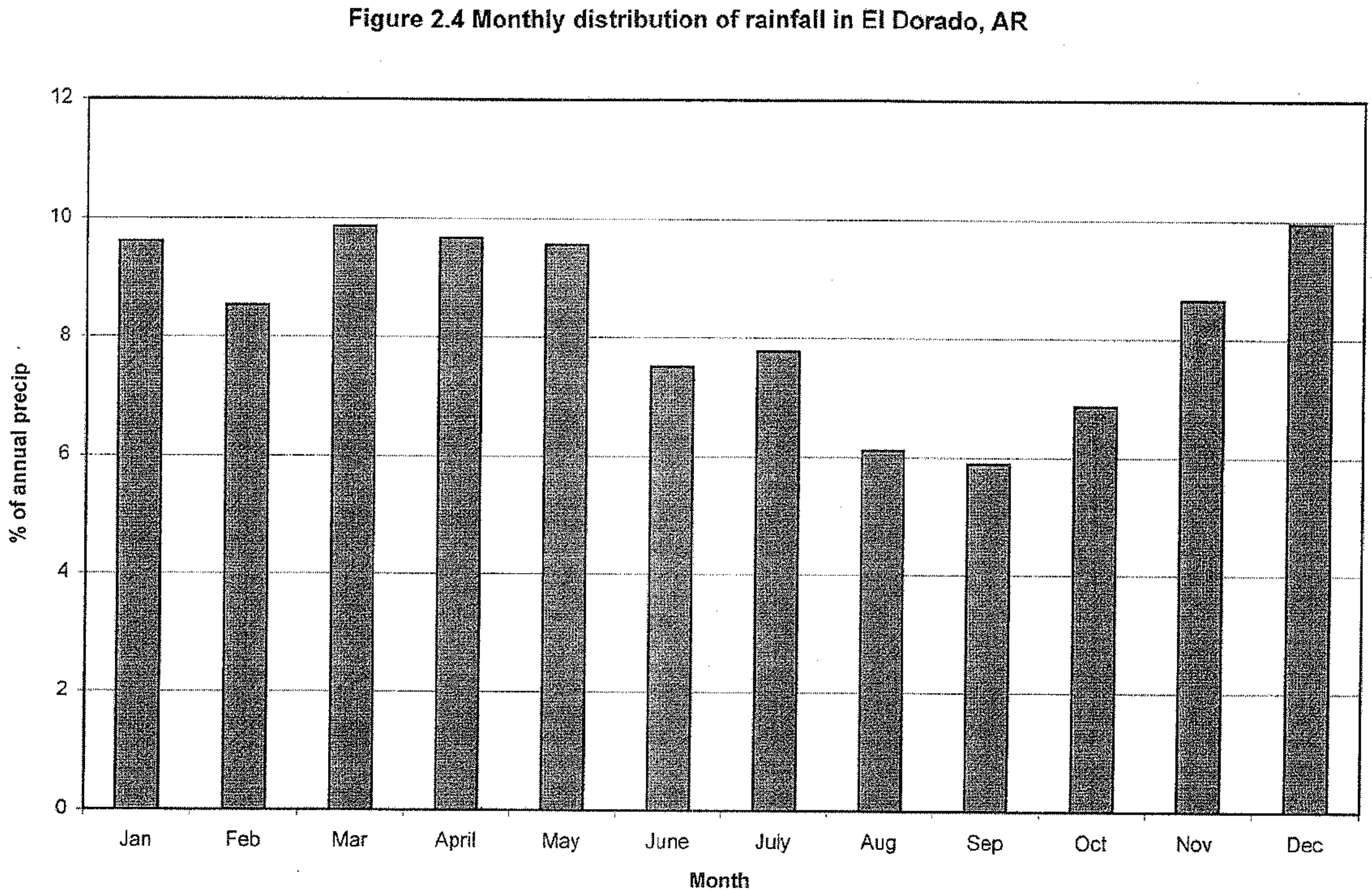

Figure 2.4. Monthly distribution of rainfall in El Dorado, Arkansas.

2.5 Point Sources

Information on point source discharges in the Flat Creek/Salt Creek basin (within HUC 08040201) was obtained by searching the Permit Compliance System (PCS) on the EPA website, reviewing ADEQ files, and reviewing information found in published technical reports. The search did not yield any facilities with point source discharges to reaches 08040201-706 (Flat Creek) or 08040201-806 (Salt Creek).

2.6 Nonpoint Sources

Nonpoint sources of pollution in the Flat Creek/Salt Creek basin have been discussed in the Arkansas 305(b) report (ADEQ 2000). ADEQ suggests that nonpoint source pollution is due to oil exploration activities from past and present. This is confirmed by the description of the soils in Section 2.1. There is no significant agricultural development with most of the land either being used for oil exploration or for timber for the forestry industry. Another source of dissolved minerals to Flat Creek may be urban runoff from El Dorado.

2.7 Previous Water Quality Studies

The following is a list of relevant water quality studies that were identified for the Flat Creek/Salt Creek basin:

1. ADEQ. 1998. TMDL Investigation of Water Quality Impairment to Unnamed Tributary to Flat Creek, Union County, Arkansas. WQ-98-04-1. Published by Arkansas Department of Environmental Quality.
2. FTN. 1991. Surface Water Quality Study for El Dorado Chemical Company. Prepared by FTN Associates, Ltd. for El Dorado Chemical Company.

3.0 CHARACTERIZATION OF EXISTING WATER QUALITY

3.1 Inventory of Data

Information on water quality monitoring stations in the Flat Creek/Salt Creek basin was obtained by searching the EPA STORET database and from reviewing technical reports of studies in the area. The search was conducted for data collected by all agencies at all water quality stations on Flat Creek/Salt Creek streams within HUC 08040201. The search yielded only the stations that were included in the ADEQ report (ADEQ 1998). One USGS water quality monitoring station was found in the watershed. Data for that station (07362203, Haynes Creek near Norphlet) were retrieved from the USGS website but included only three sampling events for chloride, sulfate, and TDS.

3.2 Assessment Report

The most relevant data for this study were collected by ADEQ and documented in a report titled "TMDL Investigation of Water Quality Impairment to Unnamed Tributary to Flat Creek, Union County, Arkansas" (ADEQ 1998). Water quality data were collected by ADEQ from 9 sampling locations on several occasions throughout the watershed from January 1995 to July 1996 and from March 1997 to December 1997. Parameters measured included flow, sulfates, chlorides, TDS, ammonia, and a suite of other parameters including biological data (Appendix A). These data were used to support this TMDL. The ADEQ report summarizes these data and presents several conclusions including the following:

a. "Water quality data demonstrates problem areas of minerals, heavy metals, ammonia, and nitrates."

b. "Flat Creek receives elevated levels of sulfates and TDS from the ELCC tributary and very high levels of chlorides from its upstream watershed; Salt Creek has chloride values as high as 3,000 mg/L contributed from its upstream watershed."

3.3 Data Analysis

Table 3.1 summarizes the dissolved minerals data collected by ADEQ (1998) for representative stations for the two reaches of interest in this study (08040201-706 and -806).

Data for all the ADEQ stations are summarized in Appendix A. For Salt Creek, 100% of the chloride and TDS samples exceeded the state water quality standards (WQS). No exceedances of the sulfate standard were recorded in Salt Creek; therefore, a TMDL for sulfates was not needed for Salt Creek. TDS and chloride concentrations were lower in Flat Creek compared to Salt Creek, but still exceeded WQS 100% and 91% of the time, respectively. Sulfate concentrations were higher in Flat Creek than Salt Creek, and exceeded WQS in 55% of the samples.

The seasonal variability in dissolved mineral concentrations is illustrated on Figures 3.1 through 3.3 for Flat Creek and Figure 3.4 through 3.6 for Salt Creek (these figures are located in Appendix B). Although there appears to be a trend of higher concentrations during the summer low flow period, limited data and large variability make it difficult to conclude the seasonal trend is significant. However, higher concentrations are expected during the summer because of less dilution from uncontaminated surface runoff.

Table 3.1. Summary of instream dissolved mineral data.

	Flat Creek (08040201-706) OUA137C	Salt Creek (08040201-806) OUA137D
Chloride (mg/L)		
Period of Record for statistics	Jan 1995 to Dec 1997	Jan 1995 to Dec 1997
Number of samples	11	12
Minimum	16.6	170
Maximum	1,160	2,970
Median	287	948
Number above standards	10	12
Percent above standards	91%	100%
Sulfate (mg/L)		
Period of Record for statistics	Jan 1995 to Dec 1997	Jan 1995 to Dec 1997
Number of samples	11	12
Minimum	9.3	0.5
Maximum	125	11.6
Median	43.6	6.7
Number above standards	6	0
Percent above standards	55%	0%
TDS (mg/L)		
Period of Record for statistics	Jan 1995 to Dec 1997	Jan 1995 to Dec 1997
Number of samples	11	12
Minimum	496	780
Maximum	2,000	5,231
Median	675	1,693
Number above standards	11	12
Percent above standards	100%	100%

4.0 TMDL DEVELOPMENT

4.1 Dissolved Minerals for Salt and Flat Creeks

In this section, the TMDLs for dissolved minerals (chlorides, sulfates, and TDS) for Salt Creek and for Flat Creek (excluding the ELCC tributary) are developed. Since the major sources of dissolved minerals are located in the upper parts of Flat Creek and the ELCC tributary, it is assumed that successful implementation of the TMDL for upper Flat Creek and the ELCC tributary will result in water quality standards being maintained in the lower part of Flat Creek (i.e., downstream of the confluence with the ELCC tributary). Printouts of spreadsheets with the TMDL computations are included in Appendices C and D.

4.1.1 Seasonality and Determination of Critical Conditions

The historical data and analyses discussed in Section 3.0 were used to evaluate whether there were certain flow conditions, spatial locations, or certain periods of the year that could be used to characterize critical conditions. Although dissolved mineral concentrations appeared to be slightly higher during the summer low flow months, no significant relationships were found for dissolved minerals with flow or season. The exceedances of water quality standards for dissolved minerals occurred fairly uniformly throughout the year in both Salt and Flat Creeks. Also, Arkansas's water quality standards for dissolved minerals are not seasonal. Due to year-round standards and limited data, including no flow data, no critical conditions were identified for the dissolved minerals TMDLs for Flat and Salt Creeks, and mean annual conditions were used.

4.1.2 Linking Water Quality and Pollutant Sources

The high dissolved mineral concentrations in Flat Creek and Salt Creek have been attributed to historical oil field development that left oil waste and salt water. It has been estimated that approximately 60% of lands occupied by forest and wetlands have been impacted (Section 2.1). For Salt Creek, all chloride and TDS concentrations exceeded standards but sulfate concentrations did not. For Flat Creek, chlorides, TDS, and sulfate concentrations exceeded water quality standards, indicating an additional source of pollution in the Flat Creek basin possibly attributable to nonpoint source runoff from urban and industrial areas as indicated by the differences in land use (Figure 2.2). There are no point sources for either reach (08040201-706 or 08040201-806).

4.1.3 Current Load

Current loads of dissolved minerals for Flat and Salt Creeks were calculated using the average concentrations and the average annual flow for each stream. The following equation was used to compute the loads:

Load in lbs/day = C x Q x 8.34

where C = concentration in mg/L and Q = flow in MGD.

Mean annual conditions were used since the limited available data did not indicate any significant seasonality or critical conditions. For Salt Creek, the mean concentrations for all data collected at station OUA137D were used. The mean annual flow was estimated by using the watershed area at its confluence with Flat Creek and multiplying it by the mean annual runoff for the USGS gage at Smackover (i.e., 15 inches per year). The resulting loads are summarized in Table 4.1.

For Flat Creek, the mean concentrations of data collected at station OUA137C were used and the flow was estimated by multiplying the watershed area of Flat Creek at its mouth (excluding the ELCC tributary) by the mean annual runoff from the USGS gage at Smackover. The results are summarized in Table 4.1.

4.1.4 TMDL

The allowable loads (i.e., TMDLs) for dissolved minerals were calculated by multiplying the existing water quality standards (Section 2.4) by the same mean annual flows that were used to calculate current loads. The results are summarized in Table 4.1. As shown on Figure 3.5 in Appendix B, none of the observed sulfate concentrations in Salt Creek exceeded the water quality standard of 41 mg/L. Therefore, a sulfate TMDL was not developed for Salt Creek.

Table 4.1. Dissolved minerals TMDLs for Flat and Salt Creeks in lbs/day.

	Flat Creek (08040201-706)			Salt Creek (08040201-806)	
	Chlorides	Sulfates	TDS	Chlorides	TDS
WLA for point sources	0	0	0	0	0
LA for NPS	1,093	2,185	5,543	1,346	6,826
Background	434	1,128	5,811	534	7,158
MOS for all sources	121	243	616	150	759
TMDL	1,648	3,556	11,970	2,030	14,743
Percent Reduction	97%	12%	93%	99%	97%

4.1.5 Wasteload Allocations

There are no point sources in these two reaches and the wasteload allocations (WLAs) are therefore zero.

4.1.6 Load Allocations

Load allocations (LAs) for nonpoint source contributions were calculated using the following equation:

LA = (TMDL – Background – WLA) x (1-MOS)

Therefore, these LAs represent man-induced nonpoint source contributions. Natural background loads were estimated using ADEQ reference stream data for the Gulf Coastal Plain ecoregion as defined in the ADEQ Continuing Planning Process (CPP).

The reductions in existing man-induced loads that are needed to maintain the dissolved minerals standards in Salt and Flat Creeks were estimated using the following equations:

Current man-induced load = Current total load – background load

% Reduction = 100% x (Current man-induced load – LA) / Current man-induced load

The percent reductions for each constituent are shown in Table 4.1.

4.1.7 Margin of Safety

Section 303(d) of the Federal Clean Water Act and EPA's regulations at 40 CFR 130.7 both require the inclusion of a margin of safety (MOS) in the development of a TMDL. An explicit MOS was incorporated in these TMDLs; it was calculated as 10% of the allowable man-induced load (i.e., 10% x (TMDL minus background)).

5.0 MONITORING AND IMPLEMENTATION

In accordance with Section 106 of the Federal Clean Water Act and under its own authority, ADEQ has established a comprehensive program for monitoring the quality of the State's surface waters. ADEQ collects surface water samples at various locations, utilizing appropriate sampling methods and procedures for ensuring the quality of the data collected. The objectives of the surface water monitoring program are to determine the quality of the state's surface waters, to develop a long-term data base for long term trend analysis, and to monitor the effectiveness of pollution controls. The data obtained through the surface water monitoring program is used to develop the state's biennial 305(b) report (*Water Quality Inventory*) and the 303(d) list of impaired waters.

6.0 PUBLIC PARTICIPATION

When EPA establishes a TMDL, federal regulations require EPA to publicly notice and seek comment concerning the TMDL. Pursuant to a May 2000 consent decree, these TMDLs were prepared under contract to EPA. After developing these TMDLs, EPA prepared a notice seeking comments, information, and data from the general public and affected public. Comments were submitted during the public comment period, and these TMDLs were revised accordingly. Responses to these comments are included in Appendix E. EPA has transmitted the revised TMDLs to the ADEQ for implementation and incorporation into ADEQ's current water quality management plan.

7.0 REFERENCES

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APPENDIX A

Summary of ADEQ Water Quality Data

Table A1. Summary of In-Stream Chloride Data.

Station Name	OUA0137A	OUA0137B	OUA0137C	OUA0137D	OUA0137E	OUA0137H	OUA0137F	OUA0137G	OUA0137I
Period of Record for statisitics	1997 March to December								
Number of samples	1	1	1	1	5	4	4	5	1
MIN	25.498	27.92	254.4	771	19.0	41.8	23.8	18.3	16.475
MAX	NA	NA	NA	NA	46.7	77.9	70.1	31.4	NA
MEDIAN	NA	NA	NA	NA	35.1	63.4	33.3	22.9	NA
# above standards	1	1	1	1	4	3	4	3	0
% above standards	100	100	100	100	80	75	100	60	0

Station Name	OUA0137A	OUA0137B	OUA0137C	OUA0137D
Period of Record for statisitics	1995 -1996 January to July			
Number of samples	11	11	10	11
MIN	20.1	15.0	17	170
MAX	71.9	63.6	1160	2970
MEDIAN	34.1	25.5	293	1020
# above standards	11	8	9	11
% above standards	100.0	72.7	90.0	100.0

Table A2. Summary of In-Stream Sulfate Data.

Station Name	OUA0137A	OUA0137B	OUA0137C	OUA0137D	OUA0137E	OUA0137H	OUA0137F	OUA0137G	OUA0137I
Period of Record for statisitics	1997 March to December								
Number of samples	1	1	1	1	5	4	4	5	1
MIN	73.6	50.8	70.9	1.7	3.98	184	49.8	12.5	12
MAX	NA	NA	NA	NA	16.2	553	412	74.2	NA
MEDIAN	NA	NA	NA	NA	12.7	233	77.1	38.6	NA
# above standards	1	1	1	0	0	4	4	1	0
% above standards	100	100	100	0	0	100	100	20	0

Station Name	OUA0137A	OUA0137B	OUA0137C	OUA0137D
Period of Record for statisitics	1995 -1996 January to July			
Number of samples	11	11	10	11
MIN	47.6	33.4	9.3	2.3
MAX	700	652	125	11.6
MEDIAN	124	41.7	41.7	7.4
# above standards	11	9	5	0
% above standards	100.0	81.8	50.0	0.0

Table A3. Summary of In-Stream TDS Data.

Station Name	OUA0137A	OUA0137B	OUA0137C	OUA0137D	OUA0137E	OUA0137H	OUA0137F	OUA0137G	OUA0137I
Period of Record for statisitics	1997 March to December								
Number of samples	1	1	1	1	5	4	4	5	1
MIN	303	229	675	1562	104	734	307	163	131
MAX	NA	NA	NA	NA	174	1769	1373	284	NA
MEDIAN	NA	NA	NA	NA	144	1238	355	216	NA
# above standards	1	1	1	1	4	4	4	5	0
% above standards	100	100	100	100	80	100	100	100	0

Station Name	OUA0137A	OUA0137B	OUA0137C	OUA0137D
Period of Record for statisitics	1995 -1996 January to July			
Number of samples	11	11	10	11
MIN	206	159	496	780
MAX	1589	1447	2000	5231
MEDIAN	440	393	659	1704
# above standards	11	11	10	11
% above standards	100.0	100.0	100.0	100.0

APPENDIX B

Figures 3.1 Through 3.6

Figure 3.1 Chloride Concentrations Measured in Flat Creek (OUA137C).

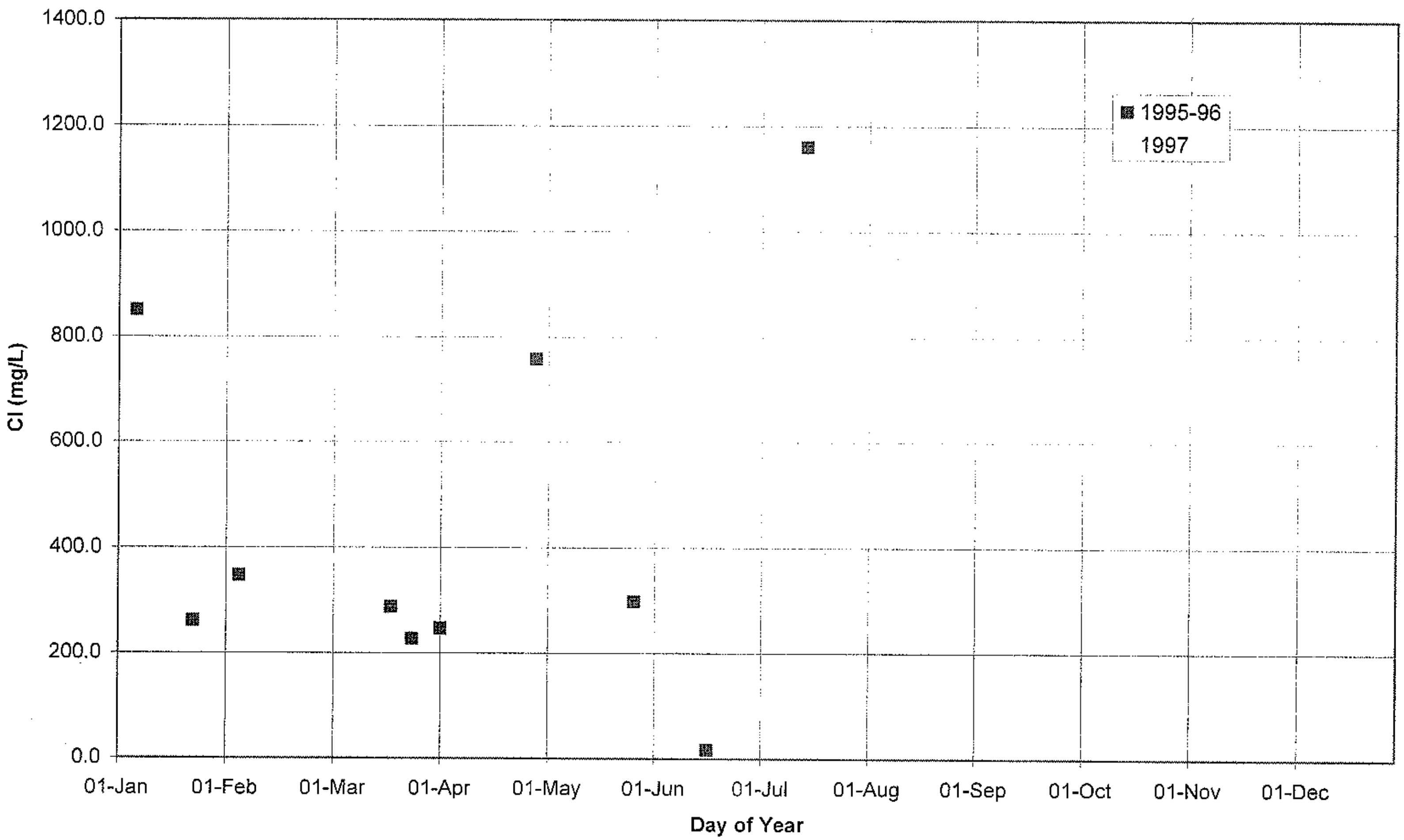


Figure 3.2 Sulfate Concentrations Measured in FLat Creek (OUA137C).

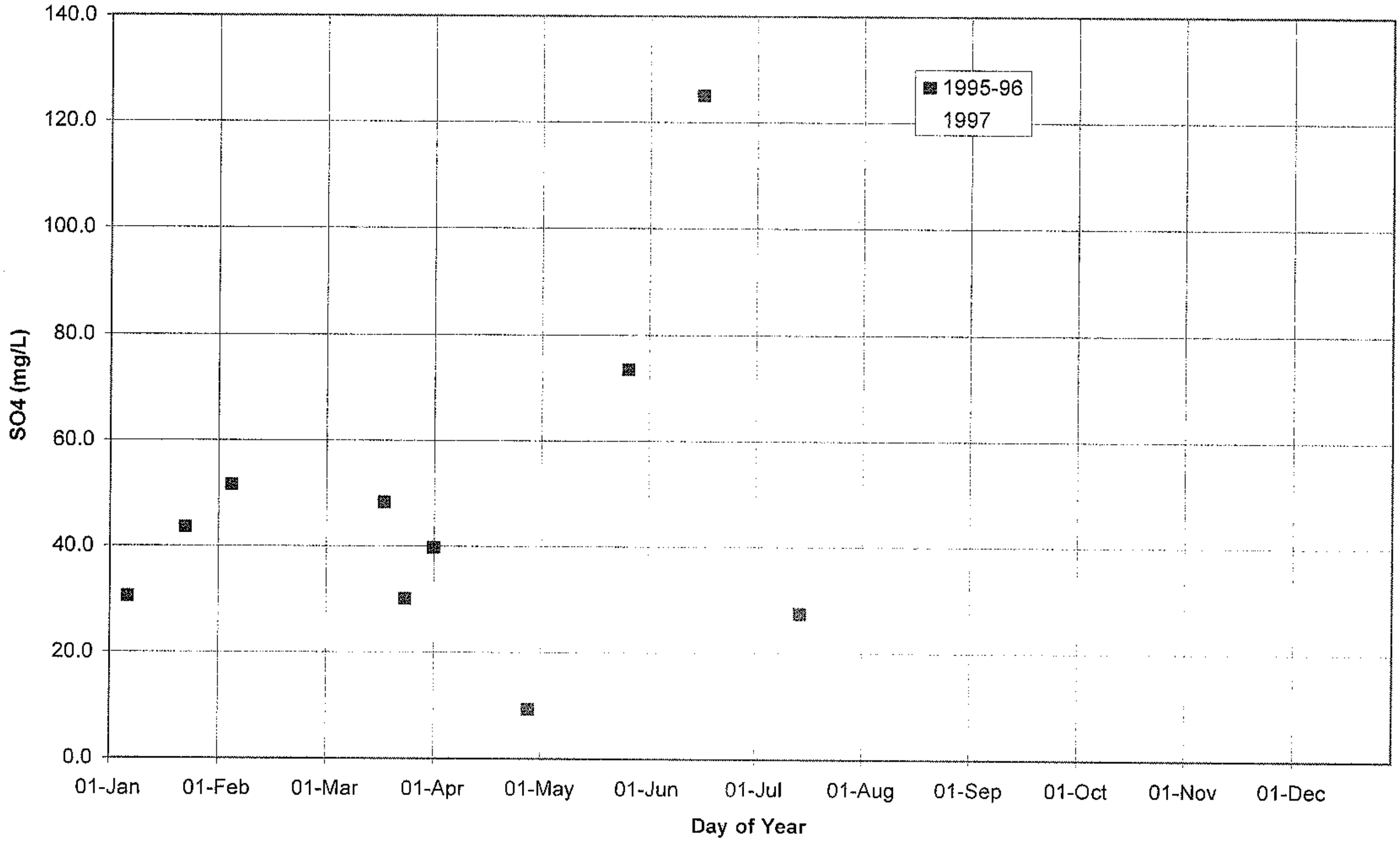


Figure 3.3 TDS Concentrations Measured in Flat Creek (OUA137C).

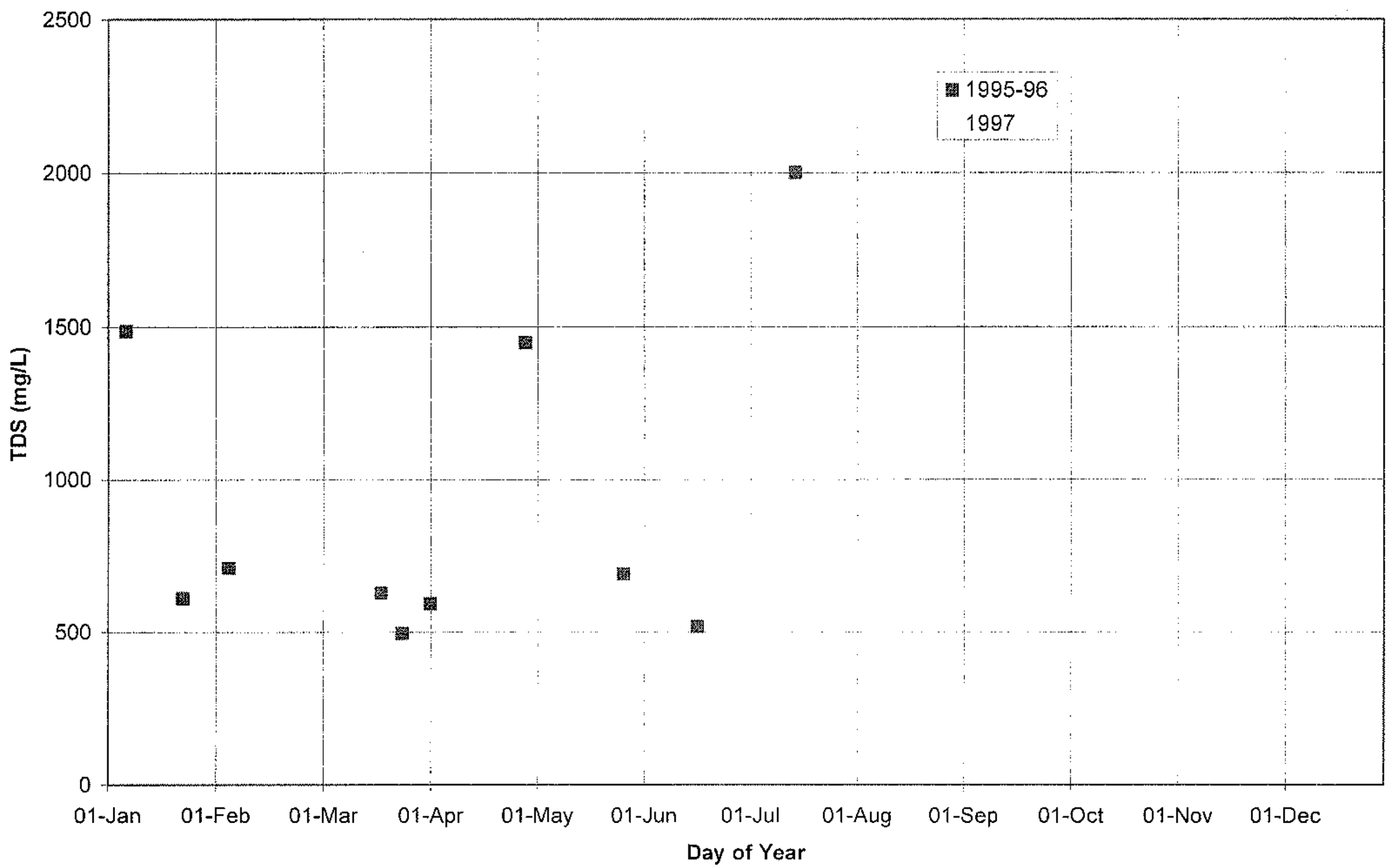


Figure 3.4 Chloride Concetrations Measured in Salt Creek (OUA137D).

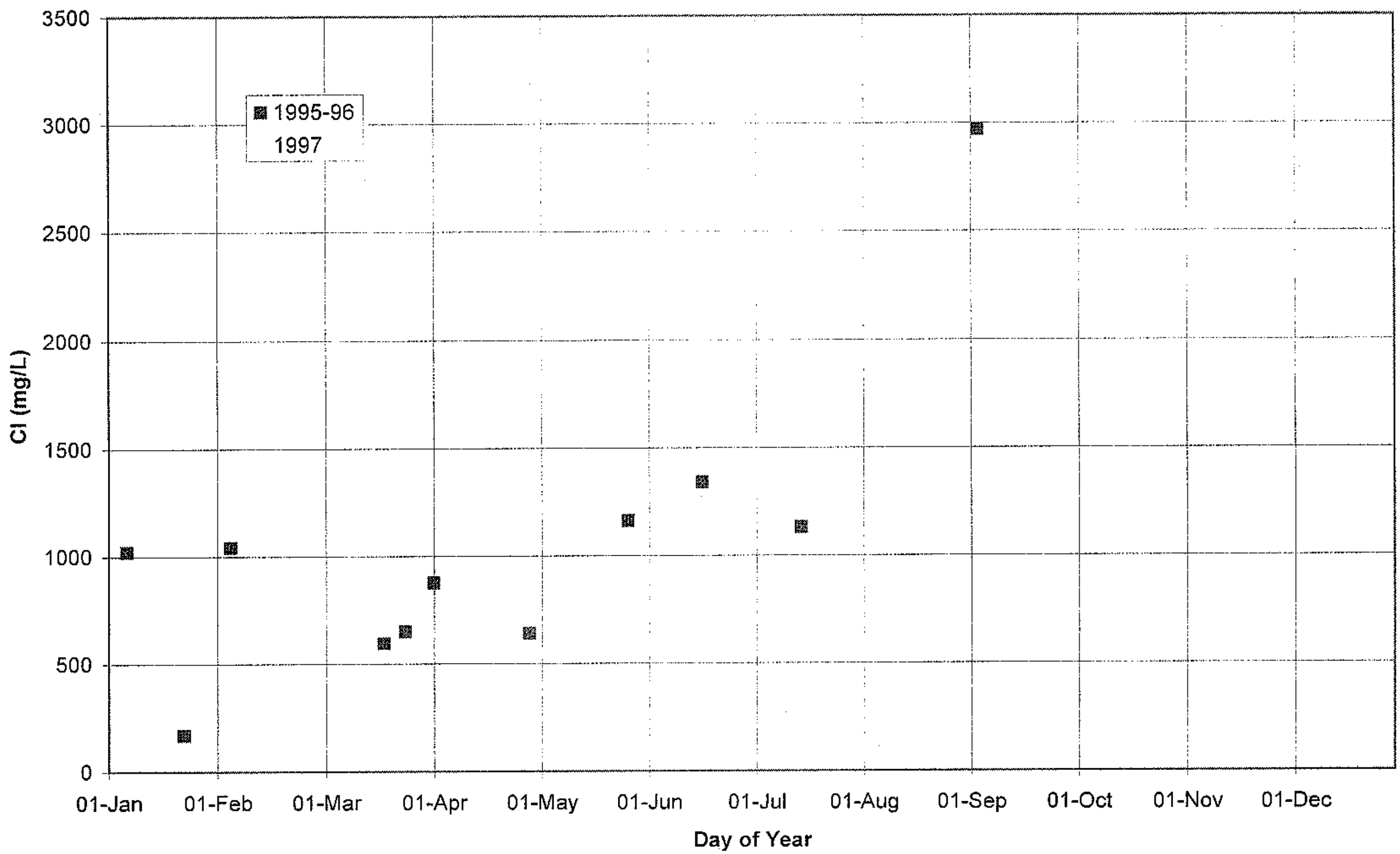


Figure 3.5 Sulfate Concentration Measured in Salt Creek (OUA137D).

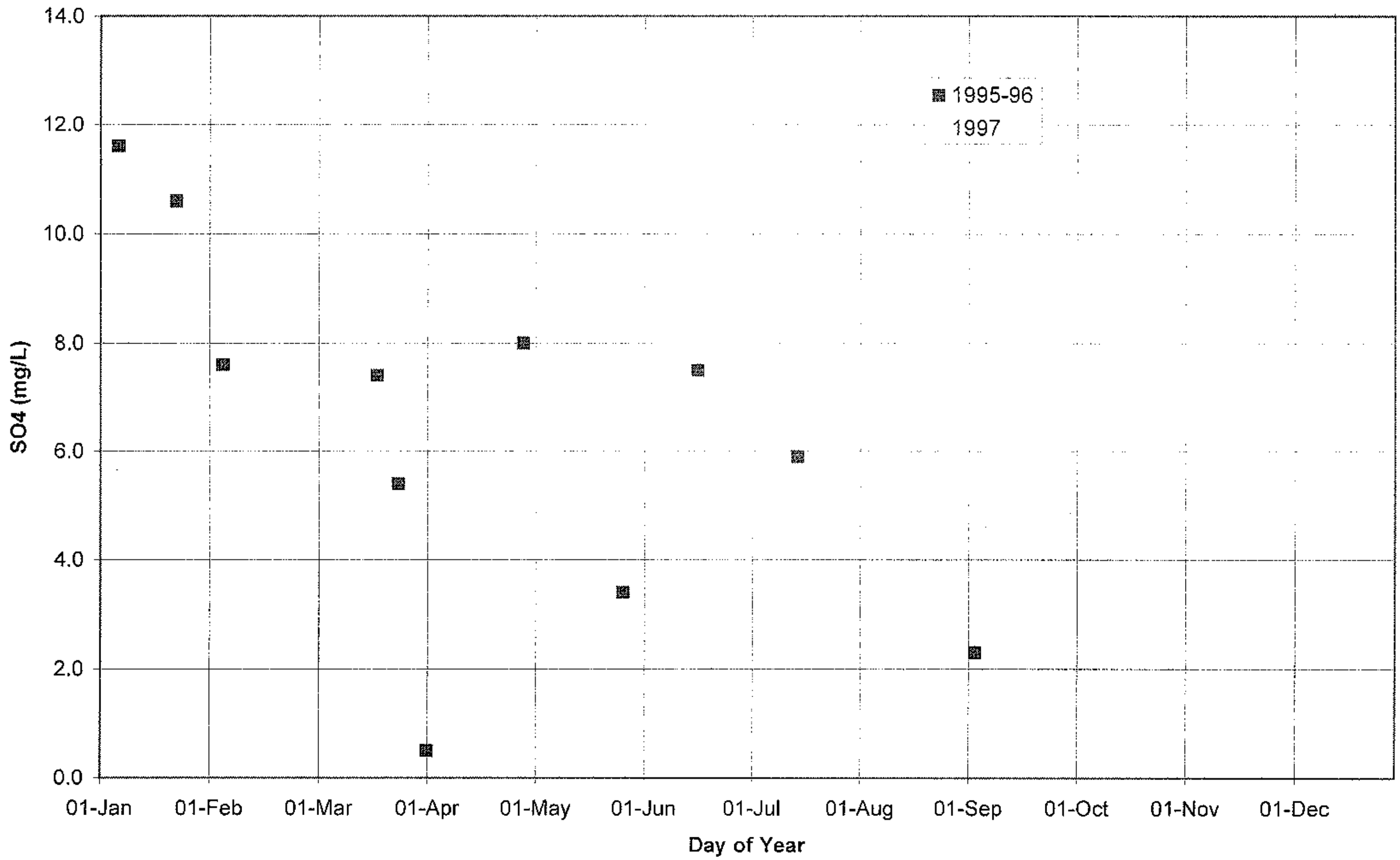
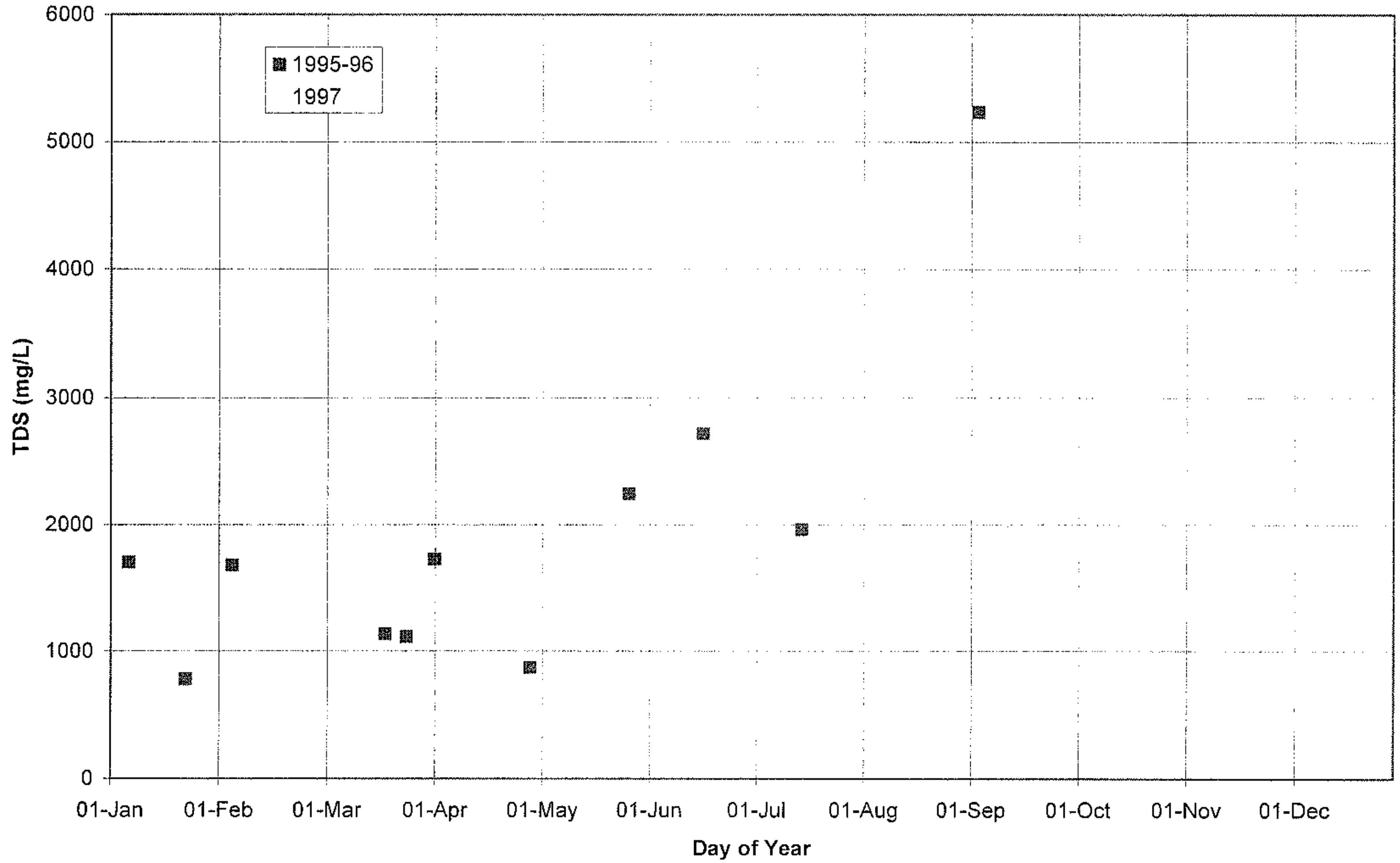


Figure 3.6 TDS Concentrations Measured in Salt Creek (OUA137D).



APPENDIX C

Dissolved Mineral TMDL Calculations for Flat Creek

TABLE C.1. TOTAL **CURRENT** LOADS OF DISSOLVED MINERALS FOR FLAT CREEK

Measured concentrations at Station OUA137C:
(upstream of confluence with ELCC Tributary)

	Chlorides (mg/L)	Sulfates (mg/L)	TDS (mg/L)
5/17/94	278	9.0	1137
6/21/94	404	17.3	839
7/26/94	159	20.8	395
9/26/94	349	56.9	1730
10/18/94	382	37.6	763
12/6/94	1240	11.3	1900
1/24/95	261	43.6	610
3/21/95	287	48.3	628
4/4/95	247	39.7	592
9/5/95	936	46.2	1745
1/8/96	850	30.5	1485
2/6/96	347	51.6	710
3/26/96	227	30.1	496
4/30/96	758	9.3	1448
5/28/96	298	73.5	690
6/18/96	16.6	125	518
7/16/96	1160	27.4	2000
6/3/97	254	70.9	675
Averages:	470	41.6	1020

Calculation of flow and loads at mouth of Flat Creek (excluding ELCC Tributary inputs):

Avg annual runoff for USGS gage on Smackover Creek = 15.0 in/yr
Drainage area for Flat Cr. at mouth (exclud. ELCC Trib) = 14.56 mi2

Average annual streamflow for Flat Creek = 10.40 MGD
(Flow = Runoff, in/yr * Drainage area, mi2 * conversions)

Average annual loads for Flat Creek (excluding ELCC Tributary):

(Load = Flow, MGD * Conc, mg/L * 8.34)	Chlorides =	40766 lbs/day	(using OUA137C concs)
	Sulfates =	3608 lbs/day	(using OUA137C concs)
	TDS =	88471 lbs/day	(using OUA137C concs)

Note: The flows and loads for these TMDLs are calculated for Reach 08040201-706, which includes Flat Creek but not the ELCC Tributary (which is Reach 08040201-606). As mentioned in Section 4.1, it is assumed that water quality standards will be maintained in Flat Creek downstream of the ELCC Tributary if the recently established TMDLs for the ELCC Tributary are successfully implemented and water quality standards are maintained in Flat Creek upstream of the ELCC Tributary.

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TABLE C.2. TOTAL **ALLOWABLE** LOADS (TMDLs) OF DISSOLVED MINERALS FOR FLAT CREEK

Maximum naturally occurring levels:	Chlorides =	14 mg/L	(Reg 2, page 5-11)
	Sulfates =	31 mg/L	(Reg 2, page 5-11)
	TDS =	123 mg/L	(Reg 2, page 5-11)

For chlorides and sulfates, standards are 1/3 increase or 15 mg/L increase, whichever is less, over maximum naturally occurring levels. For TDS, standard is maximum naturally occurring level plus sum of increases in chlorides and sulfates (over maximum naturally occurring levels). (Reg 2, Section 2.511)

Water quality standards:	Chlorides =	19 mg/L	
	Sulfates =	41 mg/L	
	TDS =	138 mg/L	
Average annual streamflow for Flat Creek =		10.40 MGD	(from Table C.1)

Average annual allowable loads (TMDLs) for Flat Creek (excluding ELCC Tributary):

(Load = Flow, MGD * Conc, mg/L * 8.34)	Chlorides =	1648 lbs/day	Note: Values in shaded
	Sulfates =	3556 lbs/day	cells used in Table 4.1
	TDS =	11970 lbs/day	

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TABLE C.3. ALLOCATION OF LOADS AND PERCENT REDUCTIONS FOR FLAT CREEK

Average annual streamflow for Flat Creek =	10.40 MGD			(from Table C.1)
	Chlorides (mg/L)	Sulfates (mg/L)	TDS (mg/L)	
Concentrations for background sources: (based on reference stream data):	5	13	67	(from CPP)
	Chlorides (lbs/day)	Sulfates (lbs/day)	TDS (lbs/day)	
Avg annual loads for background sources: (Load = Flow, MGD * Conc, mg/L * 8.34)	434	1128	5811	Note: Values in shaded cells used in Table 4.1
LA for man-induced nonpoint sources + MOS:				
TMDL for Flat Creek	1648	3556	11970	(from Table C.2)
minus background load	-434	-1128	-5811	(from immed. above)
minus WLA for point sources	-0	-0	-0	(no point sources)
Totals:	1214	2428	6159	
times 90% (to incorporate MOS)	x 90%	x 90%	x 90%	
equals LA for man-induced NPS	1093	2185	5543	Note: Values in shaded cells used in Table 4.1
Margin of safety (MOS):				
Totals from above (before multiplying by 90%)	1214	2428	6159	
times 10%	x 10%	x 10%	x 10%	
equals margin of safety	121	243	616	
Total CURRENT load for man-induced NPS:				
Total current load for Flat Creek	40766	3608	88471	(from Table C.1)
minus background load	-434	-1128	-5811	(from above)
minus current point source loading	-0	-0	-0	
equals total current load for man-induced NPS:	40332	2480	82660	
Load allocation for man-induced NPS (i.e., allowable):	1093	2185	5543	(from above)
Percent reduction needed for man-induced NPS: % reduc. = 100% x (current load - LA) / current load	97%	12%	93%	

FILE: R:\PROJECTS\2110-550\TMDL_FLAT_MINERALS.XLS

APPENDIX D

Dissolved Mineral TMDL Calculations for Salt Creek

TABLE D.1. TOTAL **CURRENT** LOADS OF DISSOLVED MINERALS FOR SALT CREEK

Measured concentrations at Station OUA137D:

	Chlorides (mg/L)	TDS (mg/L)
5/17/94	490	1819
6/21/94	1300	2482
7/26/94	928	1730
9/26/94	746	3200
10/18/94	938	1642
12/6/94	1290	2060
1/24/95	170	780
3/21/95	594	1136
4/4/95	876	1724
9/5/95	2970	5231
1/8/96	1020	1704
2/6/96	1040	1681
3/26/96	650	1114
4/30/96	642	871
5/28/96	1160	2242
6/18/96	1340	2714
7/16/96	1130	1961
6/3/97	771	1562
Averages:	1003	1981

Note: Sulfate data are not shown here because a TMDL for sulfates is not needed for Salt Creek.

Calculation of flow and loads at mouth of Salt Creek:

Avg annual runoff for USGS gage on Smackover Creek = 15.0 in/yr
Drainage area for Salt Creek at mouth = 17.94 mi2

Average annual streamflow for Salt Creek at mouth = 12.81 MGD
(Flow = Runoff, in/yr * Drainage area, mi2 * conversions)

Average annual loads for Salt Creek at mouth:
(Load = Flow, MGD * Conc, mg/L * 8.34)

Chlorides =	107156 lbs/day	(using OUA137D concs)
TDS =	211641 lbs/day	(using OUA137D concs)

FILE: R:\PROJECTS\2110-550\TMDL_SALT_MINERALS.XLS

TABLE D.2. TOTAL **ALLOWABLE** LOADS (TMDLs) OF DISSOLVED MINERALS FOR SALT CREEK

Maximum naturally occurring levels:	Chlorides =	14 mg/L	(Reg 2, page 5-11)
	Sulfates =	31 mg/L	(Reg 2, page 5-11)
	TDS =	123 mg/L	(Reg 2, page 5-11)

For chlorides and sulfates, standards are 1/3 increase or 15 mg/L increase, whichever is less, over maximum naturally occurring levels. For TDS, standard is maximum naturally occurring level plus sum of increases in chlorides and sulfates (over maximum naturally occurring levels). (Reg 2, Section 2.511)

Water quality standards:	Chlorides =	19 mg/L
	Sulfates =	41 mg/L
	TDS =	138 mg/L

Average annual streamflow for Salt Creek at mouth = 12.81 MGD (from Table D.1)

Average annual allowable loads (TMDLs) for Salt Creek at mouth:

(Load = Flow, MGD * Conc, mg/L * 8.34)	Chlorides =	2030 lbs/day	Note: Values in shaded
	TDS =	14743 lbs/day	cells used in Table 4.1

Note: No TMDL for sulfates is needed for Salt Creek.

FILE: R:\PROJECTS\2110-550\TMDL_SALT_MINERALS.XLS

TABLE D.3. ALLOCATION OF LOADS AND PERCENT REDUCTIONS FOR SALT CREEK

Average annual streamflow for Salt Creek at mouth =	12.81 MGD		(from Table D.1)
	Chlorides (mg/L)	TDS (mg/L)	
Concentrations for background sources: (based on reference stream data):	5	67	(from CPP)
	Chlorides (lbs/day)	TDS (lbs/day)	
Avg annual loads for background sources: (Load = Flow, MGD * Conc, mg/L * 8.34)	534	7158	Note: Values in shaded cells used in Table 4.1
LA for man-induced nonpoint sources + MOS:			
TMDL for Salt Creek at mouth	2030	14743	(from Table D.2)
minus background load	-534	-7158	(from immed. above)
minus WLA for point sources	-0	-0	(no point sources)
Totals:	1496	7585	
times 90% (to incorporate MOS)	x 90%	x 90%	
equals LA for man-induced NPS	1346	6826	Note: Values in shaded cells used in Table 4.1
Margin of safety (MOS):			
Totals from above (before multiplying by 90%)	1496	7585	
times 10%	x 10%	x 10%	
equals margin of safety	150	759	
Total CURRENT load for man-induced NPS:			
Total current load for Flat Creek	107156	211641	(from Table D.1)
minus background load	-534	-7158	(from above)
minus current point source loading	-0	-0	
equals total current load for man-induced NPS:	106622	204483	
Load allocation for man-induced NPS (i.e., allowable):	1346	6826	(from above)
Percent reduction needed for man-induced NPS: % reduc. = 100% x (current load - LA) / current load	99%	97%	

FILE: R:\PROJECTS\2110-550\TMDL_SALT_MINERALS.XLS

APPENDIX E

Responses to Public Comments

COMMENTS AND RESPONSES
TMDLs FOR CHLORIDE, SULFATE, AND TDS
IN FLAT CREEK AND SALT CREEK, ARKANSAS
October 8, 2003

EPA appreciates all comments concerning these TMDLs. Comments that were received are shown below with EPA responses or notes inserted in a different font.

COMMENTS FROM GBMc & ASSOCIATES ON BEHALF OF EL DORADO CHEMICAL COMPANY:

We have reviewed the referenced TMDLs and the related documentation. As you may be aware, El Dorado Chemical Company (EDCC) discharges into an unnamed tributary of Flat Creek. This unnamed tributary was the subject of a previous TMDL and is "incorporated" into this TMDL for Flat Creek by reference. As we commented on during the preparation of the TMDL for the unnamed tributary of Flat Creek (reach 08040201-606), there were technical and regulatory issues which needed to be resolved before that TMDL could be finalized in a satisfactory manner. As such, the Flat Creek TMDL continues several of the same deficiencies. EDCC has no discharges in direct relation to Salt Creek. Our comments are as follows:

Ambient Water Quality Data Limitations

The ambient water quality data for both Flat and Salt Creeks, as used in the preparation of the TMDLs, has significant deficiencies. As is seen upon review, the data were collected between January 1995 to December 1997. Data that old is not normally used to assess current conditions and we do not see how it can be considered to be representative.

Response: The allowable loadings of dissolved minerals for these streams were calculated based on water quality standards, not ambient water quality data. The ambient data were used to characterize current conditions and estimate percent reductions needed to meet standards. These TMDLs were developed using the most recent set of ambient data that were available for the whole watershed. In 2000, ADEQ collected a limited amount of water quality data at stations OUA137C (Flat Creek) and OUA137D (Salt Creek). The 2000 data are summarized and compared to the 1995-97 data in the table below. The 2000 data are similar to the 1995-97 data. This is not surprising because there have been no major land use changes or remediation activities on a widespread scale in the watershed. Therefore, EPA considers the 1995-97 data to be appropriate for use in these TMDLs.

Table E.1. Comparison of dissolved mineral data for 1995-97 and 2000.

	Flat Creek (OUA137C)		Salt Creek (OUA137D)	
	1995-97	2000	1995-97	2000
Chloride (mg/L)				
Number of samples	11	4	12	4
Minimum	16.6	287	170	155
Maximum	1,160	810	2,970	925
Median	287	406	948	804
Number above standards	10	4	12	4
Percent above standards	91%	100%	100%	100%
Sulfate (mg/L)				
Number of samples	11	5	12	5
Minimum	9.3	7.6	0.5	1.3
Maximum	125	151	11.6	4.7
Median	43.6	12.7	6.7	2.0
Number above standards	6	2	0	0
Percent above standards	55%	40%	0%	0%
TDS (mg/L)				
Number of samples	11	4	12	4
Minimum	496	478	780	380
Maximum	2,000	1,629	5,231	1,846
Median	675	817	1,693	1,824
Number above standards	11	4	12	4
Percent above standards	100%	100%	100%	100%

In addition, although the dissolved mineral TMDLs are based upon the maintenance of water quality criteria under average flow conditions, there is no information to correlate the ambient monitoring data to waterbody flows. Based on the data presented, it appears that no storm event sampling was utilized in either study nor was the sampling data for Flat Creek correlated with the intermittent discharges from EDCC. It should be noted that EDCC's Outfall 001, which discharges to Flat Creek, does not have a constant discharge and often is shut off for months during the summer. EDCC has NPDES permitted storm water outfalls which discharge solely in response to rain events at which time elevated stream flows occur. These characteristics were not considered in the TMDL report for Flat Creek.

Response: As discussed in Section 4.1.1 of the report, the determination of critical conditions was based on analysis of available data, which did not include continuous stream flow data or daily effluent flow data from El Dorado Chemical Company. EPA agrees that it would be useful to have flow data to correlate with water quality data, but having flow data is not required for development of TMDLs. The available water quality data did not show any significant patterns that suggested a strong correlation with flows.

The TMDL study does not appropriately document current ambient waterbody conditions as needed to correctly assess either point or nonpoint source loadings. This is due to the age of the data and because the data was not collected under a long-term sampling program designed specifically to characterize the variable water quality resulting from the intermittent nature of the flow regime of the waterbodies. In addition the discharges from EDCC into the unnamed tributary to Flat Creek were not correlated to instream Flat Creek data in any way. We recommend that no TMDL be finalized for either waterbody until such time as appropriate ambient monitoring (including flow measurement) is conducted.

Response: Because there are no point source discharges to either of these two reaches (08040201-706 and -806), there are no point source loadings to assess for these TMDLs. The ELCC facility has no impact on Salt Creek, and the ambient water quality data for Flat Creek were collected upstream of where the ELCC tributary flows into Flat Creek. The available data were sufficient for assessing nonpoint source loadings for these two reaches.

Regulatory Context for Dissolved Minerals

The TMDL allocations as developed for dissolved mineral (chloride, sulfate and TDS) are based on erroneous regulatory interpretations of Regulation No.2, the State of Arkansas Water Quality Standards (WQS). This misinterpretation is based on the definition of critical flow as contained in Section 2.106 of the WQS. This section reads as follows:

"Critical flows: The flow volume used as background dilution flows in calculating concentrations of pollutants from permitted discharges. These flows may be adjusted for mixing zones. The following critical flows are applicable:

For a seasonal fishery – 1 cfs minus the design flow of any point source discharge (may not be less than zero).

For human health criteria – harmonic mean flow or long term average flow.

For minerals criteria – harmonic mean flow or 4 cfs, except in those waters listed in Section 2.510. Those waters in Section 2.510 which are noted with an asterisk will have a critical flow of 4 cfs. (Also see minerals implementation procedure in CPP).

For all others – the critical flow will be Q7 – 10."

As is evident by this definition, under the WQS critical flows are specifically applicable to permitted discharges and nonpoint sources are not mentioned. Under this regulatory framework, the allocation of dissolved minerals loadings from permitted discharges are primary to those for nonpoint sources.

In this context, the TMDL for Flat Creek (which includes point source loadings to the unnamed tributary) should be amended to allocate dissolved minerals loadings at the appropriate critical flows to the permitted point source discharges pursuant to the definition of the WQS. The Flat Creek TMDLs' current allocation processes, which treats unpermitted nonpoint sources as equal to permitted discharges in the unnamed tributary at the critical flow, is not supported by the WQS. Through its inclusion of nonpoint sources as being equal to permitted discharges, the TMDL constitutes a revision to the critical flow definition of the WQS without the benefit of rulemaking and due process.

Response: As evident from Section 4 of this report, the TMDL for Flat Creek does not include loadings from point sources that discharge into the ELCC Tributary. Those loadings were already accounted for in the ELCC Tributary TMDL (final report dated December 16, 2002). Therefore, the language cited by the commenter is applicable for "calculating concentrations of pollutants from permitted dischargers." Since there are no permitted dischargers this language does not apply.

As noted in the comment above, the critical flows were developed for calculating concentrations of pollutants from permitted discharges. Federal regulations (40 CFR 130.7) require TMDLs to take into account critical conditions. Because the available water quality data did not show any significant patterns related to seasonal variation or other factors, the TMDLs were developed for mean annual conditions (i.e., using mean annual flow conditions).

Conclusion

The TMDLs for both Flat Creek and Salt Creek as developed have significant limitations. These include the interpretation of the WQS and the use of outdated ambient water quality data. For these reasons we request that the TMDLs be revised to address these concerns. Due to the fact that the Flat Creek TMDL incorporates the previously completed unnamed tributary TMDL by reference, we request that our letter of November 15, 2002 regarding dissolved minerals be made part of the record for the Flat Creek TMDL. For your convenience, we have attached those comments to this letter.

Response: See responses to specific comments above. EPA's responses to the comments on the ELCC Tributary TMDL are included in the last appendix in the ELCC Tributary TMDL report dated December 16, 2002.

Revising Criteria for Chloride, Sulfate and Total Dissolved Solids

By revising Iowa's water quality standards, the Iowa Department of Natural Resources (DNR) is working for improved water quality and safety in Iowa. Water Quality Standards are the goals that we set for Iowa's streams, rivers and lakes.

Water Quality Standards have three components:

- Designate the use or uses of the waterbody (aquatic life and recreational uses)
- Set the criteria for protecting those uses
- Protect and maintain existing water quality

Recently, the DNR began to compile all research related to toxicity of total dissolved solids, chloride and sulfate. The purpose was to update and develop criteria for these parameters to better protect aquatic life based on new scientific information.

The DNR worked with the U.S. Environmental Protection Agency to ensure that the research compiled met certain scientific standards. Gaps were identified in the research and resulted in new toxicity tests being performed in 2008.

With the availability of new research and toxicity data, the information is now available to propose numeric criteria for chloride and sulfate to better protect river, stream and lake aquatic life uses and revaluate the current interim approach for total dissolved solids criteria.

Chloride Criteria

Results of the research and toxicity testing completed for chloride showed that chloride toxicity is heavily dependent on water hardness, and to a lesser degree, sulfate levels in the water. Using all of the literature and this most recent toxicity testing, EPA developed an equation (see below) for the acute and chronic chloride criteria to protect Iowa's waters.

Proposed chloride criteria

To calculate the applicable acute and chronic criteria for chloride, use the equations below. Statewide default values for hardness and sulfate will be used unless site specific data is available. The DNR updated its proposed chloride criteria on March 3, 2009, based on new EPA toxicity data.

Acute Chloride Criteria Equation

$287.8(\text{Hardness})^{0.205797}(\text{Sulfate})^{-0.07452}$ = Acute Criteria Value (mg/L)

Chronic Chloride Criteria Equation

$177.87(\text{Hardness})^{0.205797}(\text{Sulfate})^{-0.07452}$ = Chronic Criteria Value (mg/L)

The following statewide background values were determined by analyzing DNR ambient water monitoring data from 2000 to 2007:

- Hardness: 200 mg/L as $CaCO_3$
- Sulfate: 63 mg/L
- Chloride: 34 mg/L

For example, if a Hardness value of 200 mg/L and a Sulfate value of 63 mg/L are used:

The acute criteria value for chloride would be:
$287.8(200\ \text{mg/L})^{0.205797}(63\ \text{mg/L})^{-0.07452}$
= 629 mg/L Chloride

The chronic criteria value for chloride would be:
$177.87(200\ \text{mg/L})^{0.205797}(63\ \text{mg/L})^{-0.07452}$
= 389 mg/L Chloride

Sulfate Criteria

In 2005 and 2006, the State of Illinois worked with U.S. EPA

Chloride is a major ion commonly found in streams and wastewater. Chloride may get into surface water from several sources, including:

- Wastewater from certain industries
- Wastewater from communities that soften water
- Road salting
- Agricultural runoff
- Produced water from oil and gas wells

to complete a review of research related to sulfate toxicity similar to the work done for chloride. The result of that work was a proposed criteria equation for sulfate based on background hardness and chloride levels. The similarities between the landscape and waterbodies of Iowa and Illinois and the high level of scientific review of this data allow for the same sulfate criteria proposed by Illinois to apply to protect aquatic life in Iowa's waters.

The proposed sulfate criteria also incorporates an upper limit of 2,000 mg/L to ensure that other beneficial uses of the waterbody, such as livestock watering, are protected in addition to aquatic life.

Total Dissolved Solids
The current interim approach for total dissolved solids levels through Whole Effluent Toxicity Testing will be replaced by the proposed criteria for chloride and sulfate.

This revision is based on scientific review that demonstrates individual ions cause toxicity to aquatic life. This review revealed that in Iowa, chloride and sulfate are the specific ions of concern.

As a result, ion criteria for chloride and sulfate are better indicators than integral parameters such as TDS, conductivity and salinity for water quality protection.

Proposed Sulfate Criteria for Iowa Waters
The results of the following equations provide sulfate water quality standards in mg/L for the specified ranges of hardness (in mg/L as $CaCO_3$) and chloride (in mg/L) and must be met at all times:

- If the hardness concentration of waters is between 100 mg/L and 500 mg/L and if the chloride concentration of waters is between 25 mg/L and 500 mg/L:

  [1276.7 + 5.508 (hardness) – 1.457 (chloride)] * 0.65

- If the hardness concentration of waters is between 100 mg/L and 500 mg/L and if the chloride concentration of waters ranges between 5 mg/L and less than 25 mg/L:

  [-57.478 + 5.79 (hardness) + 54.163 (chloride)] * 0.65

The following sulfate standards must be met at all times when hardness (in mg/L as $CaCO_3$) and chloride (in mg/L) concentrations other than specified are present:

- If the hardness concentration of waters is less than 100 mg/L, or chloride concentration of waters is less than 5 mg/L, the sulfate standard is 500 mg/L.

- If hardness concentration of waters is greater than 500 mg/L, the sulfate standard is 2,000 mg/L.

PROPOSED SULFATE CRITERIA FOR IOWA WATERS

Hardness mg/L as $CaCO_3$ \ Chloride	Cl- < 5 mg/L	5 ≤ Cl- < 25	25 ≤ Cl- ≤ 500
H < 100 mg/L	500	500	500
100 ≤ H ≤ 500	500	[-57.478 + 5.79 (hardness) + 54.163 (chloride)] * 0.65	[1276.7 + 5.508 (hardness) – 1.457 (chloride)] * 0.65
H > 500	500	2,000	2,000

Total Dissolved Solids is a measure of all constituents, or elements, dissolved in water. This can include inorganic anions (negatively charged ions) like carbonates, chlorides, sulfates and nitrates. The inorganic cations (positively charged ions) include sodium, potassium, calcium and magnesium.

Sulfate is a constituent of TDS and may form salts with sodium, potassium, magnesium and other cations. Sulfate is widely distributed in nature and may be present in natural waters at concentrations ranging from a few to several hundred milligrams per liter.

For more information:

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Table 1. Proposed Chloride Criteria at Various Concentrations of Hardness and Sulfate

Acute Criteria:

Sulfate	Hardness (as $CaCO_3$)												
	50	100	150	200	250	300	350	400	450	500	600	700	800
5	571	659	716	760	795	826	852	876	897	917	952	983	1010
10	542	625	680	721	755	784	809	832	852	871	904	933	959
15	526	607	660	700	733	761	785	807	827	845	877	906	931
20	515	594	646	685	717	745	769	790	809	827	859	886	911
25	506	584	635	674	705	732	756	777	796	813	845	872	896
50	481	555	603	640	670	695	718	738	756	773	802	828	851
100	457	527	573	608	636	660	682	701	718	734	762	786	808
150	443	511	556	589	617	641	661	680	697	712	739	763	784
200	434	500	544	577	604	627	647	665	682	697	723	747	767
250	427	492	535	567	594	617	637	654	671	685	711	734	755
300	421	485	528	560	586	609	628	646	661	676	702	724	745
350	416	480	522	553	579	602	621	638	654	668	694	716	736
400	412	475	516	548	574	596	615	632	647	662	687	709	729
450	408	471	512	543	569	590	609	626	642	656	681	703	722
500	405	467	508	539	564	586	605	622	637	651	676	697	717

Chronic Criteria:

Sulfate	Hardness (as CaCO3)											
	50	100	150	200	250	300	350	400	450	500	600	700	800
5	353	407	442	469	491	510	527	541	555	567	589	607	624
10	335	387	420	446	467	485	500	514	527	538	559	577	593
15	325	375	408	433	453	470	485	499	511	522	542	560	575
20	318	367	399	423	443	460	475	488	500	511	531	548	563
25	313	361	392	416	436	453	467	480	492	503	522	539	554
50	297	343	373	395	414	430	444	456	467	477	496	512	526
100	282	326	354	375	393	408	421	433	444	453	471	486	499
150	274	316	343	364	381	396	409	420	430	440	457	471	485
200	268	309	336	357	373	388	400	411	421	431	447	461	474
250	264	304	331	351	367	381	394	404	414	423	440	454	467
300	260	300	326	346	362	376	388	399	409	418	434	448	460
350	257	297	322	342	358	372	384	394	404	413	429	443	455
400	255	294	319	339	355	368	380	391	400	409	425	438	450
450	252	291	316	336	351	365	377	387	397	405	421	434	447
500	250	289	314	333	349	362	374	384	394	402	418	431	443

Table 1. Proposed Sulfate Criteria at Various Concentrations of Hardness and Chloride

Chloride	Hardness as CaCO3 (mg/L)										
(mg/L)	<100	100	150	200	250	300	350	400	450	500	>500
<5	500	500	500	500	500	500	500	500	500	500	500
5	500	515	703	891	1080	1268	1456	1644	1832	2020	2000
10	500	691	879	1067	1256	1444	1632	1820	2008	2196	2000
15	500	867	1055	1243	1432	1620	1808	1996	2184	2372	2000
20	500	1043	1231	1419	1608	1796	1984	2172	2360	2549	2000
25	500	1164	1343	1522	1701	1880	2059	2238	2417	2596	2000
50	500	1141	1320	1499	1678	1857	2036	2215	2394	2573	2000
100	500	1093	1272	1451	1630	1809	1988	2167	2346	2525	2000
150	500	1046	1225	1404	1583	1762	1941	2120	2299	2478	2000
200	500	998	1177	1356	1535	1715	1894	2073	2252	2431	2000
250	500	951	1130	1309	1488	1667	1846	2025	2204	2383	2000
300	500	904	1083	1262	1441	1620	1799	1978	2157	2336	2000
350	500	856	1035	1214	1393	1572	1751	1930	2109	2288	2000
400	500	809	988	1167	1346	1525	1704	1883	2062	2241	2000
450	500	762	941	1120	1299	1478	1657	1836	2015	2194	2000
500	500	714	893	1072	1251	1430	1609	1788	1967	2146	2000

Proposed Chloride Criteria at Various Concentrations of Hardness and Sulfate

Acute Chloride Criteria:

Sulfate mg/L	Hardness (as $CaCO_3$) mg/L											
	50	100	150	200	250	300	350	400	450	500	600	700	800
5	571	659	716	760	795	826	852	876	897	917	952	983	1010
10	542	625	680	721	755	784	809	832	852	871	904	933	959
15	526	607	660	700	733	761	785	807	827	845	877	906	931
20	515	594	646	685	717	745	769	790	809	827	859	886	911
25	506	584	635	674	705	732	756	777	796	813	845	872	896
50	481	555	603	640	670	695	718	738	756	773	802	828	851
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200	434	500	544	577	604	627	647	665	682	697	723	747	767
250	427	492	535	567	594	617	637	654	671	685	711	734	755
300	421	485	528	560	586	609	628	646	661	676	702	724	745
350	416	480	522	553	579	602	621	638	654	668	694	716	736
400	412	475	516	548	574	596	615	632	647	662	687	709	729
450	408	471	512	543	569	590	609	626	642	656	681	703	722
500	405	467	508	539	564	586	605	622	637	651	676	697	717

Chronic Chloride Criteria:

Sulfate mg/L	Hardness (as $CaCO_3$) mg/L												
	50	100	150	200	250	300	350	400	450	500	600	700	800
5	353	407	442	469	491	510	527	541	555	567	589	607	624
10	335	387	420	446	467	485	500	514	527	538	559	577	593
15	325	375	408	433	453	470	485	499	511	522	542	560	575
20	318	367	399	423	443	460	475	488	500	511	531	548	563
25	313	361	392	416	436	453	467	480	492	503	522	539	554
50	297	343	373	395	414	430	444	456	467	477	496	512	526
100	282	326	354	375	393	408	421	433	444	453	471	486	499
150	274	316	343	364	381	396	409	420	430	440	457	471	485
200	268	309	336	357	373	388	400	411	421	431	447	461	474
250	264	304	331	351	367	381	394	404	414	423	440	454	467
300	260	300	326	346	362	376	388	399	409	418	434	448	460
350	257	297	322	342	358	372	384	394	404	413	429	443	455
400	255	294	319	339	355	368	380	391	400	409	425	438	450
450	252	291	316	336	351	365	377	387	397	405	421	434	447
500	250	289	314	333	349	362	374	384	394	402	418	431	443

Proposed Sulfate Criteria at Various Concentrations of Hardness and Chloride

Chloride	Hardness as $CaCO_3$ (mg/L)										
(mg/L)	<100	100	150	200	250	300	350	400	450	500	>500
<5	500	500	500	500	500	500	500	500	500	500	2000
5	500	515	703	891	1080	1268	1456	1644	1832	2020	2000
10	500	691	879	1067	1256	1444	1632	1820	2008	2196	2000
15	500	867	1055	1243	1432	1620	1808	1996	2184	2372	2000
20	500	1043	1231	1419	1608	1796	1984	2172	2360	2549	2000
25	500	1164	1343	1522	1701	1880	2059	2238	2417	2596	2000
50	500	1141	1320	1499	1678	1857	2036	2215	2394	2573	2000
100	500	1093	1272	1451	1630	1809	1988	2167	2346	2525	2000
150	500	1046	1225	1404	1583	1762	1941	2120	2299	2478	2000
200	500	998	1177	1356	1535	1715	1894	2073	2252	2431	2000
250	500	951	1130	1309	1488	1667	1846	2025	2204	2383	2000
300	500	904	1083	1262	1441	1620	1799	1978	2157	2336	2000
350	500	856	1035	1214	1393	1572	1751	1930	2109	2288	2000
400	500	809	988	1167	1346	1525	1704	1883	2062	2241	2000
450	500	762	941	1120	1299	1478	1657	1836	2015	2194	2000
500	500	714	893	1072	1251	1430	1609	1788	1967	2146	2000

Chloride and TDS Water Quality Standards Update
January 15, 2008
Gregory L. Sindt, P.E.

Introduction and Summary

IDNR is currently developing new chloride water quality standards. Two Technical Advisory Committee (TAC) meetings have been held. The IDNR staff are currently reviewing the technical information and TAC discussion and will be making some important decisions regarding the chloride standards. Some members of the TAC have suggested that laboratory chloride toxicity tests be conducted to validate data used by EPA, the IDNR adopt new sulfate water quality standards and IDNR delete the "interim site specific" total dissolved solids (TDS) standards as part of this rule package.

TDS, chloride, and sulfate water quality standards impact discharges from cities with well water supplies that have high hardness or TDS concentrations, cooling towers, and industrial processes such as meat and food processing plants.

The IDNR recently adopted numerical water quality standards for several toxic pollutants that are identical for all three warm water aquatic life use designations. The standards required full life cycle protection for any species that could be present in any Iowa water for all streams. Therefore, most dischargers to very low flow, effluent dominated streams will have to meet excessively stringent water quality standards at the end of pipe discharge, including any new chloride standard.

IDNR is under pressure from environmental interest groups to adopt chloride standards now, without validation of questionable data used by EPA in its derivation of chloride standards, and not include new sulfate standards or delete the interim TDS standards.

In 2004, the Environmental Protection Commission (EPC) adopted an interim TDS standard that replaced the old, nebulous 750 mg/L TDS standard with a site specific standard approach that requires toxicity testing in situations where discharges result in receiving stream TDS concentrations greater than 1,000 mg/L. The EPC directed the IDNR to develop final standards by 2007 that address the TDS issue.

The current interim TDS standards are problematic because the IDNR is requiring chronic whole effluent toxicity testing for establishing TDS or specific constituent discharge limits. Chronic toxicity testing is expensive and the results are extremely variable. IDNR technical staff agree that the interim TDS standards should be replaced with standards for specific constituents of TDS such as chloride and sulfate.

Under pressure from legal action against USEPA, IDNR has worked with EPA in developing chloride standards and has ignored the TDS standards issue. The USEPA has recalculated the chloride standards with the inclusion of significantly more data than used as the basis for the

1988 EPA national guideline criteria. The inclusion of some particularly suspect 1961 data on the fingernail clam is the major issue with the EPA recalculation method.

The following is a summary of the acute and chronic chloride standards for the various recalculation options:

Calculation Method	Acute Standard, mg/L	Chronic Standard, mg/L
1988 USEPA Guidelines	860	230
USEPA Proposed Revision	546	425
USEPA Proposed data set with Fingernail clam deleted	852	663

IDNR staff and some TAC members recommend that additional acute toxicity tests be conducted on the fingernail clam and, if appropriate, replace the 1961 fingernail clam data with the new data. Experts expect that new fingernail clam data will prove a much higher acute value when the tests are conducted on species commonly found in Iowa and under hard water test conditions.

TAC members have received a proposal from Advent Environ and the Illinois Natural History Survey for the conducting the toxicity testing on the fingernail clam. These two groups conducted work on the Illinois sulfate standards development and have established very good credibility with the USEPA toxicologists.

IDNR does not have funds for conducting the tests. The Iowa Water Pollution Control Association (IWPCA) has budgeted some funds for partial support of the $20,000 to $25,000 cost for the toxicity testing program. The IWPCA can coordinate funding from other organizations and individual dischargers.

Some TAC members and IDNR technical staff agree that the new chloride standards rule package should include new sulfate standards and repeal of the interim TDS standards. This approach would address the 2004 directives from the EPC and would more efficient than addressing these issues piece meal. Illinois is currently in the final stages of rule making that includes repeal of its 1,000 mg/L TDS standard and adoption of new sulfate standards. The technical support for the Illinois standards can easily be applied to the Iowa standards development.

There is some pressure, however, from environmental interest groups to adopt chloride standards now. The Settlement Agreement between EPA and the environmental groups requires EPA to determine if an Iowa chloride standard is required and to establish as standard in the event an Iowa standard was not adopted by December 31, 2007. In the near future, IDNR management will decide whether to proceed now with final chloride standards in response to the legal action by environmental groups or take the time to develop chloride standards based on new fingernail clam toxicity tests, include new sulfate standards, and repeal the interim TDS standard in one rule revision package.

Historical Background

June 2004 EPC adopted interim TDS standards with direction to develop final TDS and/or specific parameter standards by 2007.

The Environmental Protection Commission (EPC) adopted the interim site specific TDS water quality standards in 2004 after they could not reach consensus on final TDS or chloride standards and it became evident that the IDNR economic impact analysis was flawed. The interim site specific TDS standard replaced a nebulous 750 mg/L TDS standard that was seldom applied to NPDES permits. The EPC directed the IDNR to conduct a state-wide TDS and chloride monitoring program in an effort to build a better data base for use in the economic impact analysis of any future TDS and chloride standards. The IWPCA members cooperated in conducting this monitoring program.

The EPC also directed the IDNR to develop TDS standards and/or standards for specific TDS constituents such as chloride by June 2007.

June 2005 Iowa environmental groups sued USEPA regarding chloride standards and ultimately entered into a Settlement Agreement that requires IDNR to adopt chloride standards by December 31, 2007.

Environmental interest groups (Iowa Environmental Council, Northeast Iowa Citizens for Clean Water, the Sierra Club, and Steve Veysey) filed a Civil Action in U.S. District Court against USEPA that objected to the EPA's December 2004 approval of the revised TDS water quality standards. The subsequent August 2006 Settlement Agreement includes a provision for the IDNR to adopt <u>chloride</u> standards and includes the following provision for EPA action in the event IDNR does not perform per the schedule:

> "The parties expect that the IDNR will adopt acute and chronic water quality criteria for chloride and submit those criteria to EPA for approval/disapproval pursuant to CWA section 303(c)(2)(A) no later than December 31, 2007. If, however, the IDNR does not submit new or revised criteria for chloride by December 31, 2007, EPA agrees to determine, on or before April 15, 2008, whether new or revised water quality criteria for chloride are necessary for Iowa pursuant to CWA section 303(c)(4)(B). EPA's obligation to make such a determination will terminate if the IDNR submits new or revised water quality criteria for chloride before this determination is signed."

March 2006 INDR adopted new stream use designation standards that results in significantly more stringent discharge limits to small streams.

IDNR adopted major revisions to the water quality standards by revising the designated uses for all streams to the highest level of aquatic life and recreational use protection. This action was in response to the threat of litigation by environmental groups for alleged IDNR failure to adequately address the Clean Water Act "fishable and swimmable" level of water quality protection. Many small steams and drainage ways that were previously classified as General Use are now classified as B-WW-1. Discharge permits to General Use streams were based on preventing acute toxicity to the fathead minnow. Discharge permits to B-WW-1 streams are based on preventing chronic toxicity to all life stages of any organism that could be present in Iowa waters.

IDNR is currently attempting to revise the designated uses on many small streams with the Use Attainability Analysis (UAA) approach. The revision in aquatic life use designations from B-WW-1 to B-WW-2 and B-WW-3 will have little, if any, impact on discharge limits because the numeric standards for most standards are identical for all three aquatic life use designations.

Since many small towns discharge to streams that were previously classified as General Use, this revision to the designated uses and levels of aquatic life protection has a very significant impact on the application of any numerical water quality standards such as ammonia and chloride. For many dischargers to small streams, the future discharge limits will be equal to the chronic water quality standards.

January 2007 IDNR administrators submitted rules for 25 chemical parameter standards that included the same numerical standards for all warm water aquatic life designated uses and may have set precedent that requires the same numerical standards for all stream designations.

In its haste to adopt the March 2006 revisions to the aquatic life use designation standards under threat of lawsuit from environmental groups, IDNR failed to adequately define the appropriate levels of aquatic life protection for each of the designated uses. In late 2006, IDNR staff developed draft standards for the 25 chemical parameters that were based on different levels of protection for the three different warm water aquatic life designated uses. The TAC was in general agreement with the IDNR staff approach as it was an attempt to apply different standards to the different stream use designations.

INDR administrative staff ignored the IDNR staff and TAC recommendations regarding the 25 chemical criteria and elected to submit the draft rules for EPC approval with the same numerical standards for all warm water use designations. The Director justified this action because the USEPA was delaying approval of the 2006 rules pending adoption of the chemical parameter standards and any deviation from the EPA national guideline criteria for these parameters would cause further delay.

Prior to this action, many TAC members thought that the IDNR would develop different numerical standards for the three different warm water use designations. This action may have set a precedent that does not provide for different numerical standards for each warm water use designation. This raises the obvious questions:

1. What is the purpose of three different warm water aquatic life use designations if the numerical standards are the same for all use designations?

2. What is the purpose for performing the Use Attainability Analyses for aquatic life protection if the standards are the same for all use designations?

November 26, 2007 IDNR and USEPA presented proposals for chloride standards at the first TAC meeting.

IDNR held the first TAC meeting on November 26 for discussion of chloride water quality standards. The IDNR delayed this initial TAC meeting due to a new, more efficient rule development approach that was developed in a Kaisan meeting between IDNR and EPA Region 7 staff. IDNR staff worked with EPA staff in technical review of chloride water quality standards issues prior to the initial TAC meeting. The intent of this process was to present proposed standards to the TAC that would be approved by EPA. IDNR staff worked extensively with toxicologists from the EPA Duluth laboratory. EPA Region 7 and Duluth toxicologists participated in the TAC meeting.

EPA staff acknowledged that the 1988 EPA national guideline criteria for chloride were too stringent and they presented alternative, less stringent standards based on a much larger data base than used in the 1988 national guideline development. EPA staff proposed to use data from a 1961 study that were not included in the data set used in the 1988 guidelines. The inclusion of this 1961 data has a significant impact on the recalculation of the chloride criterion.

December 14, 2007 TAC members presented a technical review of the EPA proposed chloride standards and recommended the rule package include new sulfate standards and elimination of the interim TDS standard at the second TAC meeting.

IDNR held the second TAC meeting on December 14. Some of the TAC members presented a technical review of the EPA proposed chloride criterion and questioned the validity of the 1961 data that EPA included in the chloride criterion calculation. They also recommended that the proposed rule revision package include elimination of the interim TDS standards rule and addition of a sulfate standard. This is similar to the TDS and sulfate standards rule revisions that Illinois is adopting with USEPA approval. IDNR and EPA Region 7 staff indicated that they are under legal pressure of the Settlement Agreement with the environmental interest groups to adopt chloride standards very soon and they may not have time to perform laboratory tests to replace the questionable 1961 data, develop sulfate standards, or develop the technical justification for eliminating the interim TDS standard.

IDNR staff indicated that they would make a decision on how to proceed with the chloride standards rule revision after they review the December 14 TAC comments. They indicated that "upper level IDNR management" would make the decision.

Chloride Standards

IDNR staff reviewed technical literature and information on chloride toxicity submitted by TAC members. The IDNR staff also consulted with USEPA toxicologists at the EPA Duluth laboratory and Region 7 office in review of the development of chloride water quality standards.

The USEPA 1988 national guideline criteria for chloride toxicity are considered by IDNR and many USEPA staff as too stringent. USEPA staff significantly expanded the data base of published chloride toxicity data in its review of the 1988 guidelines and recalculated the acute and chloride standards. They included some 1961 chloride toxicity data for the fingernail clam that has a significant impact on the chloride acute and chronic value determination. This 1961 data was not included in the development of the USEPA 1988 guideline criteria, apparently due to EPA lack of awareness of the data availability in 1988.

While fingernail clams are common in Iowa, the species used in the 1961 study cited by EPA are not common in Iowa. Toxicologists indicated concern that the 1961 tests were conducted at higher temperatures than the fingernail clams' normal environment. The clams' sensitivity to chloride in the 1961 tests may be attributed in part to thermal stress at the elevated test temperature.

The acute and chronic chloride standards are very dependent on the acute toxicity of the four most sensitive organisms in the data base. The following four organisms and associated acute chloride values were used by USEPA in its recalculation of the chloride standards:

Fingernail clam (*Sphaerium tenue*)	682 mg/L (1961 data)
Cladoceran (*Ceriodaphnia dubia*)	1,402 mg/L
Snail (*Gyraulus circumstriatus*)	1,941 mg/L
Cladoceran (*Daphnia magna*)	2,142 mg/L

As indicated above, the 1961 data on the fingernail clam is significantly lower than the other three most sensitive species. The most sensitive mussel in the data base, *Lampsilis siliquoidea*, has a published acute toxicity of 2,295 mg/L, or over three times the fingernail clam value. Based on recent work on fingernail clams conducted by the state of Illinois in developing new sulfate standards, toxicologists expect that the toxicity of chloride to fingernail clams is similar to *Ceriodaphnia dubia*, or about 1,400 mg/L. Therefore, the 1961 fingernail clam data appear suspect.

The following is a summary of the acute and chronic chloride standards for the various recalculation options:

Calculation Method	Acute Standard, mg/L	Chronic Standard, mg/L
1988 USEPA Guidelines	860	230
USEPA Proposed Revision	546	425
USEPA Proposed data set with Fingernail clam deleted	852	663

As indicated above, deleting the questionable fingernail clam data results in a 56% increase in both the acute and chronic standards.

The IDNR could replace the 1961 data with results of new tests of chloride toxicity on the fingernail clam. As demonstrated in the recent Illinois development of new sulfate standards, the toxicity of chloride is probably a function of hardness. Chloride is probably less toxic at higher hardness, typical of Iowa waters, than at the lower hardness used in standard laboratory toxicity test methods. Therefore, it appears most prudent to conduct a battery of acute chloride toxicity tests on the fingernail clam at various hardness values when evaluating chloride toxicity in Iowa waters. These data would be used in replacing the questionable 1961 data in the derivation of chloride standards for Iowa.

There are two potential problems to this approach of replacing the 1961 data with new fingernail clam test results:

1. The IDNR does not have funds for conducting the $20,000 to $25,000 toxicity study on the fingernail clam.

2. The USEPA is under pressure from the August 2006 Settlement Agreement with environmental interest groups for adoption of final chloride standards in Iowa now.

A member of one of the environmental groups is a TAC member. This environmental group representative indicated support for conducting the study on the fingernail clam and thereby delay the adoption of final chloride standards for about six months.

TAC members have a proposal from Advent Environ, the firm that worked on the recent development of the Illinois sulfate standards and the Illinois Natural History Survey, the lab that conducted the toxicity tests on organisms including the fingernail clam for the Illinois sulfate standards development. The scope of work includes developing the test protocol with USEPA review and concurrence, parallel acute toxicity tests at two labs using the fingernail clam at three hardness concentrations to define acute chloride concentration as a function of hardness, and final data presentation.

The cost for the chloride toxicity testing and report is $20,000 to $25,000. The IWPCA Board of Directors has included some funds for partial support of the study in its 2008 budget. IWPCA can receive funds from other organizations and dischargers that wish to contribute to this effort.

TDS Standards

In 2004, the EPC directed the IDNR to review the TDS standards issue and develop final rules for TDS and/or the specific toxic constituents that make up TDS by 2007. Therefore, it was the intent of EPC that IDNR would develop standards in addition to chloride as appropriate to address the TDS standards issue.

The interim "site specific" TDS standards have serious implementation problems. The IDNR is requiring the use of chronic toxicity testing on fathead minnow and *Ceriodaphnia dubia* for any discharge that results in greater than 1,000 mg/L TDS in the receiving stream. The chronic test is a very difficult laboratory procedure, expensive, and has very poor reproducibility. IDNR has concluded that the interim "site specific" TDS standard is not a good long term method for establishing discharge limitations for toxic dissolved solids.

IDNR staff have concluded, and most TAC members agree, that the TDS interim standard should be eliminated. The protection from toxic dissolved solids should be achieved with standards for specific chemical parameters such as chloride and sulfate rather than a standard for the nonspecific TDS parameter.

Illinois is currently in the final rule making stages of eliminating its 1,000 mg/L TDS standard and adopting new sulfate standards. Illinois has had a 500 mg/L chloride standard for several years. Illinois has conducted an extensive, multi year study and evaluation of the TDS and sulfate standards issue. Illinois worked closely with USEPA toxicologists at the Duluth laboratory, the same toxicologists that worked with IDNR staff in evaluating the Iowa chloride standards. Therefore, USEPA toxicologists should support a proposed elimination of the Iowa interim TDS standards.

There are two potential problems with eliminating the interim TDS standards as part of the chloride standards rules:

1. Even though USEPA Region 5 and Duluth toxicologists agree with the Illinois approach to replacing the TDS standard with sulfate and chloride, the USEPA Region 7 staff may not agree to this approach. (They may need additional "proof" that the proposed rules provide the same level of aquatic life protection as the current interim TDS standards.)

2. IDNR administrative staff may claim there is not adequate time to develop the rules for elimination of the interim TDS standards due to the 2005 USEPA Settlement Agreement that pressures Iowa to adopt final chloride standards now.

It appears that the Illinois technical evaluations of TDS can be easily and expediently transferred to the Iowa TDS standard elimination issue. Therefore, the elimination of the TDS interim standards could probably be included with the chloride rule package if the USEPA Region 7 staff agree that there is not an immediate need to adopt a chloride standard as per the 2006 EPA Settlement Agreement with the environmental groups.

Sulfate Standards

If the TDS interim standards are eliminated, the discharge of toxic constituents will be controlled by numerical standards on specific dissolved solids such as chloride. Over time, the list of toxic parameters will be expanded as the base of knowledge on toxicity of specific constituents grows. This is the purpose of the USEPA requirement for triennial review of state water quality standards.

Sulfate is a toxic constituent that could be present in Iowa discharges. It seems prudent to include new sulfate standards as part of the chloride standards and TDS standards elimination rule package. This would also address potential concerns that the elimination of the interim TDS standards does not provide protection equivalent to the current standards.

Illinois is currently in the final stages of sulfate standards rule making. The proposed Illinois sulfate standards were developed from extensive laboratory toxicity studies and literature review. The proposed numeric sulfate standards are variable, based on the hardness and chloride concentrations.

The proposed Illinois sulfate standard varies from 500 mg/L at hardness less than 100 mg/L to 2,000 mg/L at hardness greater than 500 mg/L and chloride greater than 5 mg/L. At 100 mg/L hardness and 500 mg/L chloride, the sulfate standard is 714 mg/L.

These proposed sulfate standards could impact some industrial and noncontact cooling water dischargers with high sulfate concentrations to low flow streams. Approximately 60 municipal water supplies exceed 700 mg/L sulfate and 32 supplies exceed 1,000 mg/L sulfate.

Since Illinois worked closely with USEPA Duluth laboratory toxicologists in developing the sulfate standards, it appears USEPA should approve the same sulfate in standards in Iowa. Iowa could simply use the Illinois technical documents in support of new Iowa sulfate standards.

More Information

For more information on these issues or to contribute funds for the chloride toxicity testing program, contact Greg Sindt at gregsi@bolton-menk.com or 515-290-0274.

Iowa Water Quality Standards Update
TDS, Chloride, and Sulfate

AMI Environmental Conference
Kansas City, Missouri
June 5, 2008

Gregory L. Sindt, P.E.
Bolton & Menk, Inc.

History

- Prior to June 2004 – 750 mg/L TDS Standard
  - Seldom applied to NPDES permits
  - Probably over 100 dischargers exceeded 750 mg/L

- June 2004 – IDNR Enacted Interim TDS Standard
  - Requires WET test if >1,000 mg/L TDS
  - EPC directed IDNR to develop standards by 2007
  - Problems in implementation

History

- June 2005 – IEC, Sierra Club, et. al. Lawsuit
  - Sued US EPA for failure to disapprove the interim TDS standards
  - Requires IDNR to develop chloride standards by Dec. 31, 2007
  - Extended deadline to Dec. 31, 2008

History

- November 2007 IDNR TAC meeting
  - US EPA presented proposed recalculation of National Guidelines for chloride water quality standards
  - US EPA proposed to use very old and technically questionable data in recalculation
  - IDNR and TAC suggested more thorough review of National Guidelines and lab WET tests
  - EPA claimed they had no money for research

History

- January 2008 IWPCA, AMI members and others raised funds for technical support
  - Retained services of Environ (expert toxicologists)
- March 2008 EPA draft work plan on chloride toxicity testing for National Guideline revision

EPA Work Plan Development

- EPA proposed WET tests to establish new national chloride guidelines
  - Initial acute WET tests on one species
  - Low hardness (50 mg/L) – not indicative of toxicity in Iowa waters (300 – 400 mg/L)
  - Forces states and dischargers to perform additional testing or site specific studies at higher hardness for less stringent standards

EPA Work Plan Development

- Results of initial Iowa WET tests at higher hardness for less stringent chloride standards
  - *C. dubia* preliminary data on hardness effects

Hardness (mg/L $CaCO_3$)	LC_{50} (mg/L chloride)
40	1,370
80	1,700
160	2,370

EPA Work Plan Development

- Iowa IDNR Technical Advisory Committee Input to USEPA
  - Proposed to conduct additional tests to establish relationship between chloride toxicity and hardness (supplement EPA research)
  - EPA revised their Work Plan and Scope for National Guideline Review
  - EPA responded to interest (threat) of Iowa group consideration of conducting additional research

EPA Work Plan Development

- EPA revised proposed WET tests to establish new national chloride guidelines
  - Initial acute WET tests on one species
    - Water flea (*Ceriodaphnia dubia*)
    - Test at seven hardness concentrations
      - 25, 50, 100, 200, 300, 600, and 800 mg/L hardness
    - Ca/Mg mass ratio 2.25
    - Test at seven sulfate concentrations
      - 25, 50, 100, 200, 300, and 600 mg/L sulfate
    - Organisms will be fed during test for reduced stress

EPA Work Plan Development

- After tests on *Ceriodaphnia dubia,* conduct acute WET tests on two of the following three identified sensitive species:
  - Fingernail clam (*Sphaerium simile*)
  - Snail (*Gyraulus circumstriatus*)
  - Tubificid worm (*Tubifex tubifex*)
- Develop revised Acute Value based on four most sensitive organisms in data base

EPA Work Plan Development

- No plans to conduct chronic tests for revising Acute Chronic Ratio (ACR)
  - But revise ACR by deleting rainbow trout data
- EPA may replace old toxicity data or add new data to existing data base
- Eliminate some old chronic data on rainbow trout
  - Results in lower Acute Chronic Ratio (ACR)
  - Results in less stringent chronic standard

EPA Work Plan Development

- Develop new National Chloride Guideline that is a function of hardness

Current Status

- Great Lakes Environmental Laboratory under contract to perform WET tests
- EPA developing final Work Plan
  - Iowa (IWPCA TAC members) requested review of final EPA Work Plan
- Lab work started May 9 (acclimating *C. dubia* to test conditions)
- EPA report on lab tests by October 1

Projected Iowa Standards

- Expected range of revised EPA guideline chloride standards:
  - Acute 600 – 850 mg/L (860 mg/L current)
  - Chronic 300 – 500 mg/L (230 mg/L current)
  - Could be more stringent at low hardness
  - May adopt a single value standard for average state water hardness rather than a hardness variable standard

Projected Iowa Standards

- Repeal the interim TDS standard
- New sulfate standards
  - Based on new Illinois standards
  - Hardness and chloride conc. dependent
  - 500 – 2,000 mg/L
- Adopt new standards by December 31, 2008

Impact of New Standards

- Most dischargers will comply with sulfate standards
- Many dischargers will not comply with chloride standards
  - Cities with hard water and ion exchange softeners
  - Discharges from industries that use salt or hydrochloric acid in production operations
  - Discharges to low flow streams

Potential Relief from Chloride Stds

- Site specific standards
- Economic hardship
- Dilution (standard is not technology based)

Other States

- Illinois new standards
  - Repeal old 1,000 mg/L TDS standard
  - Adopt new sulfate standard (hardness dependent)
  - Keep existing 500 mg/L chloride standard
- Missouri: Replace current standards with new Iowa standards
- Kansas: Currently no chloride standard, but may adopt Iowa standard

Other States

- Nebraska: Adopted 230 mg/L chloride standard a few years ago and has problems
- Wisconsin:
  - 760 mg/L chloride acute
  - 395 mg/L chloride chronic
  - Considering revising standards to less stringent based on new State of Wisconsin WET test data

EXHIBIT E

Assessment of Potential Environmental Effects of Modifying Water Quality Standards for Delta Ecoregion Streams within the Bayou Meto Basin Project

ASSESSMENT OF POTENTIAL ENVIRONMENTAL EFFECTS OF MODIFYING WATER QUALITY STANDARDS FOR DELTA ECOREGION STREAMS WITHIN THE BAYOU METO BASIN PROJECT

Introduction

The Bayou Meto Water Management District (BMWMD) is requesting a modification of the Arkansas Water Quality Standards (WQS) set forth in Regulation No. 2 of the Arkansas Pollution Control and Ecology Commission (APCEC). BMWMD requests modification of the chloride and sulfate criteria for forty-three water bodies in the Delta Ecoregion (Appendix 1) and presents this report in support of this modification request. BMWMD requests this WQS modification in order to operate an irrigation project in the Bayou Meto Basin that will pump water from the Arkansas River into a series of streams, tributaries, ditches, and canals in the Delta Ecoregion before delivering the water to individual farms. The levels of chlorides and sulfates in the Arkansas River are higher than the criteria for Delta Ecoregion streams but lower than federal standards for drinking water. Arkansas Department of Environmental Quality (ADEQ) has already stated that a change in mineral standards to allow this activity should not impair the designated uses of the Delta Ecoregion streams.

Designated uses for the Bayou Meto basin streams are propagation of fish and wildlife; recreation; and public, industrial, and agricultural water supply. Both the Arkansas River and Bayou Meto receiving streams currently support their designated uses and would continue to do so after implementation of the needed agricultural water supply component of the Bayou Meto Basin Project.

Background

Previous draft and final Environmental Impact Statements (EIS) for this project have assessed the effects of Arkansas River diversions on farmlands. Two of the main concerns of using Arkansas River water for irrigation were the accumulation of salt in the soil and mineral toxicity to plants. It was concluded in the EIS that Arkansas River water would be safe to use and of better overall quality than the alluvial well water that is currently being used to irrigate farmland. The EIS reported the Arkansas River water had mean concentrations of chlorides and sulfates that were higher than other project area streams; however the U.S. Environmental Protection Agency has not set formal limits for concentrations of chlorides or sulfates for the protection of aquatic life. As such, the EIS did not evaluate the impact of introducing higher levels of chlorides and sulfates from the Arkansas River on receiving streams and associated wetland communities in the Bayou Meto basin. Additional evaluations were performed after receipt of the conditional water quality certification to assess the potential effects of these higher chloride and sulfate concentrations on the project area's aquatic and wetland ecosystems.

Dr. Todd Tietjen, a Limnologist from Mississippi State University; Dr. Mickey Hietimeyer, a Bottomland Hardwood Ecologist, from the University of Missouri, Gaylord Memorial Laboratory; Dr. Jack Killgore, a Fishery Biologist from the U.S. Army Engineer Research and Development Center (ERDC), and Alan Kennedy, and Environmental Toxicologist, from ERDC were consulted and provided assessments using data derived from the ADEQ water quality sampling program and other existing databases.

Arkansas River water has mean Chloride (Cl) and Sulfate (SO_4) levels of 90 mg/L and 50 mg/L, respectively. The lowermost reach of Bayou Meto has mean Cl and SO_4 levels of 25-30 mg/L and 15-20 mg/L, respectively. The concentrations of Cl and SO_4 resulting from the introduction of Arkansas River water would be expected to fall between these two ranges.

Discussion

Aquatic Life

The concentrations for Cl and SO_4 are well below both the chronic and acute toxicity levels for fish. Chronic toxicity refers to toxicity involving a stimulus that lingers or continues for a relatively long period of time and can be measured in terms of reduced growth, reduced reproduction, etc., in addition to lethality (APHA, 1992). Chronic, long-term levels for freshwater organisms are 230 mg/L for Cl and >300 mg/L for SO_4 (as published in Kennedy, *et al.*, 2003). Acute toxicity refers to relatively short-term lethal or other effect, usually defined as occurring within 4 days for fish and invertebrates (APHA, 1992). Acute toxicity concentrations for larval fish is approximately 860 mg/L for Cl and >1,000 mg/L for SO_4 (as published in Kennedy, *et al.*, 2003).

Additionally, comparisons of fish species composition between the two basins were made using existing ERDC databases. Both of the basins are dominated by more tolerant fish species typical of lower Mississippi River tributary fish assemblages (*e.g.*, catfish, gizzard shad, minnows, suckers, and sunfishes). Every species of fish found in the Arkansas River basin occurs in the Bayou Meto Basin. As a group, darters were more common in Bayou Meto than in the Arkansas River Basin; this greater abundance is primarily due to the Bayou Meto Basin having more habitat preferred by the darters common to the Delta Ecoregion. Therefore the lower numbers of darters in the Arkansas River is reflective of poorer quality habitat and is not due to the higher levels of Cl or SO_4. The fisheries in the Bayou Meto basin would not be impacted by the relatively minor changes in Cl and SO_4 levels.

Aquatic freshwater invertebrates, such as the crustaceans (*Ceriodaphnia dubia* and *Hyalella azteca*) have been shown to be more sensitive to Cl or SO_4 than fathead minnows (*Pimephales promelas*) (Kennedy *et al.*, 2003; Kennedy *et al.*, 2004; Kennedy *et al.*, 2005; Soucek and Kennedy, 2005). However the anticipated levels of Cl and SO_4 resulting from the introduction of Arkansas River water into the Bayou Meto Basin are well below these published values and would not negatively impact invertebrates found in this Delta Ecoregion (Kennedy, pers. comm.; Soucek, 2007).

Wetland Ecosystem

Chloride levels found in the Arkansas River are only a small fraction of the levels that could cause adverse impacts to wetland vegetation. Freshwater wetland vegetation is sensitive to elevated salinity/chloride levels but not until levels of 5,000 – 8,000 mg/L (or 5 - 8 ppt). Considerable data indicate baldcypress and water tupelo are capable of enduring sustained flooding by water with salinity levels up to 7,000 -8,000 mg/L (McLeod *et al.*, 1996, Allen *et al.*, 1997, Conner *et al.*, 1997). Bottomland oaks are tolerant of salinity up to 5,000 – 6,000 mg/L

(Conner *et al.*, 1998). Consequently, chloride levels of 95 mg/L are only a very small fraction of levels that might cause negative vegetation responses or community changes.

Bottomland hardwood (BLH) wetlands have naturally high sulfur levels (Hupp *et al.*, 2005) due to an extremely large detrital decomposition base. The low-levels of SO_4 from introducing Arkansas River water into the Bayou Meto basin is minor compared to naturally occurring levels in BLH. Further, one of the most important values of forested wetlands is their ability to improve water quality by filtering or removing nutrients and pollutants from the water (Winger 1986). Forested wetland sediments are effective sinks for most metal and elemental contaminants (Kitchens *et al.*, 1975). This occurs because the forest floor detritus filters and transforms nutrients, removing the more toxic dissolved, inorganic ions and releases them as particulate organic material that is a food source for invertebrates and other higher trophic level consumers (*e.g.*, Brinson *et al.*, 1984). In total, the maximum expected SO_4 concentrations of 45 mg/L are not unusual or problematic in BLH systems.

Conclusions

The Bayou Meto project has been thoroughly studied and the minor increases in chloride and sulfate levels have been demonstrated not to have a detrimental impact to aquatic life, sediment biochemistry, or bottomland hardwood wetland communities. In addition, the implementation of the project would increase fish habitat in the receiving streams due to the removal of excess sediment, pooling effect of weirs, and increased minimum flows. Furthermore, the modification of current Water Quality Standards would not impair any existing uses nor would it preclude the attainment of any designated uses.

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Appendix 1. List of Streams and Their Proposed Amended Mineral Concentrations for the Bayou Meto Basin Project

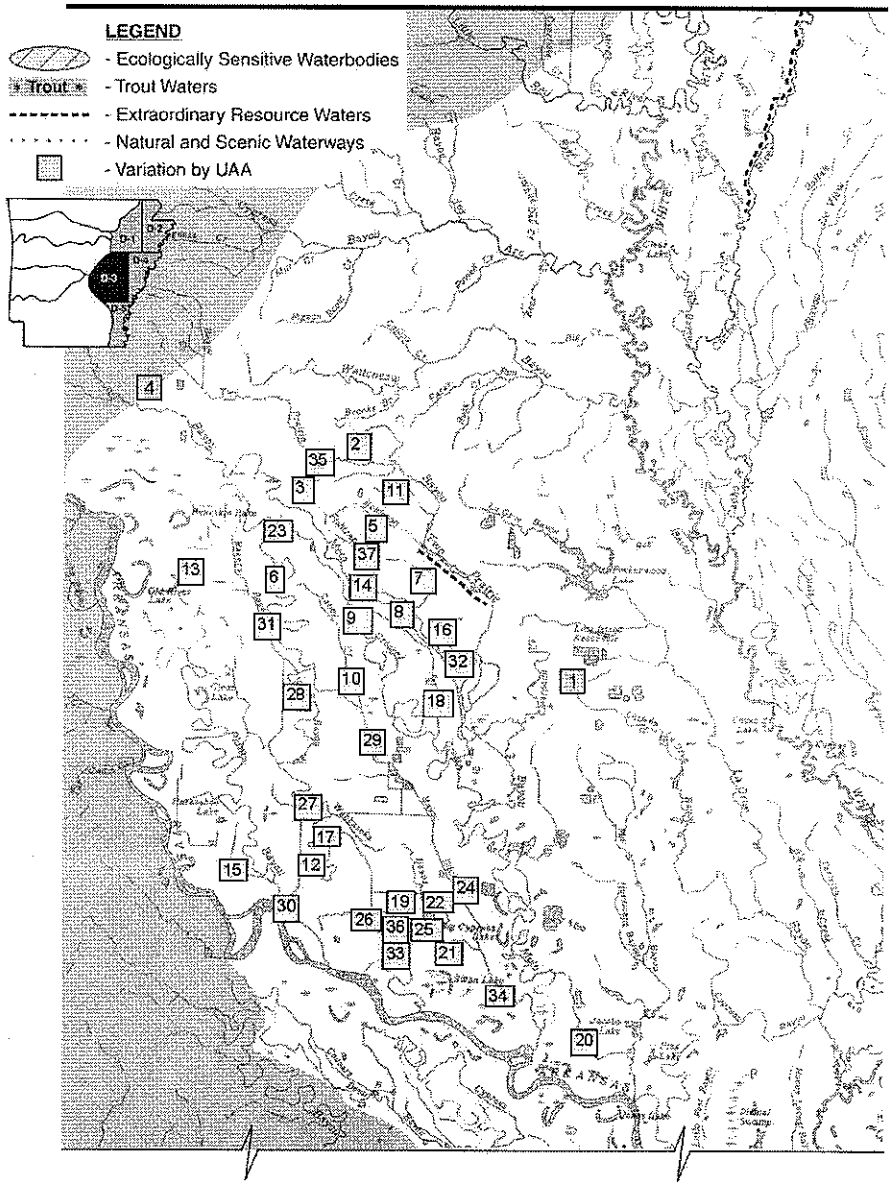
Pursuant to Section 2.306 of the APCEC Regulation No. 2, Section 3.4 of Regulation No. 8 and the Continuing Planning Process, Bayou Meto Water Management District is requesting the following modifications to Regulation No. 2; modify the dissolved mineral standards (sulfates from 37 mg/L to 45 mg/L and chlorides from 48 mg/L to 95 mg/L) for the reaches of the following streams that occur in the counties listed:

Waterbody Name	County/Counties Location	Plate D3 Identifier
1. Bakers Bayou	Lonoke	6
2. Bayou Meto*	Arkansas, Lonoke, Prairie	4
3. Bayou Two Prairie	Lonoke and Prairie	2
4. Bear Bayou	Jefferson	20
5. Big Ditch	Arkansas and Lonoke	8
6. Blue Point Ditch	Lonoke	7
7. Boggy Bayou	Jefferson	19
8. Bradley Slough	Jefferson	17
9. Brownsville Branch	Lonoke	35
10. Brushy Slough	Arkansas	23
11. Bubbling Slough	Arkansas	21
12. Buffalo Slough	Lonoke	32
13. Caney Creek	Lonoke	10
14. Caney Creek Ditch	Lonoke	10
15. Castor Bayou	Arkansas	26
16. Crooked Creek Ditch	Arkansas, Jefferson, and Lonoke	9
17. Cross Bayou	Arkansas	41
18. Dennis Slough	Lonoke	16
19. Eagle Branch	Lonoke	37
20. Fish Trap Slough	Lonoke	14
21. Five Forks Bayou	Arkansas and Jefferson	33
22. Flat Bayou	Jefferson	12
23. Flynn Slough	Lonoke	18
24. Government Cypress Slough	Arkansas	22
25. Hurricane Slough	Arkansas	24
26. Indian Bayou	Jefferson and Lonoke	28
27. Indian Bayou Ditch	Jefferson and Lonoke	31
28. Little Bayou Meto	Arkansas and Jefferson	34
29. Long Pond Slough	Arkansas	40
30. Main Ditch	Jefferson	15
31. Newton Bayou	Arkansas	25
32. Plum Bayou	Jefferson and Lonoke	30
33. Rickey Branch	Lonoke	2
34. Salt Bayou	Arkansas, Jefferson, and Lonoke	29

Waterbody Name	County/Counties Location	Plate D3 Identifier
35. Salt Bayou Ditch	Arkansas, Jefferson, and Lonoke	29
36. Shumaker Branch	Lonoke	11
37. Skinner Branch (Robinson Branch)	Lonoke	5
38. Snow Bayou	Lonoke	13
39. Tipton Ditch	Arkansas	38
40. Tupelo Bayou	Jefferson	36
41. Wabbaseka Bayou	Jefferson and Lonoke	27
42. West Bayou	Arkansas	39
43. White Oak Branch	Lonoke	3

* modify the dissolved mineral standards for Bayou Meto as follows: sulfates from 37 mg/L to 45 mg/L and chlorides from 64 mg/L to 95 mg/L

Plate D-3 (Delta)



From APECE Regulation No. 2.

GRI-94/0369

Topical Report

The GRI Freshwater STR Model and Computer Program: Overview, Validation, and Application

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Gas Research Institute

Environment and Safety Research Group
December 1994

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THE GRI FRESHWATER STR MODEL AND COMPUTER PROGRAM: OVERVIEW, VALIDATION, AND APPLICATION

TOPICAL REPORT

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Contract No. 5084-253-2160

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December 1994

REPORT DOCUMENTATION PAGE	1. REPORT NO. GRI-94/0369	2.	3. Recipient's Accession No.
4. Title and Subtitle The GRI Freshwater STR Model and Computer Program: Overview, Validation, and Application			5. Report Date December 1994 6.
7. Author(s) Joseph E. Tietge, David R. Mount, and David D. Gulley			8. Performing Organization Rept. No. 2950-006-255
9. Performing Organization Name and Address ENSR Consulting and Engineering 4413 W. Laporte Ave. Fort Collins, CO 80521			10. Project Task/Work Unit No. 11. Contract (C) or Grant (G) No. (C) 5091-253-2160 (G)
12. Sponsoring Organization Name and Address Gas Research Institute 8600 West Bryn Mawr Avenue Chicago, IL 60631			13. Type of Report & Period Covered Topical April 1992 - June 1994 14.
15. Supplementary Notes			

16. Abstract (Limit: 200 words)

The freshwater Salinity Toxicity Relationship (FW STR) models (Mount and Gulley, 1992) developed by GRI, predict the toxicity of seven common ions, Na^+, K^+, Ca^{++}, Mg^{++}, Cl^-, SO_4^{--}, and HCO_3^-, to three freshwater test organisms, *Ceriodaphnia dubia*, *Daphnia magna*, and *Pimephales promelas*. The toxicity predictions are based on empirically derived coefficients of toxicity which were developed by multivariate regression of data from over 3,000 toxicity determinations of different ion combinations. Stepwise logistic regression was used to determine the combination of variables and variable coefficients which best fit the data for each species. The STR model allows for an *a priori* prediction of acute toxicity of high salinity effluents based on concentrations of major ions. This report presents an overview of the original research to develop the STR models. Validation of the FW STR models is conducted by comparing model predictions to published data. In addition, six produced water samples from the field were tested and the acute toxicity results were compared to FW STR model predictions. The validation work supports the efficacy of the FW STR models and develops insight for application of the *GRI-FW STR Program*. This report also provides software operating instructions for the *GRI-FW STR Program*.

17. Document Analysis **a. Descriptors**

Effluents	*Ceriodaphnia dubia*	*Pimephales promelas*
Daphnia magna	Aquatic Toxicity	Produced waters
Salinity	Natural gas industry	Total Dissolved Solids

c. COSATI Field/Group

18. Availability Statement:	**19. Security Class (This Report)** Unclassified	**21. No. of Pages**
	20. Security Class (This Page) Unclassified	**22. Price**

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RESEARCH SUMMARY

Title:	Overview, Validation, and Application of the GRI Freshwater Salinity Toxicity Relationship Models and *GRI-FW STR Program*
Contractor:	ENSR Consulting and Engineering GRI Contract No. 5091-253-2160
Principal Investigators:	Joseph E. Tietge, David R. Mount, and David D. Gulley
Report Period:	June 1990 to May 1994
Objective:	The objective of this research was to develop a statistical relationship between concentrations of major ions and acute toxicity responses for three common freshwater organisms. These relationships, Freshwater Salinity Toxicity Relationships (FW STR), can be used to predict the acute toxicity of saline waters and aid in the management of regulated discharges from the gas industry.
Technical Perspective:	The discharge of produced water by the gas industry into surface waters, like effluent discharged by other industries, is generally regulated by the National Pollutant Discharge Elimination System (NPDES). The NPDES program has increased the use of aquatic toxicity tests (sometimes called "biomonitoring" tests) as a tool to monitor releases of potentially toxic materials. Aquatic toxicity limits, based on biomonitoring results, may be incorporated into discharge permit language. If the toxicity of an effluent exceeds the permit requirements, the permittee may need to take action to control effluent toxicity. Previous studies have demonstrated that high concentrations of the major ions found in produced waters (e.g., sodium, chloride) cause toxicity to freshwater organisms. Therefore, understanding the toxicity of major ions is critical to evaluating options for meeting NPDES permit toxicity limits. This study focused on developing an empirical ion toxicity database from which predictive ion toxicity models could be developed.
Technical Approach:	Laboratory toxicity tests using three common laboratory species (*Ceriodaphnia dubia*, *Daphnia magna*, and fathead minnows (*Pimephales promelas*)) were conducted on over 3,000 combinations of major ions (sodium, potassium, calcium, magnesium, chloride, sulfate, and bicarbonate). Test methods paralleled those recommended by USEPA for acute toxicity testing of effluents. Multivariate regression techniques were then used to relate survival of test organisms to specific major ion concentrations. Resultant species specific relationships, or Freshwater Salinity Toxicity Relationship (FW STR) models, are able to predict the

toxicity of high salinity effluents to the test organisms based on concentrations of the major ions.

Subsequent to the development of the FW STR models, a software program was developed which incorporates the FW STR models into a user friendly, DOS-based computer program, *GRI-FW STR Program*.

FW STR models were validated through a review of published toxicity data and by testing of six produced waters.

Results:

Laboratory toxicity data were successfully generated and incorporated into multi-variate logistic regression equations that predict the acute toxicity of major ions (sodium, potassium, calcium, magnesium, chloride, sulfate, and bicarbonate) and major ion combinations to *Ceriodaphnia dubia*, *Daphnia magna*, and fathead minnows (*Pimephales promelas*). Fit of the FW STR models to the toxicity data was quite high, generally accounting for 80 percent or more of the overall variance in survival.

The literature data demonstrate the general applicability of the model, since high salinity waters from various sources tested in different laboratories over several years had high agreement with the toxicity predictions of the FW STR models. The produced water testing, in addition to supporting the validity of the FW STR models, demonstrates the utility of the models when used in conjunction with TIE and mock effluent studies. This combination of techniques allows one to quantify the relative toxicity attributable to ions compared to other toxicants present in an effluent.

Project Implications:

The costs of complying with toxicity limitations in discharge permits drives the need for tools to understand and manage the toxicity of high salinity effluents. The FW STR models meet this need by providing a statistically derived quantitative relationship between ion concentration and toxic response. Combining these models with other techniques provides new approaches for quantifying the relative toxicity of the various chemicals in complex mixtures. The ability to quantify ion toxicity and discriminate between ion and non-ion toxicity will be of great value to permittees managing high salinity effluents. And, the development and distribution of the *GRI-FW STR Program* will go a long way toward relieving the pressure to meet NPDES biomonitoring requirements by making these research results readily accessible.

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1.0 EXECUTIVE SUMMARY

The freshwater Salinity Toxicity Relationship (FW STR) models (Mount and Gulley, 1992) developed by GRI, predict the toxicity of seven common ions, sodium (Na^+), potassium (K^+), calcium (Ca^{++}), magnesium (Mg^{++}), chloride (Cl^-), sulfate (SO_4^{--}), and bicarbonate (HCO_3^-), to three freshwater test organisms, *Ceriodaphnia dubia* (*C. dubia*), *Daphnia magna* (*D. magna*), and *Pimephales promelas* (*P. promelas*). The toxicity predictions are based on empirically derived coefficients of toxicity, which were developed by multivariate regression of data from over 3,000 toxicity determinations of different ion combinations. Stepwise logistic regression was used to determine the combination of variables and variable coefficients that best fit the data for each species. The resultant equations, or FW STR models, were incorporated into a user-friendly software program, *GRI FW-STR Program*. This software calculates and graphically displays the toxicity of a solution based on the concentrations of the seven major ions entered by the user.

The *GRI-FW STR Program* enables the user to make *a priori* predictions of the acute toxicity of high salinity effluents based on the concentrations of major ions. If actual acute toxicity data are available for a particular water, then the measured toxicity can be compared to the toxicity predicted by the *GRI-FW STR Program.* If there is little difference between the actual and predicted toxicity, then one can assume that observed toxicity is due primarily to the major ions. If the actual toxicity is substantially higher than the predicted toxicity, then one can assume that other toxicants are present in the effluent. This understanding afforded by the *GRI-FW STR Program* can be valuable in determining appropriate management strategies for produced waters discharged under existing effluent regulations. Accordingly, use of the *GRI-FW STR Program* should help reduce expenditures by operators with regulatory programs related to the surface discharge of produced waters. Furthermore, for processes where ionic composition can be modulated, the *GRI-FW STR Program* model can be used to simulate the toxicity of different operating conditions. Simulations can give plant managers and operators an understanding of the likely effects of process changes on biomonitoring results before the process changes are implemented.

The three predictive FW STR models were evaluated using toxicity data in the published literature and data collected from laboratory tests of produced waters from the field. The literature-based toxicity results that were used to evaluate the FW STR models were for a variety of water types, including: oil shale leachates, irrigation waters, and produced waters. Despite this diversity, the *GRI-FW STR Program* toxicity predictions agreed well with the actual toxicity results in 30 of 32 cases. The FW STR models predicted lower toxicity for the two samples which did not concur with the predictions, suggesting that the discrepancy was due to the presence of other toxicants. The close agreement between actual and predicted toxicity for high salinity waters of variable origin and composition supports the general validity of the models and suggest that the application of the models extends to high salinity waters in general and should not be limited to assessing the ion toxicity of produced waters alone.

The six produced water samples used to evaluate the models ranged in total salinity from 1.7 to 58.1 g/L. Initial acute toxicities of all six samples were compared to the respective FW STR model predictions for each species. Two of the produced waters were found to have acute toxicity substantially above that expected from ion concentrations alone. These samples were subjected to Phase I Toxicity Identification Evaluation (TIE) procedures and toxicities were reduced to those predicted by the FW STR model. Mock effluents, made with deionized water and salts to match the ionic concentrations of the original produced waters, were used to verify the results. Overall, accuracy of the model predictions were best for *C. dubia*, followed by *P. promelas*, and *D. magna*.

The *GRI-FW STR Program* can be used in combination with other toxicological techniques, such as TIE, mock effluent, and ion modification studies. The program, used in conjunction with TIE methodologies provides a powerful technique to aid in understanding the toxicity of samples where salinity toxicity is expected. As demonstrated in the produced water validation study, the base salinity-related toxicity of a sample can be quantified independently of other toxicants which are removable by Phase I TIE procedures. Salinity toxicity simulations and ion modification studies may also be a useful combination of techniques in the application of the FW STR models. This approach allows the permittee to propose changes in plant operation or effluent treatment and test the effect of the changes through model simulations. The efficacy of the changes can then be tested empirically in the laboratory with mock effluents modified to mimic the expected conditions.

This topical report presents an overview of the original research to develop the three species specific FW STR models, summarizes the validation task results, and provides software operating instructions for the *GRI-FW STR Program*.

2.0 FRESHWATER STR MODEL DEVELOPMENT

2.1 Background

Salinity in effluents can cause acute toxicity to freshwater organisms. Often, the toxicity of the water is due to an excess of common ions, which usually are not thought of as toxicants. Although standard toxicity identification and evaluation (TIE) procedures are effective at identifying toxicity due to total dissolved solids, they are not very effective at characterizing or removing ion-specific toxicity. Therefore, the disposal of high salinity effluents can be problematic for the producer of the water, since there is no well established method to identify and quantify ion toxicity. Several sources of high salinity effluents have been observed. These include many industries and processes such as:

- Produced water from oil and gas production
- Plastics
- Reverse osmosis processes
- Specialty chemical processes
- Mining
- Wastewater treatment

The objective of this research program was to develop an empirical understanding of the ion specific toxicity of seven common ions to three freshwater organisms commonly used in toxicity testing and bio-monitoring requirements. The species included two water fleas, *Ceriodaphnia dubia* (*C. dubia*) and *Daphnia magna* (*D. magna)*, and a small fish, the fathead minnow, *Pimephales promelas* (*P. promelas*). The common ions considered in this research include: Na^{+}, K^{+}, Mg^{++}, Ca^{++}, Cl^{-}, SO_4^{--}, and HCO_3^{-}. Over 3,000 toxicity determinations were made which led to the development of three species-specific statistical models known as FW STR Models. Each FW STR model is able to predict the acute toxicity of a solution based on ionic composition.

Once the statistical models were complete, the equations were incorporated into a user friendly DOS-based computer program, *GRI-FW STR Program*. This program facilitates the use the FW STR models, requiring the user to only enter the ionic composition of the sample of interest.

The FW STR models, as they are represented in the computer program, were then validated using a series of six produced water samples from the field. The results of this validation exercise are presented in Chapter 3.0 .

2.2 Approach

2.2.1 Test Procedures

C. dubia, *D. magna*, and fathead minnows (*Pimephales promelas*) used in testing were obtained from ENSR's in-house cultures at the Environmental Toxicology Laboratory, Fort Collins, Colorado. *C. dubia* and *D. magna* were less than 24 hours old at test initiation; fathead minnows were 1 to 7 days old. *C. dubia* were cultured in either moderately hard reconstituted water or 20 percent mineral water (USEPA 1989) at 25° C, while *D. magna* were cultured in hard reconstituted water (USEPA 1989) at 20° C. Both *C. dubia* and *D. magna* were fed a mixture of an incubated slurry of yeast, trout chow, and alfalfa (YTC; USEPA 1989) and the alga, *Selenastrum capricornutum*. Fathead minnow brood stock were cultured in City of Fort Collins tap water that was pre-treated with activated carbon to remove chlorine and related oxidants. Culture temperature was between 20° and 25° C; brood stock were fed frozen adult brine shrimp *ad libitum* twice daily. Eggs produced by spawning adults were removed from the spawning tanks when they reached the eyed stage; incubation was then completed in moderately hard reconstituted water at 25° C using moderate aeration to clean and aerate the eggs. Fathead minnow fry were fed brine shrimp nauplii (*Artemia* sp.) twice daily until they were used in testing.

Toxicity test methods used in developing the FW STR models followed the general guidance of USEPA (1985a; 1988b) for conducting whole effluent acute toxicity tests. All tests were conducted in 30-ml plastic beakers containing 10 ml of test solution. Five organisms were exposed in each chamber; replicate chambers were tested, but generally on different days to provide a more comprehensive assessment of measurement error. Tests were conducted under a 16h:8h light:dark photoperiod; *C. dubia* and fathead minnows were tested at 25° C, while *D. magna* were tested at 20° C. Dilution/control water for all tests was moderately hard reconstituted water (USEPA 1989).

Exposure periods were 48 hours for *C. dubia* and *D. magna* and 96 hours for fathead minnows. During initial experimentation with *C. dubia*, mortality observations were made after 2, 4, 6, 8, 12, 24, and 48 hours; these frequent observations were made to collect data for the survival time analysis. Initial data review indicated that survival time analysis was not efficacious, so mortality observations in subsequent tests were limited to 24-hour intervals conducted monthly on in-house cultures for each of the test species. Additional reference toxicant tests were conducted concurrently with each set of tests conducted as part of the FW STR model development.

Concentrations of major ions were determined analytically in all stock solutions used in testing. Calcium, sodium, magnesium, potassium, chloride, and sulfate concentrations were analyzed by Analytical Technologies, Inc., Fort Collins, Colorado. Cation concentrations were determined using inductively coupled plasma emission spectroscopy (ICP) according to USEPA Method 200.0. Chloride and sulfate concentrations were determined by anion chromatography using USEPA Method 300.0. Bicarbonate concentrations were determined indirectly by the measurement of phenolphthalein alkalinity according to American Public Health Association (APHA) methods (APHA 1989) and dividing the alkalinity by 0.82.

Measurements of pH and dissolved oxygen (DO) were made on selected test solutions during actual toxicity testing, primarily on solutions near the threshold for acute toxicity. Measurements of pH were completed using an Orion pH meter model SA250 (Boston, Massachusetts), while DO was measured using a Yellow Springs Instrument model 54 DO meter (Yellow Springs, Ohio). Measured DO concentrations were always within an acceptable range (>40 percent saturation; USEPA 1985a). Measured pH varied according to the components of the solution, but was generally between pH 7.5 and 9.0.

To calculate ion concentrations in actual test solutions, the concentrations in the applicable stock solutions were multiplied by the relative proportion of each solution in the test solution. Because the dilution water also contained small concentrations of each ion, these concentrations were then added to the calculated contributions from the stock solutions. The composition of dilution water used for this calculation is given in Table 2-1. As an example, Table 2-2 shows the calculation for a 25 percent solution (75 percent dilution water) of 10,000 mg/L NaCl (10,000 mg/L NaCl contains 3,932 mg/L Na^+ and 6,068 mg/L Cl^-).

Table 2-1

Nominal Concentrations of Major Ions in Moderately Hard Reconstituted Water

Ion	Concentration in Dilution Water (mg/L)
Sodium	26.3
Potassium	2.1
Calcium	14.0
Magnesium	12.0
Chloride	1.9
Sulfate	81.4
Bicarbonate	69.7

Table 2-2

Example Calculation of Ion Concentrations in Test Sample

Ion	Contribution from Stock Solution (mg/L)	Concentration in Dilution Water (mg/L)	Concentration in Test Solution (mg/L)
Sodium	983 (3,932 x 0.25)	26.3	1,009
Potassium	0	2.1	2.1
Calcium	0	14.0	14.0
Magnesium	0	12.0	12.0
Chloride	1,517 (6,068 x 0.25)	1.9	1,519
Sulfate	0	81.4	81.4
Bicarbonate	0	69.7	69.7

2.2.2 Statistical Analysis

Statistical analyses of the toxicity data were completed using step-wise logistic regressions performed with BMDP statistical software (Dixon 1985) and using the LR program. All analyses were performed on the University of Wyoming's VAX mainframe computers.

Logistic regression is a technique to relate binary observations (e.g., alive or dead) to one or more independent variables (in this case, ion concentrations). The completed regression predicts a probability of survival based on concentrations of ions showing relationships to survival. The linear logistic regression model used is of the form:

$$\text{logit}(P) = \ln(P/(1-P)) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 ... + \beta_n X_n$$

where P = proportion surviving
ß = regression coefficient
X = ion concentration
n = total number of significant terms in the model.

A fitted logistic regression line is typically an "S"-shaped curve with a maximum value approaching 1 (100 percent survival) and a minimum value approaching 0 (0 percent survival; Figure 2-1). Although Figure 2-1 represents the logistic regression in two dimensions, the actual regressions derived from this research exist in five or six dimensions, depending on the number of independent variables used in each model.

During FW STR development, several data transformations (e.g., log) and independent variable interactions (e.g., anion*anion interactions) were considered. Each potential model was evaluated using the following criteria: 1) each independent variable in the model must significantly improve the fit of the model to the data; 2) the model should maximize R^2 (maximize the amount of variance in the data that is explained by the model) and minimize the number of independent variables; and 3) the model should provide realistic predictions even when extrapolating outside the limits of the data used to generate the model. Thus, the goal was to create the simplest model that explained the most variance while making reasonable predictions for ion combinations outside those used in developing the model (e.g., total ion concentrations in excess of 10,000 mg/L).

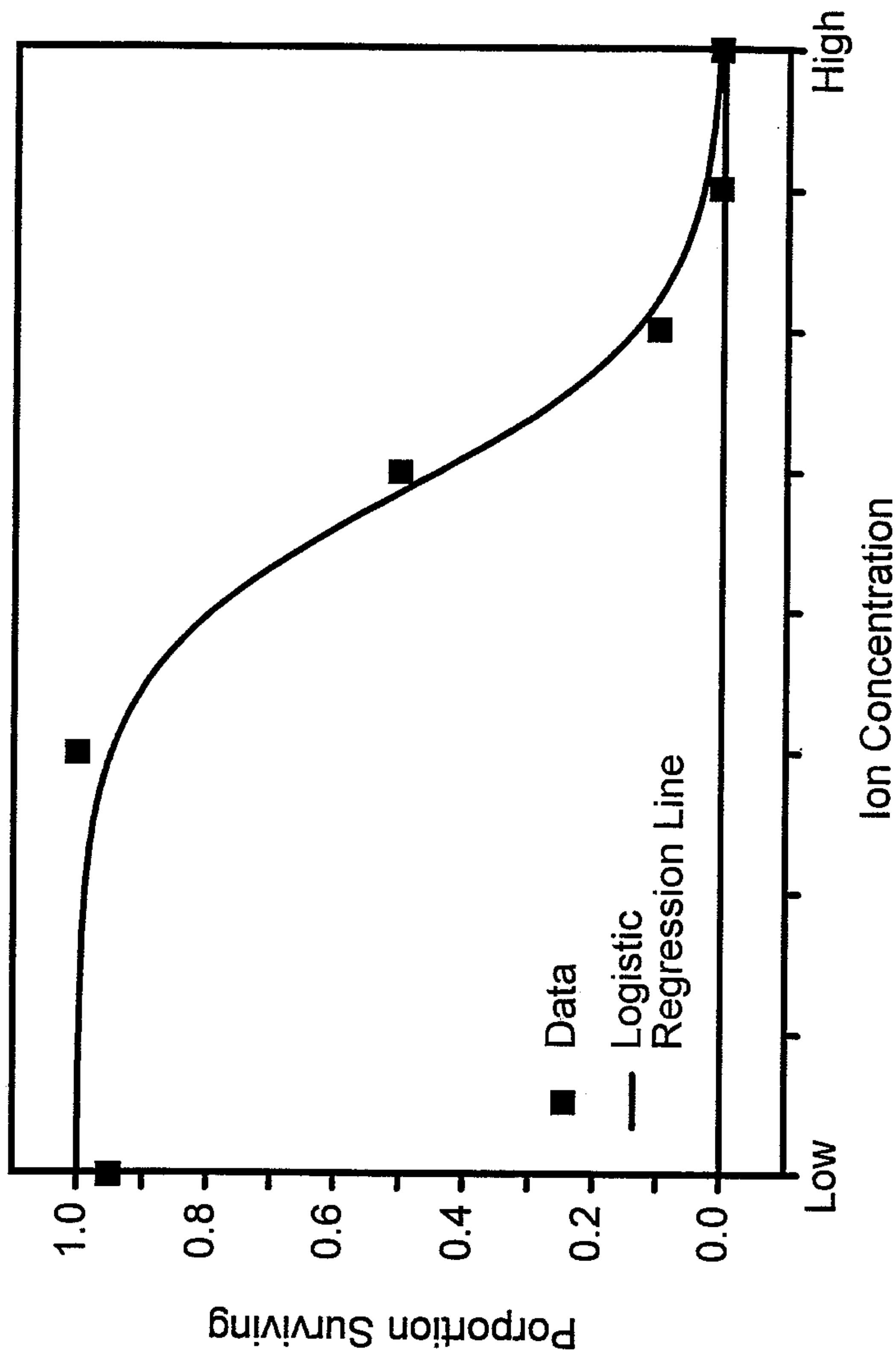


Figure 2-1. Typical Logistic Regression

2.3 Results and Discussion

2.3.1 Development of the FW STR Models

As described previously, the development of the FW STR equations was an iterative process in which a series of statistical models (regressions) was developed. Initially, data were generated for single ion pairs (e.g., sodium plus chloride, calcium plus chloride). Based on these data, an initial FW STR equation was developed. Next, additional toxicity data were generated using two cations with one anion (e.g., a sodium plus sulfate and magnesium plus sulfate mixture) and one cation with two anions (e.g., a sodium plus chloride and sodium plus sulfate mixture). This iterative approach of data collection and model building continued throughout the FW STR development. Thus, data collection determined the model structure, but any deficiencies (e.g., poor predictions for particular ion combinations) identified in each successive model determined the type of data to be generated and incorporated in the next model.

Throughout the project, over 3,000 toxicity determinations were made resulting in the development of 74 distinct models for consideration. The majority of these models were discarded, either because they were superseded by later models that incorporated larger data sets or were found to have undesirable characteristics (e.g., poor predictive ability). The general development of the FW STR equations can be illustrated using three representative models that depict the major advances in the design of the FW STR models. These three *C. dubia* models, called the single-salt, double-salt, and double-salt with NumCat models, correspond to the chronology of data collection and modifications of the FW STR model design.

2.3.2 Single-Salt Model

The single-salt model was developed from data for *C. dubia* tested with single salts only (e.g., sodium chloride). This regression equation fit the observed survival values very well, with an R^2 value of 0.95. This indicates that 95 percent of the variance in survival can be explained by ion concentration. Significant variables in this equation (in order of decreasing toxicity) were the concentrations of K^+, Mg^{++}, HCO_3^-, Cl^-, and SO_4^{--}. Na^+ and Ca^{++} were not significant variables.

2.3.3 Double-Salt Model

Following the single salt experiments and the development of the single-salt model, additional tests were conducted using ion combinations with two cations and one anion (e.g., sodium and calcium chloride) and one cation with two anions (e.g., sodium chloride and sulfate). When the single-salt model was used to predict survival for these more complex ion solutions, it was not nearly as effective.

In response to this finding, another logistic regression equation, the double-salt model, was developed using data from all tests conducted, including single and double salt tests. This model had the same significant variables as those of the single-salt model but gave better predictions for the ion combinations tested to date. The R^2 value for this model (0.84) was, however, lower than that for the initial development of the single-salt model. The lower R^2 value indicated that while the double-salt model was better at predicting survival for a variety of ion combinations, its overall fit to the full data set was not as good as the fit of the single-salt model to the single salt data.

A closer examination of the double salt data revealed that solutions containing two cations were generally less toxic than solutions containing only one cation. For example, a given concentration of NaCl is more toxic than a combination of NaCl plus $CaCl_2$, when compared on a mg/L chloride basis. Because of this phenomenon, the single-salt model tends to underestimate survival in salt solutions containing two cations and a single anion.

The double-salt model compensated for the lower toxicity of two cation solutions, but only partially. It simply split the difference between the two types of data and predicted a "mean" probability of survival somewhere between the observed single-salt and two-salt survival values. This poor fit by the double-salt model resulted from an inability to distinguish between solutions with one or two cations. Fitting the protective effect of two cations was particularly difficult for the regression equation, because it was receiving mixed signals from the data; for single-salt data, more cation was bad (either because it was directly toxic or was associated with a toxic anion), while in two-cation/single-anion solutions, the presence of cations could be protective. The regression was allowed to consider two-way interaction terms to account for the inaccuracies in the double-salt model, but these were not considered significant by the regression algorithm. A variable to describe the number of cations present in the solution was clearly required.

2.3.4 Creation of the NumCat Variable

To address the need for a variable describing the number of cations in solution, the NumCat variable was created. The NumCat variable was intended to simply represent the number of major cations in the solution. For the initial modeling trials, the NumCat variable was arbitrarily defined as the number of cations in the solution that (a) individually represented at least 10 percent of the total molar cation concentration and (b) were also present at a concentration greater than 100 mg/L. NumCat was then calculated for all test solutions and the new data were used to develop a new model containing NumCat. This new model was able to account for the number of cations in the solution and, therefore, was better able to predict survival for a variety of test solutions.

Although the initial applications of NumCat appeared very promising, its original definition (greater than 10 percent and 100 mg/L) had been arbitrary. To provide a stronger technical basis for NumCat, we evaluated many different criteria to calculate NumCat. We wanted the simplest formula that would allow NumCat to explain the greatest amount of variance in the survival data. To be counted in NumCat, a cation had to meet two criteria. The first was that the absolute concentration had to be over a specified limit; the second was that the relative molar concentration of the cation had to be greater than a specified percentage of the total molar concentration of cations in solution. Then, 20 different models were developed using all *C. dubia* data while defining NumCat using several different values for the two criteria. For the absolute criterion, values of 0, 100, 200, and 300 mg/L were used. For the relative concentration, 0, 5, 10, 15, 20, and 25 percent were used.

The resultant models were evaluated based on their R^2 values . The NumCat criteria values that produced the model with the highest R^2 (best fit of the model to the observed data) were the 15 percent with >100 mg/L (R^2 = 0.8559) and the 10 percent with >100 mg/L (R^2 = 0.8553) criteria. Given that the difference in R^2 was only 0.0006 (0.06 percent of the variance) and that extensive work had been done with the 10 percent and >100 mg/L criteria, these criteria values were selected in the final FW STR models.

Within the range of data used for FW STR model development, these NumCat criteria allowed NumCat to range from 0 to 3, depending upon the number of cations in solution. However, additional analyses showed that the main effect of NumCat on survival is exhibited when NumCat goes from 1 to 2. Increasing NumCat from 2 to 3 seemed to have little additional effect on the observed survival, even though it did increase the percent survival predicted by the FW STR equation. In addition, the overall database contained only a few *C. dubia* data for solutions containing three cations and none for *D. magna* and fathead minnows. Due to lack of apparent effect and lack of relevant data, the value of the NumCat variable was limited to a maximum of 2. For any solution with more than two cations meeting the NumCat criteria, the value of NumCat was reset to 2.

During experimentation with the NumCat variable, an analogous variable defining the number of major anions in the test solution was evaluated. This variable was not considered significant by the regression algorithm ($R^2<0.01$) and was not considered further.

2.3.5 Double-Salt Model with NumCat

Inclusion of the NumCat variable into the FW STR equations improved the predictive ability of the models by allowing it to distinguish between solutions with different numbers of major cations. Significant variables in this double-salt model with NumCat were the same five ions in the single-and double-salt models, plus NumCat, NumCat*chloride, NumCat*sulfate, and NumCat*potassium. These interactions indicate that sulfate, in addition to chloride, is less toxic when present in combination with two cations. Interestingly, it also appears that potassium has lower toxicity when present with another major cation.

2.3.6 Modeling of *D. magna* Data

Model development for *D. magna* proceeded along the same lines as those described for *C. dubia*. The initial model developed using only single-salt data fit those data very well (R^2 = 0.97) but was not as good at predicting survival for more complex ion mixtures. As was observed for *C. dubia*, solutions with multiple cations tended to be less toxic than comparable solutions with only one cation. As a result, when all *D. magna* data were analyzed, NumCat was again selected as a significant variable, both by itself and through its interactions with chloride, sulfate, and potassium. In fact, all significant terms in the *C. dubia* double-salt model with NumCat were also significant for *D. magna*.

2.3.7 Modeling of Fathead Minnow Data

The modeling results for fathead minnows were slightly different from those for *C. dubia* and *D. magna*. While both *C. dubia* and *D. magna* had shown different responses, depending on the number of cations present in the solution, responses of fathead minnows did not vary appreciably with the number of cations. Accordingly, the final models developed for fathead minnows included only the effects of potassium, magnesium, bicarbonate, chloride, and sulfate; neither NumCat nor any interaction terms were effective at explaining the remaining variation in the survival of fathead minnows. Consistent with results for *C. dubia* and *D. magna*, neither sodium nor calcium was selected as a significant variable.

2.3.8 Regression Equations

The final FW STR equation for each species survival model are presented in Table 2-3. Equations were developed for all species for both 24- and 48-hour exposures. In addition, a 96-hour exposure equation was developed for fathead minnows only. According to most acute test guidelines, acute tests using *C. dubia* and *D. magna* last 48 hours, while tests with fathead minnows and other fish species typically last 96 hours. Nonetheless, there are applications for which shorter exposure periods may be relevant.

To determine the predicted toxicity of any given solution, the concentration of each ion is multiplied by the corresponding coefficients in the model. The sum of these ion and coefficient products is referred to as logit survival (i.e., the logit transform of the predicted probability of survival; this is sometimes referred to as "log odds"). This logit survival value can easily be transformed into predicted probability of survival.

2.3.9 Species Sensitivity

Generally speaking, the larger a variable's model coefficient, the greater effect that variable has on survival. In addition, the sign of the variable's coefficient indicates the type of effect on survival. Negative coefficients indicate that as the variable increases, survival decreases and vice versa for positive coefficients. For example, in the 24-hour *C. dubia* model, the coefficients for K^+ and SO_4^{--} are both negative (Table 2-3), indicating that the response to an increased concentration of these two ions is a decrease in survival. However, the coefficient for K^+ is almost an order of magnitude greater than the coefficient for SO_4^{--}. This means that the survival response to K^+ has a greater negative slope, and that survival drops much faster for a given increase in the concentration of K^+ than for an equivalent increase in the concentration of SO_4^{--}.

When making comparisons between coefficients, one must be careful to compare only variables that have the same measurement units (e.g., mg/L). For example, the coefficient of NumCat cannot be compared to the K^+ coefficient as the units of their respective variables do not match. In the 24-hour *D. magna* model, the coefficient for NumCat is very large compared to the coefficient for K^+. However, the effect of K^+ is much greater as the K^+ coefficient is multiplied by a much larger number (e.g., 1,500 mg/L) than the NumCat coefficient (e.g., 0, 1, or 2).

The relative sensitivities of each species to each ion in the 48-hour models are shown in Figure 2-2. Table 2-4 summarizes the sensitivity of each species to each ion in the 48- and

96-hour models. All three species were most sensitive to the toxic effects of K^+ and least sensitive to the toxic effects of SO_4^{--}. *C. dubia* was the most sensitive to all ions except Mg^{++}, to which *D. magna* was the most sensitive. Fathead minnows were the most tolerant of salinity, especially with respect to SO_4^{--} and Cl^-. Survival for any given species decreased with the length of exposure (up to 96 hours). Survival predicted by 48- and 96-hour FW STR equations was always less than or equal to the survival predicted by the corresponding 24-hour equation.

Table 2-3

STR Coefficients for *Ceriodaphnia dubia*, *Daphnia magna*, and Fathead Minnows

	Ceriodaphnia dubia		*Daphnia magna*		Fathead minnow		
Variable	24-hour STR	48-hour STR	24-hour STR	48-hour STR	24-hour STR	48-hour STR	96-hour STR
Constant	9.11	8.83	5.91	5.83	5.69	5.51	4.70
K^+	-0.0320	-0.0299	-0.0200	-0.0185	-0.0108	-0.0113	-0.00987
Mg^{++}	-0.00594	-0.00668	-0.00450	-0.00510	-0.00225	-0.00316	-0.00327
Na^+	NS[1]	NS	NS	NS	NS	NS	NS
Ca^{++}	NS	NS	NS	NS	NS	NS	NS
Cl^-	-0.00706	-0.00813	-0.00330	-0.00395	-0.00117	-0.00125	-0.00120
SO_4^{--}	-0.00424	-0.00439	-0.000204	-0.00255	-0.000728	-0.000750	-0.000750
HCO_3^-	-0.00745	-0.00775	-0.00276	-0.00397	-0.00200	-0.00274	-0.00443
NumCat	0.0332	-0.446	-0.410	-0.511	NS	NS	NS
NumCat*K^+ interaction	0.00888	0.00870	0.00778	0.00677	NS	NS	NS
NumCat*Cl^- interaction	0.00196	0.00248	0.00110	0.00146	NS	NS	NS
NumCat*SO_4^{--} interaction	0.00121	0.00140	0.000998	0.00132	NS	NS	NS
Model R^2	86.1%	84.2%	81.2%	79.9%	83.2%	82.8%	76.7%

[1]NS indicates that this particular variable was not significant and was excluded from the model.

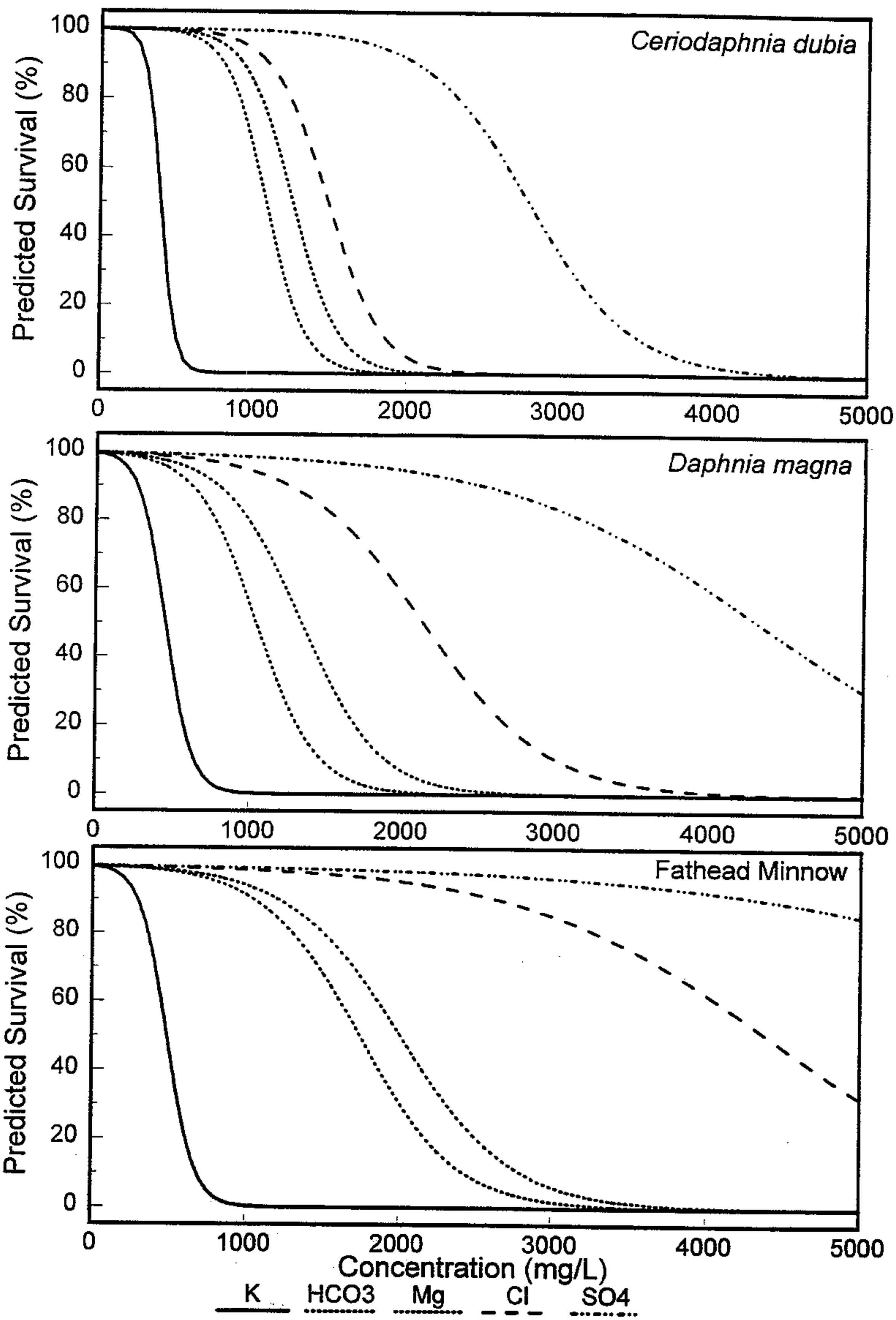


Figure 2-2. Comparitive Sensitivity of Three Test Species to Major Ions

Table 2-4

Comparative Sensitivities of the Three Species to the Ions That Affect Survival in the STR Model

Species	48-Hour Observation	96-Hour Observation
C. dubia	$K^+ > HCO_3^- > Mg^{++} > Cl^- > SO_4^{--}$	NA
D. magna	$K^+ > Mg^{++} > HCO_3^- > Cl^- > SO_4^{--}$	NA
P. promelas	$K^+ > Mg^{++} > HCO_3^- > Cl^- > SO_4^{--}$	$K^+ > HCO_3^- > Mg^{++} > Cl^- > SO_4^{--}$

3.0 FRESHWATER STR MODEL VALIDATION

3.1 Introduction

While each STR model was validated throughout its development by comparing the toxicity of high salinity waters to the model predictions, further review and testing were conducted to strengthen the validity of the model. For external validation of the FW STR models, published data on the toxicity of high salinity waters were reviewed. These data represent a diverse data set which is derived from many laboratories over time using various sources of high salinity waters. For additional internal validation of the FW STR models, six additional produced water samples were analyzed and tested independently of the model development. The objective of this aspect of the validation was to specifically assess the performance of the models when applied to produced waters and to provide insight for application purposes.

3.2 Comparison with Other Data

Several studies have been conducted that document the toxicity of high salinity waters to freshwater organisms. These studies, summarized in Table 3-1, include produced waters, irrigation waters, oil shale leachate waters, and other miscellaneous high salinity waters representing a range of salinity from 2,600 mg/L to 47,400 mg/L. This table includes the results of nineteen *C. dubia*, nine *D. magna*, and four *P. promelas* acute toxicity tests. The content of the table was limited to high salinity waters that produced LC_{50}s in acute toxicity tests.

The accuracy of the FW STR model toxicity predictions for *C. dubia* were very good. Most of the predictions were within the 95 percent confidence intervals of the actual toxicity determinations and any differences were relatively small in magnitude. The model did not under-predict toxicity for any of these samples, suggesting that toxicity of all nineteen samples could be explained by ion toxicity alone.

The accuracy of the FW STR model toxicity predictions for *D. magna* were also quite good. Six of the nine predictions were close to the actual toxicity. The model over predicted the toxicity of two irrigation water samples, *TJ Drain* and *Pintail Bay*, suggesting that other components in the complex mixture reduced toxicity. This observation is contrary to the conclusions of the authors of that study, who suggest that the toxicity was not due to salinity stress alone (Ingersoll et al., 1992). In another case, ***Oil Shale Leachate: C-b 9/81 combined,***

Table 3-1
Comparison of Toxicity Data of High Salinity Waters with FW STR Model Predictions.

Species	Water Source	Actual LC_{50} % (95%CI)	Predicted LC_{50} %	Na^+	K^+	Mg^{++}	Ca^{++}	Cl^-	$SO_4^{=}$	HCO_3^-	Reference
C. dubia	Produced Water: Big Sandy 10/91	7.1 (5-10)	8	10,000	27	320	1,300	19,000	0	140	O'Neil, et al. 1993
C. dubia	Produced Water: Mud Creek 8/91	35.4 (25-50)	34	2,400	3.1	30	93	3,600	0	520	O'Neil, et al. 1993
C. dubia	Produced Water: Black Warrior Basin 1	43.5	42	2,000	7	22	49	3,000	< 5	405	Mount, et al. 1993
C. dubia	Produced Water: Black Warrior Basin 4	4.7	6	15,000	290	320	1,800	26,000	< 5	49	Mount, et al. 1993
C. dubia	Produced Water: Black Warrior Basin 5	57.4	38	2,300	12	31	99	3,100	< 5	500	Mount, et al. 1993
C. dubia	Produced Water: Black Warrior Basin 6	10.9	9	9,000	450	240	1,100	15,000	< 5	122	Mount, et al. 1993
C. dubia	Produced Water: LIN 9/89	66 (50-75)	48	1,015	39	21	16	1,301	543	956	Boelter, et al. 1992
C. dubia	Produced Water: LIN 5/88	71 (50-100)	64	1,255	18	52	55	1,042	383	712	Boelter, Personal Communication
C. dubia	Produced Water: LIN 8/88	59 (50-100)	58	1,420	14	24	24	1,123	204	927	Boelter, Personal Communication
C. dubia	Produced Water: CSC 8/88	66 (50-100)	57	1,430	15	20	20	1,238	215	859	Boelter, Personal Communication
C. dubia	Produced Water: HBR 8/88	62 (25-100)	60	1,290	14	24	24	1,118	249	831	Boelter, Personal Communication

Table 3-1
(continued)

Species	Water Source	Actual LC_{50} % (95%CI)	Predicted LC_{50} %	Na^{+}	K^{+}	Mg^{++}	Ca^{++}	Cl^{-}	$SO_4^{=}$	HCO_3^{-}	Reference
C. dubia	Produced Water: IRY 8/88	71 (50-100)	71	1,205	15	37	37	1,006	322	599	Boelter, Personal Communication
C. dubia	Produced Water LIN 10/88	50 (25-100)	54	1,390	16	30	30	1,294	242	934	Boelter, Personal Communication
C. dubia	Produced Water: CSC 10/88	62 (25-100)	54	1,395	16	33	25	1,299	260	876	Boelter, Personal Communication
C. dubia	Produced Water: HBR 10/88	100 (>50)	81	845	9	42	51	777	282	604	Boelter, Personal Communication
C. dubia	Reconstituted Water	58 (50-75)	48	1,270	0	24	15	1,740	427	827	Boelter, et al. 1992
C. dubia	Produced Water	71.8	62	970	140	54	370	1,500	2,500	278	Fusik 1992
C. dubia	Produced Water	71 (50-100)	56	820	12	2.6	9	100	< 5	1,805	ENSR unpublished
C. dubia	Chemical Production	93 (50-100)	> 100	930	0	1.4	5	10	1,500	252	ENSR unpublished
D. magna	Irrigation Water: TJ Drain	35 (25-50)	16	4,940	69	511	379	10,400	3,020	450	Ingersoll, et al. 1992
D. magna	Irrigation Water: Pintail Bay	35 (25-50)	14	6,730	230	165	24	11,200	2,660	1,188	Ingersoll, et al. 1992
D. magna	Oil Shale Leachate: C-a 5/81 4.6 m	14	14	1,310	< 39	7,300	561	390	36,900	180	Meyer, et al. 1985
D. magna	Oil Shale Leachate: C-a 7/81 1.5 m	32	22	897	< 39	4,540	662	178	18,200	240	Meyer, et al. 1985

Table 3-1
(continued)

Species	Water Source	Actual LC_{50} % (95%CI)	Predicted LC_{50} %	Na^+	K^+	Mg^{++}	Ca^{++}	Cl^-	$SO_4^=$	HCO_3^-	Reference
D. magna	Oil Shale Leachate: C-a 7/81 4.6 m	13	12	1,240	< 39	8,310	1,120	390	31,100	370	Meyer, et al.. 1985
D. magna	Oil Shale Leachate: C-a 9/81 combined	14	22	1,380	< 39	4,290	521	142	17,900	370	Meyer, et al.. 1985
D. magna	Oil Shale Leachate: C-a 4/82 combined	13	12	1,700	< 39	8,680	461	284	36,000	240	Meyer, et al.. 1985
D. magna	Oil Shale Leachate: C-b 9/81 combined	66	> 100	1,260	< 39	267	481	< 35	3,890	180	Meyer, et al.. 1985
D. magna	Produced Water	91 (58- >100)	70	820	12	2.6	9	100	< 5	1,805	ENSR unpublished
P. promelas	Produced Water: Big Sandy 9/91	24.5 (20-40)	26	7,500	21	170	620	14,000	0	180	O'Neil, et al.. 1993
P. promelas	Produced Water: Mud Creek 8/91	46.5 (38-59)	70	2,400	3.1	30	93	3,600	0	520	O'Neil, et al.. 1993
P. promelas	Irrigation Water: TJ Drain	28 (19-39)	25	4,940	69	511	379	10,400	3,020	450	Ingersoll, et al.. 1992
P. promelas	Irrigation Water: Pintail Bay	26 (17-36)	20	6,730	230	165	24	11,200	2,660	1,188	Ingersoll, et al.. 1992

Note: LC_{50} values are percentages of origninal sample. Ion concentrations represent composition of original sample and are expressed as mg/L. Actual LC_{50} values include 95% confidence intervals for each determination in parentheses (when available).

the FW STR model under-predicted toxicity, suggesting that additional toxicants were present in the sample.

Although there are only four samples to compare, the accuracy of the FW STR model toxicity predictions for *P. promelas* were also quite good. Three of the predictions were within the 95 percent confidence intervals of the actual toxicity determinations and again the differences were minor. The FW STR model under-predicted the toxicity of one sample, *Produced Water: Mud Creek 8/91*, suggesting that additional toxicants were present in the sample.

In summary, the *GRI-FW STR Program* toxicity predictions agreed well with the actual toxicity results in 30 of 32 cases, indicating that salinity accounted for the toxicity of most of these samples. The model under-predicted the actual toxicity of two samples (*D magna, Oil shale leachate C-b 9/81 combined*; and *P. promelas*, Produced water from *Mud Creek 8/91*), suggesting that additional toxicants were present.

Several other samples are documented in the references in Table 3-1 which were non-toxic at 100 percent. The FW STR model toxicity predictions for the non-toxic samples agreed well with the actual toxicity test results.

Each type of high salinity water presented in Table 3-1 tended to have dissimilar composition. The salinity of the produced waters was dominated by Na^{+}, Cl^{-}, and HCO_3^{-} with 73 percent of the salinity due to NaCl and 17 percent due to HCO_3^{-}. This composition is consistent with the produced waters used in the validation tests (Section 3.3). The salinity of the irrigation water was dominated by Na^{+}, Cl^{-}, and SO_4^{--} with 79 percent of the salinity due to NaCl and 14 percent due to SO_4^{--}. The salinity of the oil shale leachate was dominated by SO_4^{--} and Mg^{++} with 73 percent due to SO_4^{--} and 16 percent due to Mg^{++}. Even with the apparent diversity in the composition of these high salinity waters, the *GRI-FW STR Program* toxicity predictions agreed well with the actual toxicities. This close agreement between actual and predicted toxicity for the high salinity waters of variable origin and composition supports the general validity of the model and suggests that the application of the model extends to high salinity waters in general.

3.3 Produced Water Validation: Materials and Methods

3.3.1 Rationale

Validation of the FW STR models using produced waters from the field was planned to test the validity of the model and to help develop the application of the program. To achieve this, produced waters were tested to determine initial toxicity. The samples were then analyzed for major ion content and FW STR toxicity predictions were made. The actual initial toxicity of the sample was compared to the predicted toxicity. If the predicted toxicity was the same or higher than the initial toxicity, then it was concluded that ion toxicity was responsible for most or all of the toxicity of the sample. If, however, the toxicity of the sample was higher than the predicted toxicity, then it was concluded that additional toxicants were present in the sample. If additional toxicants were present, then the sample was subjected to Phase I TIE procedures in an attempt to characterize the toxicant and quantify the amount of toxicity that the non-ion components contributed to the sample. Finally, mock effluents (i.e., samples made to match the ionic composition of the original produced water using deionized water and reagent grade salts) were subject to toxicity testing to confirm the results.

3.3.2 Sample Origin

Six different produced water samples were collected at a variety of sites in the U.S. and shipped overnight in coolers to ENSR's Toxicology Laboratory in Fort Collins, CO. The six samples will be referred to as PW-1 through PW-6.

3.3.3 Chemistry

Subsamples of each produced water were analyzed for the seven major ions considered in the FW STR models: Na^+, K^+, Ca^{++}, Mg^{++}, Cl^-, SO_4^{--}, and HCO_3^-. The cations were analyzed by inductively coupled plasma atomic emission spectroscopy (Method 6010; U.S. EPA, 1986) and sulfate was determined titrametrically (Method 375.4; U.S. EPA, 1986)(ATI Laboratories, Fort Collins, CO). Chloride analysis was either conducted by anion chromatography (Colorado State University, Fort Collins, CO) or by titration (ENSR, Fort Collins, CO). Alkalinity was determined by sulfuric acid titration (Method 2320; American Public Health Association, 1989) (ENSR). Bicarbonate was calculated from the alkalinity number by dividing the alkalinity by 0.82. Salinities were calculated as the total concentration of anions and cations considered in the FW STR models.

3.3.4 Toxicity Testing and TIE Procedures

All six samples were tested for initial acute toxicity with all three species upon arrival at the laboratory. Organisms were obtained from ENSR's in-house cultures. Toxicity tests were conducted at 25° C for *C. dubia* and *P. promelas*, and at 20° C for *D. magna*. Ten ml of test solution was used in each test chamber. Test methods followed U.S. EPA guidelines for acute toxicity tests for freshwater organisms (1993).

TIE studies (US EPA, 1991) were conducted on PW-1 and PW-6. TIE studies employ procedures for systematically identifying the causative toxicants present in effluents and other waters. Phase I Toxicity Characterization procedures involve subjecting effluent solutions to a series of physical/chemical manipulations, each of which has been shown to be effective at removing specific toxicants. The Phase I Toxicity Characterization manipulations used in this study were:

- Baseline whole effluent tests,
- pH 3 and 11 adjustment tests,
- Filtration tests at ambient and pH 3 and 11,
- Aeration tests at ambient and pH 3 and 11,
- Solid phase extraction (SPE) with C_{18} at ambient pH, pH 3, and pH 11,
- Oxidant reduction tests,
- EDTA chelation tests, and
- Graduated pH tests.

After each manipulation, toxicity tests were conducted with the respective aliquots. The toxicity data from each manipulated aliquot were interpreted based on the baseline toxicity determined for the unaltered effluent.

The general characteristics of the toxic components are defined through Phase I toxicity characterization manipulations and toxicity testing. With this data, Phase II toxicity identification studies can be conducted to further characterize the toxicants. Phase II procedures generally entail fractionation and concentration procedures and are selected based on the Phase I results. Limited Phase II TIE procedures were used (U.S. EPA, 1989) on PW-1 and PW-6. SPE elution with a graded methanol series was used on both PW-1 and PW-6. Centrifugation was used on PW-1 only.

Mock produced water samples were made for all six produced waters. These samples were prepared with deionized water and reagent grade salts to match the concentrations of the seven ions considered in the FW STR model. If the initial LC_{50} of any of the produced water samples was above 50 percent for any of the three species, then the mock effluent was made with double the concentrations of the salts present. This allowed for testing to be conducted above the total ion concentrations present in the 100 percent produced waters. Each mock sample was tested with all three species as an independent determination of the accuracy of the FW STR toxicity predictions and to verify that the toxicity of the ions were sufficient to explain some or all of the toxicity associated with each produced water sample.

3.3.5 Data Analysis

The LC_{50} and 95 percent confidence interval calculations for the toxicity results were conducted using the binomial distribution method or the probit method, depending on the nature of each data set (US EPA, 1993). When the analytical data were returned, the data were entered into the *GRI-FW STR Program*, and predictions of acute toxicity were generated. While the models have the ability to predict toxicity at different times for each species, this validation focussed only on the end-of-test median survival (LC_{50}) prediction for each species (48 hours for *C. dubia* and *D. magna*, and 96 hours for *P. promelas*). The acute toxicity predictions based on the ionic composition of the samples were then compared to the initial toxicity. If the initial toxicity was similar to or less than the model prediction, then no further testing was conducted. However, if the initial toxicity was substantially higher than predicted by the model (as indicated by a lower LC_{50}), and the FW STR prediction fell outside of the 95 percent confidence interval surrounding the initial LC_{50}, then the sample was subjected to TIE manipulations to determine if an additional toxicant(s) may have been contributing to the overall toxicity of the sample.

3.4 Produced Water Validation: Results

The ionic composition, salinity, and charge balance of each sample are presented in Table 3-2. A summary of the toxicity testing results for each PW follows.

3.4.1 Produced Water #1

The initial LC_{50}s of PW-1 for *C. dubia*, *D. magna*, and *P. promelas* were 0.71, 1.9, and 7.3 percent of the whole produced water (Table 3-3). Analytical data indicated a total salinity of 34,452 mg/L, which was predominantly (95 percent) sodium and chloride ions (Table 3-2). Total ammonia was present at 49.6 mg/L. No ammonia toxicity was expected for *C. dubia* or *D. magna* at the pH of the test water. Toxicity to *P. promelas* was expected at concentrations above 43 percent. The FW STR models predicted the LC_{50}s of PW-1 for *C. dubia*, *D. magna*, and *P. promelas* to be 7, 10, and 16 percent, respectively, two to ten times less toxic than the initial determinations. This difference was considered substantial, so the sample was

Table 3-2

Ionic Composition, Total Salinity, and Charge Imbalance of the Produced Waters Tested in the Validation of the Freshwater STR Model

Ion	PW-1	PW-2	PW-3	PW-4	PW-5	PW-6
Na^{+}	12,721	24,000	770	2,000	430	1,900
Ca^{++}	638	730	7	83	7	210
Mg^{++}	524	260	0.8	21	1.2	28
K^{+}	114	230	3	15	3	32
Cl^{-}	20,000	32,000	119	722	70.7	829
HCO_3^{-}	415	908	1,862	3,171	1,171	2,695
SO_4^{--}	<40	<10	<10	<10	<10	<10
Total Salinity	34,452	58,138	2,772	6,022	1,693	5,704
Charge Imbalance	10	19	0	25	-11	35

Note: All concentration values are mg/L. Charge imbalance is expressed as percent with positive numbers indicating cation excess and negative numbers indicating anion excess.

Table 3-3

Comparison of Actual Initial Toxicity, the STR Model Toxicity Predictions, and the Actual Mock Toxicity for All Six Produced Water Samples.

	Ceriodaphnia dubia			*Daphnia magna*			*Pimephales promelas*		
SAMPLE	INITIAL	PREDICTED	MOCK	INITIAL	PREDICTED	MOCK	INITIAL	PREDICTED	MOCK
PW-1	0.71	7	8.0	1.9	10	21.2	7.3	16	18.7
PW-2	3.9	4	5.3	5.0	6	13.4	6.3	10	13.4
PW-3	71	56	56	>100	69	129	71	56	106
PW-4	31	29	33	82	36	109	35	32	33
PW-5	>100	88	117	>100	>100	>166	71	88	166
PW-6	2	32	38	1	40	>100	35	36	58

Note: All values are LC_{50} percentages based on the original sample. Mock values above 100 percent indicate that the mock was made and tested at a higher ionic concentration than the original produced water.

submitted to Phase I TIE manipulations and tested with *C. dubia*, the most sensitive of the three species to this produced water sample.

The results of the Phase I TIE manipulations indicated that the non-salinity related toxicity was reduced by filtration at acidic, ambient, and basic conditions, and by aeration at pH 11. Acidic, ambient, and basic filtration increased the LC_{50}s to 6.8, 5.3, and 6.8 percent respectively. The independent effect of SPE could not be determined in the first round of TIE manipulations, since SPE manipulations are normally conducted with a filtered sample to prevent plugging of the C_{18} column.

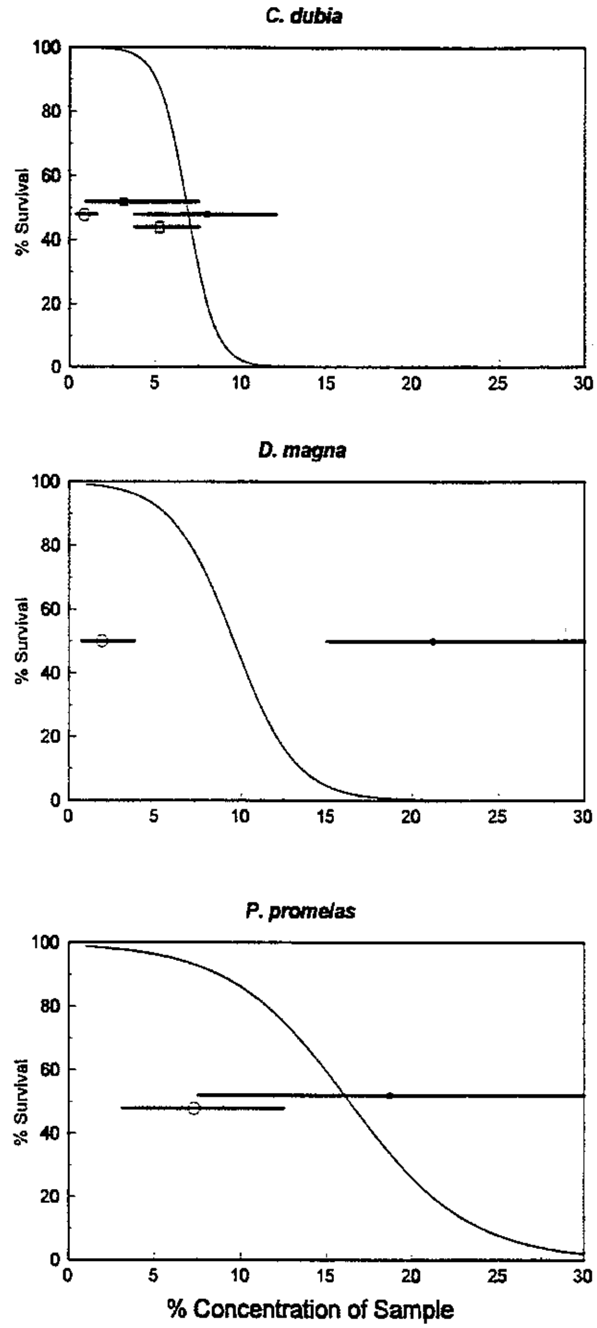
To further characterize the source of toxicity, an unfiltered sample was centrifuged at 2,000 g for 5 minutes and subjected to SPE without filtration. The C_{18} column was subsequently eluted with a graded methanol series to determine if any toxic organic material could be recovered from the column. The supernatant from the centrifugation step, the post-SPE sample, and the SPE methanol eluate were tested for toxicity. Centrifugation alone reduced toxicity to an LC_{50} of 3.2 percent. SPE of the centrifuged sample reduced toxicity further to an LC_{50} of 5.3 percent. However, methanol elutions of the C_{18} were non-toxic, indicating that the SPE was acting as a filter only and that the toxicants were probably not organic compounds sorbed to the C_{18}. Based on these results, the additive toxicant was determined to be an unidentified filterable and centrifugable non-organic compound.

To isolate and verify toxicity associated with ionic composition of the sample, a mock produced water made to the same ionic composition as determined for the original sample was tested. The model prediction fell within the 95 percent confidence intervals surrounding the mock LC_{50}s for *C. dubia* and *P. promelas*, supporting the interpretation that the toxicity of the sample to these species was due to salinity and the filterable compound. The LC_{50} for *D. magna* did not concur as well with the FW STR model prediction.

The FW STR model prediction, the initial LC_{50}, post-centrifuge LC_{50}, post-ambient filtration LC_{50}, and mock LC_{50} are plotted in Figure 3-1 for *C. dubia*. FW STR model predictions and initial and mock LC_{50}s are plotted for *D. magna* and *P. promelas*.

3.4.2 Produced Water #2

The initial LC_{50}s of PW-2 for *C. dubia*, *D. magna*, and *P. promelas* were 3.9, 5.0, and 6.3 percent respectively (Table 3-3). Analytical data indicated a total salinity of 58,138 mg/L, which was predominantly (96 percent) sodium and chloride (Table 3-2). Total ammonia was present at 84.3 mg/L. Ammonia toxicity was expected for *C. dubia*, *D. magna*, and *P. promelas* at 88, 77, and 18 percent respectively. However, since the LC_{50}s were below 10



Note: The STR model prediction of acute toxicity (solid line curve) is based on the ionic composition of PW-1. LC_{50} values are plotted as symbols. Initial toxicity (open circles) and mock toxicity (solid circles) are plotted for all three species. For *C. dubia*, post-centrifugation toxicity (solid square) and post-ambient filtration toxicity (open square) are also plotted. Horizontal bars indicate the 95% confidence intervals for each LC_{50} determination, based on binomial distribution or probit models as appropriate. LC_{50} values and confidence intervals were offset slightly for graphical clarity.

Figure 3-1. Predicted and Observed Acute Toxicity of Sample PW-1.

percent, ammonia toxicity was not considered likely. The FW STR models predicted the LC_{50}s of PW-2 for *C. dubia*, *D. magna*, and *P. promelas* to be 4, 6, and 10 percent, respectively. The FW STR model predictions fell within the 95 percent confidence intervals of the initial LC_{50}s for all three species. The differences between initial and predicted toxicity were not considered substantial, so the sample was not submitted to Phase I TIE manipulations.

A mock produced water made to the same ionic composition as determined for the original sample was tested. The model prediction fell within the 95 percent confidence intervals surrounding the mock LC_{50} for *C. dubia*. The mock LC_{50}s for *D. magna* and *P. promelas* did not concur as well with the FW STR model prediction, though the absolute differences were not large.

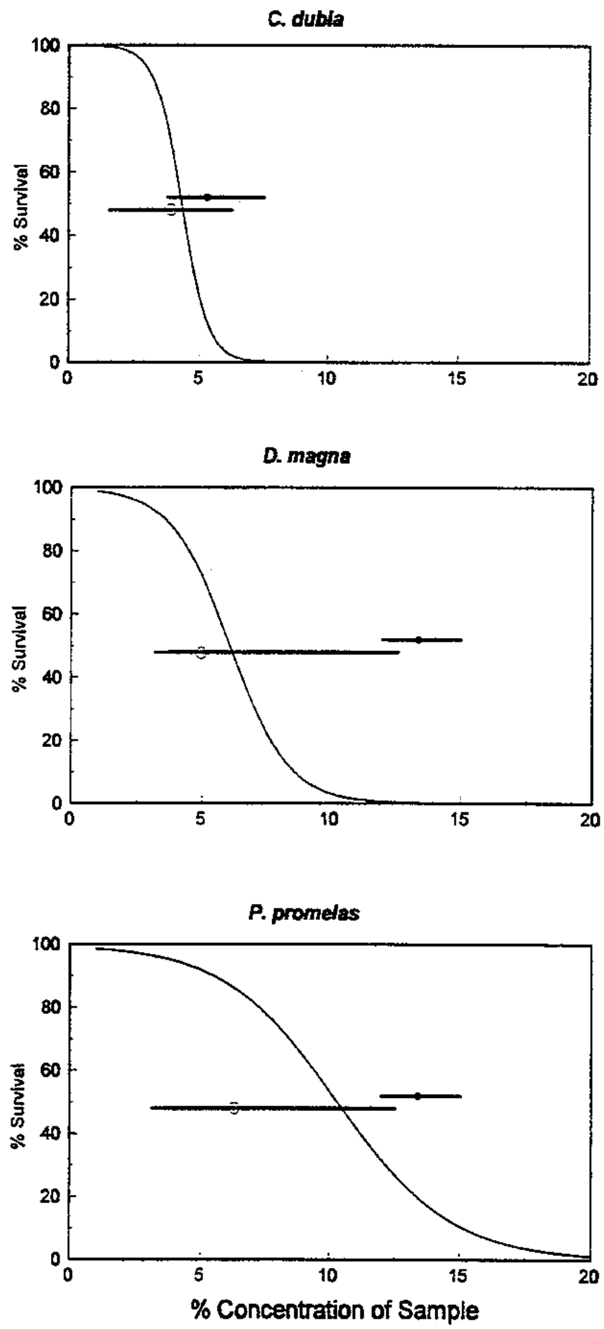
The FW STR model prediction, the initial LC_{50}, and mock LC_{50} are plotted in Figure 3-2 for each species.

3.4.3 Produced Water #3

The initial LC_{50}s of PW-3 for *C. dubia*, *D. magna*, and *P. promelas* were 71, >100, and 71 percent, respectively (Table 3-3). Analytical data indicated a total salinity of 2,771.8 mg/L, which was predominantly (95 percent) sodium and bicarbonate ions (Table 3-2). Total ammonia was present at 1 mg/L. No ammonia toxicity was expected for all three species. The FW STR model predicted the LC_{50}s of PW-3 for *C. dubia*, *D. magna*, and *P. promelas* to be 55, 69, and 56 percent, respectively. The FW STR model predictions fell within the 95 percent confidence intervals of the initial LC_{50}s for *C. dubia* and *P. promelas*. An initial LC_{50} was not determinable for *D. magna* due to the low toxicity of the sample. Since the FW STR model predicted more toxicity than was observed for all three species, the sample was not submitted to Phase I TIE manipulations.

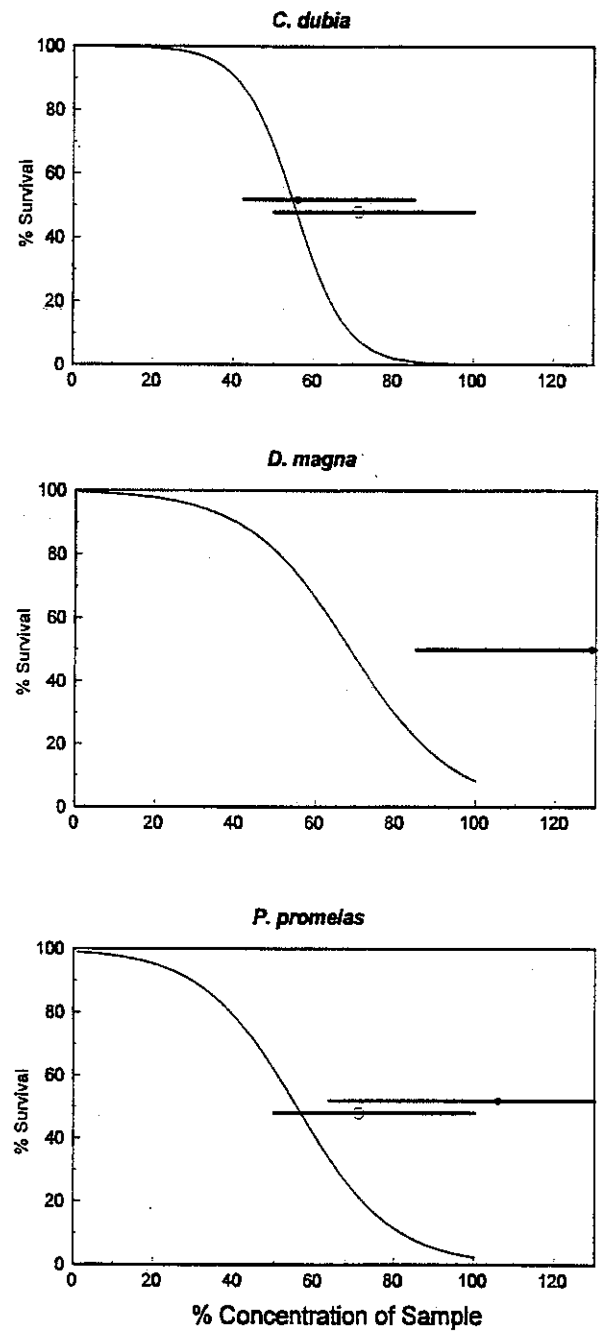
A mock produced water made to the same ionic composition as determined for the original sample was tested. The FW STR model prediction fell within the 95 percent confidence intervals surrounding the mock LC_{50} for *C. dubia*. The LC_{50}s for *D. magna* and *P. promelas* did not concur as well with the FW STR model predictions.

The FW STR model prediction, the initial LC_{50}, and mock LC_{50} are plotted in Figure 3-3 for each species.



Note: The STR model prediction of acute toxicity (solid line curve) is based on the ionic composition of sample PW-2. LC_{50} values are plotted as symbols. Initial toxicity (open circles) and mock toxicity (solid circles) are plotted for all three species. Horizontal bars indicate the 95% confidence intervals for each LC_{50} determination, based on binomial distribution or probit models as appropriate. LC_{50} values and confidence intervals were offset slightly for graphical clarity.

Figure 3-2. Predicted and Observed Acute Toxicity of Sample PW-2.



Note: The STR model prediction of acute toxicity (solid line curve) is based on the ionic composition of sample PW-3. LC_{50} values are plotted as symbols. Initial toxicity (open circles) and mock toxicity (solid circles) are plotted for all three species, except that the initial toxicity for *D. magna* was not determinable (ie.LC_{50} >100%). Horizontal bars indicate the 95% confidence intervals for each LC_{50} determination, based on binomial distribution or probit models as appropriate. LC_{50} values and confidence intervals were offset slightly for graphical clarity.

Figure 3-3. Predicted and Observed Acute Toxicity of Sample PW-3.

3.4.4 Produced Water #4

The initial LC_{50}s of PW-4 for *C. dubia*, *D. magna*, and *P. promelas* were 31, 82, and 35 percent, respectively (Table 3-3). Analytical data indicated a total salinity of 6,021.7 mg/L, which was predominantly (86 percent) sodium and bicarbonate ions (Table 3-2). Total ammonia was present at 4.5 mg/L. No ammonia toxicity was expected for *C. dubia* or *D. magna*. Toxicity from ammonia was expected for *P. promelas* at 44 percent. The FW STR model predicted the LC_{50}s of PW-4 for *C. dubia*, *D. magna*, and *P. promelas* to be 29, 36, and 32 percent, respectively. The FW STR model predictions fell within the 95 percent confidence intervals of the initial LC_{50}s for all three species. Since the FW STR model predicted more toxicity than was observed for all three species, the sample was not submitted to Phase I TIE manipulations. Furthermore, since the LC_{50} to *P. promelas* was 35 percent and the FW STR LC_{50} prediction was 32 percent, ammonia toxicity was considered unlikely.

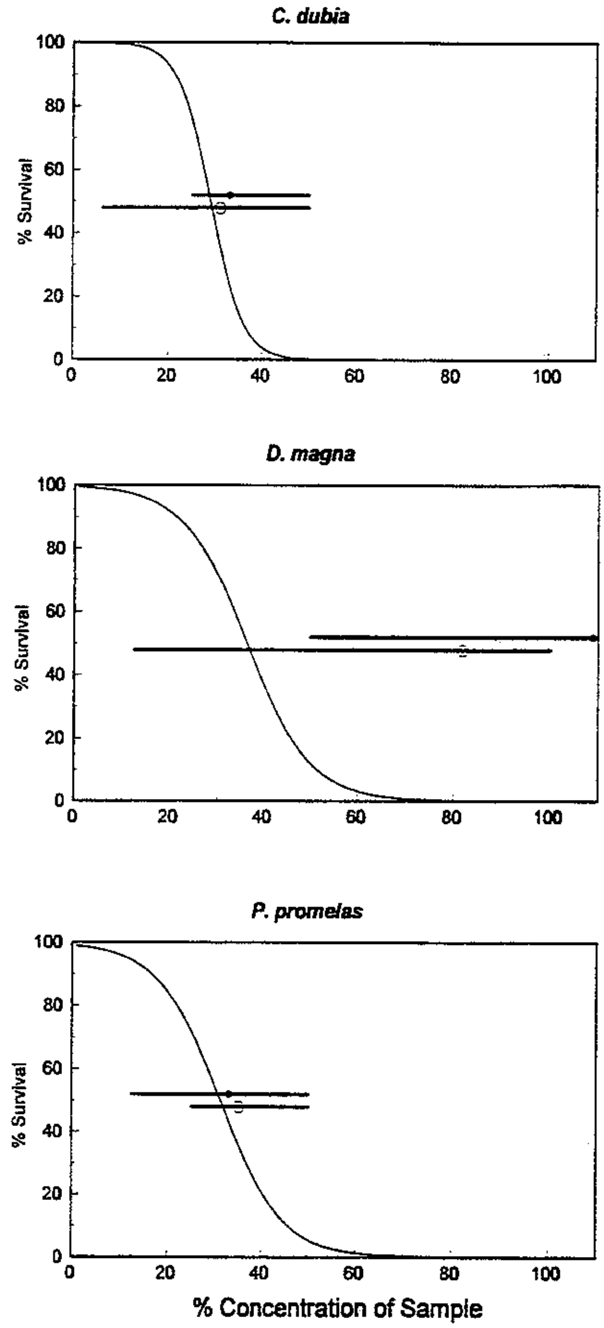
A mock produced water made to the same ionic composition as determined for the original sample was tested. The model prediction fell within the 95 percent confidence intervals surrounding the mock LC_{50}s for *C. dubia* and *P. promelas*. The mock LC_{50} for *D. magna* did not concur as well with the FW STR model prediction.

The FW STR model prediction, the initial LC_{50}, and mock LC_{50} are plotted in Figure 3-4 for each species.

3.4.5 Produced Water #5

The initial LC_{50}s of PW-3 for *C. dubia*, *D. magna*, and *P. promelas* were >100, >100, and 71 percent, respectively (Table 3-3). Analytical data indicated a total salinity of 1,692.9 mg/L, which was predominantly (95 percent) sodium and bicarbonate ions (Table 3-2). Total ammonia was present at 0.5 mg/L. No ammonia toxicity was expected for all three species. The FW STR model predicted the LC_{50}s of PW-5 for *C. dubia*, *D. magna*, and *P. promelas* to be 88, >100, and 88 percent, respectively. The FW STR model predictions fell within the 95 percent confidence intervals of the initial LC_{50} for *P. promelas*. Initial LC_{50}s were not determinable for *C. dubia* and *D. magna*. Since the FW STR model predicted more toxicity than was observed for the two invertebrate species and was similar to the toxicity observed for *P. promelas*, the sample was not submitted to Phase I TIE manipulations.

A mock produced water, made at double the ionic concentrations present in the original sample, was tested. The model prediction fell within the 95 percent confidence intervals surrounding the mock LC_{50}s for *C. dubia* and *P. promelas* . The mock LC_{50} for *D. magna* was >166 percent and did not concur as well with the FW STR model prediction.



Note: The STR model prediction of acute toxicity (solid line curve) is based on the ionic composition of sample PW-4. LC_{50} values are plotted as symbols. Initial toxicity (open circles) and mock toxicity (solid circles) are plotted for all three species. Horizontal bars indicate the 95% confidence intervals for each LC_{50} determination, based on binomial distribution or probit models as appropriate. LC_{50} values and confidence intervals were offset slightly for graphical clarity.

Figure 3-4. Predicted and Observed Acute Toxicity of Sample PW-4.

The FW STR model prediction, the initial LC_{50}, and mock LC_{50} are plotted in Figure 3-5 for each species.

3.4.6 Produced Water #6

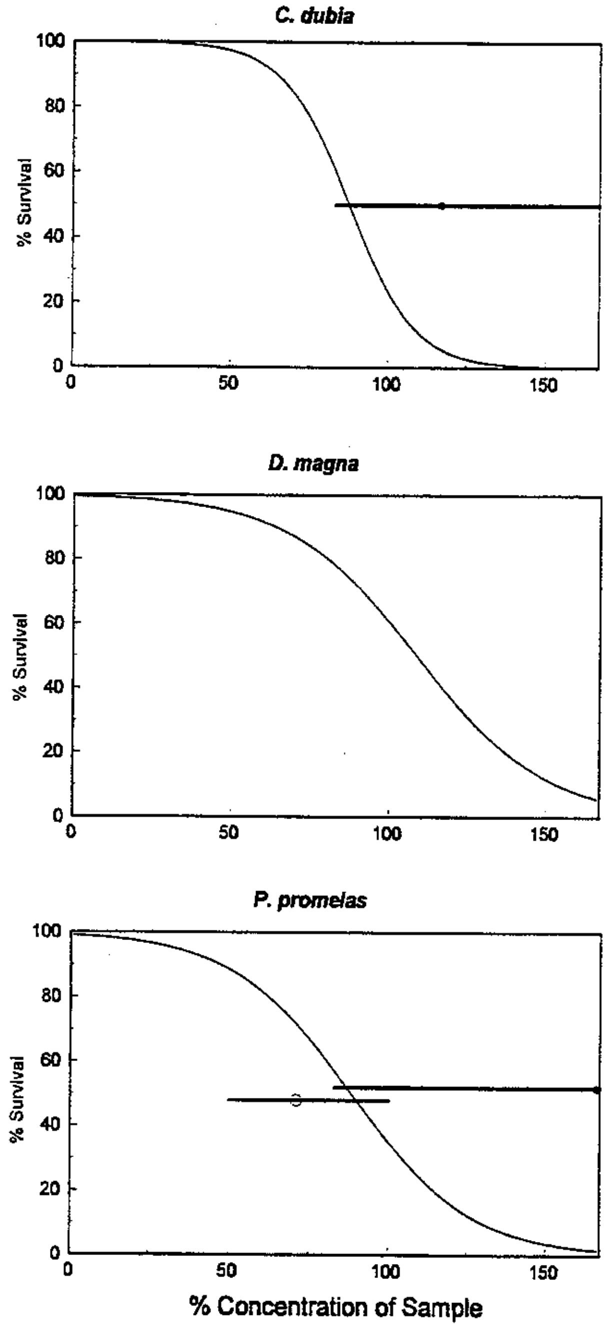
The initial LC_{50}s of PW-6 for *C. dubia*, *D. magna*, and *P. promelas* were 2, 1, and 35 percent, respectively (Table 3-3). Analytical data indicated a total salinity of 5,704 mg/L, which was predominantly (81 percent) sodium and bicarbonate ions (Table 3-2). Chloride ions contributed 15 percent to the total salinity. Total ammonia was present at 2.6 mg/L.

No ammonia toxicity was expected for all three species. The FW STR model predicted the LC_{50}s of PW-6 for *C. dubia* and *D. magna* to be 32 and 40 percent, respectively, fifteen to forty times less toxic than the initial toxicity determinations. Both of these predictions were well outside of the 95 percent confidence intervals surrounding the initial toxicity determinations. The FW STR model predicted the LC_{50} for *P. promelas* to be 36 percent, almost identical to the initial toxicity determination. The difference between the initial and predicted toxicity in the invertebrates was considered substantial, so the sample was submitted to Phase I TIE manipulations and tested with *C. dubia*, one of the two the most sensitive species to this produced water sample.

The results of the Phase I TIE manipulations indicated that the non-salinity related toxicity was only removed by solid phase extraction (SPE) using C_{18} at ambient pH and at pHs 3 and 9. All three of these manipulations reduced the toxicity to 35 percent, very close to the FW STR prediction of 32 percent. The C_{18} used in the SPE manipulation was eluted with a graded methanol series and tested to determine if the toxicant was an organic compound. The elutions of the C_{18} with 85 percent or more methanol:water (v/v) were toxic, indicating that the toxicant(s) was probably non-polar organic compounds sorbed to the C_{18}.

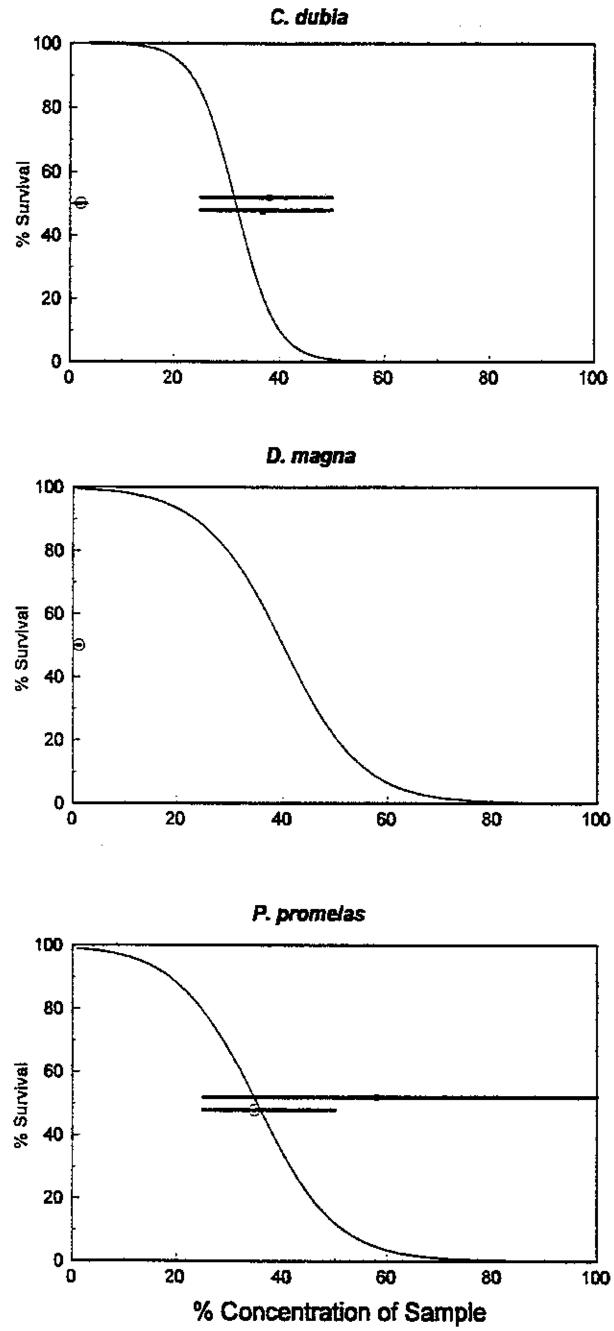
A mock produced water made to the same ionic composition as determined for the original sample was tested. The model prediction fell within the 95 percent confidence intervals surrounding the mock LC_{50}s for *C. dubia* and *P. promelas*. The LC_{50} for *D. magna* was >100 percent and did not concur as well with the FW STR model prediction.

The FW STR model prediction, the initial LC_{50} , post-SPE LC_{50}, and mock LC_{50} are plotted in Figure 3-6 for *C. dubia*. Initial and mock LC_{50}s are plotted for *P. promelas*. The initial LC_{50} is plotted for *D. magna*.



Note: The STR model prediction of acute toxicity (solid line curve) is based on the ionic composition of sample PW-5. LC_{50} values are plotted as symbols. Initial toxicity (open circles) and mock toxicity (solid circles) are plotted for all three species, except that the initial and mock toxicity were not determinable for *D. magna* (ie. LC_{50}>100% for PW-5 and LC_{50}>166% for PW-5 mock) and initial toxicity was not determinable for *C. dubia* (ie. LC_{50}>100% for PW-5). Horizontal bars indicate the 95% confidence intervals for each LC_{50} determination, based on binomial distribution or probit models as appropriate. LC_{50} values and confidence intervals were offset slightly for graphical clarity.

Figure 3-5. Predicted and Observed Acute Toxicity of Sample PW-5.



Note: The STR model prediction of acute toxicity (solid line curve) is based on the ionic composition of sample PW-6. LC_{50} values are plotted as symbols. Initial toxicity (open circles) and mock toxicity (solid circles) are plotted for all three species, except that mock toxicity was not determinable for *D. magna* (ie. LC_{50}>100% for PW-6 mock). For *C. dubia*, post-solid phase extraction toxicity (solid square) is also plotted. Horizontal bars indicate the 95% confidence intervals for each LC_{50} determination, based on binomial distribution or probit models as appropriate. LC_{50} values and confidence intervals were offset slightly for graphical clarity.

Figure 3-6. Predicted and Observed Acute Toxicity of Sample PW-6.

3.5 Produced Water Validation: Discussion

3.5.1 Charge Balance

The salinities of the six produced waters covered in this validation ranged from 1,693 to 58,138 mg/L (Table 3-2). These salinities are based on the concentrations of the seven ions included in the FW STR models. Charge balances of the solutions were calculated by subtracting the anion equivalence concentration from the cation equivalence concentration and dividing by the mean of the two. A positive charge imbalance indicates an excess of cations, while a negative charge imbalance indicates an excess of anions. *The GRI-FW STR Program* warns the user when charge imbalance exceeds 15 percent. A large difference in charge balance can be important because it indicates one of the following conditions exist:

- The ion concentrations entered into the program are incorrect;
- The analytical results are inaccurate; or,
- There are other ions present in the sample which are not considered in the FW STR models.

If the ion concentrations entered into the program are correct, then additional ions not included in the charge balance calculation are likely to be present. If the FW STR models predict toxicity similar to or higher than the actual toxicity of the sample, then the additional ions may not be problematic, that is, they probably do not contribute to toxicity. However, if the FW STR models under predict the toxicity when compared to initial toxicity results, then one should consider the charge imbalance as an indicator that an additional toxic ion(s) is present.

In this study, the three samples with the worst charge imbalance were PW-2, PW-4, and PW-6 at 19, 25, and 35 percent respectively. No additive toxicity was observed in PW-2 or PW-4, and the toxicities of the mock produced waters were not different from the FW STR model predictions (based on *C. dubia* results). Therefore, it can be concluded that the toxicity of the FW STR ions is sufficient to explain the results and the presence of an additional toxic ion at significant concentrations is unlikely. PW-6 did have non-ion related toxicity. However, the toxicants were removed by SPE (Figure 3-6) and the toxicity of the post-SPE sample was not different than the FW STR prediction. Furthermore, the toxicity of the mock effluent was not different from the FW STR prediction. Therefore, it can be concluded that the toxicity of the FW STR ions is sufficient to explain both the post-SPE toxicity and mock toxicity, and the presence of an additional toxic ion at significant concentrations is unlikely.

3.5.2 Evaluation STR Toxicity Predictions

There are two criteria that can be used to evaluate the concurrence of sample toxicity with the FW STR predictions. One is to determine if each FW STR prediction is within the 95 percent confidence intervals of the sample LC_{50} determination. The other is to judge the magnitude of the difference based on experience. The limitation of this latter approach is that it is not quantitative. Still, it provides some guidelines on how to interpret actual and predicted toxicity results.

The use of mock water samples is an important confirmatory tool in determining the presence of ion toxicity. Ideally, mock samples made to the ionic composition of the original sample, as entered into the *GRI-FW STR Program*, should match the FW STR model prediction. Mock studies were conducted on all three species for each produced water sample. The FW STR models predicted higher toxicities than were observed in the mock samples in all eighteen cases. This suggests that the FW STR models may be systematically conservative, erring in the direction of higher toxicity. In several cases, the toxicity of the produced water sample was closer to the predicted toxicity than the mocks, suggesting that the model may predict better for the produced waters. However, the characterization of the produced waters is limited to the seven FW STR ions and does not include analyses of other components in these complex mixtures.

The concurrence of mock results with FW STR model predictions for *C. dubia* was excellent in this study. All six FW STR model predictions were within the 95 percent confidence intervals of the mock LC_{50} determinations, and the differences between the mock and FW STR predictions were all relatively small in magnitude.

The concurrence of mock results with FW STR model predictions for *P. promelas* was good in this study. Four of the six FW STR model predictions (PW-1, PW-4, PW-5, and PW-6) were within the 95 percent confidence intervals of the mock LC_{50} determinations. However, the difference between the predicted toxicity and mock LC_{50} for PW-5 was relatively large. The FW STR predictions for PW-2 and PW-3 were not within the confidence intervals of the mock LC_{50} determinations. However, for PW-2, the magnitude of the difference was small (predicted LC_{50} of 10 percent compared to a mock LC_{50} 13.4 percent) . This analysis suggests that the toxicity of 4 of the six mock samples concurred with the FW STR model prediction.

The concurrence of mock results with FW STR model predictions for *D. magna* was poor. The FW STR model predictions for PW-1, PW-2, PW-3, and PW-4 were not within the 95 percent confidence intervals of the mock LC_{50} determinations, and the magnitude of differences between the mock and FW STR predictions were relatively large. The LC_{50}s were not determinable for PW-5 and PW-6.

The apparent discrepancies between the FW STR model predictions and the results of the mock studies are not readily explicable, especially for *D. magna*. There are three possible explanations for the differences:

- There has been some systematic drift in sensitivity of *D. magna* through time,
- There were technical problems with the execution of the tests, or
- The model does not predict well for *D. magna* using the specific ion concentrations present in these produced water samples.

A review of reference toxicant studies for the past several years indicate that the sensitivity of the *D. magna* to Cl^- (from NaCl) has not changed. Furthermore, the anomalous sensitivity of a specific lot of test organisms can be eliminated since the tests were conducted over a period of several months, utilizing several lots. A review of the data and laboratory notes seems to eliminate technical problems associated with the test execution. Tests with all three species were run concurrently for each mock study, eliminating the possibility of systematic solution and dilution errors.

3.6 FW STR Models Validation Summary

In evaluating the combined validation data from the literature and from the produced water validation testing, there are apparent discrepancies between model predictions and actual toxicities. The two types of errors possible, predicting too much toxicity and too little toxicity, have very different ramifications in the context of meeting environmental compliance goals.

If the model over-predicts the toxicity of a mixture, that is the LC_{50} of the prediction is substantially lower than the actual LC_{50}, then either the model is predicting poorly given the specific ion concentrations or there are components in the mixture which somehow reduce toxicity. Either way, this type of difference is not very problematic since the actual toxicity is less than expected. Confirming the model prediction using mock effluents made to the concentration of the sample with reagent grade salts and deionized water should determine if there are mitigating components or if there is a prediction error. If the predicted toxicity of the mock is still too high, then model performance can be concluded to be poor in the concentration ranges of the specific effluent.

If the model under-predicts the toxicity of a mixture, that is the LC_{50} of the prediction is substantially higher than the actual LC_{50}, then either the model is predicting poorly given the specific ion concentrations or there are other components in the mixture which increase the toxicity. Once again, the use of mock effluents can determine if the model prediction is representing the ion toxicity accurately. If the predicted toxicity of the mock is equal to or greater than the actual toxicity of the mock and the toxicity of the mock is lower than the original sample, then the presence of an additional toxicant is suggested. The only cases where the model under predicted toxicity in the PW validation work was for PW-1 and PW-6. Both of these samples had an additional toxicant as defined by TIE procedures.

When interpreting model performance and applying the model, one can look at the difference between predicted and actual toxicity for a single species in the model or for all three species. Interpreting the toxicity of a sample based on all three species may be advantageous, since it allows one to consider species sensitivity and to use a weight of evidence approach. The multi-species approach to biomonitoring (USEPA, 1985b) and ambient water quality criteria development (USEPA,1985c) reflects the need to use multiple species in order to account for species sensitivity. In PW-6, the initial toxicity was greater than the FW STR models predictions for *C dubia* and *D. magna*, indicating the presence of an additional toxicant. The initial toxicity of PW-6 was no different than the FW STR prediction for *P. promelas*. These results demonstrated that the invertebrates were more sensitive to the additional toxicant and that two of three species indicated the presence of an additional toxicant. If only the results of the *P. promelas* tests were considered, a very different interpretation would have resulted. In contrast, for PW-1, all three species indicated the presence of an additional toxicant. In addition, differential toxicity between species can provide insight when trying to identify a toxicant. Relative species sensitivity patterns toward a number of chemicals or chemical classes are well understood.

3.7 Application of the *GRI-FW STR Program*

This program is a tool that should be of interest and utility to effluent permitters, effluent permittees, and researchers in aquatic toxicology as a means to help understand the contribution of salinity to the toxicity of effluents. The FW STR models provide diagnostic information which can help determine the source of toxicity in a sample. This guidance can be of great value in determining the course of action necessary to understand the toxicity of a sample and to propose (if appropriate) corrective action for bringing an effluent into compliance with biomonitoring requirements.

The FW STR models do not have the ability to statistically differentiate between samples which are toxic due to salinity alone and those which are toxic due to salinity and other toxicants. Therefore, when a water sample is determined to be more or less toxic than predicted by the *GRI-FW STR Program* (i.e., the LC_{50} does not coincide with the predicted toxicity curve), there is no simple quantitative method to determine if it falls within the error expected of the model. This poses some limitation on how the data can be interpreted and requires the use of professional judgement as to how the model is applied.

The *GRI-FW STR Program* can be used in combination with other toxicological techniques, such as TIE studies, mock effluent studies, and ion modification studies. A general application flow chart for the *GRI-FW STR Program* is presented in Figure 3-7. There are four decision points in the flow chart.

Is effluent sample acutely toxic?
If the sample is acutely toxic, then determine the concentrations of the following ions: Na^+, K^+, Ca^{++}, Mg^{++}, Cl^-, SO_4^{--}, and HCO_3^-. Enter ion concentration data into the STR Program and run model to predict the LC_{50} values and proceed to the next decision. Usually the STR Program is not needed if the effluent is non-toxic. However, if the effluent is expected to change in a predictable fashion (i.e., the salinity is going to increase for some reason) or if there is concern over the potential for salinity toxicity, then the model could be used (after ionic composition is analyzed) to determine how close the effluent is to being toxic and what effect changes in ionic composition might have on effluent toxicity.

Is toxicity of the sample similar to or less than the STR prediction?
If there is concurrence between the model prediction and the actual toxicity, then there may not be any reason to proceed. However, if confirmatory evidence is necessary, then a mock effluent may be prepared to match the ionic composition of the original effluent and tested for toxicity. Ideally, all three LC_{50} determinations should be similar. If the toxicity of the sample is substantially greater than the STR prediction, then the presence of an additional toxicant(s) is suggested. At this point, Phase I TIE testing can be conducted to characterize the additional toxicant(s).

Was additional toxicity removable by TIE manipulations?
If the additional toxicity was removable by one or more TIE manipulations, then proceed to the next decision. If no toxicity was removed or reduced by the TIE procedures, then the toxicant may be of a type not affected by standard Phase I TIE manipulations.

Was toxicity of post-TIE manipulated water similar to STR prediction?
If the post TIE manipulated water has the same toxicity as predicted by the model, then all of the toxicity is accounted for (i.e., total toxicity is equal to the sum of the residual ion toxicity and the toxicity removed by TIE manipulations). If the toxicity of the post TIE manipulated water is still considerably more toxic than the STR prediction, then additional

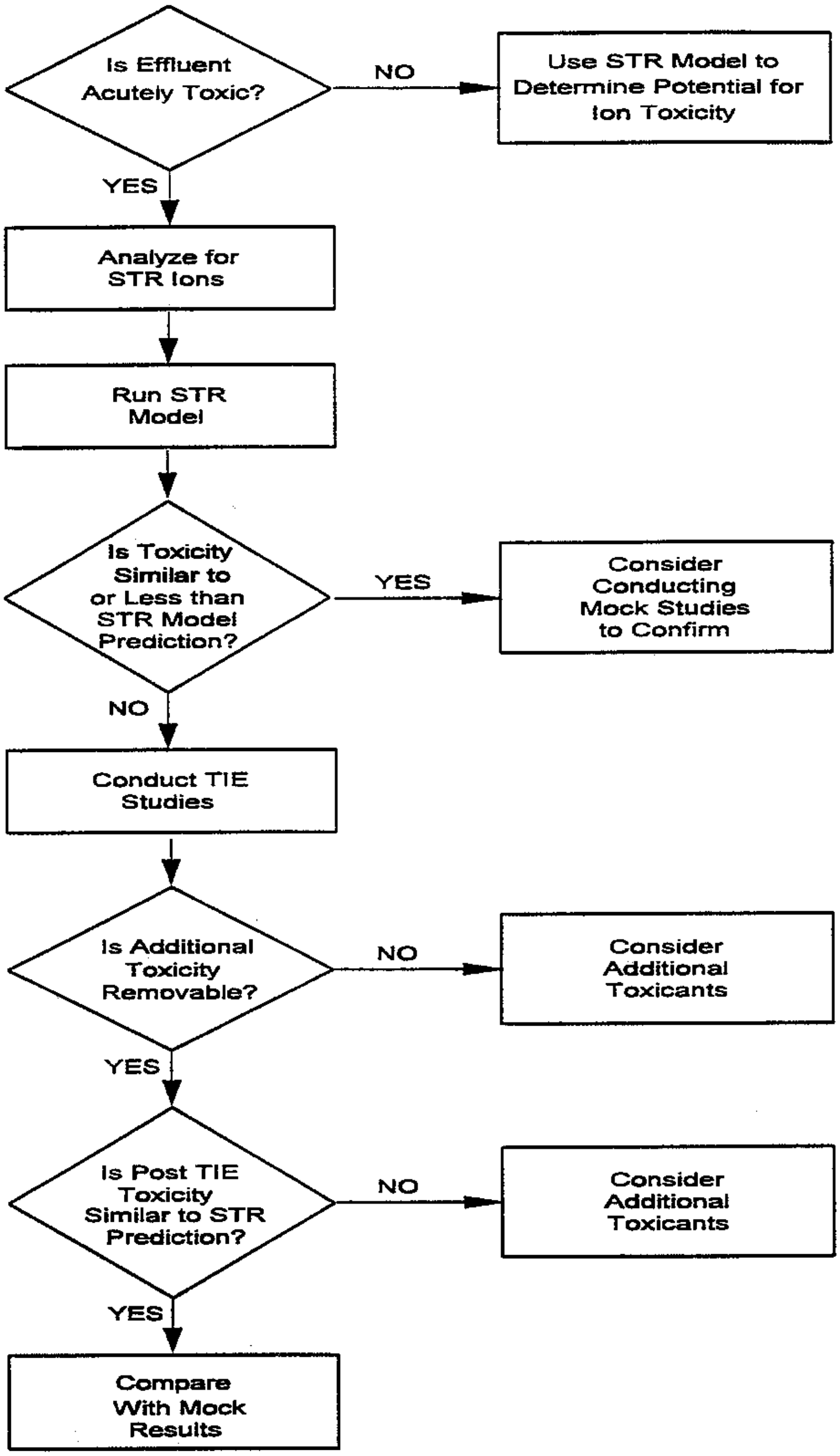


Figure 3-7. Flow Chart for the General Application of the *GRI-FW STR Program*.

toxicant(s) may be present. Ideally, the toxicity of a mock effluent made to the ionic composition of the original effluent should match with the toxicity of the post TIE manipulated water.

The *GRI-FW STR Program* used in conjunction with TIE methodologies provides a powerful technique to understand the toxicity of samples where salinity toxicity is expected. As demonstrated in the produced water validation study, the base salinity-related toxicity of a sample can be quantified independently of other toxicants which are removable by Phase I TIE procedures. In PW-1, a filterable and centrifugable toxic compound was removed from the original sample; the remaining toxicity attributable to ion toxicity alone. In PW-6, a non-polar organic compound was removable by SPE; again, the remaining toxicity was attributable to ion toxicity alone.

Combining salinity toxicity simulations and ion modification studies may also prove useful when applying the FW STR models. In cases where effluents are toxic due to salinity, and/or where changes in the salinity of an effluent are planned, the *GRI-FW STR Program* can be used to simulate the toxicity of different conditions. This approach allows the permittee to propose changes in plant operation or effluent treatment and test the effect of the changes through model simulations. The efficacy of the changes can then be tested empirically in the laboratory with mock effluents modified to mimic the expected conditions. The simulation process should help improve the cost-effectiveness of implementing changes in plant operation and effluent treatment procedures by targeting changes that will reduce toxicity and eliminating changes which may not.

4.0 *GRI-FW STR PROGRAM* USER'S MANUAL

4.1 Software Installation and Start-Up

The *GRI-FW STR Program* was designed to run on IBM compatible personal computers with graphics capabilities under the MS-DOS operating system. A system with 512 Kb of random access memory (RAM) and one floppy drive should be able to run the program. However, in order to print the graphics displays, a laser printer is necessary.

The *GRI-FW STR Program* can be run from a hard drive or directly from the floppy diskette. To run it from a floppy drive, switch to the floppy drive by typing "A:" and pressing return or "B:" and pressing return. If you do not install the *GRI-FW STR Program* on your system's hard drive, be sure to make a back up copy of the original program diskette.

To install the software on a hard drive:

1. From the "C:> " prompt, create an STR directory by typing: "MD STR" and press return.

2. Make the new STR directory the default directory by typing "CD STR" and press return.

3. Copy all of the files from the STR disk to the hard disk: If your STR disk is in the "A" drive type "Copy A:*.*" and press return. If your STR disk is in the "B" drive, type "Copy B:*.*" and press return.

To start the program:

1. Make sure that you are in the STR directory on your hard disk.

2. Type "STR" and press return.

The *GRI-FW STR Program* is menu driven and is generally self-explanatory. However, for more detailed information on the operation and use of the software, please consult the "Readme.txt" file. This file will provide the most recent information on system operation. The readme.txt file can be viewed: (1) through the "About" choice in the main menu of the *GRI-*

FW STR Program, (2) onscreen in DOS using the "type" command, or (3) as a printed document for convenient reference. To view the readme.txt file on-screen: Type "type readme.txt |m". This will display the file screen by screen. To print the readme.txt file: type "print readme.txt" and press enter. Since the readme.txt file is an ASCII text file, you can also import it into your word processing program.

After you start the *GRI-FW STR Program*, you will be presented with a brief introduction and then a menu with seven options:

- File Options
- Enter Major Ion Concentrations
- Enter Observed Survival Data
- Output Values Predicted by the STR
- Plot Predicted Survival Response
- About the STR Program
- Quit and Return to DOS

Options in this and all other menus within the program can be selected in three different ways:

1) The cursor (arrow) keys can be used to move the highlighted bars between options; hitting the return key will select the highlighted option.

2) A mouse can be used to move the highlighted bar; clicking the left mouse key will select that option.

3) One letter in each of the menu options is highlighted. That option can be chosen by typing the highlighted letter.

The Tab key can also be used to move between data fields in most of the data entry screens.

Several of the program options use a system of cascading windows to present a series of options to the user. To back up a level of windows, just press <ESC>. The escape key will also allow you to move from data entry screens back to the option menus.

4.2 File Options

This option presents the user with the choice to load ion concentrations from an existing file or to save current ion concentrations in a file for later use.

For demonstration purposes, the program comes with files containing the ion concentrations of the six produced water samples that were tested in the validation of the model. (For more information on the validation results, please refer to the Section 3 of this manual). The file names for these are PW1.CON through PW6.CON.

4.3 Enter Major Ion Concentrations

This option presents a data entry screen so you can enter the ion concentrations in the solution. The STR considers seven different ions: calcium, potassium, magnesium, sodium, chloride, alkalinity, and sulfate. There are two columns on the screen; the first is for the ion concentration and the second is for specifying the unit of measure. You can press the tab key or use the arrow keys to move to the second column. The unit type can be toggled by pressing the space bar. Note that the bicarbonate concentration can be entered either as HCO_3^- or as $CaCO_3$ (the *GRI-FW STR Program* will automatically convert alkalinity expressed as $CaCO_3$ into HCO_3^-); pressing the space bar while the bicarbonate units are highlighted will toggle through all the different options. Ion concentrations cannot exceed 999,999 mg/L (ppm).

When all ion data have been entered, press the control and <ENTER> keys simultaneously. This tells the program you are done entering data. The program will run the FW STR model calculations for the solution.

Note: If you return to this screen to modify ion concentrations and you have previously entered actual survival data, the program will ask you if you wish to discard the current survival data. Simply indicate your preference and continue.

4.4 Enter Observed Survival Data

This option allows you to enter actual survival (toxicity) data for the solution in question (if available). Entering observed data will allow you to compare FW STR model predictions to the actual observed survival responses. However, it is not necessary to have observed survival data to run the program.

Initially, the table will show all concentrations as "0" values and the survival data as all "-1" values. The "-1" values indicate to the program that no data have been entered in that particular field. Use the arrow or tab keys to move around the table and enter the applicable concentrations and survival data. Solution concentrations should be entered as percent (i.e., the unaltered solution, or 100 percent solution, is entered as "100"). Survival data are also entered as percent values (0 to 100). If some of the data are not available, leave the value as -1. For example, if you have only 48-hour survival data to enter, fill in the appropriate values in the 48-hour column and leave the 24-hour column (and 96-hour column, if applicable) as -1 values.

When all observed data have been entered, press the control and <ENTER> keys simultaneously.

4.5 Output Values Predicted by the STR

If you select this option, a second window will appear that offers five sub-options.

4.5.1 Output Analysis of Test Solution

This option displays a summary of ions entered. Ion concentrations are presented as parts per million (ppm or mg/L), molar concentration (millimoles per liter or mmol/L), and equivalent (charge) concentrations (milliequivalents per liter or meq/L).

The *GRI-FW STR Program* also calculates a charge balance for the solution based on the seven ions entered (hydrogen and hydroxide ions are disregarded on the assumption that for saline waters with circumneutral pH these will be very minor contributors to overall charge balance). A charge balance sums all the positive and negative charges in the solution. It is a physical requirement that the positive and negative charges "balance" each other (assuming that all major ionic species have been measured and entered); in reality, solutions typically only have approximate charge balance because of variability in analytical measurements. As a rule of thumb, charge balance should be within 15 percent; if the ion analysis lies outside this range, a warning message will appear, indicating that the ion analysis input to the program may be inaccurate or incomplete.

Also appearing on this screen is the value of the NumCat variable. NumCat represents the number of cations in the solution that are present at both >100 mg/L and >10 percent of the total molar cation concentration. NumCat is used in the calculation of predicted survival; for more information on NumCat, consult Mount and Gulley (1992).

After viewing the information, press any key to continue. A message will appear asking if you want to have a copy of the ion summary table sent to the printer ("Y" for yes, "N" for no).

4.5.2 Output Predicted LC_{50}s and Survival Values

This option displays the results of the FW STR models in tabular form. Predicted LC_{50} values will appear for each of the three test species, expressed as both total ion concentration (the sum of all individual ion concentrations) and as a percent of the solution. Also displayed is the predicted percent survival for each species in the solution as input. Both LC_{50} and percent survival predictions are provided for 24- and 48-hour exposures for all three species, and also 96-hours for fathead minnows only. It should be noted that when the program calculates an LC_{50} value, it assumes that the solution was diluted with pure water (i.e., concentrations of all ions equal to 0 mg/L). In reality, of course, most dilution waters actually contain measurable concentrations of most ions. While assuming pure water in dilution calculations does introduce some error, this error should be quite small except when the dilution water contains high concentrations of ions also. In this case, it may be more appropriate to independently calculate ion concentrations in dilutions of the original solution and input them as separate solutions.

If a "Cannot Calc" message appears in any of the LC_{50} boxes, this indicates that the predicted survival in the 100 percent solution is greater than 50 percent, so an LC_{50} cannot be calculated. The results of the calculations will still be plotted and can be viewed or printed as usual.

After viewing the information, press any key to continue. A message will appear asking if you want to have a copy of the table sent to the printer ("Y" for yes, "N" for no).

4.5.3 Output Predicted Versus Observed Survival Values for *C. dubia*

If observed survival data for *C. dubia* were input under the "Enter Observed Survival Data," this option will present a summary of the observed and predicted survival values for *C. dubia*. After selecting this option, a third window will appear asking whether the comparison is for 24- or 48-hour data. After selecting one of these options, the program will display a table comparing the observed survival values with those predicted by each FW STR model for each of the concentrations entered previously. Also displayed is the difference (in percent) between the observed and predicted values.

As noted previously, the program assumed that the dilution water used to prepare lower concentrations of the original solution was pure water (ion concentrations equal to 0).

Although the resulting error should be generally be very small, this error could be significant in the dilution water contains high concentrations of one or more ions.

After viewing the information, press any key to continue. A message will appear asking if you want to have a copy of the table sent to the printer ("Y" for yes, "N" for no).

4.5.4 Output Predicted Versus Observed Survival Values for *D. magna*

This is just like the previous option except it displays data for *D. magna*.

4.5.5 Output Predicted Versus Observed Survival Values for Fathead Minnows

This is just like the previous options for *C. dubia* and *D. magna* except it displays data for fathead minnows. Another difference is that 96-hour data can be displayed in addition to 24-hour and 48-hour data.

4.6 Plot Predicted Survival Response

This option will plot XY graphs of the FW STR models survival predictions. Observed survival data will also be plotted (if they have been entered). As with the previous option, the plot options are presented in a series of windows. First, select the species plots you wish to display (either *C. dubia, D. magna*, or fathead minnows, or all three at once). After selecting the species, another window will appear asking what time period the plot should be prepared for. After selecting the time period, a graph will appear showing predicted survival as a function of solution concentration. The LC_{50} value for each species will be printed at the top of each graph.

Each graph can be printed on a Hewlett Packard Laser Jet compatible printer by pressing "P" while the graph is displayed.

If actual survival data were entered for the species and time period selected, the actual survival data will appear as "+" symbols (yellow on color monitors) on the graph.

As noted previously, the program assumed that the dilution water used to prepare lower concentrations of the original solution was pure water (ion concentrations equal to 0). Although the resulting error should be generally be very small, this error could be significant if the dilution water contains high concentrations of one or more ions.

When you are done viewing the graph, press any key to continue.

4.7 About the *GRI-FW STR Program*

This option provides the user with on-line access to the read-me file, which contains updated information on the program.

4.8 Quit and Return to DOS

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GRI-94/0369

Topical Report

The GRI Freshwater STR Model and Computer Program: Overview, Validation, and Application

December 1994

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Adopted January 10, 2007
EPA Approval March 14, 2007

Three Total Maximum Daily Loads for Chloride, Sulfate, and Total Dissolved Solids in Petronila Creek Above Tidal

For Segment Number 2204

Prepared by the:
Chief Engineer's Office, Water Programs, TMDL Section
TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

Distributed by the
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TMDL Project Reports are also available on the TCEQ Web site at:
www.tceq.state.tx.us/implementation/water/tmdl/

Development of this TMDL was funded in part by the
U.S. Environmental Protection Agency.

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Three Total Maximum Daily Loads for Chloride, Sulfate, and TDS in Petronila Creek Above Tidal

Executive Summary

This document describes a project developed by the Texas Commission on Environmental Quality (TCEQ) to address water quality impairments related to excessive chloride, sulfate, and total dissolved solids (TDS) in Petronila Creek Above Tidal (Segment 2204). Petronila Creek is a freshwater stream approximately 44 miles long, with a 526-square-mile watershed, in Nueces and Kleberg Counties. General water quality uses were identified as impaired in the *2000 Texas Water Quality Inventory and 303(d) List.*

Petronila Creek Above Tidal is designated for contact recreation and intermediate aquatic life uses under the Texas Administrative Code (TAC) [Title 30, Chapter 307 (30 TAC 307): *Texas Surface Water Quality Standards*, §307.7 Site-specific Uses].

The goal for this TMDL is to determine the allowable loading that will still make it possible to meet water quality standards. Current numeric standards for annual averages to support aquatic life uses are defined in the *Texas Surface Water Quality Standards* as 1,500 milligrams per liter of chloride, 500 milligrams per liter of sulfate, and 4,000 milligrams per liter of TDS.

The TCEQ conducted an investigation to identify possible point and nonpoint sources of chloride, sulfate, and TDS, and to quantify the appropriate reductions necessary to comply with established water quality standards. Field investigations identified that excessive chloride, sulfate, and TDS concentrations occur in the downstream section of Petronila Creek, southeast of U.S. Hwy 77, in an area where man-made nonpoint sources such as produced water, brine pits, and brine injection wells are most numerous (EA, 2006).

Based on the analysis of the load allocation scenario, a TMDL allocation to meet the respective water quality standards requires:

- 100 percent reduction of loading from abandoned brine pits, and;
- 88 percent reduction of loading from the produced water.

Overall, the loading from nonpoint sources of chloride and TDS must be reduced by 88 percent and the loading of sulfate must be reduced by 78 percent to meet the goal.

Introduction

Section 303(d) of the federal Clean Water Act requires a state to identify waters that do not meet, or are not expected to meet, applicable water quality standards. For each listed water body that does not meet a standard, a state must develop a total maximum daily load (TMDL) for each pollutant that contributes to the impairment of water. The TCEQ is responsible for ensuring that TMDLs are developed for impaired surface waters in Texas.

In simple terms, a TMDL is like a budget that determines the amount of a particular pollutant that a water body can receive and still meet its applicable water quality standards. In other words, TMDLs are the best possible estimates of the assimilative capacity of the water body for a pollutant under consideration. A TMDL is commonly expressed as a load with units of mass per period of time, but may be expressed in other ways. TMDLs must also estimate how much the pollutant load must be reduced from current levels in order to achieve water quality standards.

The TMDL Program is a major component of Texas' effort to improve and manage surface water quality. The Program addresses impaired or threatened streams, reservoirs, lakes, bays, and estuaries (water bodies) in the state of Texas. The primary objective of the TMDL Program is to restore and maintain the beneficial uses — such as drinking water supply, recreation, support of aquatic life, or fishing — of impaired water bodies. This TMDL addresses impairments to general uses from chloride, sulfate, and TDS in Petronila Creek above Tidal. General use supports aquatic life with a moderately diverse habitat.

Section 303(d) of the Clean Water Act and the implementing regulations of the U.S. Environmental Protection Agency (EPA) (40 Code of Federal Regulations, Part 130) describe the statutory and regulatory requirements for acceptable TMDLs. Following these guidelines, this document describes the key elements of the TMDL, as are summarized in the following sections:

- Problem Definition
- Endpoint Identification
- Source Analysis
- Seasonal Variation
- Linkage between Sources and Receiving Waters
- Margin of Safety
- Pollutant Load Allocation
- Public Participation
- Implementation and Reasonable Assurance

This TMDL document was prepared based upon the report titled "Petronila Creek Above Tidal (Segment 2204) Total Maximum Daily Load for Chloride, Sulfate, and Total Dissolved Solids" prepared by:

- EA Engineering, Science, and Technology, Inc. in Lewisville, Texas;
- The Louis Berger Group, Inc. in Washington, D.C.; and
- The TMDL Section in the Water Programs of the Chief Engineer's Office at the TCEQ.

This TMDL document was adopted by the Texas Commission on Environmental Quality on January 10, 2007. The EPA approved the TMDLs on March 14, 2007, at which time they became part of the state's Water Quality Management Plan.

PROBLEM DEFINITION

This document describes a project developed to address water quality impairments related to chloride, sulfate, and total dissolved solids (TDS) in Petronila Creek (Segment 2204). Petronila Creek is a freshwater stream approximately 44 miles long, with a 526-square-mile watershed. Petronila Creek begins at the confluence of Agua Dulce Creek and Banquete Creek, west of Robstown in Nueces County. It flows generally southeast for about 43.5 miles across Nueces County and into Kleberg County, where it ultimately empties into Alazan Bay, part of the Baffin Bay estuarine complex (Paine et al, 2005) (Figure 1). General water quality uses were identified as impaired in the *2000 Texas Water Quality Inventory and 303(d) List.*

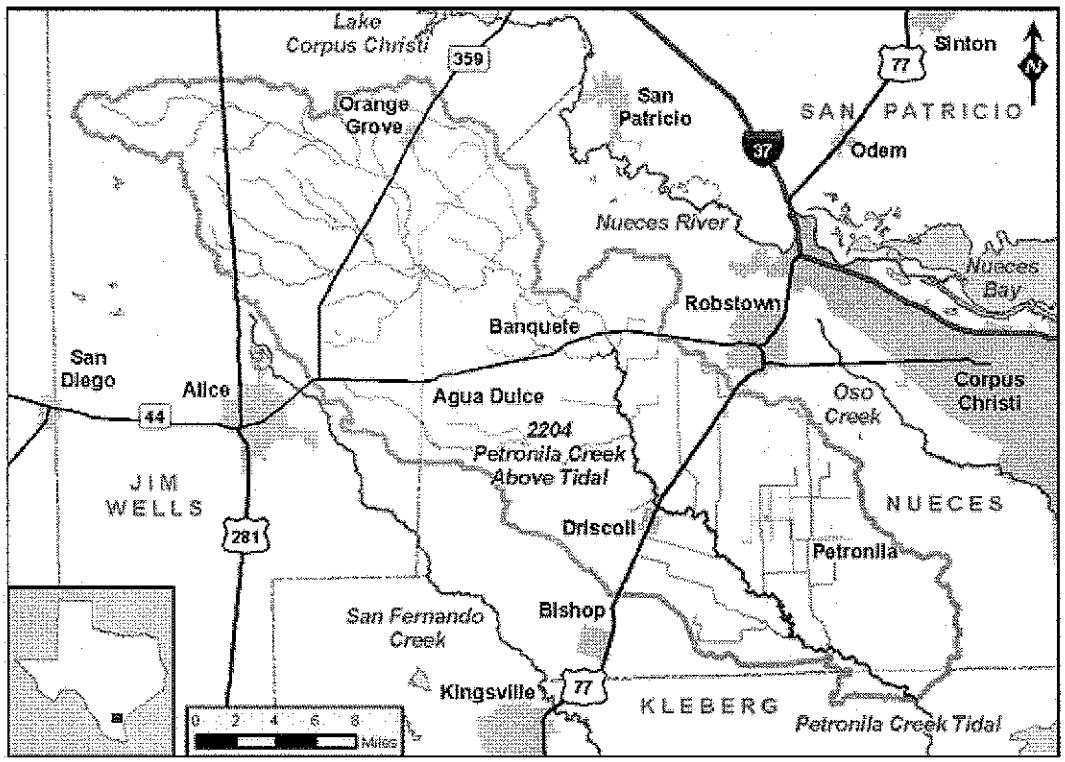


Figure 1. Petronila Creek Watershed

The designated uses for Petronila Creek Above Tidal are contact recreation use and intermediate aquatic life use (30 TAC 307, §307.7). Aquatic life uses recognize the natural variability of aquatic community requirements and local environmental conditions.

The goal of this TMDL for Petronila Creek is to achieve the water quality standards. The water quality standards provide numeric and narrative criteria to meet designated uses. Current numeric standards to support general uses are as follows: chloride concentration of 1,500 milligrams per liter (mg/L), sulfate of 500 mg/L, and TDS of 4,000 mg/L (Table 1). Violations of the chloride, sulfate, and TDS standards resulted in the listing of segment 2204 on the 2000 Texas 303(d) list.

In response to the listing, the TCEQ conducted a project to identify possible point and nonpoint sources of chloride, sulfate, and TDS, and to quantify the reductions necessary to comply with established water quality standards. Possible sources and/or causes include:

a) the presence of primary saline pore water in the Beaumont Formation, a local shallow aquifer present in this coastal area;
b) salt particles blown inland and deposited by prevailing onshore winds;
c) extensive inland flooding of saline gulf and estuarine water during recurrent tropical storms;
d) surface and near-surface discharge of saline water during hydrocarbon exploration and production, including discharge and infiltration from surface brine pits;
e) direct discharge into creeks and ditches; and
f) leaking injection or brine-disposal wells (Paine et al, 2005).

Table 1: Numeric Criteria for Petronila Creek Above Tidal

Segment	Criteria						
	Cl (mg/L)	SO4 (mg/L)	TDS (mg/L)	Dissolved Oxygen (mg/L)	pH Range (standard units)	Indicator Bacteria #/100ml (E. coli)	Temperature (°F)
2204: Petronila Creek Above Tidal	1,500*	500*	4,000*	4.0	6.5-9.0	126+/ 394++	95

* expressed as annual average values
\+ expressed as a geometric mean
++ expressed as an instantaneous grab sample

Petronila Creek above Tidal was added to the Texas 303(d) list for 2000 because average chloride, sulfate, and TDS exceed the segment-specific criteria of 1500 mg/L, 500 mg/L, and 4000 mg/L respectively. Recent chemical analysis and field investigations of surface water in Petronila Creek, its tributaries, and in local drainage ditches indicate that TDS and chloride concentrations are low upstream from the U.S.77 bridge at Driscoll, but increase to levels that fail to meet surface water quality standards downstream from US 77 where man-made nonpoint sources such as produced water, brine pits, and brine injection wells are more numerous, as shown in Figures 2 and 3.

A variety of man-made and natural sources can be responsible for elevated levels of chloride, sulfate, and TDS. For example, a common man-made source of dissolved solids is "brine," a byproduct of oil production that can run off soil and into water bodies. In response to these conditions, the TCEQ initiated a TMDL project to determine the measures necessary to restore water quality in Petronila Creek Above Tidal. Chemical and biological conditions in Petronila Creek were dominated for more than 50 years by oil field brine discharges of about 50 times the stream salinity (Shipley 1991). In 1969, the Texas Legislature passed a law prohibiting open pit disposal of oil field brine. Direct brine discharges to Petronila Creek ceased in January, 1987.

Designated Uses and Water Quality Standards

The State of Texas requires water in Petronila Creek Above Tidal to be suitable for contact recreation and intermediate aquatic life use. The Nueces River Authority (NRA), the TCEQ, and the United States Geological Survey (USGS) conduct water quality monitoring in the Nueces Rio-Grande Coastal Basin. Their testing has found that elevated levels of chloride, sulfate, and TDS are affecting the water quality in a section of Petronila Creek, designated as "Segment 2204, Petronila Creek above Tidal" in the Texas Surface Water Quality Standards.

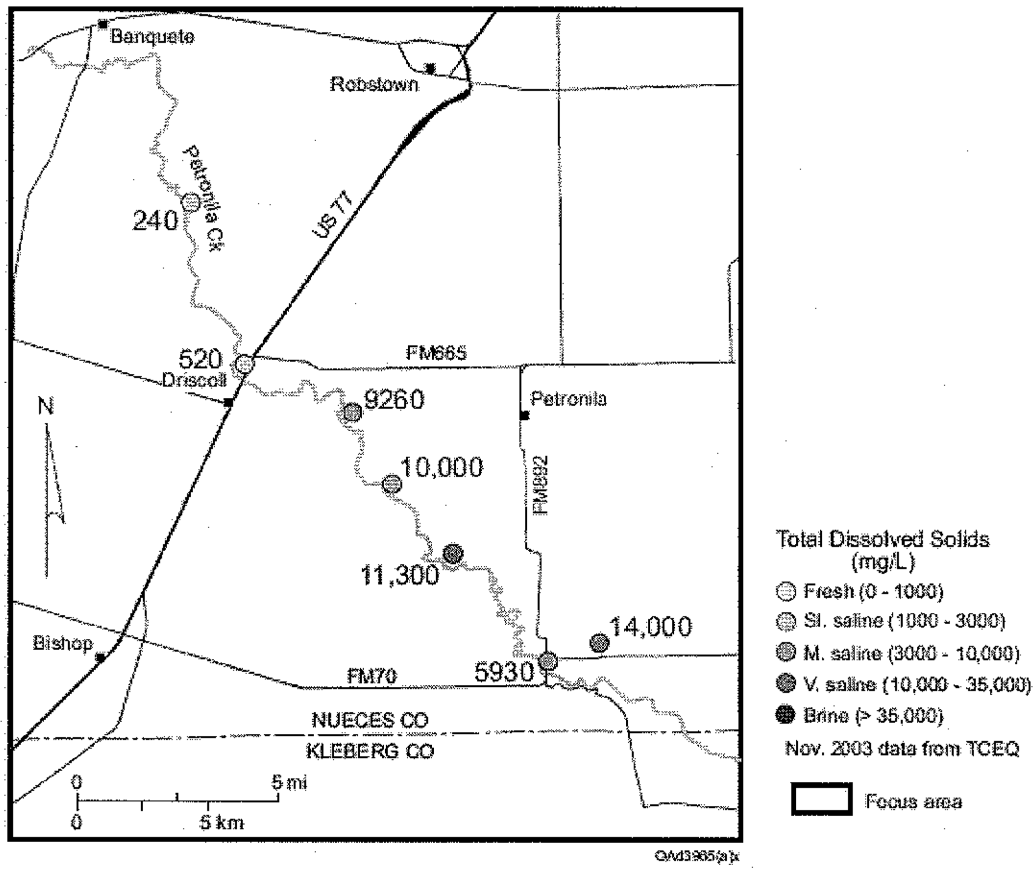


Figure 2. Map of Petronila Creek depicting TDS concentration along the creek in November 2003 (Paine et al, 2005)

High chloride concentrations can cause bad-tasting water, harm plumbing, and increase the risk of hypertension in humans. High sulfate concentrations can cause odor and taste problems in drinking water. Large amounts of dissolved solids can be toxic to species that live in freshwater (Shipley, 1991).

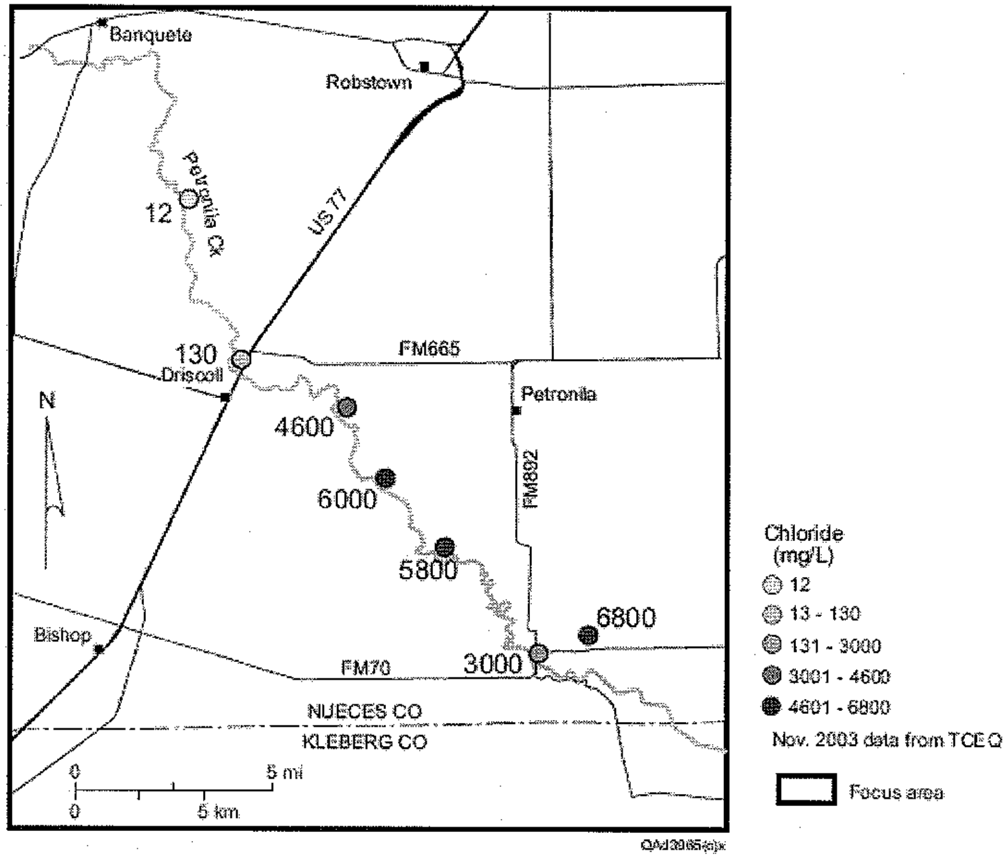


Figure 3. Map of Petronila Creek depicting Chloride concentration in surface water samples along the creek in November 2003 (Paine et al, 2005)

Description of the Watershed

Petronila Creek is a 44-mile long freshwater stream. The stream is formed by the confluence of Agua Dulce and Banquete creeks, which occurs one mile southeast of Banquete in western Nueces County (at 27° 48' N, 97° 47' W), and is located within the Nueces-Rio Grande Coastal Basin southwest of Corpus Christi, Texas. Nearby cities include Petronila, Driscoll, Bishop, Agua Dulce, Banquete, Corpus Christi, Orange Grove, San Pedro, and Robstown.

The Nueces-Rio Grande Coastal Basin has a drainage area of about 10,442 square miles. Petronila Creek drains approximately 543 square miles of this basin, and is a part of the Baffin Bay watershed. Petronila Creek runs southeast to its outlet on Alazan Bay, 16 miles northeast of Riviera Beach in eastern Kleberg County (at 27° 28' N, 97° 32' W). The surrounding terrain varies from flat with local shallow depressions to some rolling areas. Surface features include clay and sandy loams that support grasses, some scrub brush, and cacti. The streambed crosses tidal flats in its last six miles, and is designated as a tidal stream.

Climatic, Economic, and Geographic Conditions

Conditions related to the climate, economy, and geography of the watershed directly affect water quality in a stream.

Climate

In Nueces County, thunderstorms are recorded on an average of 30 days per year, peaking in May and September. The 30-year record (1961-90) indicates that normal precipitation in the coastal basin ranges from about 30 to 40 inches per year. Mean precipitation per year is 31.41 inches; the number of days per year with precipitation of 0.1 inches is 39 days. Temperatures are generally moderate, with temperatures at or below freezing only about seven days of each year, and with 101 days above 90 °F.

Economy

Nueces County is comprised of 1,166 square miles and has a population of 313,645. The county has grown in population, with the majority of the increase occurring in the Corpus Christi metro area, which is primarily outside of the Petronila Creek watershed. Approximately 89% of the county population lives in urban areas. The county contains 330 square miles of navigable waterways. Oil, gas, and petrochemical production contribute significantly to the economy; tourism, area retailing, seaport activity, farming, ranching and military facilities are also contributors to the local economy.

Nueces County is the center of agribusiness activity for the Coastal Bend region of Texas. In 1997, there were 282 full time farms located in the county, with an average farm size of 770 acres. Total land area for farms and ranches in the county decreased by 1% between 1992 and 1997, but farms and ranches still comprise 82% of the total land area (534,976 acres) in the county. The majority of livestock production is cattle and calf farms, with a few hog and sheep farms also. The primary crops in Nueces County are cotton and grain or seed sorghum.

Stream Segment Geology and Hydrogeology

The geology of the southern Texas Gulf Coast region encompassing Petronila Creek is composed of clay, silt, sand, and gravel deposits. The primary geologic unit in the study area is the Beaumont Formation. The formation includes iron oxide and iron-manganese oxide concretions, along with concretions and massive accumulations of calcium carbonate (caliche) in weathered zones. This underlying geologic formation controls topography, area drainage, and soil types that represent stream channel, coastal marsh, mud flats, and backswamp environments.

Groundwater in the area is associated with the Gulf Coast aquifer, also known as the coastal lowlands aquifer system. The aquifer system lies beneath relatively level, low-lying coastal plains. The amount of sand within the aquifer decreases from east to west, with a maximum sand thickness of about 1,300 feet in the east and about 700 feet in the west.

Soils

Soil characterization in the Petronila Creek watershed was based on the Soil Survey of Nueces County, Texas (USDA Soil Conservation Service Series 1960). The predominant soil in Petronila Creek is a Victoria association, which covers 66% of Nueces County. Victoria soils have a surface layer of dark-gray, calcareous heavy clay. This clay is about three feet thick and is underlain by a layer of light and dark-gray clay that is 18-inches thick.

Land Use

Land use characterization was based on the most recent National Land Cover Data (NLCD), developed by USGS in 1992. Dominant land uses for this area are agricultural (83%) and rangeland (15%), which together account for 98% of the land area draining to the impaired segment of Petronila Creek. Cropland is ubiquitous throughout the watershed. Rangeland occurs predominantly in the northwest section of the watershed of Petronila Creek Above Tidal. Urban and residential areas are scattered throughout the boundaries of the watershed. The land use distribution in the watershed of Petronila Creek Above Tidal is shown in Figure 4.

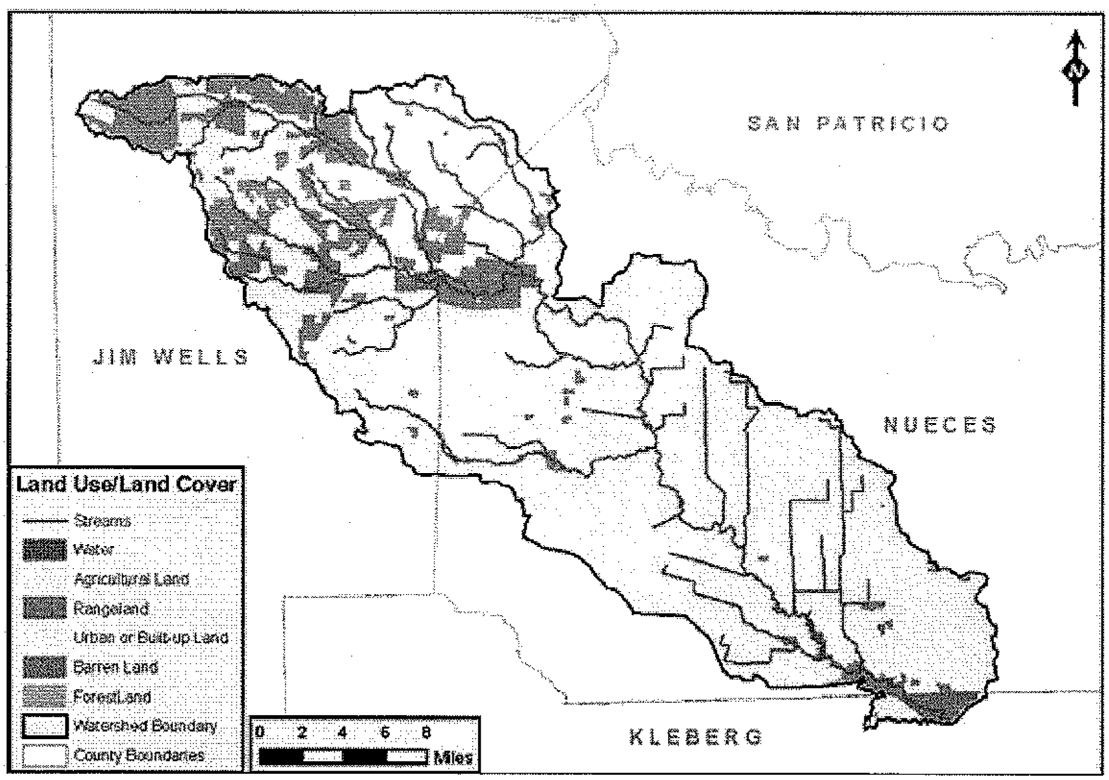


Figure 4: Petronila Creek Land Use Distribution

Oil and Gas Production

Oil and gas production and exploration are the dominant industrial activity in the Petronila Creek watershed. As of September 2001, there were a total of 1,248 gas wells in

Nueces County. Of these, 696 were active, regularly producing wells, 55 were temporarily abandoned, 479 were inactive, and 18 were used to inject fluid (water, air, CO2) into productive formations. There are currently 627 oil wells in Nueces County, with 209 of these regularly producing, 387 inactive, and 31 serving as injection wells. Figure 5 depicts non-compliant (abandoned and orphaned) oil and gas wells and injection wells present in the watershed. This information is based on data provided by the Railroad Commission of Texas. The TCEQ Nonpoint Source Program has and continues to work with the RRC to eliminate potential sources of salinity in the watershed of Petronila Creek Above Tidal by plugging abandoned, non-compliant oil and gas wells and re-plugging improperly plugged wells.

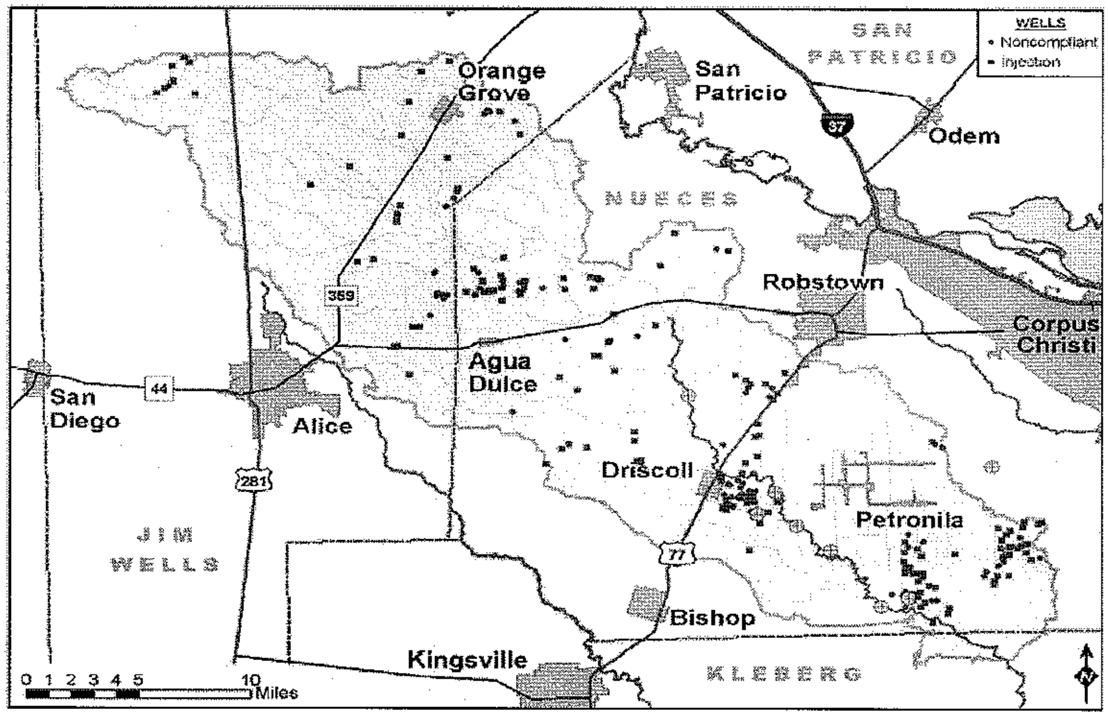


Figure 5: Non-Compliant Oil and Gas Wells and Injection Wells in the Watershed of Petronila Creek Above Tidal

ASSESSMENT OF POLLUTANT SOURCES

The data used to assess the sources affecting Petronila Creek Above Tidal are discussed in the following sections. The inventory of data and information is outlined, along with monitoring, water quality, stream flow, and meteorological weather data.

Data and Information Inventory

A wide range of data and information were used in the development of the TMDLs for Petronila Creek Above Tidal. Categories of data used include the following:

1) Hydrographic data that describe the physical conditions of the stream, such as the network and connectivity of the stream reach, and the depth, width, slope, and elevation of the stream channel.
2) Watershed physiographic data that describe physical conditions such as topography, soils, and land use.
3) Data and information related to the use of, and activities in, the watershed that can be used in the identification of possible chloride, sulfate, and TDS sources.
4) Environmental monitoring data that describe stream flow and water quality conditions in the stream.

Water Quality Monitoring

The NRA is responsible for coordinating the Clean Rivers Program monitoring activities in the Nueces Rio-Grande Coastal Basin for inclusion in the TCEQ's Surface Water Quality Monitoring (SWQM) database. The TCEQ and the USGS also collect data within the basin.

Table 2: Monitoring Stations on Segment 2204

Station I.D. Number	Period of Record	
	From	To
13030	2003	2005
13032	2003	2005
13093	2003	2005
13094	1994	2005
13095	2003	2005
13096	2003	2005
13098	2003	2005
13099	1998	2005

Data collected at eight stations on Segment 2204 were used in the development of these TMDLs (Table 2). Field and chemical parameters included water temperature, pH, dissolved oxygen, specific conductivity, flow, TDS, chloride, and sulfate.

Water Quality Data

Review of the available water quality data reinforced early assessments that Petronila Creek contains moderate to high levels of TDS, chloride, and sulfate. Tables 3, 4, and 5 summarize the data collected on segment 2204, including the number of samples collected, exceedances of the water quality standard, and the observed concentration ranges for chloride, sulfate, and TDS. Figures 7, 8, and 9 display the data in charts depicting the high, low, and median values observed over the respective term of collection.

Stream Flow and Weather Data

Stream flow measurements are necessary to calibrate watershed and water quality models, calculate loadings of pollutants from point and nonpoint sources, characterize transport processes, and evaluate impacts of pollutant loadings. However, no recent source of continuous flow data is available for the watershed of Petronila Creek Above Tidal. Therefore, a paired watershed approach was used to develop a source of flow data for TMDL modeling. The basis of this approach was to develop a model for a hydrologically similar watershed where sufficient stream flow and other data were available. This model was then transferred to the watershed of Petronila Creek Above Tidal. Criteria used to evaluate the hydrologic similarity of the paired watersheds included mean annual precipitation and physiographic characteristics such as drainage area, main channel slope, main channel length, mean basin elevation, soil type distribution, and land use/land cover.

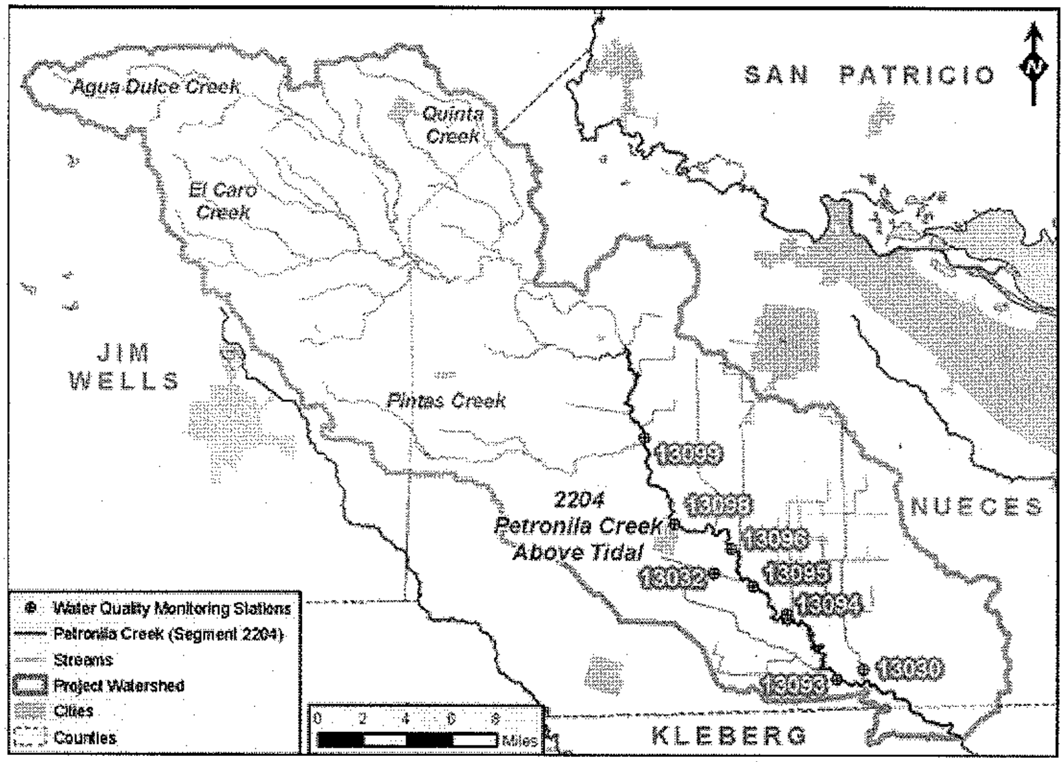


Figure 6. Water Quality Monitoring Stations Located on Segment 2204

Oso Creek, located within the Nueces-Rio Grande Coastal Basin in the watershed of Corpus Christi Bay, was chosen to simulate stream flow because of its hydrologic and physiographic similarities to the watershed of Petronila Creek Above Tidal. The Oso Creek watershed is also immediately adjacent to the Petronila Creek watershed.

The flow monitoring station for Oso Creek (USGS08211520) is located near Corpus Christi, Texas. Flow data for Oso Creek were retrieved for the period of 1973 to 2004 from USGS, and were used in model set-up, hydrological calibration, and validation. The calibrated hydrologic model was then used to develop the watershed of Petronila Creek Above Tidal TMDL.

Table 3: Summary of Chloride Data for Petronila Creek

Station I.D.	# of Samples	# of Exceedances	Data Range (mg/L)	Dates Collected
13030	17	10	60 - 30,000	1/27/2003 - 6/3/2005
13032	12	9	11 - 29,000	1/21/2003 - 6/2/2005
13093	16	11	14 - 8,800	1/27/2003 - 6/2/2005
13094	42	33	9 - 11,200	5/8/95 - 6/3/2005
13095	15	9	9 - 10,000	1/27/2003 - 6/2/2005
13096	21	13	7 - 11,000	10/17/95 - 6/3/2005
13098	14	1	3 - 5,800	5/9/2003 - 6/3/2005
13099	9	0	2 - 16	1/27/2003 - 6/2/2005

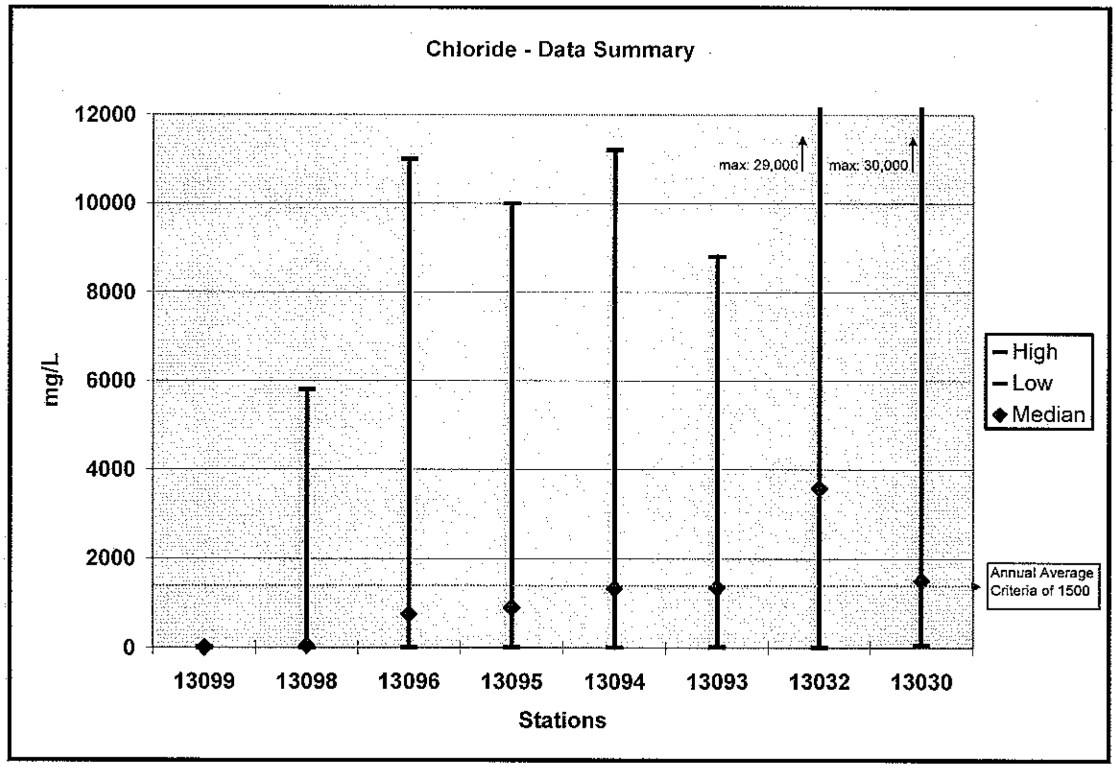


Figure 7: Summary of Chloride Data for Petronila Creek

Table 4: Summary of Sulfate Data for Petronila Creek

Station I.D.	# of Samples	# of Exceedances	Data Range (mg/L)	Date Collected
13030	17	10	42 - 4,170	1/27/2003 - 6/3/2005
13032	12	9	13 - 6,000	1/21/2003 - 6/2/2005
13093	17	11	8 - 1,570	1/27/2003 - 6/2/2005
13094	42	20	4 - 1,680	5/8/95 - 6/3/2005
13095	16	9	4 - 1,660	1/27/2003 - 3/22/2005
13096	21	11	3 - 2,000	1/24/96 - 6/2/2005
13098	14	0	3 - 400	5/9/2003 - 6/3/2005
13099	9	0	2 - 8	1/27/2003 - 6/2/2005

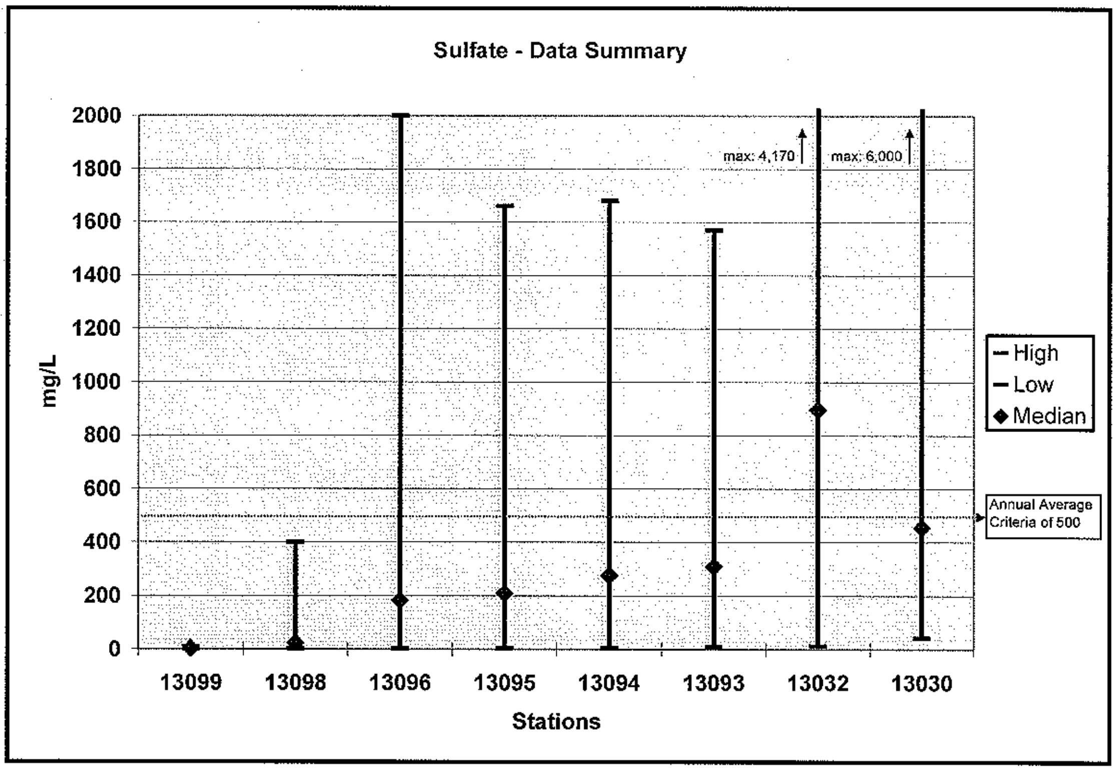


Figure 8: Summary of Sulfate Data for Petronila Creek

Table 5: Summary of TDS Data for Petronila Creek

Station I.D.	# of Samples	# of Exceedances	Data Range (mg/L)	Date Collected
13030	17	10	360 - 34,000	1/27/2003 - 6/3/2005
13032	12	9	260 - 32,800	1/21/2003 - 6/3/2005
13093	17	12	240 - 17,400	1/27/2003 - 6/2/2005
13094	45	34	140 - 20,200	4/25/94 - 6/3/2005
13095	15	9	130 - 17,400	1/27/2003 - 6/2/2005
13096	20	13	130 - 20,900	10/17/95 - 6/3/2005
13098	14	0	180 - 3,250	5/9/2003 - 6/3/2005
13099	12	0	110 - 240	11/4/97 - 6/2/2005

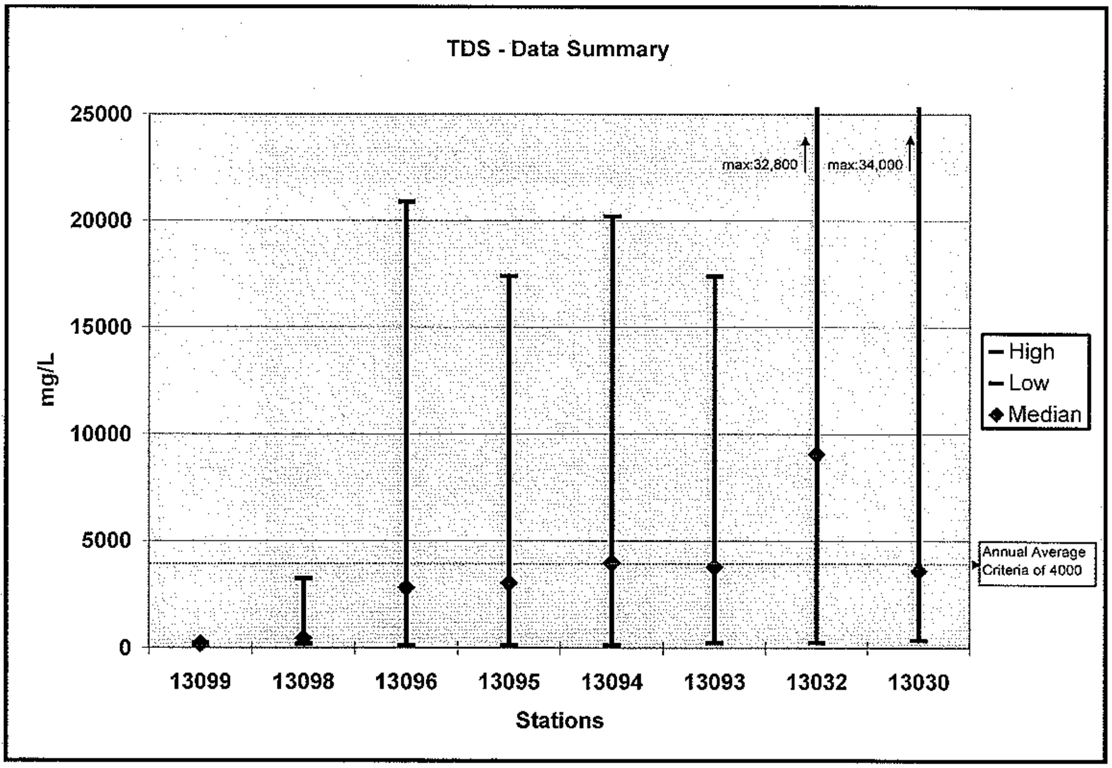


Figure 9: Summary of TDS Data for Petronila Creek

Hourly precipitation and weather data are used to simulate the hydrologic cycle in modeling. Precipitation and weather data collected at the Corpus Christi airport (east of the Petronila Creek watershed in Corpus Christi, Texas) were obtained from the National Climatic Data Center for use in the model.

The Critical Condition

Federal regulations in 40 CFR 130.7 (c) (1) require that TMDLs take into account the critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that water quality is protected during times when it is most vulnerable. The critical condition is considered the "worst case scenario" of environmental conditions in the watershed of Petronila Creek Above Tidal. If the TMDL is developed so that the water quality targets are met under the critical condition, then the water quality targets are most likely to be met under all other conditions. Critical conditions are important because they describe the factors that combine to cause a violation of water quality standards and help in identifying the actions that may have to be undertaken to meet water quality standards.

Chloride, sulfate, and TDS loadings result from sources that can contribute these pollutants during wet weather and dry weather. The critical conditions for the impaired segment of Petronila Creek were determined using the paired-watershed approach from the available instream water quality data collected by the TCEQ and from USGS streamflow data. Plotting chloride, sulfate, and TDS water quality data along with streamflow data revealed that the standard exceedances were occurring throughout the impaired segment, independent of the season, and mainly under low flow conditions (see Figures 10, 11, and 12). Since chloride, sulfate, and TDS loadings are based on an annual average and occur throughout the year, their impacts are a function of cumulative loading rather than particular events. Since it is appropriate to consider chloride, sulfate, and TDS loadings on an annual basis, pollutant loadings and TMDL allocation scenarios were developed based on average annual loads determined from a 10-year model simulation period.

Consideration of Seasonal Variations

Seasonal variations involve changes in stream flow and water quality as a result of hydrologic and climatic patterns. Seasonal variations were evaluated in the modeling approach for these TMDLs. This allowed the consideration of temporal variability in chloride, sulfate, and TDS loadings within the Petronila Creek impaired segment. Exceedances occur throughout the impaired segment independent of the season.

ENDPOINT IDENTIFICATION

TMDLs must identify a quantifiable water quality target for each constituent that causes a body of water to appear on the §303(d) list. For chloride, sulfate, and TDS, the primary water quality targets have been established through the *Texas Surface Water Quality Standards*.

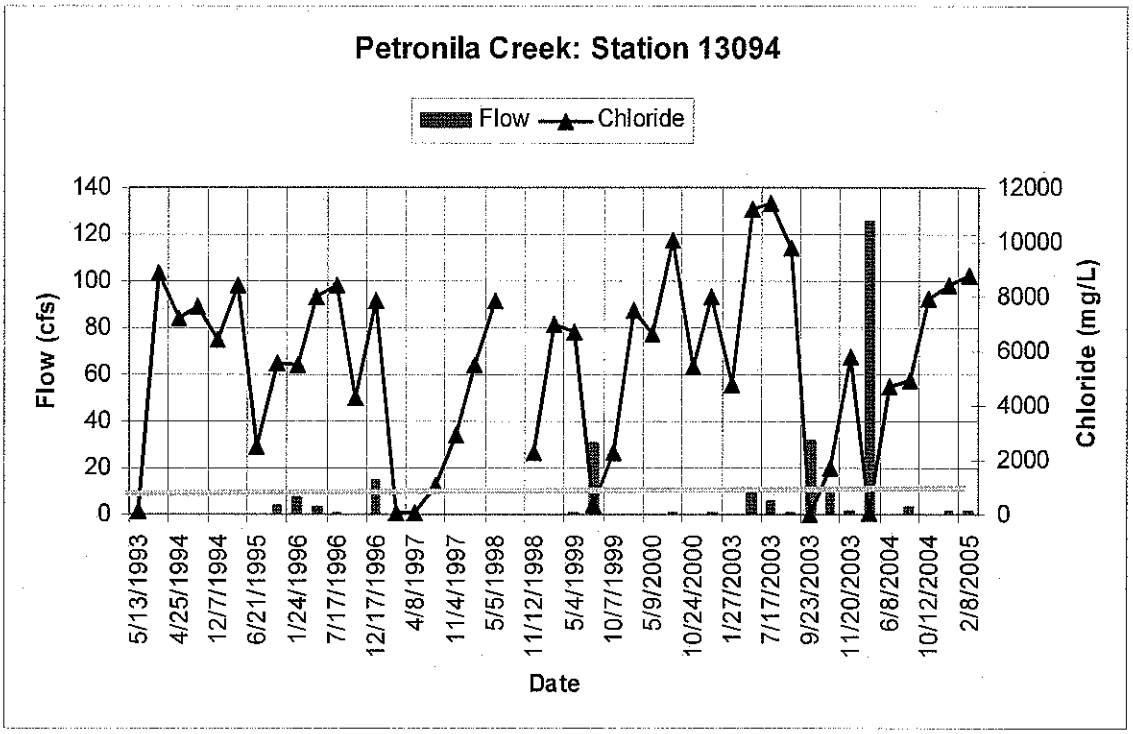


Figure 10: Flow and Chloride Concentrations at Station 13094

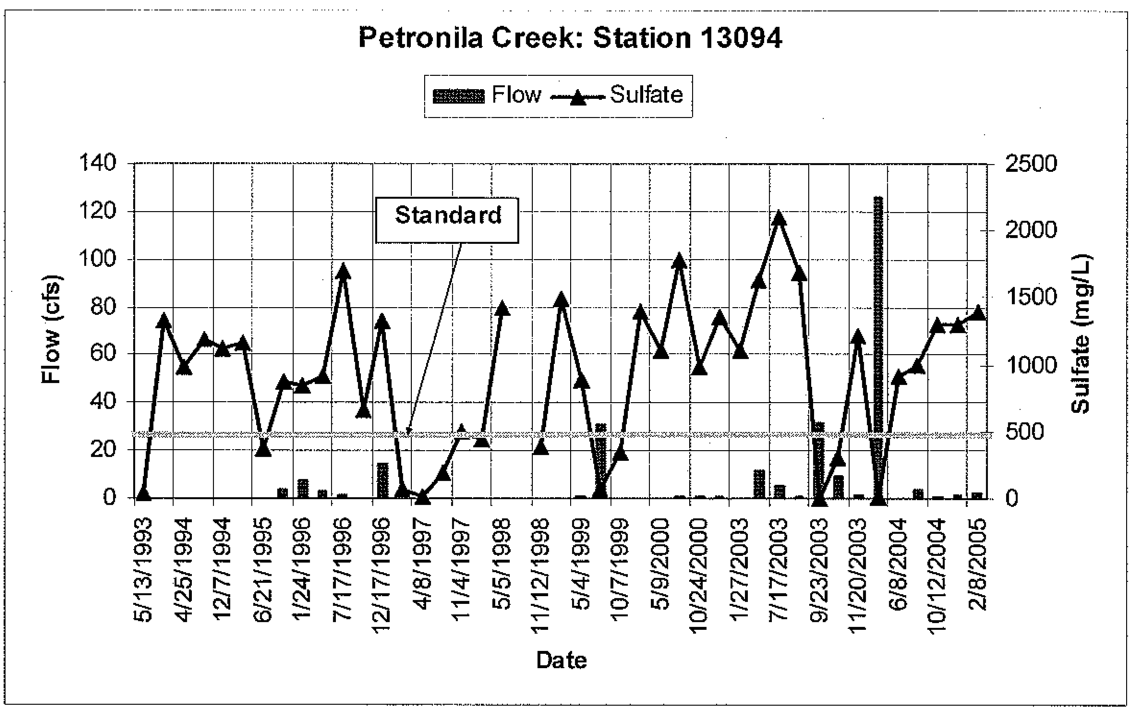


Figure 11: Flow and Sulfate Concentrations at Station 13094

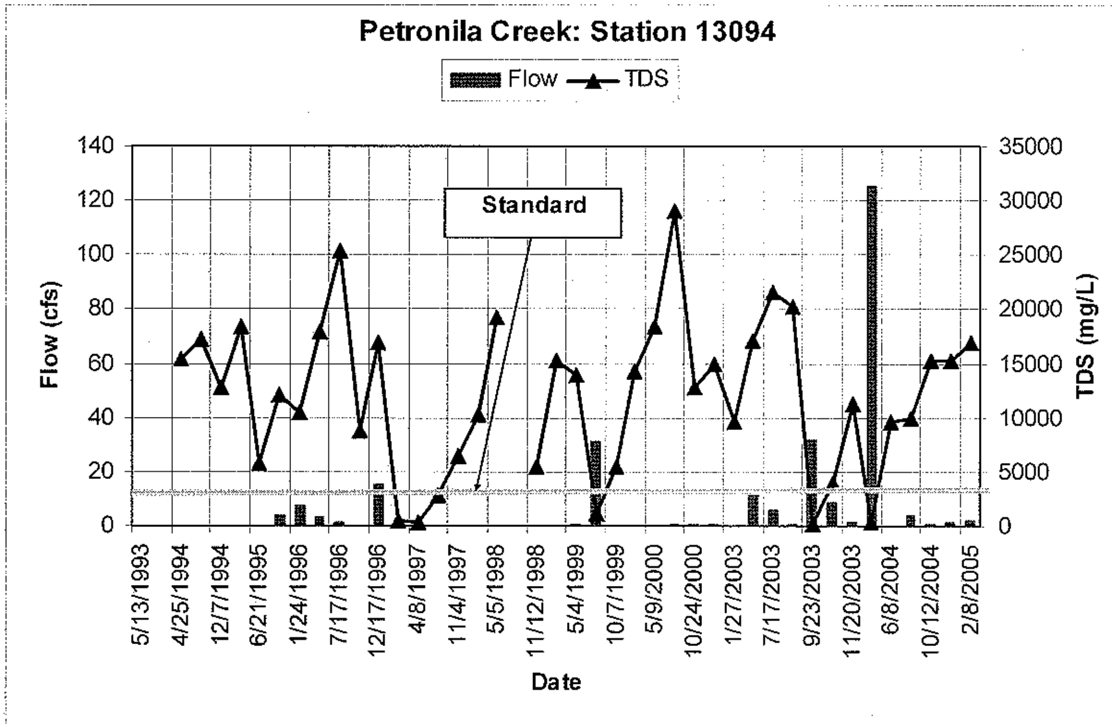


Figure 12: Flow and TDS Concentrations at Station 13094

Chloride

Texas water quality standards specify that the annual average chloride concentrations in the impaired segment of Petronila Creek should not exceed 1,500 mg/L.

Sulfate

Texas water quality standards specify that the annual average sulfate concentrations in the impaired segment of Petronila Creek should not exceed 500 mg/L.

Total Dissolved Solids

Texas water quality standards specify that the annual average TDS concentrations in the impaired segment of Petronila Creek should not exceed 4,000 mg/L.

Source Analysis

Pollutants may come from several sources, both point and nonpoint. The possible sources of salts in Petronila Creek Above Tidal are discussed in this section.

Point Source Dischargers

Point source pollutants come from a discernible, confined, and discrete conveyance, such as any pipe, ditch, channel, tunnel, conduit, well, container, or from concentrated animal-feeding operations, vessels or floating crafts from which pollutants are discharged to surface water bodies. Point sources are regulated by permits under the Texas Pollutant Discharge Elimination System (TPDES), which may include effluent limitations, monitoring, and reporting requirements. Storm water discharges from separate storm sewer systems of cities and those associated with industry and construction are also considered point sources of pollution.

The only regulated point sources with permit limits discharging to the impaired segment are six permitted municipal wastewater plants and industrial plants. The point sources present in the impaired segment are identified in Table 6.

Table 6: Permitted Dischargers with Permit Limits in Watershed of Petronila Creek Above Tidal

Permit #	Name of Facility	Flow (MGD)
WQ0010140-001	City of Agua Dulce	0.16
WQ0010592-001	City of Orange Grove	0.2
WQ0011541-001	Driscoll Plant, City of Driscoll	0.1
WQ0011583-001	Banquete Plant, Nueces CO WCID 5	0.1
WQ0011689-001	City of Coastal Bend Youth City	0.015
WQ0011754-001	Petronila Elementary	0.008

Produced Water

There has been significant oil and gas exploration and production activity in the study area. As of 2001, there were 1,875 documented oil and gas wells (EA Engineering et al, 2006). Currently active fields include the Clara Driscoll and North Clara Driscoll oil fields, which are bisected by Petronila Creek. Oil exploration is a major industry in the watershed. The production of oil is usually accompanied by the production of brine, which occurs in the same strata as the oil. During primary production of oil, the ratio of salt water to oil is usually less than 1:4 but as the well ages, the ratio of salt water to oil becomes closer to 1:1 and may be as high as 10:1. As the ratio increases, the well becomes unprofitable to operate and is either properly plugged or abandoned. Some of these abandoned wells occasionally have cracks and leaks that may eventually allow brine to reach the surface and contaminate ground water and surface water (Paine et al, 2005).

Brine Pits

Historically, operators disposed of brine in large, shallow, unlined pits where water would be lost due to evaporation and seepage. When brine evaporates, dissolved solids are left behind as salt crusts that can cause infiltration to the shallow subsurface and local ground water. Brine disposal pits were used extensively in areas of oil production until 1969, when a statewide ban was placed on their use.

Brine Injection

The practice of injecting brine into subsurface strata is used for both disposal of excess brine and for recovering oil from under-pressurized formations. Many disposal wells inject brine into formations immediately below shallow aquifers. This relatively shallow disposal presents a higher risk of migration into groundwater and surface water bodies at the point where the formation outcrops. Surface and subsurface contamination associated with injection wells are often traced to cracked casings, leaking boreholes, or wells that are not operated properly.

Phreatophytic Brush

The proliferation of invasive species of brush (phreatophytic brush) into the southwestern portions of the United States is a recognized problem in water management. Species of phreatophytic brush that are found in the Nueces-Rio Grande Coastal Basin are prickly pear, juniper, retama, huisache, and mesquite. Phreatophytic brush species have a high water consumption rate compared to most native vegetation and easily out-compete most native species in disturbed areas. Thus, there may be a correlation between decreased stream flows, higher ambient salinity, and increasing brush coverage.

Additional Salinity Sources

Additional potential sources of salinity in Petronila Creek include: the presence of primary saline pore water in Beaumont Formation strata that was deposited in a late Pleistocene coastal environment; salt particles blown inland and deposited by prevailing onshore winds; and extensive inland flooding of saline gulf and estuarine water during recurrent tropical storms.

Field Monitoring Surveys

Field surveys of the Petronila Creek watershed were conducted by EA Engineering Science and Technology (EA) from January 2003 through July 2005 to enhance understanding of the nature and extent of salinity loading in the watershed of Petronila Creek Above Tidal. Reconnaissance ground-based measurements supplemented available water quality data and confirmed that little salinization exists upstream from U.S. Highway 77, but that significant salinization occurs within a short distance of U.S. Highway 77 and continues to the downstream section surveyed. Local areas of elevated ground conductivity suggest that there are local sources of salinization that degrade surface water quality, including several sites near Driscoll and within the Driscoll Oil Field area.

Electromagnetic Induction (EM) Surveys

Geophysical instruments can also be used to non-invasively identify saline ground that might contribute to the elevated salinity of Petronila Creek. The electrical conductivity of the ground (McNeill, 1980) is generally dominated by electrolytic flow of ions in pore water. Because the salinity of water is strongly correlated to its electrical conductivity (Robinove and others, 1958), the electrical conductivity of soil and sediment is also strongly influenced by the salinity of pore water. As pore-water salinity increases, so does the electrical conductivity of the ground.

In order to better define the sources of chloride, sulfate, and TDS in the Petronila Creek impaired segment, the University of Texas Bureau of Economic Geology (BEG) conducted TCEQ-sponsored ground-based and airborne geophysical surveys using ground and airborne electromagnetic (EM) induction instruments to delineate the extent and intensity of salinization and identify salinity sources that degrade surface water quality in Petronila Creek downstream from U.S. 77.

EM methods employ a changing primary magnetic field created around a transmitter coil to induce current to flow in the ground, which in turn creates a secondary magnetic field that is sensed by the receiver coil (Paransis, 1973; Frischknecht and others, 1991; West and Macnae, 1991). The strength of the secondary field is a complex function of EM frequency and ground conductivity (McNeill, 1980b), but generally increases with ground conductivity and constant frequency. This section summarizes results of the BEG's EM surveys (Paine et al, 2005).

The BEG used evident lateral and vertical conductivity trends to interpret the extent and intensity of salinization, whether it has shallow or deep sources, and, by combining geophysical patterns with chemical surface water patterns, interpreted the likely source type. A Geonics EM31 ground conductivity meter was used to take ground conductivity measurements at 166 locations along Petronila Creek, accessible tributaries, and drainage ditches that flow into Petronila Creek and across adjacent fields between June 22 and 26, 2004. The instrument operates at a frequency of 9.8 kilohertz (kHzs), measuring apparent conductivity to a depth of about 3meters (horizontal dipole [HD] orientation) and 6meters (vertical dipole [VD] orientation). Measurements were taken in both the HD and the VD.

Aerial conductivity measurements were acquired in early February 2005 within a northwest-southeast oriented block measuring 3.7 miles by 15.5 miles centered on the axis and within a corridor centered on Petronila Creek, from a point above U.S. 77 to about 1.2 miles downstream from where Petronila Creek enters Kleberg County. The survey subcontractor, Geophex, provided the technical survey crew and their GEM-2A airborne instrument. Airlift Helicopters provided the flight crew and helicopter to tow the instrument.

The GEM-2A is an EM instrument that employs a single pair of transmitter and receiver induction coils in horizontal coplanar orientation that operate at multiple effective frequencies (and exploration depths) simultaneously (Won and others, 2003). Five primary frequencies: 450, 1350, 4170, 12,810, and 39,030 Hz yield exploration depths ranging from a few meters at the highest frequency to several tens of meters at the lowest frequency.

The BEG received final processed geophysical data from Geophex, the survey subcontractor, in mid-April 2005, and converted final processed data into images showing trends and variations in apparent conductivity laterally and with depth along and near the creek. Chemical analyses of the surface water flowing in the creek during the airborne survey depict a chemistry that changes from fresh meteoric water upstream from U.S. 77 to highly saline water below U.S. 77 that is (a) a mixture between two non-seawater sources (probably produced oilfield water), and (b) a mixture of seawater and another highly saline source (probably produced water).

Survey Results

The exploration depth of the airborne EM instrument is governed by instrument frequency and ground conductivity. The BEG explored at five frequencies ranging from 450 Hz (the deepest-exploring frequency at an average exploration depth of about 28 meters (92 feet) for this area) to 39 kHz (the shallowest-exploring frequency at an average exploration depth of about 2 meters (7 feet)). Apparent conductivity trends plotted from creek-axis data allow delineation of three areas of generally elevated apparent ground conductivity along the creek (Figure 13). From upstream to downstream, these include the Driscoll area, extending a total creek length of about 4.8 miles downstream from the U.S. 77 bridge to the FM 665 bridge; the Concordia area, extending a total creek length of about 5.6 miles from about 0.6 miles below the FM 665 bridge to about 1.2 miles below the FM 892 bridge; and the Luby area, extending from the FM 70 bridge to near the end of the survey about 5.2 miles farther downstream. These areas represent the stream reaches most likely to be contributing highly saline water that degrades water quality in Petronila Creek.

Driscoll Area

The Driscoll reach lies adjacent to the Clara Driscoll Oil Field south of the creek and the North Clara Driscoll Oil Field north of the creek (Figure 13). Elevated apparent conductivities are evident across the Clara Driscoll field at all frequencies and at the North Clara Driscoll field at low to intermediate frequencies, suggesting that oil field-related, near-surface salinization has occurred in these areas, probably largely from past surface discharge of produced water into pits and ditches (Figure 14).

Assuming that there has been no significant surface discharge of produced water for more than a decade, the most likely mechanism for infiltration of highly saline water into this creek reach is: (1) direct infiltration of produced water into the shallow subsurface from pits and drainage ditches; (2) lateral migration of saline water through sandy Beaumont Formation channels; and (3) discharge as local, shallow-source base flow into Petronila Creek in places along the 4.8-mile reach.

At the upstream end at U.S. 77, flow on February 8, 2005 (one day after the airborne survey was completed) was 0.1 cubic feet per second at a total dissolved solids (TDS) concentration of 2,460 mg/L. This translates to an incoming TDS load of 1327 pounds per day (lbs/day). At FM 665 at the end of the Driscoll, flow was 0.562 cubic feet per second with a TDS concentration of 15,100 mg/L at station 13096, translating to an outgoing salinity load of 45,772 lbs/day, an increase of about 44,445 lbs/day. This loading is predominantly attributed to the local base flow mechanism described above.

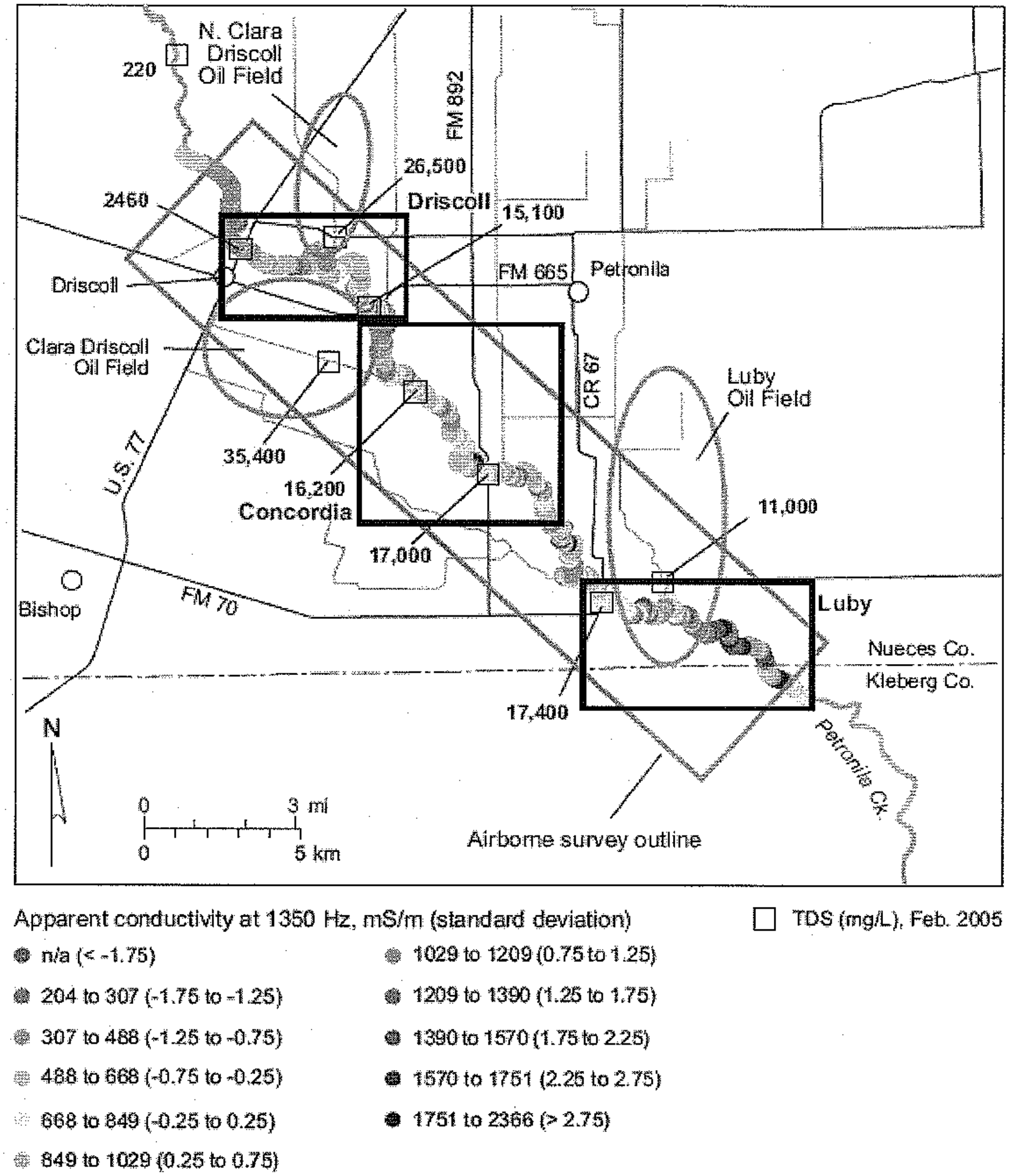
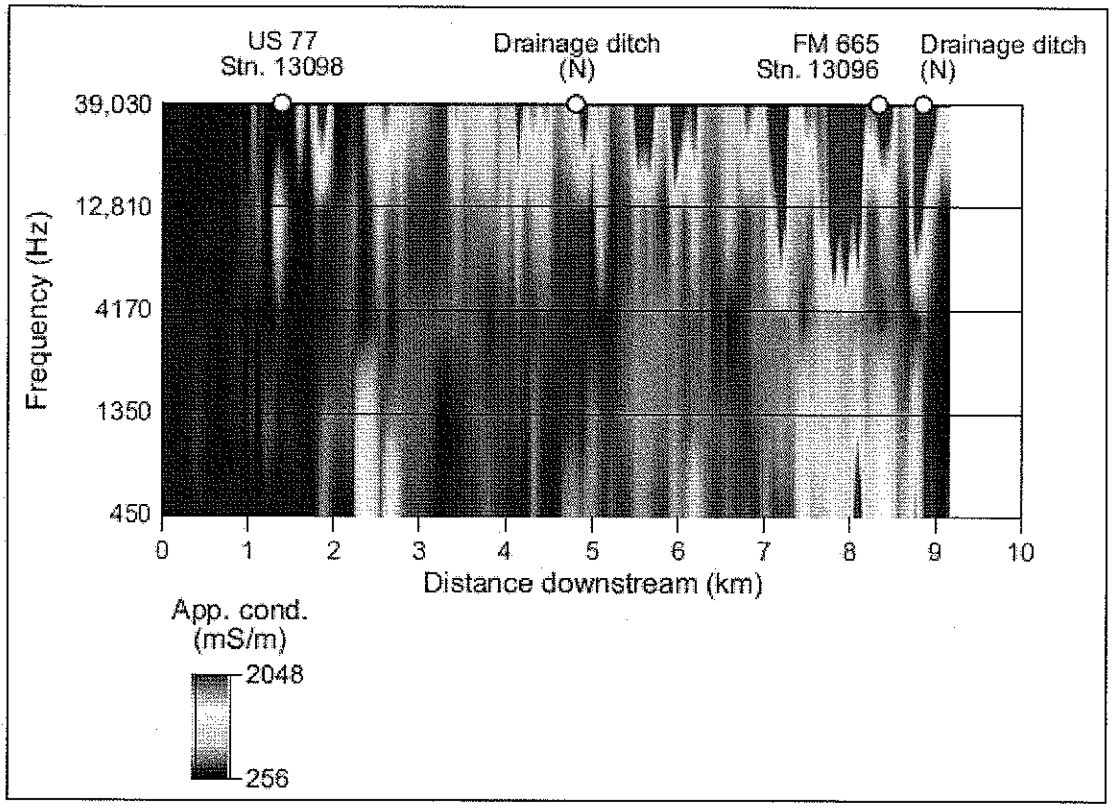


Figure 13: Areas of Elevated Conductivity Measured in Petronila Creek Impaired Reach

Concordia Area

The Concordia area encloses a 5.6-mile-long segment of Petronila Creek that begins about 0.6 miles downstream from FM 665 and continues to about 1.2 miles downstream from FM 892 (Figure 13). EM data shown on the pseudosection (Figure 15) indicate that the most conductive reach is about 3.7 miles long, extending from the upstream limit of the Concordia area to a point about 1.2 miles downstream from FM 892. Conductivities at the two highest frequencies are particularly high, implying highly conductive, near-surface strata beneath the creek. There are relatively few oil and gas wells within the

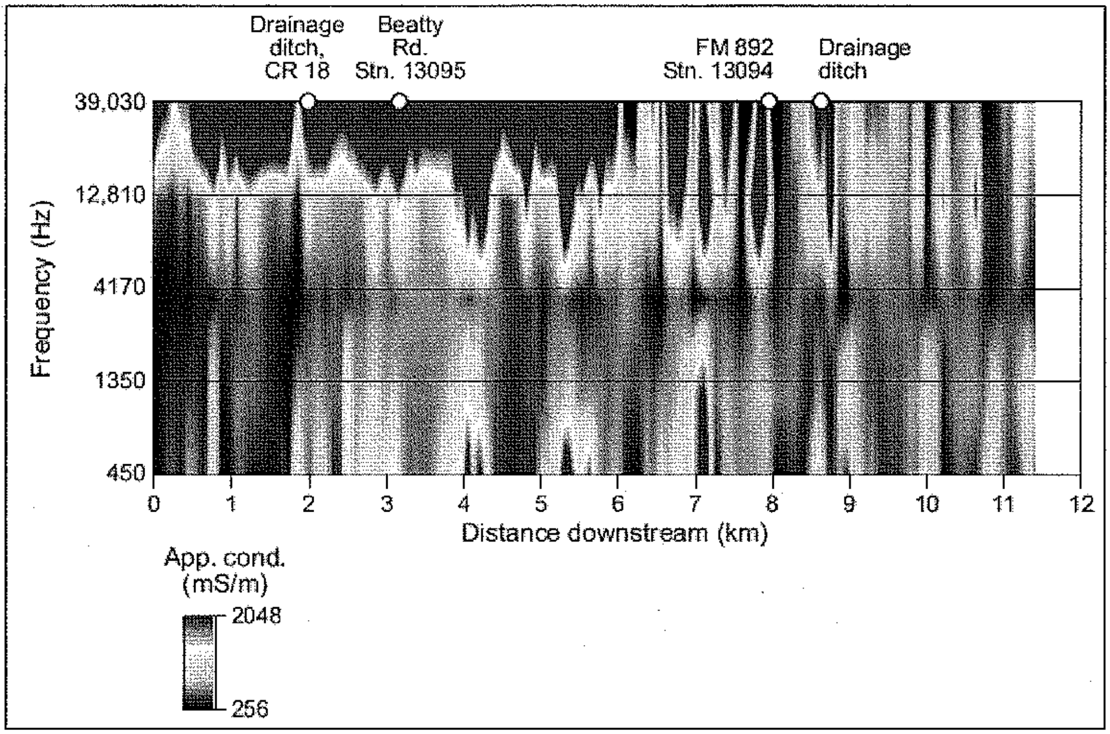
Concordia area, but there are at least two ditch-drainage systems that carried water produced from wells farther west across the area south of Petronila Creek. We interpret that the elevated conductivity south of Petronila Creek represents relatively shallow accumulations of saline produced water that was discharged into the drainage ditches when that practice was permitted and entered the subsurface along the ditches where they intersect the sandy Beaumont Formation channels. This water has migrated laterally toward Petronila Creek, providing locally sourced saline base flow to Petronila Creek.



Note: The shallowest-exploring frequency is along the top of the image and the deepest-exploring frequency is along the bottom.

Figure 14: Combined apparent conductivity pseudosection along the Driscoll reach using all frequencies acquired during the airborne stream-axis survey (UTBEG, 2005)

The BEG estimated salinity loading along the Concordia segment using EA's February 2005 sampling and analyses. Loading at the upstream end of the segment is represented by the 45,772 lbs/day TDS value calculated at FM 665 (station 13096). At the Beatty Road crossing (station 13095) within the upper part of the Concordia segment, flow had increased to 1.253 cubic feet per second at 16,200 mg/L TDS, representing a TDS load of 109,545 lbs/day, an increase of about 63,944 lbs/day above the value at FM 665.



Note: The shallowest-exploring frequency is along the top of the image and the deepest-exploring frequency is along the bottom

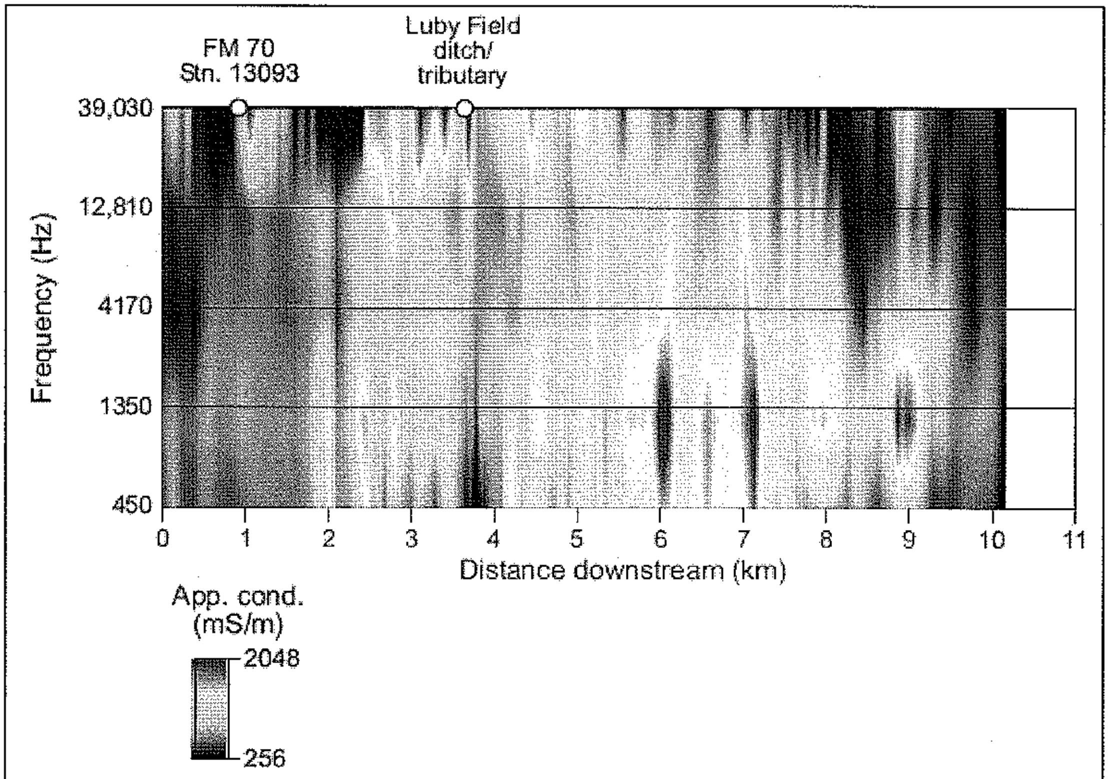
Figure 15: Combined apparent conductivity pseudosection along the Concordia reach using all frequencies acquired during the airborne stream-axis survey (UTBEG, 2005)

At FM 892 (station 13094) farther downstream within the Concordia segment, combining the flow of 1.974 cubic feet per second with the 17,000 mg/L TDS concentration translates to a TDS load of 181,003 lbs/day, an increase of more than 70,547 lbs/day from the Beatty Road crossing. Total loading increase along the Concordia segment was thus more than 134,481 lbs/day. Though these calculations were instantaneous and cannot realistically be used for meaningful annual loading calculations, the BEG interpreted that this increase is dominated by local-source, near-surface base flow from produced water that was once discharged into the two major drainage ditches crossing the area, entered the shallow subsurface along the ditches, and migrated toward the creek along sandy subsurface Beaumont Formation channels.

Luby Area

The Luby area differs from the Driscoll and Concordia areas in that the patterns are best developed in the lowest frequency (deepest exploring) data (Figure 16). Maps and sections produced from airborne geophysical data show a relatively distinct upstream boundary that crosses Petronila Creek near the FM 70 bridge and coincides with part of the Luby Oil Field.

Multi-frequency conductivity sections constructed from stream-axis conductivity profiles differ markedly from the Driscoll and Concordia sections, indicating relatively little evidence for shallow salinization and more pronounced elevated conductivity at the lower (deeper) frequencies. The BEG interpreted these data to suggest that this area may mark the upstream limit of the subsurface incursion of saline coastal water, rather than representing further significant addition of produced water to the stream environment.



Note: The shallowest-exploring frequency is along the top of the image and the deepest-exploring frequency is along the bottom.

Figure 16: Combined apparent conductivity pseudosection along the Luby reach using all frequencies acquired during the airborne stream-axis survey (UTBEG, 2005)

Minor amounts of produced water may reach this segment along drainage ditches from the Luby Oil Field area, but the elevated subsurface conductivities appear to be dominated by incursion of coastal saline water. There are insufficient data available to estimate possible TDS loading changes along this most downstream, coastal-influenced segment. At FM 70 (station 13093) at the upstream end of the segment, combining EA's February 2005 flow of 0.787 cubic feet with a TDS concentration of 17,400 mg/L translates to an incoming load of 73,861 lbs/day. The reduction in TDS load of more than 105,821 lbs/day from 181,003 lbs/day at the downstream limit of the Concordia segment to the Luby segment is thus likely caused by flow losses along the creek.

LINKAGE BETWEEN SOURCES AND RECEIVING WATERS

There has been significant oil and gas exploration and production activity in the watershed downstream of U.S. Hwy 77. As of September 2001, there were 1,875 documented oil and gas wells in Nueces County (EA Engineering et al, 2006). Active or once-active fields on or adjacent to the creek include the Clara Driscoll, North Clara Driscoll, and Luby oil fields. Records from the Railroad Commission of Texas indicate that 900 wells have been drilled within the boundary of the airborne geophysical survey. These include 359 active or plugged oil wells, 113 active or plugged gas wells, 215 active or plugged oil and gas wells, 187 dry holes, 16 injection or disposal wells, and 10 sidetrack wells.

Produced brine discharge into surface pits presumably ceased with the implementation of the Railroad Commission's no-pit order in 1969. The RRC no longer permitted discharge of produced water to area drainage ditches and streams beginning in 1987 (Shipley, 1991). Water produced from area oil fields is highly saline; Gaither (1986) reports a TDS concentration of 49,300 mg/L and chloride concentration of 28,904 mg/L in water produced from the Vicksburg Formation in the Clara Driscoll Oil Field. Shipley (1991) cites chloride concentrations of 36,500 to 55,700 mg/L in raw produced brines from the Petronila Creek area.

The past oil industry practice of discharging highly saline produced water at the surface into drainage ditches, pits, and Petronila Creek has been shown to have degraded surface-water quality and affected aquatic species in Petronila Creek (Shipley, 1991). In a study covering seven years during which produced brine was discharged directly or indirectly into the creek and one year of monitoring after permitted discharge ceased in 1987, Shipley (1991) showed that creek salinities remained high below U.S. 77 after discharge ceased, except at the most upstream station monitored, and pore-water salinities in creek-bottom sediments along the affected segment also remained high after discharge ceased, despite flushing storm events. Further, the chemical signature of saline water in Petronila Creek more closely matched that of discharged produced water than that of saline water in Baffin Bay downstream (Paine et al, 2005).

MARGIN OF SAFETY

The margin of safety (MOS) is a required component of the TMDL to account for any lack of knowledge concerning the relationship between effluent limitations and water quality. According to EPA guidance (*Guidance for Water Quality-Based Decisions: The TMDL Process, 1991*), the MOS can be incorporated into the TMDL using two methods:

- Implicitly incorporating the MOS using conservative model assumptions to develop allocations; or
- Explicitly specifying a portion of the TMDL as the MOS and using the remainder for allocations.

The MOS will be explicitly incorporated into this TMDL. An explicit margin of safety is more appropriate when there is some degree of uncertainty in input data and model results. In flow calibration, there was a good agreement between observed and simulated stream flows. However, model validation shows less robust flow calibration results, though still within acceptable range. Flow was calibrated using a reference station (paired watershed) in Oso Creek which introduces additional uncertainty. Consequently, a 5% explicit margin of safety was used to account for these uncertainties. Incorporating a MOS of 5% will require that allocation scenarios be designed to meet annual average sulfate, chloride, and TDS standards of 475, 1425, and 3800 mg/L, respectively (as compared to the segment-specific standards of 500, 1500, and 4000 mg/L).

POLLUTANT LOAD ALLOCATION

For Petronila Creek, the TMDL allocation analysis for chloride, sulfate, and TDS is the third stage in the overall TMDL development process. Its purpose is to develop the framework for reducing sulfate, chloride, and TDS loadings under the existing watershed conditions so water quality standards can be met. The TMDL represents the maximum amount of pollutant that the stream can receive without exceeding the water quality standard. The load allocations for the selected scenarios are calculated using the following equation:

$$TMDL = \sum WLA + \sum LA + MOS$$

Where

WLA = wasteload allocation (point source pollutant contributions);
LA = load allocation (nonpoint source pollutant contributions);
MOS = margin of safety; and
$\sum$ = summation.

Typically, there are several potential allocation strategies that would achieve the TMDL endpoint and water quality standards. Available control options depend on the number, location, and character of pollutant sources.

Allocation Scenario Development

Allocation scenarios that would reduce the existing sulfate, chloride, and TDS loads to meet the corresponding water quality standards were simulated using the Hydrological Simulation Program – FORTRAN (HSPF) model (Bicknell et al., 1993).

Wasteload Allocation

There are six permitted point source dischargers in the impaired reach of the Petronila Creek watershed. For this TMDL, the wasteload allocations for the dischargers were set equal to the water quality standards minus the MOS. The wasteload allocations are provided in Table 7. For this TMDL, the "existing condition" point source loads were calculated using the design flows and typical chloride, sulfate, and TDS concentrations ordinarily present in domestic wastewater effluent (50 mg/L, 30 mg/L and 105 mg/L, respectively) based on literature (Metcalf and Eddy, 1995). The allocated loads or percent reductions were calculated using the design flows and the water quality standards for chloride, sulfate, and TDS (1425 mg/L, 475 mg/L and 3800 mg/L, respectively) with five percent reserved for MOS. Table 7 shows the waste load allocations.

Load Allocation

The reductions of loading from nonpoint sources are incorporated into the load allocation, and include abandoned brine pits, produced water, and groundwater. A number of load allocation scenarios were run to identify various TMDL load allocations. First, a set of scenarios were designed and used to isolate and assess the reductions of chlorides. These scenarios, presented in Table 8, also apply to TDS since it is directly estimated from the chloride sources.

- Scenario 0 represents "base condition" loading, which shows no pollutant reduction of any of the sources, and point source contributions are computed based on the water quality standards. The base condition model is slightly different from the existing condition model. In the base condition model, the point source loads are computed based on design flows, the water quality standards, and the margin of safety. Point source loads in the existing condition model were computed using design flows and the typical concentrations of pollutants in the effluent. The nonpoint source loads for the base condition model are identical to those in the existing condition model.
- Scenarios 1 through 3 represent incremental reductions in loadings from abandoned brine pits and produced water. The intent is to assess the resulting effect of jointly controlling the abandoned brine pit and produced water sources of pollutants.
- Scenario 4 represents a complete reduction in loadings from the abandoned brine pits.
- Scenarios 5 through 8 represent an incremental reduction in loadings from the produced water in addition to a complete reduction in loadings from the abandoned brine pits.

Table 7: Petronila Creek Wasteload Allocation

Name of Facility	Existing Condition Loads Based on Avg Flow (lbs/day)			Allocated Loads Based on Design Flow (lbs/day)			Percent Reductions		
	Cl	SO_4	TDS	Cl	SO_4	TDS	Cl	SO_4	TDS
City of Agua Dulce	67	40	142	1903	634	5074	0	0	0
City of Orange Grove	83	50	177	2378	793	6342	0	0	0
Driscoll Plant, City of Driscoll	42	25	89	1189	396	3171	0	0	0
Banquete Plant, Nueces CO WCID 5	42	25	89	1189	396	3171	0	0	0
City of Coastal Bend Youth City	6	4	13	178	59	476	0	0	0
Petronila Elementary	3	2	7	95	32	254	0	0	0

Table 8: Load Allocation Scenarios for Chlorides and TDS in Petronila Creek

Scenario	Chloride, Sulfate and TDS Reduction in Loadings from Existing Conditions (%)		
	Abandoned brine Pits	Produced Water	Groundwater
0	0	0	0
1	25	25	0
2	50	50	0
3	75	75	0
4	100	0	0
5	100	50	0
6	100	75	0
7	100	78	0
8	100	88	0

Table 9: Petronila Creek Load Reduction Analysis

Scenario Number	Reduction in Loadings from Existing Conditions (%)			Percent of Time that Simulated Annual Average Exceeded the Water Quality Standard		
	Abandoned Brine Pits	Produced Water	Groundwater	Chlorides	Sulfates	TDS
0	0	0	0	100	100	100
1	25	25	0	100	100	100
2	50	50	0	100	100	100
3	75	75	0	100	5	98
4	100	0	0	100	100	100
5	100	50	0	100	100	100
6	100	75	0	100	5	98
7	100	78	0	100	0	71
8	100	88	0	0	0	0

For the hydrologic period spanning from January 2000 to December 2004, the sulfate, chloride, and TDS simulated concentrations were compared against the corresponding standards to estimate the number and frequency of exceedances. Table 9 summarizes the results for all the scenarios.

The following conclusions can be made:

1) Under the base condition (Scenario 0) loadings, the water quality standards were exceeded 100% of the time for chloride, sulfate and TDS ;
2) Elimination of loadings from the abandoned brine pits (Scenario 4) would result in no reduction in the percent exceedance of the water quality standards;
3) Elimination of loadings from the abandoned brine pits and a reduction of 75% from the produced water (Scenario 6 for) would result in a 100 percent ex-

ceedance of the chloride standard, 5% exceedance of the sulfate standard, and 98% exceedance of the TDS standard; and

4) To meet the water quality standard for sulfate a complete (100%) load reduction from the abandoned brine pits and a 78% load reduction from produced water is required (Scenario 7).
5) To meet the water quality standard for chlorides and TDS a complete (100%) load reduction from the abandoned brine pits and an 88% load reduction from the produced water is required (Scenario 8).

Scenario 7 was used to derive the sulfate load allocation plan. Scenario 8 was used to derive the chloride and the TDS load allocation plans.

TMDL Summary

Based on the analysis of the load allocation scenario, a TMDL allocation plan to meet the respective water quality standard goals requires:

- 100% reduction of loading from abandoned brine pits, and;
- 88% reduction of loading from the produced water.
- Overall, the loading from nonpoint sources of chloride and TDS must be reduced by 88% and the loading of sulfate must be reduced by 78% to meet the goal.

Figures 17 through 19 show the modeled chloride, sulfate, and TDS concentrations at station 13093 with the applicable water quality standards. Station 13093 is located at the downstream end of Petronila Creek, and is the most appropriate location for an index site to gage the future trends of salinity in Petronila Creek. These plots show that the water quality standards are not violated under the TMDL allocation scenario. A summary of the sulfate, chloride, and TDS TMDL allocation loads for Petronila Creek is presented in Table 10.

TMDL Expressions

The total load allocations, wasteload allocations, and margins of safety for chloride, sulfate and TDS are summarized in Tables 11 and 13. The background chloride, sulfate and TDS loads are included in groundwater and surface runoff contributions and explicitly considered in LA allocations. The sum of WLA and LA is divided by 0.95 to obtain the TMDL. The margin of safety (MOS) is calculated by subtracting WLA and LA from the TMDL.

PUBLIC PARTICIPATION

The TCEQ maintains an inclusive public participation process. From the inception of the investigation, the project team sought to ensure that stakeholders were informed and involved. The project team also recognized that communication and comments from stakeholders in the watershed would strengthen the project and its implementation actions.

In accordance with requirements of law promulgated in 2001 under TX House Bill 2912, an official steering committee of stakeholders was established and notices of meetings were posted on the TCEQ calendar and in the *Texas Register*. Two weeks prior to sched-

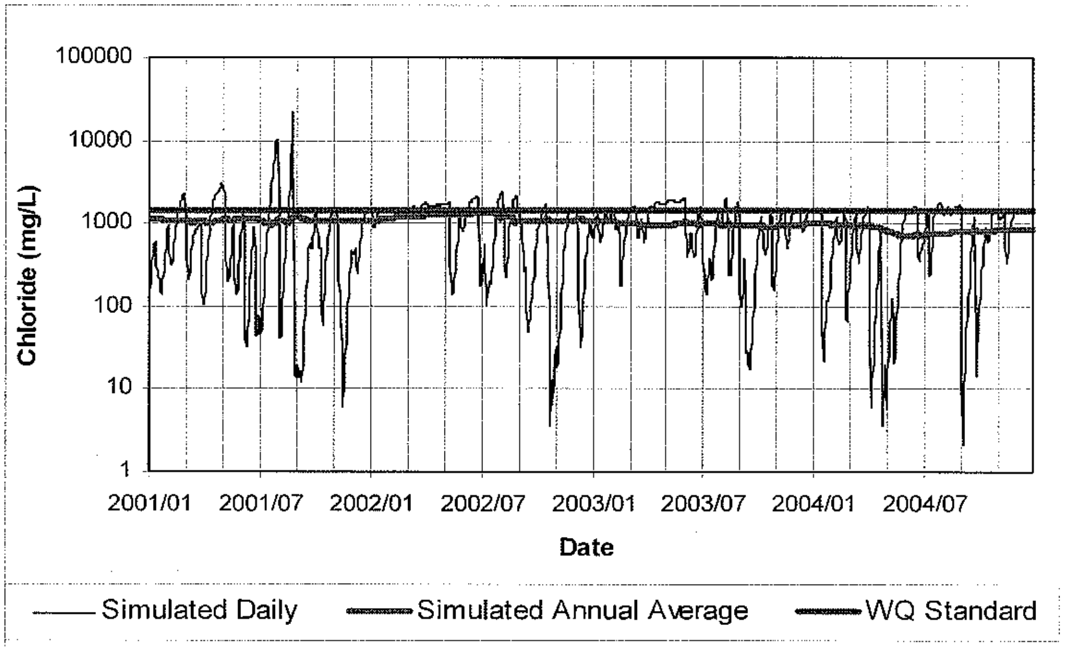


Figure 17: Simulated Chloride Concentrations at Station 13093 under TMDL Allocation

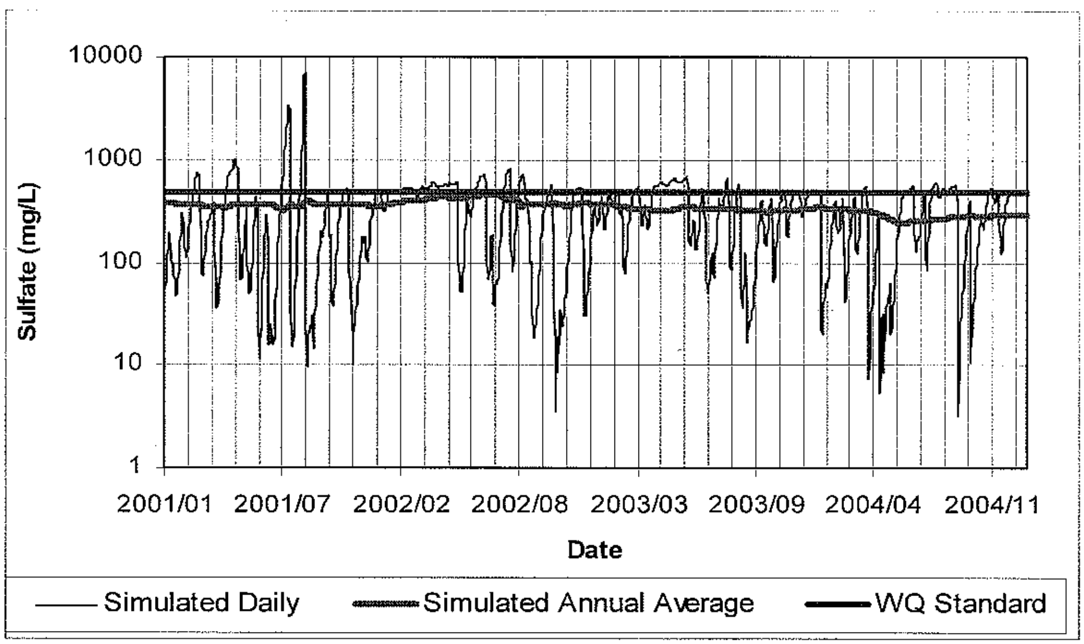


Figure 18: Simulated Sulfate Concentrations at Station 13093 under TMDL Allocation

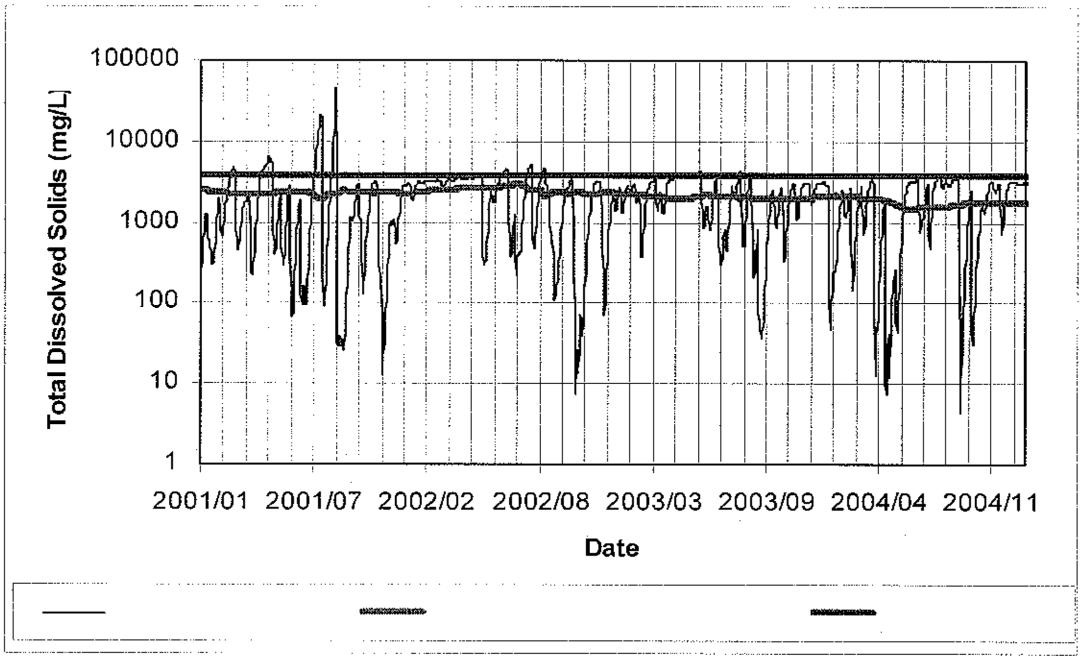


Figure 19: Simulated TDS Concentrations at Station 13093 under TMDL Allocation

Table 10: TDS, Chloride, and Sulfate TMDL Allocation Load Distributions by Source

Source	Annual Average Loads (lbs/Year)					
	Chlorides	% Total	Sulfates	% Total	TDS	% Total
Abandoned Brine Pits	0.00E+00	0.00%	0.00E+00	0.00%	0.00E+00	0.00%
Produced Water	3.78E+07	85.25%	8.98E+06	46.09%	8.04E+07	90.69%
Groundwater	5.17E+04	0.12%	8.56E+05	4.39%	1.10E+05	0.12%
Other Background Sources	1.74E+06	3.92%	8.67E+06	44.50%	3.70E+06	4.17%
Point Sources	2.53E+06	5.71%	2.31E+03	0.01%	1.85E+04	0.02%
Margin of Safety*	2.22E+06	5.00%	9.74E+05	5.00%	4.43E+06	5.00%
Total	**4.43E+07**	**100%**	**1.95E+07**	**100%**	**8.87E+07**	**100%**

*Margin of safety taken as 5% of all the allocations (see Margin of Safety)

Table 11: Chloride TMDL

TMDL (lbs/year)	WLA (lbs/year)	LA (lbs/year)	MOS (lbs/year)
4.43E+07	2.53E+06	3.96E+07	2.22E+06

Table 12: Sulfate TMDL

TMDL (lbs/year)	WLA (lbs/year)	LA (lbs/year)	MOS (lbs/year)
1.95E+07	2.31E+03	1.85E+07	9.74E+05

Table 13: TDS TMDL

TMDL (lbs/year)	WLA (lbs/year)	LA (lbs/year)	MOS (lbs/year)
8.87E+07	1.85E+04	8.42E+07	4.43E+06

uled meetings, media releases were initiated and steering committee stakeholders were formally invited to attend. To ensure that absent stakeholders and the public were informed of past meetings and pertinent material, a project web page was established to provide meeting summaries, presentations, ground rules, and a list of official steering committee stakeholders.

Throughout the term of the project, from 2002 to 2006, a total of seven meetings were held in Robstown, in Nueces County. Based on interest and attendance, meetings were held in both the afternoon and evening. The objectives of the first stakeholders meeting were to:

- Introduce the project team and summarize the public participation process.
- Define what the project was intended to accomplish.
- Provide historical monitoring data, information, issues, and potential sources.

During the first meeting in September of 2002, the project team received and responded to a number of questions and comments which were taken into account when developing the sampling plan. The objectives of the second stakeholders meeting were to:

- Inform the stakeholders on the status of work being performed on the project.
- Provide information on the TMDL stakeholder process; specifically, involvement, consultation, and collaboration.
- Provide information on the monitoring plan and monitoring schedule.
- Provide information on of the project's phases; specifically, historical data review, data collection, modeling, approval, and implementation.

During the second meeting in December of 2003, the project team received a number of constructive comments and suggestions. The objectives of the third stakeholders meeting were to:

- Inform the stakeholders on the status of work being performed on the project.
- Provide a survey questionnaire to assist in evaluating how effective the information about the project is being understood by the stakeholders and the public
- Provide information and data to summarize results.

- Inform stakeholders about a prospective study through the BEG to conduct electromagnetic surveys on Petronila Creek.
- Provide information on the selected model, the Hydrologic Simulation Program Fortran (HSPF), and its process.

During the third meeting in April of 2004, the project team received a number of informative comments and suggestions. The objectives of the fourth stakeholders meeting were to:

- Inform the stakeholders on the status of work being performed on the project.
- Provide information about Phase I of the BEG electromagnetic conductivity survey study.
- Provide an update on the status of the modeling phase of the project.

During the fourth meeting in December of 2004, the project team received a number of questions and comments concerning the project and the BEG study. The objectives of the fifth stakeholders meeting were to:

- Provide information on the stakeholder goals and the public participation process.
- Provide a re-cap of the TMDL process.
- Present results of the airborne geological survey.

During the fifth meeting in June of 2005, the project team received a great deal of comments and questions. The BEG electromagnetic conductivity survey results were posted on the project web page. The objectives of the sixth stakeholders meeting were to:

- Summarize the last three years of progress on the TMDL project.
- Present a re-cap of data including the most recent sample collection.
- Present an abbreviated version of results from the airborne geophysical survey performed in January 2005, and make interpretations about the mechanisms of the contamination.
- Present a re-cap of the TMDL process, model, and draft TMDL.
- Provide an overview of Texas Watch and proposed education and outreach for the watershed to address illegal dumping.
- Speak about a RRC project to address salinity; specifically, abatement practices and remediation.

During the sixth meeting in July of 2005, the project team received a great deal of comments concerning the project, specifically concerning the RRC and Texas Watch. The objectives of the seventh stakeholders meeting were to:

- Provide information on the draft TMDL and load allocation.
- Provide information on Texas Watch and progress toward education and outreach concerning illegal dumping.

IMPLEMENTATION AND REASONABLE ASSURANCES

The TMDL development process involves the preparation of two documents:

1) a TMDL, which determines the amount of pollutant a water body can receive and continue to meet applicable water quality standards, and
2) an implementation plan, which is a detailed description and schedule of regulatory and voluntary management measures necessary to achieve the pollutant reductions identified in the TMDL.

It is the policy of the TCEQ to develop implementation plans for all TMDLs adopted by the commission, and to assure the plans are implemented. Implementation plans are not subject to EPA approval.

During TMDL implementation, the TCEQ works with stakeholders to develop the management strategies needed to restore water quality to an impaired water body. This information is summarized in a TMDL implementation plan (I-Plan), which is separate from the TMDL document. Preparation of an I-Plan is critical to ensure water quality standards are restored and maintained.

Several implementation activities have already been initiated during the later phase of the TMDL project to achieve pollutant reductions.

1) The EPA has awarded a nonpoint source grant through the TCEQ to the RRC for the investigation of the nature and extent of known salinity contamination thought to be contributing to water quality problems in Petronila Creek, the development of remediation and/or abatement alternatives or BMPs, and the implementation of the BMPs.
2) The Nueces River Authority, Nueces County, Coastal Bend Council of Governments, and Texas Watch will coordinate restoration actions to remove refuse that has been illegally dumped in the watershed, community river-cleanup events, and development of education outreach and media exposure.
3) The TCEQ Continuous Water Quality Network and Nueces River Authority will deploy a continuous monitor to measure specific conductivity hourly at water quality station 13093, Petronila Creek at FM 70. A link to continuous water quality data will be provided to the RRC to assist in enforcing oil and gas well compliance in the watershed.

Preparation of the implementation plan for Petronila Creek will begin upon commission approval of the TMDL. The I-Plan will detail any activities such as mitigation measures, permit actions, best management practices, and additional sampling and monitoring determined to be necessary to restore water quality. Additional sampling at appropriate locations and frequencies will allow tracking and evaluation of progress toward the targeted and primary endpoints. These steps will provide reasonable assurances that the regulatory and voluntary activities necessary to achieve the pollutant reductions will be implemented.

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Final Report

Development of a Salinity/Toxicity Relationship to Predict Acute Toxicity of Saline Waters to Freshwater Organisms

Prepared by:
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U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL INFORMATION SERVICE
SPRINGFIELD, VA. 22161

Gas Research Institute

Environment and Safety Research Department
October 1992

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REPORT DOCUMENTATION PAGE	1. REPORT NO. GRI-92/0301	2.	3. PB93-127074

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elopment of a Salinity/Toxicity Relationship to Predict
te Toxicity of Saline Waters to Freshwater Organisms

5. Report Date
April 1992

6.

r(s) David R. Mount and David D. Gulley

8. Performing Organization Rept. No.
2950-006-253

ming Organization Name and Address

R Consulting and Engineering
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Collins, Colorado 80524

11. Contract (C) or Grant (G) No.
(C) 5091-253-2160
(G)

oring Organization Name and Address

Research Institute
West Bryn Mawr Avenue
ago, Illinois 60631

13. Type of Report & Period Covered
Interim Report
June 1990 and March 1992

14.

mentary Notes

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arge of produced water to surface waters is generally regulated as part of the NPDES permit program and, fore, may be subject to discharge limits for aquatic toxicity. Most produced waters contain elevated (relative h water) concentrations of major ions (e.g., sodium, chloride) that can be toxic to fresh water organisms dless of other organic and inorganic constituents. The objective of this research was to develop a y/Toxicity Relationship (STR) that predicts the acute toxicity of saline waters to freshwater organisms based concentrations of major ions in solution. Laboratory toxicity tests were conducted to measure the acute y of major ions to three freshwater species (*Ceriodaphnia dubia, Daphnia magna,* and fathead minnows). laboratory toxicity data were then incorporated into multi-variate logistic regression equations that predict ute toxicity of any combination of major ions. Logistic regression equations represented the toxicity data well, generally explaining in excess of 80 percent of the overall variance in survival. Application of the *aphnia* STR to field data collected from surface waters receiving produced water discharges showed very correlation of STR predictions with the results of toxicity tests conducted on field-collected samples.

nt Analysis a. Descriptors

produced water
aquatic toxicity
Ceriodaphnia dubia
Daphnia magna
Pimephales promelas
total dissolved solids
chloride

Identifiers/Open-Ended Terms

salinity
gas production
whole effluent toxicity
NPDES
fish
invertebrates

COSATI Field/Group

y Statement:

19. Security Class (This Report)	21. No. of Pages
Unclassified	
20. Security Class (This Page)	22. Price
Unclassified	

9.18)

See Instructions on Reverse

OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)
Department of Commerce

DEVELOPMENT OF A SALINITY/TOXICITY RELATIONSHIP TO PREDICT ACUTE TOXICITY OF SALINE WATERS TO FRESHWATER ORGANISMS

FINAL REPORT

By

David R. Mount
ENSR Consulting and Engineering

and

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University of Wyoming

FOR

GAS RESEARCH INSTITUTE

ENSR CONTRACT NO. 5091-253-2160

GRI PROJECT MANAGER

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RESEARCH SUMMARY

Title:	Development of a Salinity/Toxicity Relationship to Predict Acute Toxicity of Saline Waters to Freshwater Organisms
Contractor:	ENSR Consulting and Engineering GRI Contract No. 5091-253-2160
Principal Investigators:	David R. Mcunt and David D. Gulley
Report Period:	June 1990 to March 1992
Objective:	The objective of this research was to develop a predictive statistical relationship (the Salinity/Toxicity Relationship or STR) that can predict the acute toxicity of saline waters to freshwater organisms based on the concentrations of major ions in solution.
Technical Perspective:	Discharge of produced water (and other waters produced by the gas industry) to surface waters is generally regulated as part of the National Pollutant Discharge Elimination System (NPDES). Recent trends in the NPDES program are toward increased use of aquatic toxicity tests (sometimes called "biomonitoring" tests) as a tool to monitor releases of potentially toxic materials. Actual limitations of aquatic toxicity may be incorporated into discharge permits, which, in turn, may require control of effluent toxicity to meet permit limits. Previous studies have demonstrated that high concentrations of major ions (e.g., sodium, chloride) can cause toxicity to freshwater organisms. Given the prevalence of these major ions in produced waters, understanding the role of major ions in causing aquatic toxicity is critical to evaluating options for meeting NPDES permit limitations for toxicity. This study focused on intensive toxicity testing of solutions containing major ions to provide this understanding and to develop a tool with which to assess major ion toxicity in any given produced water.
Results:	Laboratory toxicity data were successfully incorporated into multivariate logistic regression equations that predict the acute toxicity of any combination of major ions (sodium, potassium, calcium, magnesium, chloride, sulfate, and bicarbonate) to *Ceriodaphnia*, *Daphnia magna*, and fathead minnows. Fit of the STR equations to the toxicity data was quite high, with STR equations generally accounting for 80 percent or more of the overall variance in survival. Application of the *Ceriodaphnia* STR to data collected from the Salt Creek area of Wyoming (which receives produced water discharges) showed very strong correlation of STR predictions with the results of toxicity tests conducted on field-collected samples. Example calculations are included to demonstrate the use of the STR equations.

Beyond the studies described herein, two groups of additional studies are planned to validate the STR equations. First, the ability of the STR equations to discriminate between solutions with and without sources of toxicity other than major ions will be evaluated by conducting experiments on simulated produced waters to which specific trace toxicants (e.g., ammonia, arsenic) have been added. Second, the STR equations will be applied to actual produced water samples from a variety of sources; results of concurrent toxicity identification evaluation (TIE) studies will be used to assess the accuracy of STR predictions. After completion of these studies, the STR equations will be released in the form of a user-friendly, PC-based computer program.

Technical Approach:

Laboratory toxicity tests using three common laboratory species (*Ceriodaphnia*, *Daphnia magna*, and fathead minnows) were conducted on over 3,000 combinations of major ions (sodium, potassium, calcium, magnesium, chloride, sulfate, and bicarbonate). Test methods paralleled those recommended by USEPA for acute toxicity testing of effluents. Multivariate regression techniques were then used to relate survival of test organisms to specific major ion concentrations.

Project Implications:

With the rising costs associated with toxicity testing and compliance with toxicity limitations, the need for a means to reduce these costs is escalating rapidly in areas where produced waters are discharged to surface waters. The first phase of this innovative effort has been extraordinarily successful; when completed, the STR approach will provide a thorough understanding of saline water toxicity and will go a long way toward relieving the pressure felt by many producers practicing surface water discharge.

GRI Project Manager
James M. Evans
Environment and Safety Research

EXECUTIVE SUMMARY

Water is a by-product of several activities within the natural gas industry, most notably the extraction of gas from production and storage fields. These waters, referred to as produced waters, can contain trace concentrations of many different organic and inorganic constituents, but most all contain elevated (relative to fresh water) concentrations of major ions (e.g., sodium, chloride). Aside from any potential effects of trace constituents, these major ions can cause toxicity to freshwater organisms if present in sufficient concentration. With the current regulatory emphasis on the use of toxicity testing for monitoring and regulating effluent discharges, surface discharges of produced water are becoming subject to toxicity-based discharge requirements. For this reason, an increased understanding of major ion effects on freshwater organisms is needed to allow informed decision-making with regard to produced water management.

The objective of the present research was to develop a Salinity/Toxicity Relationship (STR) that can predict acute toxicity of saline waters to freshwater organisms based on major ion composition. This relationship could allow *a priori* prediction of anticipated acute toxicity of a produced water based on measured or anticipated concentrations of major ions. Equally or even more important, if actual acute toxicity data are available for a particular water, measured toxicity can be compared to toxicity predicted by the STR to evaluate whether toxicity due to major ions can account for the observed toxicity, or if the presence of other toxicants is indicated. The understanding afforded by the STR could be a valuable tool in determining appropriate management of produced waters under existing and future toxicity-based discharge regulations. Accordingly, use of the STR should help reduce expenditures by operators on compliance with regulatory programs related to surface discharge of produced waters.

Development of the STR focused on seven major ions (sodium, potassium, calcium, magnesium, chloride, sulfate, and bicarbonate) and three freshwater test organisms (the water fleas *Ceriodaphnia dubia* and *Daphnia magna*, and the fathead minnow, *Pimephales promelas*). Laboratory toxicity tests were conducted on over 3,000 combinations of major ions; data from these experiments were used to develop multivariate regression equations that relate major ion concentrations to survival of the three test species. These STR equations can be used to predict survival of the three species for any combination of major ions.

In developing the final STR equations, a number of different analysis techniques and variables were evaluated. Survival time analysis (an analysis technique predicting the average time of survival under a given exposure) was evaluated initially, but was not pursued because logistic regression appeared to provide accurate representations of the survival responses with less complex regression equations. The effect of feeding test organisms during testing on the responses of *Ceriodaphnia* was evaluated as part of the experimental design; analysis of this factor indicated that feeding did increase survival slightly, but was a relatively minor determinant of *Ceriodaphnia* survival in the laboratory exposures (representing less than 1 percent of the overall variance). Concurrent reference toxicant tests (using sodium chloride) were also evaluated as a means to reduce error from inter-test variability in *Ceriodaphnia* responses. However, regression analysis indicated that there was

no significant relationship between the results of reference toxicant tests and the overall response of *Ceriodaphnia* to mixtures of major ions.

Multivariate logistic regression was chosen as the best tool for developing the final STR equations. Logistic regression equations were able to represent the laboratory toxicity data quite well, generally explaining 80 percent or more of the overall variance in survival. Regression analyses showed that relative sensitivity to the major ions was the same for *Ceriodaphnia* and fathead minnows. In order of decreasing toxicity, this sensitivity was:

$$K^+ > HCO_3^- > Mg^{++} > Cl^- > SO_4^{-}$$

Sodium and calcium did not appear to be directly toxic to any of the test species, as evidenced by their absence from the final STR equations. The ranking of ion toxicity was similar for *Daphnia magna*, except that the positions of bicarbonate and magnesium were reversed. Cation*cation, anion*anion, and cation*anion interaction terms were not found to be significant by the regression algorithm.

For *Ceriodaphnia* and *Daphnia magna*, it was shown that the number of cations present in the test solutions influenced the toxicity of chloride, sulfate, and potassium; for example, chloride was less toxic when introduced as a mixture of calcium and sodium chlorides, rather than as sodium chloride alone. To allow the STR equations to incorporate and represent this effect, a new variable, NumCat, was created. For any given solution, NumCat is determined by the number of cations in the solution at both greater than 100 mg/L and greater than 10 percent of the total molar cation concentration. NumCat was defined as having values of 0, 1, or 2; if more than two cations are present that meet the 100 mg/L and 10 percent criteria, NumCat is reset to a value of two. The NumCat variable allowed the STR equations to account for differences in toxicity associated with solutions with different numbers of cations, and improved the overall fit of the STR equations to the laboratory data. An analogous variable based on the number of anions in solution was not found to be significantly related to survival. Interestingly, responses of fathead minnows were not related to the number of cations in solution; consequently, NumCat was not included as a variable in the fathead minnow STR equations.

Preliminary application of the STR equations to independent data has been very promising. Boelter et al. (1992) evaluated the chemistry and toxicity of surface waters in the Salt Creek drainage of Wyoming, an area that receives discharges of produced waters from oil production activities. When major ion concentrations from these samples were input to the applicable STR equation, the resultant survival predictions matched very closely ($R^2 = 0.94$) with the data from independent *Ceriodaphnia* toxicity tests conducted on the actual field samples. The STR also accounted for toxic interactions among ions in these samples, correctly predicting greater toxicity than would have been predicted based on the toxicity of sodium chloride alone. In another instance, the STR equation correctly predicted the presence of a toxicant other than major ions in a sample of oil field-produced water.

This report presents the results of studies conducted to initially develop the STR equations. Additional studies are planned to validate the use of the STR using actual produced water samples, as well as mock produced waters spiked with trace constituents common to produced waters. After the completion of these validation studies, the STR equations will be incorporated into a user-friendly, DOS-based computer program that will calculate predicted survival of the three test species using major ion concentrations input by the user.

ACKNOWLEDGEMENTS

Many individuals made significant contributions to the completion of this research. We thank Mr. Jim Evans, the GRI Project Manager, for his advice, encouragement, and helpful comments on the text. John Fillo (ENSR) also provided advice on the study design and comments on the draft report. Several GRI staff provided comments that greatly improved the final report. We also thank Russ Hockett, Karen Barten, and Tyler Garrison of ENSR's Fort Collins Environmental Toxicology Laboratory who conducted the laboratory toxicity tests to support development of the STR. Finally, we thank Lori Lighthart and Nancy Beauprez for word processing and editing assistance.

GLOSSARY OF TERMS AND ACRONYMS

The following is a glossary of terms and acronyms used in this report. Where relevant, definitions have been tailored to reflect the uses of terms within this report; as such, definitions provided here may not be universally applicable.

acute toxicity - toxicity that occurs during a short period of time relative to the life of the organism, typically 48 to 96 hours; in the context of this report, it also refers to severe toxic effects (i.e., mortality); see "chronic toxicity"

aliphatic - refers to organic compounds that have primarily saturated carbon-carbon bonds

anion - an ion with a negative charge (e.g., chloride [Cl^-])

APHA - American Public Health Association

API - American Petroleum institute

aromatic - refers to organic compounds (typically comprised of 5- and/or 6-carbon rings) that have primarily unsaturated carbon-carbon bonds

BEAKER - one of three data bases within the overall STR data base; contains information pertinent to a specific test chamber/solution; see Appendix B

benthic invertebrate - invertebrate organisms inhabiting the bottom of a lake or stream

biomonitoring - common term used to refer to toxicity testing of effluents

cation - an anion having a positive charge (e.g., sodium [Na^+])

Ceriodaphnia dubia - a species of water flea; a very common organism used for effluent toxicity testing

charge balance - the relative concentration of positive and negative charges in a solution

chronic toxicity - toxicity occurring over most or all of the life cycle of the organism; typically associated with more subtle (sub-lethal) effects relative to acute toxicity

(ion) concentration - in the context of this report, concentration usually refers to concentration in terms of mg/L, except when used as "molar concentration," "mmol," or "meq/L"

Daphnia magna - a species of water flea commonly used for laboratory toxicity tests

dependent variable - a parameter whose value is presumed to be dependent on the values of other parameters; in the context of this report, dependent variable generally refers to organism survival; compare with "independent variable"

divalent ion - an ion with an ionic charge of either +2 or -2

DO - dissolved oxygen

effluent - a water discharged from a municipal or industrial operation

fathead minnows - a fish species commonly used for laboratory toxicity tests; scientific name is *Pimephales promelas*

FCETL - ENSR's Fort Collins Environmental Toxicology Laboratory

GRI - Gas Research Institute

hard reconstituted water - a laboratory water prepared by adding various salts to deionized water; typical hardness of 160 to 180 mg/L as $CaCO_3$; typical alkalinity of 110 to 120 mg/L as $CaCO_3$

IC_{25} - the concentration of a material or solution estimated to cause a 25 percent reduction in organism performance relative to control organisms; sometimes considered as a threshold for chronic toxicity

independent variable - a parameter whose value is presumed to affect the value of another parameter (the "dependent variable"); in the context of this report, independent variables are frequently concentrations of specific ions

indicator variable - a regression variable used to classify data into one or more groups

K_{sp} - the $\log_{10}$ of the solubility product

LC_{50} - the concentration estimated to kill 50 percent of the test organisms within a specified time period; typically used to express the results of acute toxicity tests

logistic regression - a regression technique used to relate binary data (e.g., alive or dead) to one or more independent variables

logit survival - the logistic transformation of the probability of survival (see Section 3.5)

major ions - in the context of this report, the ions comprising the majority of the total dissolved solids in a solution; typically Na^{+}, K^{+}, Ca^{++}, Mg^{++}, Cl^{-}, HCO_3^{-}, and $SO_4^{=}$

meq/L - milliequivalents per liter; an expression of concentration based on ionic charge

mg/L - milligrams per liter; an expression of concentration based on the mass of material; often referred to as "parts per million"

MHRW - moderately hard reconstituted water

mmol - millimolar; an expression of concentration based on the number of molecules of a substance in a solution; 0.001 molar, or 6.02×10^{20} molecules per liter

model - in the context of this report, model (as a noun) is used interchangeably with regression equation, meaning the statistical relationship between the dependent and independent variables; used as a verb to describe the process of developing regression equations

moderately hard reconstituted water - a laboratory water prepared by adding various salts to de-ionized water; typical hardness of 80 to 100 mg/L as $CaCO_3$; typical alkalinity of 60 to 70 mg/L as $CaCO_3$

molar concentration - the concentration of a material expressed in terms of the number of molecules per liter of solution; see "mmol"

molecular weight - the mass of one mole (6.02×10^{23} molecules) of a substance

monovalent ion - an ion with an ionic charge of +1 or -1

multiple (logistic) regression - a regression technique in which multiple independent variables are related to a dependent variable

NPDES - National Pollutant Discharge Elimination System

NumCat - a variable developed for and used in the STR equations; determined by the number of major cations in a test solution

pH - a measurement used to express the relative acidity or alkalinity of a solution; values range from 0 to 14; most (but not all) surface waters have pH values between 6 and 9

Pimephales promelas - scientific name for the fathead minnow

produced water - in the context of this report, a water produced as a by-product of natural gas production, processing, transmission, or storage; the most common source of produced water is (geologic) formation water brought to the surface as part of natural gas production or storage operations

R^2 - correlation coefficient; a statistical parameter used to express the degree to which a regression equation can explain the variation in the dependent variable; values from 0 to 1, with 0 indicating no relationship between the independent and dependent variables and a value of 1 indicating perfect (100 percent) correspondence between the values of the dependent and independent variables

reference toxicant (test) - a toxicity test conducted using a toxicant of known properties; for the research described in this report, sodium chloride was used

regression - a statistical relationship used to relate values of a dependent variable to those of one or more independent variables (e.g., relating organism survival to chloride concentration)

Selenastrum capricornutum - a species of algae used as food for *Ceriodaphnia dubia* and *Daphnia magna*

solubility product - the (mathematical) product of the molar concentrations of a cation and anion when the cation/anion salt is present at saturation

SP1/SP2 - indicator variables used during development of multi-species ("combined") regression equations (see Section 3.5)

stepwise (logistic) regression - a regression technique in which independent variables are added sequentially to the regression equation, based on a mathematical algorithm that evaluates the relative ability of each independent variable to account for or explain variation in the dependent variable

STR - Salinity/Toxicity Relationship; refers to the statistical relationships between major ion concentrations and organism survival, developed as part of the research described in this report

STROBS - one of three data bases within the overall STR data base; contains data on actual survival observations made on a specific test chamber; see Appendix B

survival time analysis - a statistical technique that relates independent variables (e.g., ion concentration) to the length of time an organism (in this case) will survive given a set of conditions

TDS - total dissolved solids

TESTID - one of three data bases within the overall STR data base; contains data common to a group of toxicity tests conducted concurrently; see Appendix B

test solution - the solution to which an organism is exposed during a toxicity test

toxicity test - a procedure in which the biological effects (toxicity) of a material are determined by exposing living organisms to the material

USEPA - United States Environmental Protection Agency

whole effluent toxicity test - a toxicity test used to assess the biological effects (toxicity) of an unmanipulated effluent; often referred to as a "biomonitoring" test

YCT - an incubated slurry of yeast, ground alfalfa leaves, and trout chow; used as a food for *Ceriodaphnia dubia* and *Daphnia magna*

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EFFECTS OF ALKALINITY AND HARDNESS ON TOXICITY OF NaCl TO *CERIODAPHNIA DUBIA*

by

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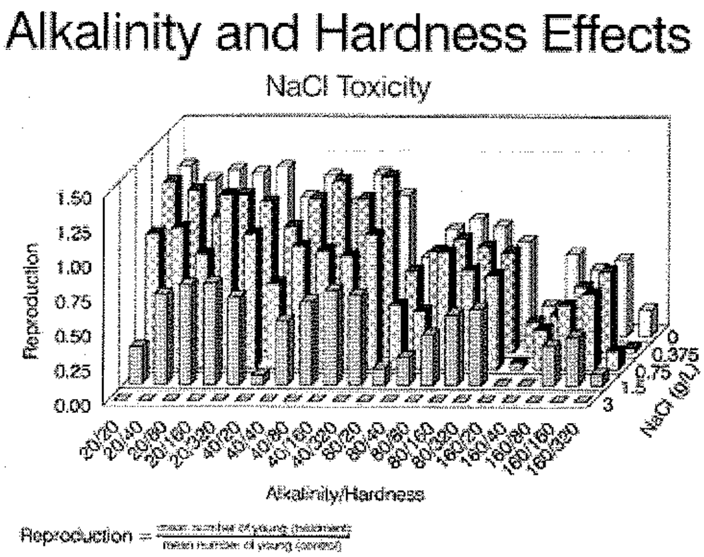
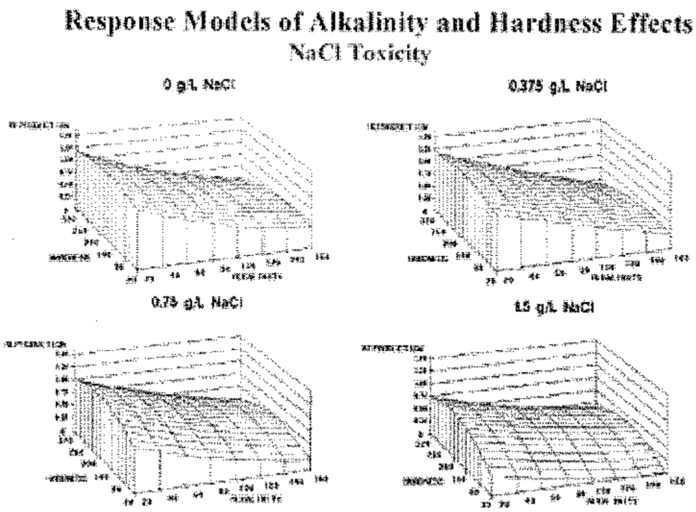
ABSTRACT

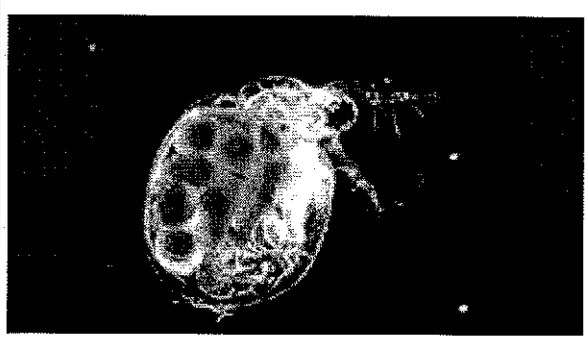
The use of reactive dyes in textile manufacturing for coloring cotton products can contribute elevated concentrations of salinity and alkalinity in effluents from municipal waste-treatment facilities, thereby causing periodic failure of permit-compliance toxicity testing. The sources of salinity from the textile manufacturing process are primarily Na, Cl, and SO_4, and the predominant sources of alkalinity are HCO_3 and B_4O_7. The effects of these major ions, as well as hardness, on effluent toxicity were evaluated using reproduction (mean number of young/female) from the chronic three-brood *Ceriodaphnia dubia* test. Reproduction was significantly increased in NaCl solutions at hardness concentrations of 80 and 160 mg/L compared to exposures at 20 and 40 mg/L hardness. Reproduction was significantly lower in 160 mg/L carbonate alkalinity than in 20 mg/L alkalinity. Salinity produced by $NaSO_4$ resulted in lower reproduction than salinity produced by NaCl, under similar conditions of alkalinity and hardness. Borate toxicity tended to increase with a decrease in hardness, and carbonate appears to add to the toxicity. These data demonstrate that: 1) alkalinity and hardness can influence the results of chronic-toxicity testing used in compliance monitoring; and 2) adjustments to the alkalinity and hardness of effluents could reduce the chronic toxicity of salinity.

INTRODUCTION

Compliance to water quality standards in permitted effluents from the textile industry is often hampered by elevated concentrations of chemicals that facilitate the dyeing process. For example, sodium chloride (NaCl) is often used to enhance the binding of reactive dyes on cotton. In general, one kilogram of salt is used for each kilogram of cotton. As part of the dyeing process, pH is also altered to enhance chemical reactions and this altered pH must be chemically adjusted back to near neutral conditions prior to leaving the plant. Chemical adjustments of the effluent often result in elevated concentrations of alkalinity. The sources of salinity in textile effluents are primarily Na, Cl and SO_4, and the predominant sources of alkalinity are HCO_3, B_4O_7 and OH. The objectives of this study were to evaluate the effects of these major ions and hardness on the toxicity of salinity imparted by NaCl using the *Ceriodaphnia dubia* three-brood chronic-toxicity tests.







METHODS

- Reconstituted test water adjusted chemically
  - NaCl toxicity
    * Hardness and alkalinity varied
    * Ion ratios remained constant
  - Source of salinity toxicity
    * NaCl vs $NaSO_4$
    * 100 mg/L hardness - 80 mg/L alkalinity
  - Boron toxicity
    * B_4O_7 source of alkalinity

* $B_4O_7 + HCO_3$ source of alkalinity

- Chronic three-brood test - *Ceriodaphnia dubia*
  - Static renewal
  - 25• C
  - 16 h light:8 h dark
  - 30 mL container
  - 15 mL test solution
  - <24-h old animal
  - 1 per container
  - 0.2 mL YCT-*Selenastrum* daily
  - Endpoint - survival & mean number of young
  - >80% survival in control & 60% with 3 broods

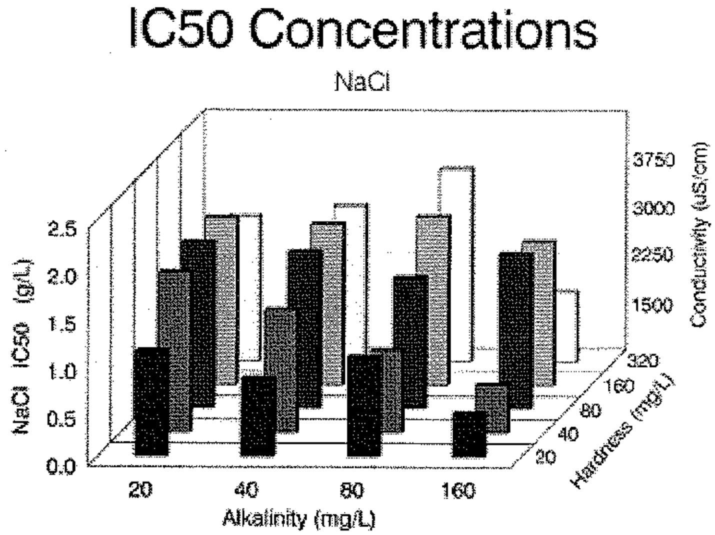
Ion concentrations in three effluents collected from the same textile mill over one year.

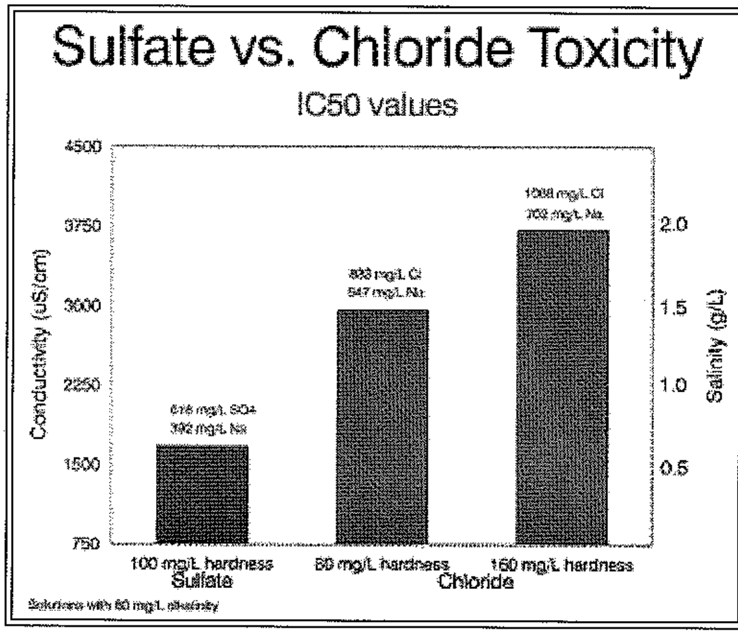
Ion	I	II	III
Cl (mg/L)	33	953	362
SO_4 (mg/L)	2507	362	156
Na (mg/L)	1050	772	794
Ca (mg/L)	20	19	13
Mg (mg/L)	1	11	5
K (mg/L)	2	146	82
Mn (Fg/L)	8	3	38
Mo (Fg/L)	3	2	28
Cu (Fg/L)	112	11	100
Pb (Fg/L)	1	4	6
Zn (Fg/L)	53	87	208

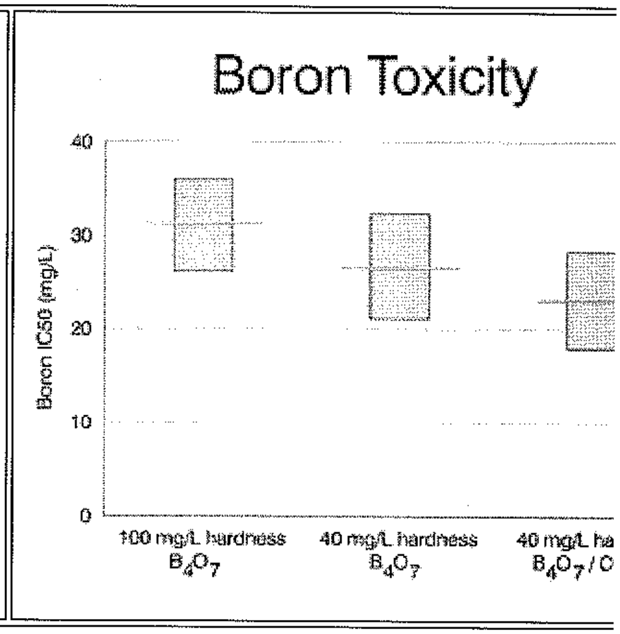
Ion Concentrations in Reconstituted Wa (m

Alkalinity (as mg/L $CaCO_3$)				
	20	40	80	160
Na	8	15	30	60
CO_3	20	39	79	158

Hardness (as mg/L $CaCO_3$)					
	20	40	80	160	320
Ca	6	12	24	48	95
Mg	1	2	5	10	19
K	2	2	2	2	2
Cl	8	15	27	53	104
SO_4	10	21	41	83	166







DISCUSSION

Water hardness and alkalinity influenced the chronic toxicity (measured as mean number of young neonates per female) of salinity produced by NaCl to *Ceriodaphnia dubia*. Reproduction was lowest in saline solutions of 20 and 40 mg/L hardness compared to 80 and 160 mg/L hardness, and reproduction was lower in 160 mg/L alkalinity than in 20 mg/L. These tests demonstrated that an increase in hardness ameliorated NaCl toxicity, but increasing alkalinity tended to negate this amelioratory effect. Alkalinity by itself resulted in reduced reproduction as concentrations increased from 20 mg/L to 160 mg/L. Salinity contributed by sulfate (Na_2SO_4) was more toxic than salinity produced by chloride (NaCl).

Sodium does not appear to contribute to the toxicity of these solutions. Increasing hardness reduced borate toxicity, but the presence of HCO_3 as an equal source of alkalinity tended to reduce reproduction.

These data suggest that adjustment of the basic chemistry contributed by alkalinity and hardness could reduce chronic toxicity of textile effluents associated with salinity.

SUMMARY AND CONCLUSIONS

- **Reproduction was higher in NaCl solutions at 80 and 160 mg/L hardness compared to 20**

and 40 mg/L hardness

- **Reproduction was lower in 160 mg/L carbonate alkalinity than in 20 mg/L alkalinity**
- **Reproduction in $NaSO_4$ salinity was lower than in NaCl salinity**
- **Hardness decreased borate toxicity**
- **Alkalinity and hardness influence chronic toxicity of salinity**
- **Adjustments of alkalinity and hardness can reduce toxicity contributed by salinity in textile effluents**

HOME

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Effects of Anions and Anion Mixtures on the Reproduction of *Ceriodaphnia dubia*

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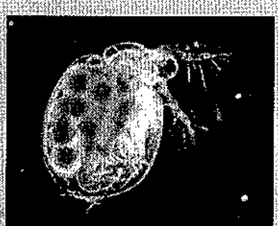
ABSTRACT

Municipal and industrial effluents often fail chronic toxicity tests due to elevated levels of osmotic or ionic strength. However, there is significant variability in the toxicity of effluents ranging from 0.1 to 1 part per thousand total dissolved solids (TDS) attributable to the effects of the individual anions (chloride, sulfate and bicarbonate) and their interactions. Manipulation of the anion concentrations in effluents has the potential to reduce toxicity. Three-brood, 7-d toxicity tests with *C. dubia* were conducted on serial dilutions of chloride (Cl^-), sulfate (SO_4^{-2}) and bicarbonate (HCO_3^-) and solutions containing mixtures of Cl^- (3, 193, 243, 340 mg/L), SO_4^{-2} (38, 308, 367, 496 mg/L) and HCO_3^- (115, 238, 336, 486 mg/L) prepared in deionized water reconstituted to 40 mg/L hardness and 100 mg/L alkalinity. Tests were conducted using Whole Effluent Toxicity testing procedures, repeated three times and accompanied by KCl reference toxicant tests. IC_{50} values for Cl^-, SO_4^{-2} and HCO_3^- averaged 637 mg/L, 780 mg/L, and 767 mg/L (alkalinity of 629 mg/L as $CaCO_3$), respectively. These toxic concentrations are often exceeded in effluents. In the tested mixtures, the IC_{50} value for TDS was determined to be 1184 mg/L (29.7 mM/L), with an IC_{25} value of 787 mg/L (19.7 mM/L). Differences in TDS accounted for about 80% of the variability in average reproduction among the tested solutions. Across the range of TDS represented by the 64 mixture solutions and within the range of tolerable TDS (< IC_{50} value), reproduction increased as the ratio of SO_4^{-2} to Cl^- increased. However, reproduction decreased as the ratio of HCO_3^- to Cl^- increased. Information from these tests was used to develop multivariate models using the solution-strength variables (TDS and ionic strength) with the SO_4^{-2}:Cl^- ratio and the HCO_3^-:Cl^- ratio to predict *C. dubia* reproduction in slightly-saline solutions. The models produced can be used to evaluate the potential toxicity of effluents and to suggest substitutions that may reduce their toxicity.

INTRODUCTION

Municipal and industrial effluents that enter the nation's waterways are generally complex mixtures of common inorganic salts and organic chemicals that are components of the myriad of commercial products used for industrial and residential purposes. Due to this complexity, their toxicities to aquatic biota are difficult to predict. This research has been undertaken as a first step in understanding interactions among effluent components and the resulting influence on the toxicity of the whole effluent. These effluents are generally dominated by elevated levels of common salts (compounds containing the cations sodium, calcium, magnesium, or potassium and the anions chloride, sulfate or bicarbonate) that can be toxic to freshwater biota in their own right. Information concerning the toxicity of these salts is limited to their acute effects which are caused primarily by the anionic portion of the salt, with the exception of potassium. However, permitted effluents are usually assessed by their chronic toxicity under the National Pollution Discharge Elimination System within the Clean Water Act. Information about the chronic effects of these salts does not exist or is limited to a small amount of ancillary data generated from their use as reference toxicants. Salinity, or total dissolved solids (TDS), is often cited as the most probable source of toxicity in many effluents permitted for discharge to freshwater systems. Yet, the actual cause of toxicity is usually unknown. This study was designed to determine the chronic toxicity of the three common anions and the interaction effects among them in order to relate this information to the impacts of many effluents on freshwater biota and to provide a foundation for further work that will examine the effects of the anions on the toxicities of common organic chemicals also present in the effluents.

The freshwater cladoceran, *Ceriodaphnia dubia*, is a standard test organism for assessments of effluents permitted for discharge to freshwater systems. It is sensitive to elevated TDS (>1000 mg/L), but there are often significant differences in the toxicities of effluents with similar TDS concentrations that indicate differences in the individual toxicities of the predominant anions. Differences in toxicity and interaction effects should reflect physiological responses of freshwater invertebrates to osmotic stress and may provide additional information to the understanding of those processes. Results from this study can be used to better understand the impact of slightly-saline effluents on freshwater communities and the significance of the various components of the effluents. This information has the potential to be used to reduce the toxicity of some effluents through substitution with less toxic components.



METHODS

- Test animal – *Ceriodaphnia dubia* (< 8 h old)

- Test type – 7-day, 3-brood static renewal reproduction test (USEPA 1994)
  - Repeated three times for each test solution

- Test procedures
  - 25-mL plastic cup used as test chambers
  - 15 mL of test solution / chamber
  - 10 replicates / test solution
  - 1 *C. dubia* / replicate
  - Fed daily – 0.1 mL *Selenastrum capricornutum* and 0.1 mL YCT
  - Maintained at 25°C with 16-h light / 8-h dark photoperiod
  - Animals transferred daily into fresh test solutions
  - Nominal concentrations used
    - Activities and ionic strength calculated by MINTEQA2
  - Average reproduction as endpoint (percent of control reproduction)

- Base water
  - 40 mg/L hardness, 100 mg/L alkalinity - similar to many receiving streams and effluents in the Southeast
  - Reconstituted deionized water
  - $MgSO_4$ (26 mg/L)
  - $NaHCO_3$ (158 mg/L)
  - KCl (6 mg/L)
  - $CaSO_4 \cdot 2H_2O$ (28 mg/L)
  - Fortified with commercial vitamin and mineral premixes

- Test solutions
  - Sodium salts (NaCl, Na_2SO_4 and $NaHCO_3$)
  - Individual anion solutions
    - Serial dilutions of chloride, sulfate or bicarbonate
  - Mixture solutions
  - Based on inhibition concentrations (IC_6, IC_{12}, IC_{25}) determined for individual anions

- Mixture effects evaluated using multivariate selection techniques to identify models with the greatest R^2 values
  - Units of terms (mass, molar, activity) kept consistent within a model
  - All selected terms added significantly ($p \leq 0.05$) to the model
  - Terms selected could not be significantly ($p \leq 0.05$) correlated

- Response models developed using full data set (n=64) and reduced data set (only solutions with concentrations of osmotic and ionic strength less than their IC_{50} values, n=24)

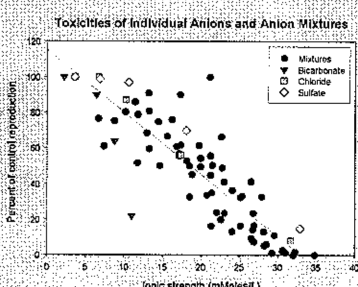


Figure 1. Response curves depicting *C. dubia* reproduction versus ionic strength generated from toxicity tests of solutions predominated by individual anions and solutions of anion mixtures. Regression line represents equation calculated from data for mixture solutions.

RESULTS

- Anions were toxic at concentrations often encountered in municipal and industrial effluents
  - Average inhibition concentrations (mg/L) that reduce reproduction of *C. dubia* by 50 and 25 percent

	IC_{50}	IC_{25}
Chloride	563	340
Sulfate	715	496
Bicarbonate		
calculated	763	568
Alkalinity (as $CaCO_3$)	626	466

- Ranking of anions according to their chronic toxicity was dependent on the metric of measurement

(Anions ranked from most to least toxic)

Concentration
- mg/L: $Cl^- > SO_4^{-2} = HCO_3^-$
- mM/L: $SO_4^{-2} > HCO_3^- > Cl^-$

Normality (for neutralization purposes)
- meq/L: $HCO_3^- > SO_4^{-2} = Cl^-$

Anion activity
- mM/L: $HCO_3^- > SO_4^{-2} > Cl^-$

Solution strength
- mg/L: $HCO_3^- > Cl^- = SO_4^{-2}$
- mM/L: $HCO_3^- = SO_4^{-2} > Cl^-$

Ionic strength (of solution)
- mM/L: $HCO_3^- > Cl^- = SO_4^{-2}$

- Osmotic (TDS) and ionic strength (IS) were the most influential variables controlling the toxicity of solutions with anion mixtures (Table 1, Figure 1)

Inhibition concentrations based on solution strength (with 95% CI, n=64)

	IC_{50}	IC_{25}
TDS (mg/L)	1184 (1137 – 1231)	787 (693 – 854)
IS (mM/L)	18.8 (17.7 – 19.9)	11.7 (9.4 – 13.2)

- In addition to TDS and IS, the best terms for predictive models (Table 2) were SO_4^{-2} and HCO_3^- normalized to Cl^- (SO_4^{-2}/Cl^-, HCO_3^-/Cl^-)
  - Consistent for the full and reduced data sets
  - Consistent for mass, molar and activity measurements

- SO_4^{-2}/Cl^- and HCO_3^-/Cl^- terms provided an additional 3 to 12% to the amount of variability explained by the models using the full data set and an additional 33 to 45% using the reduced data sets (Table 1, Table 2)

DISCUSSION

The toxicity of many effluents is due to elevated concentrations of chloride, sulfate and bicarbonate. Test results indicated that bicarbonate was more toxic than chloride and sulfate, but solution strength (osmotic or ionic) was the primary factor affecting *C. dubia* reproduction. There was, however, substantial variability in this response, particularly in mixtures with solution strength less than the IC_{50} value (1184 mg/L TDS). Models that explained the most variability in reproduction contained variables that represented the ratio of sulfate to chloride and the ratio of bicarbonate to chloride, in addition to the solution-strength term. Coefficients for these terms indicated that increasing the SO_4^{-2} to Cl^- ratio increased reproduction, and increasing the HCO_3^- to Cl^- ratio reduced reproduction. Therefore, SO_4^{-2} and HCO_3^- were antagonistic; increasing concentrations of Cl^- modified the effects of both SO_4^{-2} and HCO_3^-; and all three contributed to the overall toxicity associated with osmotic or ionic strength.

The effects of these terms can be explained by their roles in osmoregulation. Bicarbonate is excreted via a mechanism that exchanges it for Cl^- taken from the external solution. Increasing external concentrations of Cl^- may facilitate this exchange, while increasing external concentrations of HCO_3^- may make the exchange more difficult. The role of SO_4^{-2} is more obscure, but the beneficial effect may be derived by the ability of SO_4^{-2} to stabilize macromolecular structures produced internally to offset external osmotic or ionic pressure. Industrial processes that provide a substitution of SO_4^{-2} and/or Cl^- for HCO_3^- should be evaluated as potential means to reduce effluent toxicity.

Table 1. Response variability within the anion-mixtures data set explained (R^2) by individual continuous variables representing concentration or ionic strength of dissolved solutes in solution.

	Variable	R^2
Full data set (n=64)		
	Total Dissolved Solids (mg/L)	0.82
	Total Dissolved Solids (mM/L)	0.86
	Ionic Strength (mM/L)	0.74
Reduced data set (n=24)		
	Total Dissolved Solids (mg/L)	0.45
	Total Dissolved Solids (mM/L)	0.34
	Ionic Strength (mM/L)	0.31

Table 2. Models predicting the toxicity of anion mixtures to *C. dubia*.

Model: % control reproduction = intercept + terms (term coefficient)

	Terms in model	Coefficient	p > |t|	R^2
Full data set (n=64)				
	Intercept	116.99	<0.0001	0.90
	Total Dissolved Solids (mg/L)	-0.06	<0.0001	
	SO_4^{-2}/Cl^-	0.21	<0.0001	
	HCO_3^-/Cl^-	-0.06	0.0313	
	Intercept	121.18	<0.0001	0.89
	Total Dissolved Solids (mM/L)	-2.43	<0.0001	
	SO_4^{-2}/Cl^-	0.41	<0.0001	
	HCO_3^-/Cl^-	-0.16	0.0033	
	Intercept	108.33	<0.0001	0.86
	Ionic Strength (mM/L)	-3.33	<0.0001	
	SO_4^{-2}/Cl^-	1.09	<0.0001	
	HCO_3^-/Cl^-	-0.20	0.0071	
Reduced data set (n=24)				
	Intercept	104.88	<0.0001	0.78
	Total Dissolved Solids (mg/L)	-0.04	<0.0001	
	SO_4^{-2}/Cl^-	0.17	<0.0001	
	HCO_3^-/Cl^-	-0.07	0.0160	
	Intercept	99.77	<0.0001	0.67
	Total Dissolved Solids (mM/L)	-1.46	0.0002	
	SO_4^{-2}/Cl^-	0.45	0.0003	
	HCO_3^-/Cl^-	-0.14	0.0184	
	Intercept	108.37	<0.0001	0.79
	Ionic Strength (mM/L)	-3.20	<0.0001	
	SO_4^{-2}/Cl^-	0.94	<0.0001	
	HCO_3^-/Cl^-	-0.28	0.0013	

CONCLUSIONS

- The chronic toxicity of anion solutions to *C. dubia* was primarily dependent on the concentration or activity of dissolved solutes.

- Effluents (or effluent dilutions) that exceed 800 mg/L TDS will have problems consistently meeting IC_{25} requirements.

- Substituting SO_4^{-2} and/or Cl^- for HCO_3^- can reduce the toxicity of solutions despite similar TDS concentrations.

- Producers of industrial and municipal effluents with TDS concentrations in this marginal range may potentially reduce the toxicity of the effluents by selecting materials or processes that minimize HCO_3^- inputs.

LITERATURE CITED

US Environmental Protection Agency. 1994. Short-term methods for estimating the chronic toxicity of effluents and receiving water to freshwater organisms, 3rd edition. EPA 600-4-91-002. USEPA, Cincinnati, OH.

1. Introduction

This document discusses the effects of sulphate on the various water use categories which may include drinking water, aquatic life, wildlife, livestock watering, irrigation, recreation and aesthetics, and industrial water supplies.

This document focuses primarily on the protection of aquatic life. Where applicable, or where sufficient information exists, guidelines are recommended to protect other water uses from the deleterious effects of sulphate. As part of this guideline development process, water quality standards, objectives, and guidelines and accompanying rationales from other jurisdictions are reviewed and their suitability for British Columbia waters are considered.

The need for water quality guidelines for sulphate in BC has been identified by regions over the desire of some BC mines to discharge sulphate at levels which exceed those that normally occur in natural freshwater systems. There are currently no water quality guidelines specified for sulphate in Canadian waters to protect environmental resources. Generally, sulphate is not believed to be particularly toxic to aquatic organisms, except at very high concentrations.

Aquatic Life

The strategy used to derive a water quality guideline for sulphate to protect aquatic life was to assess the available aquatic toxicological data for sodium sulphate, magnesium sulphate and potassium sulphate which are soluble in water, and for calcium sulphate which is relatively insoluble. These compounds were chosen for assessment because of the innocuous nature of the cations, Na, Mg, K, and Ca, and their common occurrence in natural waters. The purpose of this assessment was to derive a guideline for SO_4 without masking by more toxic substances such as the copper in $CuSO_4$, or from acidity as in the case of sulphuric acid (H_2SO_4). In such cases the water quality guidelines for the more toxic copper or acidity should apply, and such data were not used in this assessment. However, the possibility of some toxic influence from the presence of the added cations (Na, Mg, K, and Ca) cannot be excluded.

Initially, the available toxicological data was screened for exotic species that should be excluded from the assessment such as brine shrimp (*Artemia salina*), bleak (*Alburnus alburnus*) and the harpacticoid copepod (*Nitocra spinipes*) which are brackish water inhabitants. While some species included in the data set are not indigenous to British Columbia waters, they were included as indicator species, to represent related taxonomic groups that may live in BC, but for which no data were available. The toxicity data for freshwater organisms were downloaded from the US EPA on-line aquatic toxicological data base AQUIRE, as well as data from other sources. These data are summarized in Table 2 and converted from µg/L or molar Na_2SO_4, $MgSO_4$, K_2SO_4, and $CaSO_4$ to mg/L SO_4 to ensure that the data are comparable. On reviewing original key references, numerous data points in the AQUIRE database were found to be incorrect. The incorrect values were identified and replaced with the correct data from the original references where appropriate in Table 2.

Effect values >10 000 mg/L were deleted from the data set because, to derive a water quality criterion to protect aquatic life, the lower effect levels are the most critical.
The tabulated data were screened for the more sensitive effect levels (below 1000 mg/L SO_4) and the original published studies were assessed to determine if they were appropriate to derive a guideline (*i.e.*, no unusual confounding factors such as heavy metals or pH ranges outside normal ambient levels, etc.) and if they were based on good science. These decisions are, in part, subjective but follow the principles specified in the draft "Derivation of Water Quality Guidelines to Protect Aquatic Life in British Columbia" (Water Quality Branch, 1995).

The following discussions for freshwater aquatic life will focus on the studies shown in Table 2 with harmful effect levels < 1000 mg/L SO_4.

A discussion of the toxicity of sulphate to marine life was omitted from this section and a guideline for sea water was deemed unnecessary because of the high levels of sulphate typically present in sea water (see Section 3.3.2). In addition, there was a paucity of information on the toxic effects of sulphate to marine organisms.

Effects on Algae

Freshwater Algae

Based on experiments in an early study performed by Beauchamp (1954), McKee and Wolf

(1963) reported that water containing < 0.5 mg/L sulphate will not support the growth of algae. The State of Kentucky also recognizes that sulphur is an essential plant nutient and that sulphate in excess of 0.5 mg/L is essential for algal growth (Kentucky Water Watch web site).

The lowest value of SO_4 in Table 2 that was reported toxic to phytoplankton (4 mg/L SO_4) by Jayaraj *et al.* (1992) was rejected from this assessment because the toxicity tests were designed to test for the ameliorative effects of calcium, magnesium and iron on copper, cadmium and nickel toxicity. The magnesium was added as $MgSO_4$.

The blue-green algae *Anabaena* was reported to undergo early sporulation when reared in sulphate-supplemented media at concentrations of 216 and 311 mg/L (as SO_4) according to Kanta and Sarma (1980).

The AQUIRE database reported effect levels of sodium sulphate on two algae species (*Microcystis aeruginosa* and *Selenastrum capricornutum*) from a study by Yamane *et al.* (1982). A review of the original report revealed that the compound tested was alkyl sulphate, not sodium sulphate. This data was rejected as a basis to derive a water quality guideline for sulphate because of potential interference of the alkyl group.

Bioassays performed for BC Ministry of Environment, Lands and Parks (MELP) at the Pacific Environmental Science Centre (PESC) using the freshwater algae *Selenastrum capricornutum* determined an IC_{50} for growth of 1868 mg/L SO_4 and a Lowest Observed Effect Concentration (LOEC) and No Lowest Observed Effect Concentration (NOEC) of 1111 and 370.4 mg/L, respectively. Deionized water was used as the diluent in the test which would not represent ambient conditions. (Unpublished BC MELP data, 1996).

BC Research Inc.(1998) performed a series of spiked sulphate laboratory bioassays to assess the impact of simulated mine plant effluent with elevated sulphate levels on aquatic organisms. Included in this suite of bioassays was a 72-h algal growth inhibition test using *Selanastrum capricornutum* exposed to the simulated effluent spiked with Na_2SO_4. A NOEC and LOEC of 1060 and 3650 mg/L SO_4, respectively, were reported. Also, an IC_{25} and IC_{50} for growth inhibition of 2210 and 3359 mg/L SO_4, respectively, were reported.

Effects on Aquatic Macrophytes

Aquatic mosses appear to be the most sensitive freshwater organisms to sulphate that were identified in this review. The AQUIRE database transcribed data incorrectly from a study by Frahm (1975). AQUIRE reported mortality to four species of aquatic moss, *Fontinalis antipyretica, Fissendens crassipes, Leptodictum riparium,* and *Leskea polycarpa* at concentrations of 100 mg/L, 150 mg/L, >200 mg/L and >200 mg/L as K_2SO_4, respectively, after a one-week exposure. However, the original publication by Frahm (1975) reported these values measured as SO_4, not K_2SO_4, so conversions were unnecessary and the data reported accordingly. At least one species tested, *Fontinalis antipyretica,* is known to be widely distributed throughout BC, especially near the coast and in the lower pH waters.

To challenge the scientific reliability of the aquatic moss toxicity data reported by Frahm (1975), Beak International Incorporated, together with Michigan Technological University (1998) performed 14-day bioassays on the aquatic moss, *Fontinalis neomexicana*, exposed to sodium sulphate concentrations up to 500 mg/L (as SO_4) at water hardness of 160 mg/L (as $CaCO_3$). The responses measured were chlorophyll *a* and *b* content. Based on their observations, they concluded that sulphate concentrations up to 500 mg/L would not be harmful to aquatic life in hard water conditions such as those tested here. However, in-house plant specialists (P. Warrington and R. Nordin, personal communication) expressed some concern as to the merits of monitoring chlorophyll *a* and *b* content as a measure of moss health. The measurement of chlorophyll *a* and *b* content is really a surrogate measure of plant biomass and since aquatic mosses grow very slowly, such a measurement may be a poor indicator of the relatively short-term viability of moss populations exposed to sulphate. It was considered doubtful that chlorophyll *a* and *b* content in moss cuttings would change much under the test conditions. While chlorophyll content is fairly easy to measure, photosynthetic impairment, or a test designed to measure impairment of the naked free-swimming sperm would be a far better measure of plant health, and of its ability to maintain a viable population in a stream system.

Stanley (1974) measured the effects of a number of compounds including Na_2SO_4 on the growth of Eurasian watermilfoil (*Myriophyllum spicatum L.*) over 32 days of exposure. Transposed effect values to the AQUIRE database appear to be incorrect. Corrected 32-d EC_{50}'s for root and stem growth ranged from 2785 to 7011 mg/L (as SO_4). The sodium may have been the active ingredient affecting turgor pressure. Lower concentrations of Na_2SO_4 stimulated growth.

Effects on Invertebrates

Freshwater Invertebrates

Acute Toxicity

Fisher *et al.* (1991) determined a 1-d LC_{50} of 112 mg/L for zebra mussels (*Dreissena polymorphia*) of 62 mg/L (as SO_4) exposed to K_2SO_4 as shown in Table 2. However, through a series of toxicity tests using potassium compounds, Fisher *et al.* (1991) concluded that the potassium (K^+ ion) was the toxic moiety of the compound to the zebra mussels, not the sulphate. This data was rejected as a basis to derive the sulphate water quality guideline because the sulphate did not cause the toxicity reported.

Effect levels of sodium and magnesium sulphate on amphipods (*Hyallela* sp.), mosquito larvae (*Culex* sp.), cladocerans (*Daphnia magna*), and pond snail eggs (*Lymnaea* sp.) cited from Dowden and Bennett (1965). These values appear to have been incorrectly transcribed from the original reference to the AQUIRE database. The results have been re-entered correctly to Table 2. The corrected 1- to 4-d LC_{50}'s for the amphipods exposed to Na_2SO_4 ranged from 595 to 1609 mg/L (as SO_4) The 1- and 2-d LC_{50} for the mosquito larvae exposed to Na_2SO_4 are 7727 and 9025 mg/L (as SO_4). The 1- to 4-d LC_{50} for *Daphnia magna* exposed to Na_2SO_4 and $MgSO_4$ ranged from 426 to 5668 mg/L (as SO_4). Corrected values for reduced hatching success of Lymnaea eggs exposed to Na_2SO_4 and $MgSO_4$ for 1- to 4-days ranged from 2402 to 8403 mg/L (as SO_4).

The AQUIRE database reported 1- and 2-d EC_{50}'s of 406 and 344 mg/L for *Daphnia magna* exposed to $MgSO_4$ from a study by Khangarot and Kay (1989). The concentrations in the original reference were reported as the Mg^{2+} ion concentration. Similarily, in a separate study by Khangarot (1991), the toxicity of Mg^{2+} ions were tested on tubificid worms (*Tubifex tubifex*) but the values transcribed to the AQUIRE database were reported as the Mg^{2+} ion concentration. Hence, the data were not appropriate to serve as a basis for the derivation of sulphate water quality guidelines.

Fairchild (1955) reported that the threshold toxicity concentration of sodium sulphate toward Daphnia depended on the dissolved oxygen (DO) concentration. At a DO concentration of 6.6 mg/L, the toxicity threshold of Na_2SO_4 was 5514 mg/L; but at a DO concentration of 1.46 mg/L, the toxicity threshold of Na_2SO_4 dropped to 2752 mg/L.

BC MELP had The Pacific Environmental Science Centre (PESC) perform a series of acute toxicity bioassays using the freshwater invertebrates *Daphnia*, *Hyalella*, and Chironomids exposed to SO_4 under three different water hardnesses, 25, 100, and 250 mg/L (as $CaCO_3$). Generally, for most aquatic organisms tested including fish, toxicity decreased with increased water hardness. Chironomids were the only organisms that showed the opposite trend (Figure 3). Reported 48-h LC_{50}s for *Daphnia* in soft water (hardness of 25 mg/L as $CaCO_3$), well water (hardness of 100 mg/L), and hard water (hardness of 250 mg/L), were 537, 6281, and 7442 mg/L SO_4, respectively. For *Hyalella*, reported 96-h LC_{50}s in the soft, medium and hard water were 205, 3711, and 6787 mg/L, respectively. Chironomids appeared considerably less sensitive to SO_4 in soft water than the other invertebrates tested, where 96-h LC_{50}s in the soft, medium, and hard water were 6667, 5868, and 4173 mg/L, respectively. (Unpublished PESC data, 1996). The hypersensitivity of *Hyalella* to sulphate demonstrated in the series of PESC bioassays conflicts with information cited by Beak (1997b), where *Hyalella azteca* is reported as one of a few freshwater organisms that thrives in saline prairie lakes containing 30 000 mg/L of dissolved salts, of which $MgSO_4$ is typically the dominant salt species. The reason for this discrepancy is not known but may be linked to the soft water used in the key PESC data or the acclimation of species over time.

As noted in Section 5.1.1, BC Research Inc.(1998) performed a series of spiked sulphate laboratory bioassays to assess the impact of elevated sulphate levels on aquatic organisms. Included in this suite of bioassays were a 48-h acute toxicity test using the cladoceran, *Daphnia magna*, and a 96-h survival test using the amphipod *Hyalella azteca*. Water hardness of the test solutions ranged from about 105 to 116 mg/L (as $CaCO_3$). For *Daphnia*, a NOEC and LOEC of 3650 and 7460 mg/L SO_4, respectively, and a 48-h LC_{50} of 5218 mg/L SO_4, was reported. For *Hyalella*, a NOEC and LOEC of 1060 and 3650 mg/L SO_4, respectively, were reported and, a 96-h LC_{50} of 1226 mg/L SO_4 was also determined.

Chronic Toxicity

To assess the chronic effects of elevated sulphate concentrations emanating from a Vancouver Island coal mine, Denisger (1997 draft) reported on chronic *Daphnia* bioassays performed at the Pacific Environmental Science Centre (PESC) using on-site water collected downstream from the mine. Control water for the test was laboratory source water from the Capilano River. Effects studied included reproductive success, survival time to first brood, and growth or mobility inhibition. Four of six site waters tested showed no environmental effects for *Daphnia* after chronic exposure however, reproduction and survival effects at one of the sites could not be explained by differences in water quality, and toxicity at the other site was thought possibly to be due to hydrogen sulphide detected in the test water. The highest dissolved sulphate concentration used in the *Daphnia* laboratory bioassays was 420 mg/L from settling pond and coal wash plant drainage. No significant difference in effects was noted for *Daphnia* between this test water and the control.

BC MELP requisitioned PESC to conduct 21-day chronic *Daphnia* bioassays to assess the toxicity of SO_4 in water of hardness 100 mg/L and 250 mg/L (as $CaCO_3$). No chronic *Daphnia* tests were performed in the soft water (25 mg/L as $CaCO_3$) because Daphnia typically do not survive well in soft water. A LOEC, NOEC, and an IC_{25} (25% inhibition of reproduction) of 1200, 625, and 833 mg/L SO_4, respectively were reported for medium water hardness. In hard water, a LOEC, NOEC, and an IC_{25} of 1375, 795, and 1476 mg/L SO_4 were reported (Unpublished PESC data, 1996).

As noted in Section 5.1.1, BC Research Inc.(1998) performed a series of spiked sulphate laboratory bioassays to assess elevated sulphate levels. Included in this suite of bioassays was a 7-day survival test using the cladoceran , *Ceriodaphnia*. A NOEC and LOEC of 1060 and 3650 mg/L SO_4, respectively, were reported. A 7-day IC_{25} and IC_{50} for reproduction of 1267 and 2061 mg/L SO_4, respectively, were reported, as well as a 7-day LC_{50} of 1355 mg/L SO_4.

Effects on Fish

Freshwater Fish

Acute Toxicity

The lowest toxic values to freshwater fish reported in the AQUIRE aquatic toxicological database were 15 and 22 mg/L (converted to SO_4) after five days of exposure. However, the original published study (Horn *et al.* (1949) from which these data were derived reported only one minimum lethal concentration of 100 mg/L Na_2SO_4 (equivalent to 67.6 mg/L SO_4). This value was based on a screening test using one to five emerald shiners (Notropis atherinoides). The AQUIRE reference relied upon author communication for the data reported. In view of the publication date of this study (1949), reliable confirmation of these reported values is unlikely. In addition, according to the original reference, only one fish may have been used in the test and no control tests were reported. In view of these factors, the values reported in this study were rejected as a basis to derive a water quality guideline for sulphate.

The AQUIRE database reported several LC_{50} values ranging from 55 to 744 mg/L for Na_2SO_4 (converted to SO_4 by this author) on striped bass (*Morone saxatilus*) by Hughes (1973) that were cited from a secondary reference. These secondarily reported data in the AQUIRE database do not agree with the original published data and therefore were rejected by this author. The original data from Hughes (1973) has been added to Table 2 directly below the rejected data. These corrected 1 to 4-day LC_{50}'s ranged from 2000 to 250 mg/L SO_4 , respectively for striped bass larvae. The 4-day LC_{50} of 250 mg/L SO_4 for *Morone saxatilus* larvae was the lowest (most toxic), reliable toxic concentration reported in the literature reviewed for fish. The lowest LC_0 (no mortality) for this species was 100 mg/L after four days of exposure. One to 4-day LC_{50}'s reported for striped bass fingerlings were all 3500 mg/L and the LC_0 for all exposure durations (1- to 4-day) was 2500 mg/L. While this particular species of bass is not resident in British Columbia, this species serves as an indicator for bass (largemouth and smallmouth bass) and perch (yellow perch) species that are indigenous to BC but for which no toxicological data exists.

The AQUIRE database reported several effect levels of sodium and magnesium sulphate on bluegills (*Lepomis macrochirus*) and gobbies (*M. latipinna*) cited from Dowden and Bennett (1965). These values appear to have been incorrectly transcribed from the original reference to the AQUIRE database and have now been re-entered correctly to Table 2. The corrected 1-d LC_{50}'s for exposure of *Lepomis macrochirus* to Na_2SO_4 and $MgSO_4$ are 11 831 and 15 162 mg/L (as SO_4). The corrected 1- and 2-d LC_{50}'s for exposure of *M. latipinna* to Na_2SO_4 are 11 831 and 13 548 mg/L (as SO_4).

Wallen *et al.* (1957) tested the toxicities of Na_2SO_4, $MgSO_4$ and $CaSO_4$ separately to the mosquito fish (*Gambusia affinis*) in the presence of high turbidity (measured with a Jackson turbidimeter but results reported as ppm?) which ranged from between 3000 mg/L at the onset of the tests to <25 mg/L at the end to simulate turbid water conditions in Oklahoma. The results tabulated in the AQUIRE database appear to have been incorrectly transcribed from the original reference. The corrected data was entered into Table 2. One to 6-d LC_{50} concentrations for Na_2SO_4, $MgSO_4$ and $CaSO_4$ ranged from 6761 to 44 688 mg/L (as SO_4). The highly turbid diluent water used in the tests disqualify the results as a basis for a water quality guideline for BC waters.

Tsuji *et al.* (1985) reported 1- and 2-d LC_{50}'s of >1000 mg/L for killifish (*Oryzias latipes*) exposed to $MgSO_4$ at three temperatures (10, 20 and 30°C). These concentrations were reported as the metal concentration (Mg), not $MgSO_4$ as reported in the AQUIRE database. Hence, these data are not suitable as a basis to derive a water quality guideline for sulphate.

Boge *et al.* (1982a,b) studied the effects of sulphate ions on enzymatic activities in the gut and gill of the European eel (*Anguilla anguilla*) under constant temperature conditions and when exposed to heat shock. Changes in enzyme activity were noted under both temperature regimes when exposed to 176 mg/L SO_4, when applied as K_2SO_4 and $CaSO_4$. This concentration includes the sulphate concentration of the diluent which already contained 76 mg/L SO_4. While biochemical changes were noted, these may be an adaptive response and may not result in detrimental physiological effects. The European eel is not indigenous to British Columbia.

Boge *et al.* (1982c,d) performed identical studies on enzymatic activity using rainbow trout (*Oncorhynchus mykiss*) in place of eels. No changes were noted when exposed to the same sulphate concentration (176 mg/L as SO_4) and under the same temperature regimes as the eels.

BC MELP contracted PESC to perform a series of acute toxicity bioassays using rainbow trout (*Oncorhynchus mykiss*) and coho salmon (*Oncorhynchus kisutch*) exposed to SO_4 under different water hardness conditions. Generally, for most aquatic organisms tested including fish, toxicity decreased with increased water hardness. The 96-h LC_{50}s for rainbow trout in soft water (hardness of 25 mg/L as $CaCO_3$), well water (hardness of 100 mg/L), and hard water (hardness of 250 mg/L), were 5000, 9750, and 9900 mg/L SO_4, respectively. For coho salmon, 96-h LC_{50}s for the soft, medium, and hard water were 5742, 9550, and 9875 mg/L, respectively (Unpublished BC MELP data, 1996).

Chronic Toxicity

To assess the chronic effects of elevated sulphate concentrations emanating from a coal mine, Denisger (1997 draft) performed *in-situ* chronic coho salmon (*Oncorhynchus kisutch*) egg bioassays in the Quinsam River watershed near Nanaimo, BC. An intensive water quality monitoring program was conducted in conjunction with the bioassays. Four test sites and one control site were chosen for the study. The site with the highest dissolved sulphate concentration (drainage from the settling pond and coal wash plant) ranged from 281 to 1111 mg/L. Coho egg mortality of 20% was reported at this site. The author suggested that the predominant factor affecting toxicity of the coho eggs at this site may have been the elevated sulphate levels. A sample of this same site water was used to test *Daphnia* in the laboratory (sulphate concentration of 420 mg/L) but showed no significant toxicity over the control water (see Section 6.3.1).

Beak International Incorp. (1997b) has reported field observations from sulphate-enriched waters near three separate minesites in Ontario, Quebec, and New Brunswick. At the Quebec site (Beak, 1996a), salmon survival was reportedly unimpaired at sulphate concentrations of 45 to 160 mg/L in spring and from 180 to 300 mg/L in fall. Similarly, at the New Brunswick minesite (Beak, 1997a), benthic and fish communities were reportedly unimpaired at sulphate concentrations which ranged from 170 to 250 mg/L. Any harmful effects noted in exposed aquatic organisms during these field observations were attributed to substances other than sulphate, such as metals or ammonia. Assessment of the relevance of sulphate toxicity from such field observations is often difficult due to the uncontrolled influence of confounding factors.

BC MELP had the Pacific Environmental Science Centre (PESC) perform 7-day early life stage (e-test) rainbow trout bioassays exposed to SO_4 under different water hardness conditions. Reported 7-day EC_{50}'s for the young rainbow trout in soft water (hardness of 25 mg/L as $CaCO_3$), well water (hardness of 100 mg/L), and hard water (hardness = 250 mg/L), were 1105, 1025, and 3116 mg/L SO_4, respectively (Unpublished BC MELP data, 1996).

As noted in Section 5.1.1, BC Research Inc.(1998) performed a series of spiked sulphate laboratory bioassays to assess elevated sulphate levels on aquatic organisms. Included in this suite of bioassays were a 7-day salmonid embryo viability test (e-test) using the rainbow trout, *Onchorhynchus mykiss*, and a 7-day survival and growth test using the fathead minnow *Pimephales promelas.* For rainbow trout embryo viability, a NOEC and LOEC of 1060 and 3500 mg/L SO_4, respectively, were reported. A 7-day EC_{25} and EC_{50} for viability of 1280 and 1477 mg/L SO_4, respectively, were also reported for the trout embryos. For the fathead minnow test, a NOEC and LOEC for survival of 510 and 1060 mg/L SO_4, respectively, were reported, and for growth, a NOEC and LOEC of 1060 and 3650 mg/L SO_4, respectively, were reported. Also, an IC_{25} and IC_{50} for growth of 2255 and 3450 mg/L SO_4, respectively, were determined, as well as a 7-day LC_{50} of 1355 mg/L SO_4.

In an earlier publication McKee and Wolf (1963) reported that of good game fish waters in the US, five percent of these waters contain <11 mg/L sulphates, 50 % <32 mg/L, and 95 % < 90 mg/L.

Guidelines From the Literature

A provisional water quality objective of 100 mg/L maximum for sulphate was set for the Yakoun River and its tributaries to protect aquatic life (Nijman, 1993). This objective was based on toxicity studies using eels (*Anguilla anguilla*) and fish (striped bass *Morone saxatilus*) that are not resident in BC waters (see Section 6.5.1).

A Provisional water quality objective for sulphate of 50 mg/L average concentration (five samples in 30 days) was set for Cahill Creek, Nickel Plate Mine Creek, and Red Top Gulch

Creek in the Okanagan area of BC (Swain, 1987). The rationale behind this objective is that, according to Beatty, (personal communication), above an average concentration of 71 mg/L sulphate (range of 27.7 to 189 mg/L) large sulphur bacteria growths can cover creek beds and result in significant changes to the macroinvertebrate community. However, at another location in the Okanagan area, despite sulphate concentrations which have averaged between 150 to 450 mg/L for about the past decade, no dense growths of sulphate bacteria have been observed (J. E. Bryan, personal communication).

Recommended Guideline

Freshwater Aquatic Life

To protect freshwater organisms in British Columbia, a water quality guideline of 100 mg/L for dissolved sulphate, measured as SO_4, is recommended. This guideline is a maximum concentration that should not be exceeded at any time.

Since there is conflicting evidence over the sensitivity of aquatic mosses to sulphate it is recommended that for impacted waterbodies with concentrations of dissolved sulphate that exceed 50 mg/L, the health of aquatic moss populations should be checked on an occasional basis.

Rationale

The guideline is based primarily on three studies which investigated the effects of sulphate on freshwater organisms. These are as follows:

i. Hughes (1973) reported 1-, 2-, 3-, and 4-d LC_{50}'s of 2000, 1000, 500, and 250 mg/L for SO_4, and LC_0's (no effect) of 500, 100, 100, and 100 mg/L, respectively, for striped bass (*Morone saxitilus*) larvae.

ii. Unpublished data from a series of toxicity tests performed by The Pacific Environmental Science Centre (PESC) for BC MELP in 1996 showed that the amphipod, *Hyalella*, was sensitive to sulphate in soft water, but not in medium (100 mg/L as $CaCO_3$) to hard water (250 mg/L as $CaCO_3$). PESC reported 96-h LC_{50}s for *Hyalella* in soft, medium and hard water of 205, 3711, and 6787 mg/L SO_4, respectively. A water quality guideline of 100 mg/L provides protection with a 2:1 safety factor in soft water, and a significantly greater safety factor in harder water more typical throughout BC.

iii. Frahm (1975) demonstated that a concentation of 100 mg/L SO_4 was toxic to the aquatic moss, *Fontinalis antipyretica*, a species which is known to be widely distributed throughout BC. Toxicity of SO_4 to four other species of aquatic moss ranged from 100 to >250 mg/L. There are more recent data (Beak International Incorporated and Michigan Technological University, 1998) that conflicts with these earlier (Frahm, 1975) data but the chosen endpoint of the newer data is in question.

iv. There is some evidence that elevated sulphate levels (average of 71 mg/L sulphate; range of 27.7 to 189 mg/L) can stimulate large sulphur bacteria growths which can cover creek beds and result in significant changes to the macroinvertebrate community. Anecdotal evidence is not used to derive water quality guidelines due to the absence of scientific defensibility of such information. But such information is worth noting to provide the impetus to stimulate the necessary future research into such observations.

Application of Guideline

There is some evidence that increased water hardness ameliorates sulphate toxicity which may allow for a site-specific sulphate objective that is less stringent than the guideline recommended here. " To adjust the guideline recommended here to take local conditions into consideration, the BC Environment publication, *"Methods for Deriving Site-Specific Water Quality Objectives in British Columbia and Yukon"* should be followed.

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Occurrence in the Environment

Natural Sources

Sulphur is a non-metallic element that occurs naturally in numerous minerals, including barite ($BaSO_4$), epsomite ($MgSO_4 \cdot 7H_2O$), and gypsum ($CaSO_4 \cdot 2\ H_2O$). Hexavalent sulphur combines with oxygen to form the divalent sulphate ion (SO_4^{2-}). The reversible reaction between sulphide and sulphate in the natural environment is often referred to as the "sulphur cycle." Natural sources of sulphur include volcanoes, decomposition and combustion of organic matter, and from sea salt over the oceans. Particles of sea salt formed by the breaking of myriads of bubbles are an important source of atmospheric sulphate. The atmosphere is the main vehicle for transport of sulphur from various sources (Kellogg *et al.* 1972).

Anthropogenic Sources

Sulphates are discharged into the aquatic environment in wastes from industries that use sulphates and sulphuric acid, such as mining and smelting operations, kraft pulp and paper mills, textile mills and tanneries. Iron pyrite (FeS) may be leached from abandoned coal mines and the sulphide ions converted in surface waters to sulphates. Sulphates are also released during blasting and the deposition of waste rock in dumps at metal mines. This is a significant source of sulphate generation in British Columbia (Jarman, personal communication). The burning of fossil fuels is also a major source of sulphur to the atmosphere. Most of man's emissions of sulphur to the atmosphere (about 95%) are in the form of SO_2. Sulphate fertilizers are identified as a major source of sulphate to ambient waters (Kellogg *et al.* 1972).

Sulphate Concentrations in Receiving Waters

Freshwater

Sulphate concentrations in Canadian Lakes typically range from 3 to 30 mg/L according to Katz (1977). In a survey of river waters in western Canada, excluding the province of BC, sulphate concentrations ranged from 1 to 3040 mg/L; most concentrations were below 580 mg/L (Environment Canada, 1984). Dissolved sulphate data for BC freshwaters, collected for acid rain assessment (Phippen *et al.* 1996), and for the Canada-BC Water Quality Monitoring Agreement (BC MELP and EC, 1996a-ac) are compiled in Table 1. Mean concentrations range between about 2 and 30 mg/L for most lakes and rivers throughout the province. However, some lakes in the Cariboo Region and in Richter Pass near Osoyoos have unusually high natural sulphate levels in the thousands of mg/L (Warrington, personal communication). Seasonal fluctuations in dissolved sulphate concentrations are obvious in most rivers, with low concentrations during freshet and elevated concentrations during the low winter flow periods as shown for the Bear River at Stewart BC (Figure 1). Also, in a study of rainfall-induced changes in chemistry of a British Columbia coastal creek, Whitfield *et al.* (1993) noted decreases in sulphate concentrations (1.7 to 1.0 mg/L and 1.9 to 1.5 mg/L) during two rainfall events. Concentrations returned to pre-storm conditions over a period of several days.

Seawater

Seawater contains about 2700 mg/L sulphate (Hitchcock, 1975) and it has been estimated that about 1.7 million tonnes of sulphate are added annually to the Canadian atmosphere from sea spray (Katz, 1977).

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Table 1: Summary of Ambient Dissolved Sulphate Concentrations in BC Freshwaters						
Site/Location	No. of Values	Maximum	Minimum	Mean	Standard Error	Reference
		mg/L	mg/L	mg/L	Standard Dev	
Lizard Lake,	105	1.57	1.06	1.28	SE 0.01	Phippen et al., 1996
Vancouver Island						
Marion Lake,	80	2.3	0.92	1.65	SE 0.03	Phippen et al., 1996
Lower Mainland						
Maxwell Lake,	15	4.3	3	3.43	SE 0.084	Phippen et al., 1996
Saltspring Island						
Old Wolf Lake,	19	5.1	1	1.9	SE 0.33	Phippen et al., 1996
Vancouver Island						
Spectacle Lake,	15	4.3	2	2.89	SE 0.207	Phippen et al., 1996
Vancouver Island						
Stocking Lake,	6	2	1.7	1.85	SE 0.043	Phippen et al., 1996
Vancouver Island						
Shawnigan Lake,	8	5	2.3	4.3	SD 1.20	BC MELP and EC, 1996a
Vancouver Island						
Salmon River,	300*	50*	2*	20*	NR	BC MELP and EC, 1996b
Near Hyder Alaska						
Quinsam River,	200*	14*	2*	4*	NR	BC MELP and EC, 1996c
Vancouver						

Island						
Quamichan Lake,	6	19.1	14.3	17.25	SD 2.24	BC MELP and EC, 1996d
Vancouver Island						
Prospect Lake,	5	<0.5	<0.5	<0.5	0	BC MELP and EC, 1996e
Vancouver Island						
Okanagan River,	300*	40*	15*	27*	NR	BC MELP and EC, 1996f
Oliver						
Langford Lake,	4	24.9	7.9	16.18	SD 8.523	BC MELP and EC, 1996g
Vancouver Island						
Kootenay River,	260*	60*	10*	37*	NR	BC MELP and EC, 1996h
Picture Valley						
Kootenay River,	300*	22*	3*	15*	NR	BC MELP and EC, 1996i
Creston						
Kettle River,	300*	20*	3*	10*	NR	BC MELP and EC, 1996j
Carson						
Kettle River,	300*	17*	2*	7.5*	NR	BC MELP and EC, 1996k
Midway						
Kettle River,	300*	17*	1.5*	8*	NR	BC MELP and EC, 1996m
Gilpin						
Glen Lake,	24	0.5	0.5	0.5	SD 0	BC MELP and EC, 1996n
Vancouver Island						
Fraser River,	20*	17*	2.5*	7.5*	NR	BC MELP and EC, 1996p
Red Pass						
Fraser River,	200*	15*	4*	10*	NR	BC MELP and EC, 1996q
Marguerite						
Fraser River,	225*	18*	3*	12*	NR	BC MELP and EC, 1996r
Hansard						

Elk River,	225*	40*	5*	25*	NR	BC MELP and EC, 1997a
Phillips Bridge Hwy 93						
Elk/Beaver Lakes	4	12.9	7.6	10.3	SD 2.89	BC MELP and EC, 1996s
Vancouver Island						

Sheet2

Table 1: Summary of Ambient Dissolved Sulphate Concentrations in BC Freshwaters (Cont'd)						
Site/Location	**No. of Values**	**Maximum**	**Minimum**	**Mean**	**Standard Error**	**Reference**
		mg/L	**mg/L**	**mg/L**	**Standard Dev**	
Boundary Creek,	90*	50*	5*	25*	NR	BC MELP and EC, 1996t
Midway						
Bear River,	180*	45*	7*	27*	NR	BC MELP and EC, 1996u
Stewart						
Peace River,	200*	22*	6*	13*	NR	BC MELP and EC, 1996v
Above Alces River						
Alsek River,	16*	26*	15*	20*	NR	BC MELP and EC, 1996w
Above Bates River						
Unuk River,	16*	32*	9*	24*	NR	BC MELP and EC, 1996x
Near U.S. Border						
Iskut River,	120*	35*	9*	20*	NR	BC MELP and EC, 1996y
Below Johnson River						
Stikine River,	80*	19*	6*	12*	NR	BC MELP and EC, 1996z
Above Choquette River						

Liard River,	70*	23.5*	7.5*	15*	NR	BC MELP and EC, 1996aa
At lower crossing						
Liard River,	200*	17.5*	2.5*	10*	NR	BC MELP and EC, 1996ab
At upper crossing						
Liard River,	100*	48*	15*	30*	NR	BC MELP and EC, 1996ac
At Fort Liard						
* Values are estimated visually from charted data						

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Sheet1

	Table 2: Toxic Effects of Sulphate on Freshwater Organisms						
Species Latin Name	**Duration**	**Endpoint/Effect**	**Conc XSO4**	**Conc SO4**	**Test**	**Comments**	**Ref No.**
Species Common Name	**(days)**		**(ug/L)**	**(mg/L)**	**Chemical**		see last page
Anabaena sp	20	BIO	320000	216	Na2SO4	rejected: does not agree with original study	5052
Blue-green algae							
Anabaena sp	20	BIO	460000	311	Na2SO4	rejected: does not agree with original study	5052
Blue-green algae							
Anabaena sp	20	BIO	.1MSO4	**9600**	Na2SO4	corrected from original reference	5052
Blue-green algae							
Selenastrum capricornutum	3	IC50 (growth)		**1868**	Na2SO4	water hardness = 0 mg/L (deionized water)	BC MELP
Green algae							
Selenastrum capricornutum	3	LOEC		**1111**	Na2SO4	water hardness = 0 mg/L (deionized water)	BC MELP
Green algae							
						water	

Selenastrum capricornutum	3	NOEC		**370**	Na2SO4	hardness = 0 mg/L (deionized water)	BC MELP
Green algae							
Selenastrum capricornutum	3	NOEL		**1060**	Na2SO4	water hardness: approx 100 mg/L	BC Researc
Green algae							
Selenastrum capricornutum	3	LOEL		**3650**	Na2SO4	water hardness: approx 100 mg/L	BC Researc
Green algae							
Selenastrum capricornutum	3	IC25 (growth)		**2210**	Na2SO4	water hardness: approx 100 mg/L	BC Researc
Green algae							
Selenastrum capricornutum	3	IC50 (growth)		**3359**	Na2SO4	water hardness: approx 100 mg/L	BC Researc
Green algae							
Culex sp	1	LC50 MOR	3704000	2504	Na2SO4	rejected: does not agree with original study	915
Mosquito							
Culex sp	1	LC50 MOR	2572000	1739	Na2SO4	rejected: does not agree with original study	915
Mosquito							
Culex sp	2	LC50 MOR	4325000	2924	Na2SO4	rejected: does not agree with original study	915
Mosquito							
Culex sp	2	LC50 MOR	3004000	2031	Na2SO4	rejected: does not agree with original study	915

Mosquito							
Amphipoda	1	LC50 MOR	2380000	**1609**	Na2SO4	corrected from original reference	915
species not given							
Amphipoda	2	LC50 MOR	1110000	**750**	Na2SO4	corrected from original reference	915
species not given							
Amphipoda	3	LC50 MOR	880000	**595**	Na2SO4	corrected from original reference	915
species not given							
Amphipoda	4	LC50 MOR	880000	**595**	Na2SO4	corrected from original reference	915
species not given							
Culex sp	1	LC50 MOR	11430000	**7727**	Na2SO4	corrected from original reference	915
Mosquito							
Culex sp	2	LC50 MOR	13350000	**9025**	Na2SO4	corrected from original reference	915
Mosquito							
Daphnia magna	1	LC50 MOR	8384000	**5668**	Na2SO4	corrected from original reference	915
Water flea							
Daphnia magna	2	LC50 MOR	2564000	**1733**	Na2SO4	corrected from original reference	915
Water flea							
						corrected from	

Daphnia magna	3	LC50* MOR	725000	**490**	Na2SO4*	original reference	915
Water flea							
Daphnia magna	4	LC50 MOR	630000	**426**	Na2SO4	corrected from original reference	915
Water flea							
Daphnia magna (adult)	4	LC50 MOR	4547000	**3074**	Na2SO4	corrected from original reference	915
Water flea							
Daphnia magna (young)	1	LC50 MOR	6800000	**4597**	Na2SO4	corrected from original reference	915
Water flea							
Daphnia magna (young)	2	LC50 MOR	6100000	**4124**	Na2SO4	corrected from original reference	915
Water flea							
Lepomis macrochirus	1	LC50 MOR	17500000	**11831**	Na2SO4	corrected from original reference	915
Bluegill							
Lymnaea sp	1	EC50 HAT	5401000	**3651**	Na2SO4	corrected from original reference	915
Pond snail							
Lymnaea sp	2	EC50 HAT	5400000	**3651**	Na2SO4	corrected from original reference	915
Pond snail							
Lymnaea sp	3	EC50 HAT	5400000	**3651**	Na2SO4	corrected from original reference	915
Pond snail							
Lymnaea sp	4	EC50 HAT	3553000	**2402**	Na2SO4	corrected from original reference	915

Pond snail							
M. latipinna	1	LC50 MOR	20040000	**13548**	Na2SO4	corrected from original reference	915
Molly							
M. latipinna	2	LC50 MOR	15996000	**10814**	Na2SO4	corrected from original reference	915
Molly							
Cyprinidae	1	MOR	4500000	**3042**	Na2SO4	original reference not checked	2540
Minnow , carp family							
Daphnia magna	0.01	LOC	2302000	**1556**	Na2SO4	original reference not checked	2171
Water flea							
Daphnia magna	0.01	LOC	1601000	**1082**	Na2SO4	original reference not checked	2171
Water flea							
Daphnia magna	4.2	EC50 IMM	4547000	**3074**	Na2SO4	original reference not checked	2462
Water flea							
Daphnia magna	2	LC50 MOR	64.25605 mmol/L	**9124**	Na2SO4	original reference not checked	13712
Water flea							
Daphnia magna	1	LC50 MOR	2200000	1487	Na2SO4	rejected: does not agree with original study	915
Water flea							
Daphnia						rejected: does not agree with original	

magna	1	LC50 MOR	2716000	1836	Na2SO4	study	915
Water flea							
Daphnia magna	1	LC50 MOR	8384000	**5668**	Na2SO4	original reference not checked	2465
Water flea							
Daphnia magna	1	LC50 MOR	1889000	1277	Na2SO4	rejected: does not agree with original study	915
Water flea							
Daphnia magna	1	LC50 MOR	1530000	1034	Na2SO4	rejected: does not agree with original study	915
Water flea							
Daphnia magna	2	LC50 MOR	1980000	1339	Na2SO4	rejected: does not agree with original study	915
Water flea							
Daphnia magna	2	LC50 MOR	830000	561	Na2SO4	rejected: does not agree with original study	915
Water flea							
Daphnia magna	2	LC50 MOR	578000	391	Na2SO4	rejected: does not agree with original study	915
Water flea							
Daphnia magna	2	LC50 MOR	1373000	928	Na2SO4	rejected: does not agree with original study	915
Water flea							
Daphnia magna	2	LC50* MOR	2564000	**1733**	Na2SO4	original reference not checked	2465

Water flea							
Daphnia magna	3	LC50 MOR	234000	158	Na2SO4	rejected: does not agree with original study	915
Water flea							
Daphnia magna	3	LC50 MOR	163000	110	Na2SO4	rejected: does not agree with original study	915
Water flea							
Daphnia magna	4	LC50 MOR	204000	138	Na2SO4	rejected: does not agree with original study	915
Water flea							
Daphnia magna	4	LC50 MOR	1470000	994	Na2SO4	rejected: does not agree with original study	915
Water flea							
Daphnia magna	4	LC50 MOR	142000	96	Na2SO4	rejected: does not agree with original study	915
Water flea							
Daphnia magna	4	LC50 MOR	1024000	692	Na2SO4	rejected: does not agree with original study	915
Water flea							
Daphnia magna	2	LETC IMM	5960000	**4029**	Na2SO4	original reference not checked	2130
Water flea							
Daphnia magna	2	LC50		**537**	Na2SO4	water hardness = 25 mg/L	BC MELP
Water flea							
						water	

Daphnia magna	2	LC50		**6281**	Na2SO4	hardness = 100 mg/L	BC MELP
Water flea							
Daphnia magna	2	LC50		**7442**	Na2SO4	water hardness = 250 mg/L	BC MELP
Water flea							
Daphnia magna	21	LOEC		**1200**	Na2SO4	water hardness = 100 mg/L	BC MELP
Water flea							
Daphnia magna	21	LOEC		**1375**	Na2SO4	water hardness = 250 mg/L	BC MELP
Water flea							
Daphnia magna	21	IC25 (reproduction)		**833**	Na2SO4	water hardness = 100 mg/L	BC MELP
Water flea							
Daphnia magna	21	IC25 (reproduction)		**1476**	Na2SO4	water hardness = 250 mg/L	BC MELP
Water flea							
Hyallela sp	4	LC50		**205**	Na2SO4	water hardness = 25 mg/L	BC MELP
Amphipoda							
Hyallela sp	4	LC50		**3711**	Na2SO4	water hardness = 100 mg/L	BC MELP
Amphipoda							
Hyallela sp	4	LC50		**6787**	Na2SO4	water hardness = 250 mg/L	BC MELP
Amphipoda							
Chironomus tetans	4	LC50		**6667**	Na2SO4	water hardness = 25 mg/L	BC MELP
Chironomid							
Chironomus tetans	4	LC50		**5868**	Na2SO4	water hardness = 100 mg/L	BC MELP
Chironomid							
Chironomus tetans	4	LC50		**4173**	Na2SO4	water hardness = 250 mg/L	BC MELP

Chironomid							
Daphnia Magna	2	NOEC		**3650**	Na2SO4	water hardness: approx 100 mg/L	Bc Researc
Water flea							
Daphnia Magna	2	LOEC		**7460**	Na2SO4	water hardness: approx 100 mg/L	Bc Researc
Water flea							
Daphnia Magna	2	LC50		**5218**	Na2SO4	water hardness: approx 100 mg/L	Bc Researc
Water flea							
Hyallela azteca	4	NOEC-Survival		**1060**	Na2SO4	water hardness: approx 100 mg/L	Bc Researc
Amphipoda							
Hyallela azteca	4	LOEC-Survival		**3650**	Na2SO4	water hardness: approx 100 mg/L	Bc Researc
Amphipoda							
Hyallela azteca	4	LC50		**1226**	Na2SO4	water hardness: approx 100 mg/L	Bc Researc
Amphipoda							
Ceriodaphnia	7	NOEC-Survival/reprod.		**1060**	Na2SO4	water hardness: approx 100 mg/L	Bc Researc
Cladoceran							
Ceriodaphnia	7	LOEC-Survival/reprod.		**3650**	Na2SO4	water hardness: approx 100 mg/L	Bc Researc
Cladoceran							
Ceriodaphnia	7	IC25-Reproduction		**1267**	Na2SO4	water hardness: approx 100 mg/L	Bc Researc
Cladoceran							
						water	

Ceriodaphnia	7	IC50-Reproduction		**2061**	Na2SO4	hardness: approx 100 mg/L	Bc Researc
Cladoceran							
Ceriodaphnia	7	LC50-Survival		**1967**	Na2SO4	water hardness: approx 100 mg/L	Bc Researc
Cladoceran							
Gambusia affinis	4	MOR	720000	487	Na2SO4	rejected: does not agree with original study	508
Mosquitofish							
Gambusia affinis	4	MOR	1000000	676	Na2SO4	rejected: does not agree with original study	508
Mosquitofish							
Gambusia affinis	1	LC50 MOR	5400000	3651	Na2SO4	rejected: does not agree with original study	508
Mosquitofish							
Gambusia affinis	1	LC50 MOR	7800000	5273	Na2SO4	rejected: does not agree with original study	508
Mosquitofish							
Gambusia affinis	2	LC50 MOR	3940000	2664	Na2SO4	rejected: does not agree with original study	508
Mosquitofish							
Gambusia affinis	2	LC50 MOR	5670000	3833	Na2SO4	rejected: does not agree with original study	508
Mosquitofish							
						rejected: does not agree with	

Gambusia affinis	4	LC50 MOR	3710000	2508	Na2SO4	original study	508
Mosquitofish							
Gambusia affinis	4	LC50* MOR	5350000	3617	Na2SO4*	rejected: does not agree with original study	508
Mosquitofish							
Gambusia affinis	6	LC50 MOR	2200000	1487	Na2SO4	rejected: does not agree with original study	508
Mosquitofish							
Gambusia affinis	6	LC50 MOR	3200000	2163	Na2SO4	rejected: does not agree with original study	508
Mosquitofish							
Gambusia affinis	1	LC50 MOR	24000000	16225	Na2SO4	reject: turbid diluent; corrected from orig. ref.	508
Mosquitofish							
Gambusia affinis	2	LC50 MOR	17500000	11831	Na2SO4	reject: turbid diluent; corrected from orig. ref.	508
Mosquitofish							
Gambusia affinis	4	LC50 MOR	16500000	11155	Na2SO4	reject: turbid diluent; corrected from orig. ref.	508
Mosquitofish							
Gambusia affinis	6	LC50 MOR	10000000	6761	Na2SO4	reject: turbid diluent; corrected from orig. ref.	508

Mosquitofish							
Lepomis macrochirus	1	LC50 MOR	5670000	3833	Na2SO4	rejected: does not agree with original study	915
Bluegill							
Lepomis macrochirus	1	LC50 MOR	3940000	2664	Na2SO4	rejected: does not agree with original study	915
Bluegill							
Lepomis macrochirus	4	LC50 MOR	4380000	**2961**	Na2SO4	original reference not checked	8037
Bluegill							
Lepomis macrochirus	4	LC50 MOR	3040000	**2055**	Na2SO4	original reference not checked	8037
Bluegill							
Lymnaea sp	1	EC50 HAT	1750000	1183	Na2SO4	rejected: does not agree with original study	915
Pond snail							
Lymnaea sp	1	EC50 HAT	1215000	821	Na2SO4	rejected: does not agree with original study	915
Pond snail							
Lymnaea sp	2	EC50* HAT	1750000	1183	Na2SO4*	rejected: does not agree with original study	915
Pond snail							
Lymnaea sp	2	EC50 HAT	1215000	821	Na2SO4	rejected: does not agree with original study	915
Pond snail							

Lymnaea sp	3	EC50 HAT	1750000	1183	Na2SO4	rejected: does not agree with original study	915
Pond snail							
Lymnaea sp	3	EC50 HAT	1215000	821	Na2SO4	rejected: does not agree with original study	915
Pond snail							
Lymnaea sp	4	EC50 HAT	1151000	778	Na2SO4	rejected: does not agree with original study	915
Pond snail							
Lymnaea sp	4	EC50 HAT	799000	540	Na2SO4	rejected: does not agree with original study	915
Pond snail							
Microcystis aeruginosa		NR EC50 PGR >	800000	541	Na2SO4	rejected: organic sulphates tested	9715
Blue-green algae							
Morone saxatilis	1	LC50 MOR	650000	439	Na2SO4	rejected: quoted from secondary ref by	2012
Striped bass						AQUIRE which does not agree with original	
Morone saxatilis	1	LC50 MOR	1100000	744	Na2SO4	"	2012
Striped bass							
Morone saxatilis	1	LC50 MOR	450000	304	Na2SO4	"	2012
Striped bass							
Morone saxatilis	1	LC50 MOR	790000	534	Na2SO4	"	2012

Striped bass							
Morone saxatilis	2	LC50 MOR	320000	216	Na2SO4	"	2012
Striped bass							
Morone saxatilis	2	LC50 MOR	1100000	744	Na2SO4	"	2012
Striped bass							
Morone saxatilis	2	LC50 MOR	220000	149	Na2SO4*	"	2012
Striped bass							
Morone saxatilis	2	LC50 MOR	790000	534	Na2SO4	"	2012
Striped bass							
Morone saxatilis	3	LC50 MOR	160000	108	Na2SO4	"	2012
Striped bass							
Morone saxatilis	3	LC50 MOR	1100000	744	Na2SO4	"	2012
Striped bass							
Morone saxatilis	3	LC50 MOR	110000	74	Na2SO4	"	2012
Striped bass							
Morone saxatilis	3	LC50 MOR	790000	534	Na2SO4	"	2012
Striped bass							
Morone saxatilis	4	LC50 MOR	81000	55	Na2SO4	"	2012
Striped bass							
Morone saxatilis	4	LC50 MOR	1100000	744	Na2SO4	"	2012
Striped bass							
Morone saxatilis	4	LC50 MOR	56000	38	Na2SO4	"	2012
Striped bass							
Morone saxatilis	4	LC50 MOR	790000	534	Na2SO4	"	2012
Striped bass							
Morone saxatilis	1	LC50 MOR		**2000**	Na2SO4	cited from original: data reported as SO4	2012
Striped bass larvae							

Morone saxatilis	2	LC50 MOR		**1000**	Na2SO4	cited from original: data reported as SO4	2012
Striped bass larvae							
Morone saxatilis	3	LC50 MOR		**500**	Na2SO4	cited from original: data reported as SO4	2012
Striped bass larvae							
Morone saxatilis	4	LC50 MOR		**250**	Na2SO4*	cited from original: data reported as SO4	2012
Striped bass larvae							
Morone saxatilis	1	LC50 MOR		**3500**	Na2SO4	cited from original: data reported as SO4	2012
Striped bass larvae							
Morone saxatilis	2	LC50 MOR		**3500**	Na2SO4	cited from original: data reported as SO4	2012
Striped bass larvae							
Morone saxatilis	3	LC50 MOR		**3500**	Na2SO4	cited from original: data reported as SO4	2012
Striped bass larvae							
Morone saxatilis	4	LC50 MOR		**3500**	Na2SO4	cited from original: data reported as SO4	2012
Striped bass larvae							

Myriophyllum spicatum	32	EC50 BMS	2305000	1558	Na2SO4	rejected: does not agree with original study	2262
Eurasian watermilfoil							
Myriophyllum spicatum	32	EC50 BMS	2113000	1429	Na2SO4	rejected: does not agree with original study	2262
Eurasian watermilfoil							
Myriophyllum spicatum	32	EC50 BMS	3313000	2240	Na2SO4	rejected: does not agree with original study	2262
Eurasian watermilfoil							
Myriophyllum spicatum	32	EC50 BMS	3037000	2053	Na2SO4	rejected: does not agree with original study	2262
Eurasian watermilfoil							
Myriophyllum spicatum	32	EC50 GRO	2337000	1580	Na2SO4	rejected: does not agree with original study	2262
Eurasian watermilfoil							
Myriophyllum spicatum	32	EC50 GRO	928000	627	Na2SO4	rejected: does not agree with original study	2262
Eurasian watermilfoil							
Myriophyllum spicatum	32	EC50 GRO	3360000	2272	Na2SO4	rejected: does not agree with original study	2262
Eurasian watermilfoil							

Myriophyllum spicatum	32	EC50 GRO	1335000	903	Na2SO4	rejected: does not agree with original study	2262
Eurasian watermilfoil							
Myriophyllum spicatum	32	EC50 GRO	10228000	**6915**	Na2SO4*	corrected from original reference	2262
Eurasian watermilfoil							
Myriophyllum spicatum	32	EC50 GRO	9376000	**6339**	Na2SO4	corrected from original reference	2262
Eurasian watermilfoil							
Myriophyllum spicatum	32	EC50 GRO	10370000	**7011**	Na2SO4	corrected from original reference	2262
Eurasian watermilfoil							
Myriophyllum spicatum	32	EC50 GRO	4120000	**2785**	Na2SO4	corrected from original reference	2262
Eurasian watermilfoil							
Aquatic moss	14	Chlor *a* & *b* content		**500**	Na2SO4	no observed effect @ highest level tested	Beak & MTU
Fontinalis neomexicana							
Nitzschia fonticola		NR EC50 PGR >	800000	**541**	Na2SO4	rejected: organic sulphates tested	9715
Diatom							
Nitzschia linearis	5	LC50 MOR	1900000	**1285**	Na2SO4	original reference not checked	949
Diatom							

Notropis atherinoides	5	NR-LETH MOR	32000	22	Na2SO4	rejected: screening test only using 1 to 5 fish	663
Emerald shiner						and no controls	
Notropis atherinoides	5	NR-LETH MOR	22000	15	Na2SO4	"	663
Emerald shiner							
Notropis spilopterus	5	NR-LETH MOR	32000	22	Na2SO4	"	663
Spotfin shiner							
Notropis spilopterus	5	NR-LETH MOR	22000	15	Na2SO4	"	663
Spotfin shiner							
Oncorhynchus mykiss	4	LC50 MOR		**5000**	Na2SO4	water hardness = 25 mg/L	BC MELP
Rainbow trout							
Oncorhynchus mykiss	4	LC50 MOR		**9750**	Na2SO4	water hardness = 100 mg/L	BC MELP
Rainbow trout							
Oncorhynchus mykiss	4	LC50 MOR		**9900**	Na2SO4	water hardness = 250 mg/L	BC MELP
Rainbow trout							
Oncorhynchus kisutch	4	LC50 MOR		**5742**	Na2SO4	water hardness = 25 mg/L	BC MELP
Coho salmon							
Oncorhynchus kisutch	4	LC50 MOR		**9550**	Na2SO4	water hardness = 100 mg/L	BC MELP
Coho salmon							
Oncorhynchus kisutch	4	LC50 MOR		**9875**	Na2SO4	water hardness = 250 mg/L	BC MELP
Coho salmon							
Oncorhynchus mykiss	7	Early life stage (e-test)		**1105**	Na2SO4	water hardness = 25 mg/L	BC MELP
Rainbow trout							
						water	

Oncorhynchus mykiss	7	Early life stage (e-test)		**1925**	Na2SO4	hardness = 100 mg/L	BC MELP
Rainbow trout							
Oncorhynchus mykiss	7	Early life stage (e-test)		**3116**	Na2SO4	water hardness = 250 mg/L	BC MELP
Rainbow trout							
Oncorhynchus mykiss	7	NOEC (e-test)		**1060**	Na2SO4	water hardness: approx. 100 mg/L	BC Researc
Rainbow trout							
Oncorhynchus mykiss	7	LOEC (e-test)		**3500**	Na2SO4	water hardness: approx. 100 mg/L	BC Researc
Rainbow trout							
Oncorhynchus mykiss	7	EC25 (viability)		**1280**	Na2SO4	water hardness: approx. 100 mg/L	BC Researc
Rainbow trout							
Oncorhynchus mykiss	7	EC50 (viability)		**1477**	Na2SO4	water hardness: approx. 100 mg/L	BC Researc
Rainbow trout							
Pimephales promelas	7	NOEC (survival)		**510**	Na2SO4	water hardness: approx. 100 mg/L	BC Researc
Fathead minnow							
Pimephales promelas	7	NOEC (growth)		**1060**	Na2SO4	water hardness: approx. 100 mg/L	BC Researc
Fathead minnow							
Pimephales promelas	7	LOEC (survival)		**1060**	Na2SO4	water hardness: approx. 100 mg/L	BC Researc
Fathead minnow							
						water hardness:	

Pimephales promelas	7	LOEC (growth)		**3650**	Na2SO4	approx. 100 mg/L	BC Researc
Fathead minnow							
Pimephales promelas	7	IC25 (growth)		**2255**	Na2SO4	water hardness: approx. 100 mg/L	BC Researc
Fathead minnow							
Pimephales promelas	7	IC50 (growth)		**3450**	Na2SO4	water hardness: approx. 100 mg/L	BC Researc
Fathead minnow							
Pimephales promelas	7	LC50 (survival)		**1355**	Na2SO4	water hardness: approx. 100 mg/L	BC Researc
Fathead minnow							
Polycelis nigra	2	LT50 MOR	0.048 M	**6816**	Na2SO4	original reference not checked	10013
Planarian							
Selenastrum capricornutum		NR EC50 PGR >	800000	541	Na2SO4	rejected: organic sulphates tested	9715
Green algae							
Chlorella vulgaris	91.3	LOEC PGR	1230000	**982**	MgSO4	original reference not checked	2849
Green algae	122						
Chlorella vulgaris	91.3	NOEC PGR	980000	**782**	MgSO4	original reference not checked	2849
Green algae	122						
Daphnia magna	1	EC50 IMM	405980	324	MgSO4	rejected: reported in orig. ref as Mg ion conc	6631

Water flea							
Daphnia magna	2	EC50 IMM	343560	274	MgSO4	rejected: reported in orig. ref as Mg ion conc	6631
Water flea							
Daphnia magna	1	LC50 MOR	193000	154	MgSO4	rejected: does not agree with original study	915
Water flea							
Daphnia magna	2	LC50 MOR	186000	148	MgSO4	rejected: does not agree with original study	915
Water flea							
Daphnia magna	3	LC50* MOR	172000	137	MgSO4*	rejected: does not agree with original study	915
Water flea							
Daphnia magna	4	LC50 MOR	158000	126	MgSO4	rejected: does not agree with original study	915
Water flea							
Daphnia magna	4	LC50 MOR	760600	607	MgSO4	rejected: does not agree with original study	915
Water flea							
Gambusia affinis	4	MOR	2000000	1596	MgSO4	rejected: does not agree with original study	508
Mosquitofish							
Gambusia affinis	1	LC50 MOR	3100000	2474	MgSO4	rejected: does not agree with original study	508

Mosquitofish							
Gambusia affinis	2	LC50 MOR	3100000	2474	MgSO4	rejected: does not agree with original study	508
Mosquitofish							
Gambusia affinis	4	LC50 MOR	3100000	2474	MgSO4	rejected: does not agree with original study	508
Mosquitofish							
Gambusia affinis	1	LC50 MOR	15500000	12369	MgSO4	reject: turbid diluent; corrected from orig. ref.	508
Mosquitofish							
Gambusia affinis	2	LC50 MOR	15500000	12369	MgSO4	reject: turbid diluent; corrected from orig. ref.	508
Mosquitofish							
Gambusia affinis	4	LC50 MOR	15500000	12369	MgSO4	reject: turbid diluent; corrected from orig. ref.	508
Mosquitofish							
Lepomis macrochirus	1	LC50 MOR	3800000	3032	MgSO4	rejected: does not agree with original study	915
Bluegill							
Lymnaea sp	1	EC50 HAT	2106000	1681	MgSO4	rejected: does not agree with original study	915
Pond snail							
						rejected: does not	

Lymnaea sp	2	EC50 HAT	1305000	1041	MgSO4	agree with original study	915
Pond snail							
Lymnaea sp	3	EC50* HAT	1260000	1005	MgSO4*	rejected: does not agree with original study	915
Pond snail							
Lymnaea sp	4	EC50 HAT	1250000	998	MgSO4	rejected: does not agree with original study	915
Pond snail							
Daphnia magna	1	LC50 MOR	963000	**768**	MgSO4	corrected from original reference	915
Water flea							
Daphnia magna	2	LC50 MOR	929000	**741**	MgSO4	corrected from original reference	915
Water flea							
Daphnia magna	3	LC50 MOR	861000	**687**	MgSO4	corrected from original reference	915
Water flea							
Daphnia magna	4	LC50 MOR	788000	**629**	MgSO4	corrected from original reference	915
Water flea							
Daphnia magna	4	LC50 MOR	3803000	**3035**	MgSO4	corrected from original reference	915
Water flea							
Lepomis macrochirus	1	LC50 MOR	19000000	**15162**	MgSO4	corrected from original reference	915
Bluegill							
						corrected	

Lymnaea sp	1	EC50 HAT	10530000	**8403**	MgSO4	from original reference	915
Pond snail							
Lymnaea sp	2	EC50 HAT	6525000	**5207**	MgSO4	corrected from original reference	915
Pond snail							
Lymnaea sp	2	EC50 HAT	6300000	**5027**	MgSO4	corrected from original reference	915
Pond snail							
Lymnaea sp	2	EC50 HAT	6250000	**4988**	MgSO4	corrected from original reference	915
Pond snail							
Oryzias latipes	1	LC50 MOR >	1000000	798	MgSO4	rejected: reported in orig. ref as Mg ion conc	12497
Medaka - high-eyes							
Oryzias latipes	1	LC50 MOR >	1000000	798	MgSO4	rejected: reported in orig. ref as Mg ion conc	12497
Medaka - high-eyes							
Oryzias latipes	1	LC50 MOR >	1000000	798	MgSO4	rejected: reported in orig. ref as Mg ion conc	12497
Medaka - high-eyes							
Oryzias latipes	2	LC50 MOR >	1000000	798	MgSO4	rejected: reported in orig. ref as Mg ion conc	12497
Medaka - high-eyes							
						rejected:	

Oryzias latipes	2	LC50 MOR >	1000000	798	MgSO4	reported in orig. ref as Mg ion conc	12497
Medaka - high-eyes							
Oryzias latipes	2	LC50 MOR >	1000000	798	MgSO4	rejected: reported in orig. ref as Mg ion conc	12497
Medaka - high-eyes							
Plankton	0.17	NR PRP (r=5000-60000)	5000	4	MgSO4	rejected: tests included Cu, Cd, Ni	8019
Plankton							
Tubifex tubifex	1	EC50 IMM	302790	242	MgSO4	rejected: reported in orig. ref as Mg ion conc	2918
Tubificid worm							
Tubifex tubifex	2	EC50 IMM	164820	132	MgSO4	rejected: reported in orig. ref as Mg ion conc	2918
Tubificid worm							
Tubifex tubifex	4	EC50 IMM	158130	126	MgSO4	rejected: reported in orig. ref as Mg ion conc	2918
Tubificid worm							
Chlorella vulgaris	30	PGR	2012000	**1110**	K2SO4	original reference not checked	8598
Green algae							
Dreissena polymorphia	1	LC50 MOR	112000	62	K2SO4	rejected: Potassium toxic, not the SO4	11011
Zebra mussel							
						corrected: reported in	

Fissidens crassipes	7	NR-LETH MOR	150000	**150**	K2SO4	original study as SO4	7922
Aquatic moss							
Fontinalis antipyretica	7	NR-LETH MOR	100000	**100**	K2SO4	corrected: reported in original study as SO4	7922
Aquatic moss							
Lepomis macrochirus	4	LC50* MOR	3550000	**1959**	K2SO4	original reference not checked	8037
Bluegill							
Leptodictyum riparium	7	NR-LETH MOR >	250000	**250**	K2SO4	corrected: reported in original study as SO4	7922
Aquatic moss							
Leskea polycarpa	7	NR-LETH MOR >	250000	**250**	K2SO4	corrected: reported in original study as SO4	7922
Aquatic moss							
Anguilla anguilla		NR-ENZ		176	K2SO4	rejected: biochem response but no toxic resp.	1, 2
European eel						(test conc. includes diluent SO4 conc. of 76 mg/L)	
Anguilla anguilla		NR-ENZ		176	CaSO4	rejected: biochem response but no toxic resp.	1, 2
European eel						(test conc. includes diluent SO4 conc. of 76 mg/L)	
						original	

Chlorella vulgaris	30	PGR	1872000	**1321**	CaSO4	reference not checked	8598
Green algae							
Chlorella vulgaris	30	PGR	1497000	**1056**	CaSO4	original reference not checked	8598
Green algae							
Gambusia affinis	1	LC50 MOR >	56000000	44688	CaSO4	reject: turbid diluent; corrected from orig. ref.	508
Mosquitofish							
Gambusia affinis	2	LC50 MOR >	56000000	44688	CaSO4	reject: turbid diluent; corrected from orig. ref.	508
Mosquitofish							
Gambusia affinis	4	LC50 MOR >	56000000	44688	CaSO4	reject: turbid diluent; corrected from orig. ref.	508
Mosquitofish							
Lepomis macrochirus	4	MOR	876000	**618**	CaSO4	original reference not checked	8037
Bluegill							
Lepomis macrochirus	4	LC50 MOR	2980000	**2102**	CaSO4	original reference not checked	949
Bluegill							
Nitzschia linearis	5	LC50 MOR	3200000	**2257**	CaSO4	original reference not checked	949
Bold Text Values = acceptable data							

	Table 2 AQUIRE Reference Numbers Cross Reference						
5052: Kanta, S. and T.A. Sarma. 1980				2262: Stanley, R.A. 1974			
915: Dowden, B.F. and H.J. Bennett 1965				949: Patrick, R., J. Cairns,Jr., and A. Scheier 1968			
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2171: Anderson, B.G				10013: Jones, J.R.E. 1941			
2462: Freeman, L. and I. Fowler. 1953				2849: Den Dooren de Jong, L.E. 1965			
13712: Arambasic, M.B., S. Bjelic, and G. Subakov. 1995				6631: Khangarot, B.S. and P.K. Ray. 1989			
2465: Dowden, B.F. 1961				12497: Tsuji, S., Y. Tonogai, Y. Ito, and S. Kanoh. 1986			
2130: Anderson, B.G. 1946				2918: Khangarot, B.S. 1991			
508: Wallen, I.E., W.C. Greer, and R. Lasater 1957				8598: Becker, A.J.Jr. and E.C. Keller,Jr. 1973			
8037: Trama, F.B. 1954B				11011: Fisher, S.W., P. Stromberg, K.A. Bruner, and L.D. Boulet. 1991			
9715: Yamane, A.N., M. Okada, and R. Sudo. 1984B				7922: Frahm, J.P. 1975			
2012: Hughes, J.S. 1973							

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Sheet1

	Table 2: Toxic Effects of Sulphate on Freshwater Organisms						
Species Latin Name	**Duration**	**Endpoint/Effect**	**Conc XSO4**	**Conc SO4**	**Test**	**Comments**	**Ref No.**
Species Common Name	**(days)**		**(ug/L)**	**(mg/L)**	**Chemical**		see last page
Anabaena sp	20	BIO	320000	216	Na2SO4	rejected: does not agree with original study	5052
Blue-green algae							
Anabaena sp	20	BIO	460000	311	Na2SO4	rejected: does not agree with original study	5052
Blue-green algae							
Anabaena sp	20	BIO	.1MSO4	**9600**	Na2SO4	corrected from original reference	5052
Blue-green algae							
Selenastrum capricornutum	3	IC50 (growth)		**1868**	Na2SO4	water hardness = 0 mg/L (deionized water)	BC MELP
Green algae							
Selenastrum capricornutum	3	LOEC		**1111**	Na2SO4	water hardness = 0 mg/L (deionized water)	BC MELP
Green algae							
						water	

Selenastrum capricornutum	3	NOEC		**370**	Na2SO4	hardness = 0 mg/L (deionized water)	BC MELP
Green algae							
Selenastrum capricornutum	3	NOEL		**1060**	Na2SO4	water hardness: approx 100 mg/L	BC Researc
Green algae							
Selenastrum capricornutum	3	LOEL		**3650**	Na2SO4	water hardness: approx 100 mg/L	BC Researc
Green algae							
Selenastrum capricornutum	3	IC25 (growth)		**2210**	Na2SO4	water hardness: approx 100 mg/L	BC Researc
Green algae							
Selenastrum capricornutum	3	IC50 (growth)		**3359**	Na2SO4	water hardness: approx 100 mg/L	BC Researc
Green algae							
Culex sp	1	LC50 MOR	3704000	2504	Na2SO4	rejected: does not agree with original study	915
Mosquito							
Culex sp	1	LC50 MOR	2572000	1739	Na2SO4	rejected: does not agree with original study	915
Mosquito							
Culex sp	2	LC50 MOR	4325000	2924	Na2SO4	rejected: does not agree with original study	915
Mosquito							
Culex sp	2	LC50 MOR	3004000	2031	Na2SO4	rejected: does not agree with original study	915

Mosquito							
Amphipoda	1	LC50 MOR	2380000	**1609**	Na2SO4	corrected from original reference	915
species not given							
Amphipoda	2	LC50 MOR	1110000	**750**	Na2SO4	corrected from original reference	915
species not given							
Amphipoda	3	LC50 MOR	880000	**595**	Na2SO4	corrected from original reference	915
species not given							
Amphipoda	4	LC50 MOR	880000	**595**	Na2SO4	corrected from original reference	915
species not given							
Culex sp	1	LC50 MOR	11430000	**7727**	Na2SO4	corrected from original reference	915
Mosquito							
Culex sp	2	LC50 MOR	13350000	**9025**	Na2SO4	corrected from original reference	915
Mosquito							
Daphnia magna	1	LC50 MOR	8384000	**5668**	Na2SO4	corrected from original reference	915
Water flea							
Daphnia magna	2	LC50 MOR	2564000	**1733**	Na2SO4	corrected from original reference	915
Water flea							
						corrected from	

Daphnia magna	3	LC50* MOR	725000	**490**	Na2SO4*	original reference	915
Water flea							
Daphnia magna	4	LC50 MOR	630000	**426**	Na2SO4	corrected from original reference	915
Water flea							
Daphnia magna (adult)	4	LC50 MOR	4547000	**3074**	Na2SO4	corrected from original reference	915
Water flea							
Daphnia magna (young)	1	LC50 MOR	6800000	**4597**	Na2SO4	corrected from original reference	915
Water flea							
Daphnia magna (young)	2	LC50 MOR	6100000	**4124**	Na2SO4	corrected from original reference	915
Water flea							
Lepomis macrochirus	1	LC50 MOR	17500000	**11831**	Na2SO4	corrected from original reference	915
Bluegill							
Lymnaea sp	1	EC50 HAT	5401000	**3651**	Na2SO4	corrected from original reference	915
Pond snail							
Lymnaea sp	2	EC50 HAT	5400000	**3651**	Na2SO4	corrected from original reference	915
Pond snail							
Lymnaea sp	3	EC50 HAT	5400000	**3651**	Na2SO4	corrected from original reference	915
Pond snail							
Lymnaea sp	4	EC50 HAT	3553000	**2402**	Na2SO4	corrected from original reference	915

Pond snail							
M. latipinna	1	LC50 MOR	20040000	**13548**	Na2SO4	corrected from original reference	915
Molly							
M. latipinna	2	LC50 MOR	15996000	**10814**	Na2SO4	corrected from original reference	915
Molly							
Cyprinidae	1	MOR	4500000	**3042**	Na2SO4	original reference not checked	2540
Minnow , carp family							
Daphnia magna	0.01	LOC	2302000	**1556**	Na2SO4	original reference not checked	2171
Water flea							
Daphnia magna	0.01	LOC	1601000	**1082**	Na2SO4	original reference not checked	2171
Water flea							
Daphnia magna	4.2	EC50 IMM	4547000	**3074**	Na2SO4	original reference not checked	2462
Water flea							
Daphnia magna	2	LC50 MOR	64.25605 mmol/L	**9124**	Na2SO4	original reference not checked	13712
Water flea							
Daphnia magna	1	LC50 MOR	2200000	1487	Na2SO4	rejected: does not agree with original study	915
Water flea							
Daphnia						rejected: does not agree with original	

magna	1	LC50 MOR	2716000	1836	Na2SO4	study	915
Water flea							
Daphnia magna	1	LC50 MOR	8384000	**5668**	Na2SO4	original reference not checked	2465
Water flea							
Daphnia magna	1	LC50 MOR	1889000	1277	Na2SO4	rejected: does not agree with original study	915
Water flea							
Daphnia magna	1	LC50 MOR	1530000	1034	Na2SO4	rejected: does not agree with original study	915
Water flea							
Daphnia magna	2	LC50 MOR	1980000	1339	Na2SO4	rejected: does not agree with original study	915
Water flea							
Daphnia magna	2	LC50 MOR	830000	561	Na2SO4	rejected: does not agree with original study	915
Water flea							
Daphnia magna	2	LC50 MOR	578000	391	Na2SO4	rejected: does not agree with original study	915
Water flea							
Daphnia magna	2	LC50 MOR	1373000	928	Na2SO4	rejected: does not agree with original study	915
Water flea							
Daphnia magna	2	LC50* MOR	2564000	**1733**	Na2SO4	original reference not checked	2465

Water flea							
Daphnia magna	3	LC50 MOR	234000	158	Na2SO4	rejected: does not agree with original study	915
Water flea							
Daphnia magna	3	LC50 MOR	163000	110	Na2SO4	rejected: does not agree with original study	915
Water flea							
Daphnia magna	4	LC50 MOR	204000	138	Na2SO4	rejected: does not agree with original study	915
Water flea							
Daphnia magna	4	LC50 MOR	1470000	994	Na2SO4	rejected: does not agree with original study	915
Water flea							
Daphnia magna	4	LC50 MOR	142000	96	Na2SO4	rejected: does not agree with original study	915
Water flea							
Daphnia magna	4	LC50 MOR	1024000	692	Na2SO4	rejected: does not agree with original study	915
Water flea							
Daphnia magna	2	LETC IMM	5960000	**4029**	Na2SO4	original reference not checked	2130
Water flea							
Daphnia magna	2	LC50		**537**	Na2SO4	water hardness = 25 mg/L	BC MELP
Water flea							
						water	

Daphnia magna	2	LC50		**6281**	Na2SO4	hardness = 100 mg/L	BC MELP
Water flea							
Daphnia magna	2	LC50		**7442**	Na2SO4	water hardness = 250 mg/L	BC MELP
Water flea							
Daphnia magna	21	LOEC		**1200**	Na2SO4	water hardness = 100 mg/L	BC MELP
Water flea							
Daphnia magna	21	LOEC		**1375**	Na2SO4	water hardness = 250 mg/L	BC MELP
Water flea							
Daphnia magna	21	IC25 (reproduction)		**833**	Na2SO4	water hardness = 100 mg/L	BC MELP
Water flea							
Daphnia magna	21	IC25 (reproduction)		**1476**	Na2SO4	water hardness = 250 mg/L	BC MELP
Water flea							
Hyallela sp	4	LC50		**205**	Na2SO4	water hardness = 25 mg/L	BC MELP
Amphipoda							
Hyallela sp	4	LC50		**3711**	Na2SO4	water hardness = 100 mg/L	BC MELP
Amphipoda							
Hyallela sp	4	LC50		**6787**	Na2SO4	water hardness = 250 mg/L	BC MELP
Amphipoda							
Chironomus tetans	4	LC50		**6667**	Na2SO4	water hardness = 25 mg/L	BC MELP
Chironomid							
Chironomus tetans	4	LC50		**5868**	Na2SO4	water hardness = 100 mg/L	BC MELP
Chironomid							
Chironomus tetans	4	LC50		**4173**	Na2SO4	water hardness = 250 mg/L	BC MELP

Chironomid							
Daphnia Magna	2	NOEC		**3650**	Na2SO4	water hardness: approx 100 mg/L	Bc Researc
Water flea							
Daphnia Magna	2	LOEC		**7460**	Na2SO4	water hardness: approx 100 mg/L	Bc Researc
Water flea							
Daphnia Magna	2	LC50		**5218**	Na2SO4	water hardness: approx 100 mg/L	Bc Researc
Water flea							
Hyallela azteca	4	NOEC-Survival		**1060**	Na2SO4	water hardness: approx 100 mg/L	Bc Researc
Amphipoda							
Hyallela azteca	4	LOEC-Survival		**3650**	Na2SO4	water hardness: approx 100 mg/L	Bc Researc
Amphipoda							
Hyallela azteca	4	LC50		**1226**	Na2SO4	water hardness: approx 100 mg/L	Bc Researc
Amphipoda							
Ceriodaphnia	7	NOEC-Survival/reprod.		**1060**	Na2SO4	water hardness: approx 100 mg/L	Bc Researc
Cladoceran							
Ceriodaphnia	7	LOEC-Survival/reprod.		**3650**	Na2SO4	water hardness: approx 100 mg/L	Bc Researc
Cladoceran							
Ceriodaphnia	7	IC25-Reproduction		**1267**	Na2SO4	water hardness: approx 100 mg/L	Bc Researc
Cladoceran							
						water	

Ceriodaphnia	7	IC50-Reproduction		**2061**	Na2SO4	hardness: approx 100 mg/L	Bc Researc
Cladoceran							
Ceriodaphnia	7	LC50-Survival		**1967**	Na2SO4	water hardness: approx 100 mg/L	Bc Researc
Cladoceran							
Gambusia affinis	4	MOR	720000	487	Na2SO4	rejected: does not agree with original study	508
Mosquitofish							
Gambusia affinis	4	MOR	1000000	676	Na2SO4	rejected: does not agree with original study	508
Mosquitofish							
Gambusia affinis	1	LC50 MOR	5400000	3651	Na2SO4	rejected: does not agree with original study	508
Mosquitofish							
Gambusia affinis	1	LC50 MOR	7800000	5273	Na2SO4	rejected: does not agree with original study	508
Mosquitofish							
Gambusia affinis	2	LC50 MOR	3940000	2664	Na2SO4	rejected: does not agree with original study	508
Mosquitofish							
Gambusia affinis	2	LC50 MOR	5670000	3833	Na2SO4	rejected: does not agree with original study	508
Mosquitofish							
						rejected: does not agree with	

Gambusia affinis	4	LC50 MOR	3710000	2508	Na2SO4	original study	508
Mosquitofish							
Gambusia affinis	4	LC50* MOR	5350000	3617	Na2SO4*	rejected: does not agree with original study	508
Mosquitofish							
Gambusia affinis	6	LC50 MOR	2200000	1487	Na2SO4	rejected: does not agree with original study	508
Mosquitofish							
Gambusia affinis	6	LC50 MOR	3200000	2163	Na2SO4	rejected: does not agree with original study	508
Mosquitofish							
Gambusia affinis	1	LC50 MOR	24000000	16225	Na2SO4	reject: turbid diluent; corrected from orig. ref.	508
Mosquitofish							
Gambusia affinis	2	LC50 MOR	17500000	11831	Na2SO4	reject: turbid diluent; corrected from orig. ref.	508
Mosquitofish							
Gambusia affinis	4	LC50 MOR	16500000	11155	Na2SO4	reject: turbid diluent; corrected from orig. ref.	508
Mosquitofish							
Gambusia affinis	6	LC50 MOR	10000000	6761	Na2SO4	reject: turbid diluent; corrected from orig. ref.	508

Mosquitofish							
Lepomis macrochirus	1	LC50 MOR	5670000	3833	Na2SO4	rejected: does not agree with original study	915
Bluegill							
Lepomis macrochirus	1	LC50 MOR	3940000	2664	Na2SO4	rejected: does not agree with original study	915
Bluegill							
Lepomis macrochirus	4	LC50 MOR	4380000	**2961**	Na2SO4	original reference not checked	8037
Bluegill							
Lepomis macrochirus	4	LC50 MOR	3040000	**2055**	Na2SO4	original reference not checked	8037
Bluegill							
Lymnaea sp	1	EC50 HAT	1750000	1183	Na2SO4	rejected: does not agree with original study	915
Pond snail							
Lymnaea sp	1	EC50 HAT	1215000	821	Na2SO4	rejected: does not agree with original study	915
Pond snail							
Lymnaea sp	2	EC50* HAT	1750000	1183	Na2SO4*	rejected: does not agree with original study	915
Pond snail							
Lymnaea sp	2	EC50 HAT	1215000	821	Na2SO4	rejected: does not agree with original study	915
Pond snail							

Lymnaea sp	3	EC50 HAT	1750000	1183	Na2SO4	rejected: does not agree with original study	915
Pond snail							
Lymnaea sp	3	EC50 HAT	1215000	821	Na2SO4	rejected: does not agree with original study	915
Pond snail							
Lymnaea sp	4	EC50 HAT	1151000	778	Na2SO4	rejected: does not agree with original study	915
Pond snail							
Lymnaea sp	4	EC50 HAT	799000	540	Na2SO4	rejected: does not agree with original study	915
Pond snail							
Microcystis aeruginosa		NR EC50 PGR >	800000	541	Na2SO4	rejected: organic sulphates tested	9715
Blue-green algae							
Morone saxatilis	1	LC50 MOR	650000	439	Na2SO4	rejected: quoted from secondary ref by	2012
Striped bass						AQUIRE which does not agree with original	
Morone saxatilis	1	LC50 MOR	1100000	744	Na2SO4	"	2012
Striped bass							
Morone saxatilis	1	LC50 MOR	450000	304	Na2SO4	"	2012
Striped bass							
Morone saxatilis	1	LC50 MOR	790000	534	Na2SO4	"	2012

Striped bass							
Morone saxatilis	2	LC50 MOR	320000	216	Na2SO4	"	2012
Striped bass							
Morone saxatilis	2	LC50 MOR	1100000	744	Na2SO4	"	2012
Striped bass							
Morone saxatilis	2	LC50 MOR	220000	149	Na2SO4*	"	2012
Striped bass							
Morone saxatilis	2	LC50 MOR	790000	534	Na2SO4	"	2012
Striped bass							
Morone saxatilis	3	LC50 MOR	160000	108	Na2SO4	"	2012
Striped bass							
Morone saxatilis	3	LC50 MOR	1100000	744	Na2SO4	"	2012
Striped bass							
Morone saxatilis	3	LC50 MOR	110000	74	Na2SO4	"	2012
Striped bass							
Morone saxatilis	3	LC50 MOR	790000	534	Na2SO4	"	2012
Striped bass							
Morone saxatilis	4	LC50 MOR	81000	55	Na2SO4	"	2012
Striped bass							
Morone saxatilis	4	LC50 MOR	1100000	744	Na2SO4	"	2012
Striped bass							
Morone saxatilis	4	LC50 MOR	56000	38	Na2SO4	"	2012
Striped bass							
Morone saxatilis	4	LC50 MOR	790000	534	Na2SO4	"	2012
Striped bass							
Morone saxatilis	1	LC50 MOR		**2000**	Na2SO4	cited from original: data reported as SO4	2012
Striped bass larvae							

Morone saxatilis	2	LC50 MOR		**1000**	Na2SO4	cited from original: data reported as SO4	2012
Striped bass larvae							
Morone saxatilis	3	LC50 MOR		**500**	Na2SO4	cited from original: data reported as SO4	2012
Striped bass larvae							
Morone saxatilis	4	LC50 MOR		**250**	Na2SO4*	cited from original: data reported as SO4	2012
Striped bass larvae							
Morone saxatilis	1	LC50 MOR		**3500**	Na2SO4	cited from original: data reported as SO4	2012
Striped bass larvae							
Morone saxatilis	2	LC50 MOR		**3500**	Na2SO4	cited from original: data reported as SO4	2012
Striped bass larvae							
Morone saxatilis	3	LC50 MOR		**3500**	Na2SO4	cited from original: data reported as SO4	2012
Striped bass larvae							
Morone saxatilis	4	LC50 MOR		**3500**	Na2SO4	cited from original: data reported as SO4	2012
Striped bass larvae							

Myriophyllum spicatum	32	EC50 BMS	2305000	1558	Na2SO4	rejected: does not agree with original study	2262
Eurasian watermilfoil							
Myriophyllum spicatum	32	EC50 BMS	2113000	1429	Na2SO4	rejected: does not agree with original study	2262
Eurasian watermilfoil							
Myriophyllum spicatum	32	EC50 BMS	3313000	2240	Na2SO4	rejected: does not agree with original study	2262
Eurasian watermilfoil							
Myriophyllum spicatum	32	EC50 BMS	3037000	2053	Na2SO4	rejected: does not agree with original study	2262
Eurasian watermilfoil							
Myriophyllum spicatum	32	EC50 GRO	2337000	1580	Na2SO4	rejected: does not agree with original study	2262
Eurasian watermilfoil							
Myriophyllum spicatum	32	EC50 GRO	928000	627	Na2SO4	rejected: does not agree with original study	2262
Eurasian watermilfoil							
Myriophyllum spicatum	32	EC50 GRO	3360000	2272	Na2SO4	rejected: does not agree with original study	2262
Eurasian watermilfoil							

Myriophyllum spicatum	32	EC50 GRO	1335000	903	Na2SO4	rejected: does not agree with original study	2262
Eurasian watermilfoil							
Myriophyllum spicatum	32	EC50 GRO	10228000	**6915**	Na2SO4*	corrected from original reference	2262
Eurasian watermilfoil							
Myriophyllum spicatum	32	EC50 GRO	9376000	**6339**	Na2SO4	corrected from original reference	2262
Eurasian watermilfoil							
Myriophyllum spicatum	32	EC50 GRO	10370000	**7011**	Na2SO4	corrected from original reference	2262
Eurasian watermilfoil							
Myriophyllum spicatum	32	EC50 GRO	4120000	**2785**	Na2SO4	corrected from original reference	2262
Eurasian watermilfoil							
Aquatic moss	14	Chlor *a* & *b* content		**500**	Na2SO4	no observed effect @ highest level tested	Beak & MTU
Fontinalis neomexicana							
Nitzschia fonticola		NR EC50 PGR >	800000	**541**	Na2SO4	rejected: organic sulphates tested	9715
Diatom							
Nitzschia linearis	5	LC50 MOR	1900000	**1285**	Na2SO4	original reference not checked	949
Diatom							

Notropis atherinoides	5	NR-LETH MOR	32000	22	Na2SO4	rejected: screening test only using 1 to 5 fish	663
Emerald shiner						and no controls	
Notropis atherinoides	5	NR-LETH MOR	22000	15	Na2SO4	"	663
Emerald shiner							
Notropis spilopterus	5	NR-LETH MOR	32000	22	Na2SO4	"	663
Spotfin shiner							
Notropis spilopterus	5	NR-LETH MOR	22000	15	Na2SO4	"	663
Spotfin shiner							
Oncorhynchus mykiss	4	LC50 MOR		**5000**	Na2SO4	water hardness = 25 mg/L	BC MELP
Rainbow trout							
Oncorhynchus mykiss	4	LC50 MOR		**9750**	Na2SO4	water hardness = 100 mg/L	BC MELP
Rainbow trout							
Oncorhynchus mykiss	4	LC50 MOR		**9900**	Na2SO4	water hardness = 250 mg/L	BC MELP
Rainbow trout							
Oncorhynchus kisutch	4	LC50 MOR		**5742**	Na2SO4	water hardness = 25 mg/L	BC MELP
Coho salmon							
Oncorhynchus kisutch	4	LC50 MOR		**9550**	Na2SO4	water hardness = 100 mg/L	BC MELP
Coho salmon							
Oncorhynchus kisutch	4	LC50 MOR		**9875**	Na2SO4	water hardness = 250 mg/L	BC MELP
Coho salmon							
Oncorhynchus mykiss	7	Early life stage (e-test)		**1105**	Na2SO4	water hardness = 25 mg/L	BC MELP
Rainbow trout							
						water	

Oncorhynchus mykiss	7	Early life stage (e-test)		**1925**	Na2SO4	hardness = 100 mg/L	BC MELP
Rainbow trout							
Oncorhynchus mykiss	7	Early life stage (e-test)		**3116**	Na2SO4	water hardness = 250 mg/L	BC MELP
Rainbow trout							
Oncorhynchus mykiss	7	NOEC (e-test)		**1060**	Na2SO4	water hardness: approx. 100 mg/L	BC Researc
Rainbow trout							
Oncorhynchus mykiss	7	LOEC (e-test)		**3500**	Na2SO4	water hardness: approx. 100 mg/L	BC Researc
Rainbow trout							
Oncorhynchus mykiss	7	EC25 (viability)		**1280**	Na2SO4	water hardness: approx. 100 mg/L	BC Researc
Rainbow trout							
Oncorhynchus mykiss	7	EC50 (viability)		**1477**	Na2SO4	water hardness: approx. 100 mg/L	BC Researc
Rainbow trout							
Pimephales promelas	7	NOEC (survival)		**510**	Na2SO4	water hardness: approx. 100 mg/L	BC Researc
Fathead minnow							
Pimephales promelas	7	NOEC (growth)		**1060**	Na2SO4	water hardness: approx. 100 mg/L	BC Researc
Fathead minnow							
Pimephales promelas	7	LOEC (survival)		**1060**	Na2SO4	water hardness: approx. 100 mg/L	BC Researc
Fathead minnow							
						water hardness:	

Pimephales promelas	7	LOEC (growth)		**3650**	Na2SO4	approx. 100 mg/L	BC Researc
Fathead minnow							
Pimephales promelas	7	IC25 (growth)		**2255**	Na2SO4	water hardness: approx. 100 mg/L	BC Researc
Fathead minnow							
Pimephales promelas	7	IC50 (growth)		**3450**	Na2SO4	water hardness: approx. 100 mg/L	BC Researc
Fathead minnow							
Pimephales promelas	7	LC50 (survival)		**1355**	Na2SO4	water hardness: approx. 100 mg/L	BC Researc
Fathead minnow							
Polycelis nigra	2	LT50 MOR	0.048 M	**6816**	Na2SO4	original reference not checked	10013
Planarian							
Selenastrum capricornutum		NR EC50 PGR >	800000	541	Na2SO4	rejected: organic sulphates tested	9715
Green algae							
Chlorella vulgaris	91.3	LOEC PGR	1230000	**982**	MgSO4	original reference not checked	2849
Green algae	122						
Chlorella vulgaris	91.3	NOEC PGR	980000	**782**	MgSO4	original reference not checked	2849
Green algae	122						
Daphnia magna	1	EC50 IMM	405980	324	MgSO4	rejected: reported in orig. ref as Mg ion conc	6631

Water flea							
Daphnia magna	2	EC50 IMM	343560	274	MgSO4	rejected: reported in orig. ref as Mg ion conc	6631
Water flea							
Daphnia magna	1	LC50 MOR	193000	154	MgSO4	rejected: does not agree with original study	915
Water flea							
Daphnia magna	2	LC50 MOR	186000	148	MgSO4	rejected: does not agree with original study	915
Water flea							
Daphnia magna	3	LC50* MOR	172000	137	MgSO4*	rejected: does not agree with original study	915
Water flea							
Daphnia magna	4	LC50 MOR	158000	126	MgSO4	rejected: does not agree with original study	915
Water flea							
Daphnia magna	4	LC50 MOR	760600	607	MgSO4	rejected: does not agree with original study	915
Water flea							
Gambusia affinis	4	MOR	2000000	1596	MgSO4	rejected: does not agree with original study	508
Mosquitofish							
Gambusia affinis	1	LC50 MOR	3100000	2474	MgSO4	rejected: does not agree with original study	508

Mosquitofish							
Gambusia affinis	2	LC50 MOR	3100000	2474	MgSO4	rejected: does not agree with original study	508
Mosquitofish							
Gambusia affinis	4	LC50 MOR	3100000	2474	MgSO4	rejected: does not agree with original study	508
Mosquitofish							
Gambusia affinis	1	LC50 MOR	15500000	12369	MgSO4	reject: turbid diluent; corrected from orig. ref.	508
Mosquitofish							
Gambusia affinis	2	LC50 MOR	15500000	12369	MgSO4	reject: turbid diluent; corrected from orig. ref.	508
Mosquitofish							
Gambusia affinis	4	LC50 MOR	15500000	12369	MgSO4	reject: turbid diluent; corrected from orig. ref.	508
Mosquitofish							
Lepomis macrochirus	1	LC50 MOR	3800000	3032	MgSO4	rejected: does not agree with original study	915
Bluegill							
Lymnaea sp	1	EC50 HAT	2106000	1681	MgSO4	rejected: does not agree with original study	915
Pond snail							
						rejected: does not	

Lymnaea sp	2	EC50 HAT	1305000	1041	MgSO4	agree with original study	915
Pond snail							
Lymnaea sp	3	EC50* HAT	1260000	1005	MgSO4*	rejected: does not agree with original study	915
Pond snail							
Lymnaea sp	4	EC50 HAT	1250000	998	MgSO4	rejected: does not agree with original study	915
Pond snail							
Daphnia magna	1	LC50 MOR	963000	**768**	MgSO4	corrected from original reference	915
Water flea							
Daphnia magna	2	LC50 MOR	929000	**741**	MgSO4	corrected from original reference	915
Water flea							
Daphnia magna	3	LC50 MOR	861000	**687**	MgSO4	corrected from original reference	915
Water flea							
Daphnia magna	4	LC50 MOR	788000	**629**	MgSO4	corrected from original reference	915
Water flea							
Daphnia magna	4	LC50 MOR	3803000	**3035**	MgSO4	corrected from original reference	915
Water flea							
Lepomis macrochirus	1	LC50 MOR	19000000	**15162**	MgSO4	corrected from original reference	915
Bluegill							
						corrected	

Lymnaea sp	1	EC50 HAT	10530000	**8403**	MgSO4	from original reference	915
Pond snail							
Lymnaea sp	2	EC50 HAT	6525000	**5207**	MgSO4	corrected from original reference	915
Pond snail							
Lymnaea sp	2	EC50 HAT	6300000	**5027**	MgSO4	corrected from original reference	915
Pond snail							
Lymnaea sp	2	EC50 HAT	6250000	**4988**	MgSO4	corrected from original reference	915
Pond snail							
Oryzias latipes	1	LC50 MOR >	1000000	798	MgSO4	rejected: reported in orig. ref as Mg ion conc	12497
Medaka - high-eyes							
Oryzias latipes	1	LC50 MOR >	1000000	798	MgSO4	rejected: reported in orig. ref as Mg ion conc	12497
Medaka - high-eyes							
Oryzias latipes	1	LC50 MOR >	1000000	798	MgSO4	rejected: reported in orig. ref as Mg ion conc	12497
Medaka - high-eyes							
Oryzias latipes	2	LC50 MOR >	1000000	798	MgSO4	rejected: reported in orig. ref as Mg ion conc	12497
Medaka - high-eyes							
						rejected:	

Oryzias latipes	2	LC50 MOR >	1000000	798	MgSO4	reported in orig. ref as Mg ion conc	12497
Medaka - high-eyes							
Oryzias latipes	2	LC50 MOR >	1000000	798	MgSO4	rejected: reported in orig. ref as Mg ion conc	12497
Medaka - high-eyes							
Plankton	0.17	NR PRP (r=5000-60000)	5000	4	MgSO4	rejected: tests included Cu, Cd, Ni	8019
Plankton							
Tubifex tubifex	1	EC50 IMM	302790	242	MgSO4	rejected: reported in orig. ref as Mg ion conc	2918
Tubificid worm							
Tubifex tubifex	2	EC50 IMM	164820	132	MgSO4	rejected: reported in orig. ref as Mg ion conc	2918
Tubificid worm							
Tubifex tubifex	4	EC50 IMM	158130	126	MgSO4	rejected: reported in orig. ref as Mg ion conc	2918
Tubificid worm							
Chlorella vulgaris	30	PGR	2012000	**1110**	K2SO4	original reference not checked	8598
Green algae							
Dreissena polymorphia	1	LC50 MOR	112000	62	K2SO4	rejected: Potassium toxic, not the SO4	11011
Zebra mussel							
						corrected: reported in	

Fissidens crassipes	7	NR-LETH MOR	150000	**150**	K2SO4	original study as SO4	7922
Aquatic moss							
Fontinalis antipyretica	7	NR-LETH MOR	100000	**100**	K2SO4	corrected: reported in original study as SO4	7922
Aquatic moss							
Lepomis macrochirus	4	LC50* MOR	3550000	**1959**	K2SO4	original reference not checked	8037
Bluegill							
Leptodictyum riparium	7	NR-LETH MOR >	250000	**250**	K2SO4	corrected: reported in original study as SO4	7922
Aquatic moss							
Leskea polycarpa	7	NR-LETH MOR >	250000	**250**	K2SO4	corrected: reported in original study as SO4	7922
Aquatic moss							
Anguilla anguilla		NR-ENZ		176	K2SO4	rejected: biochem response but no toxic resp.	1, 2
European eel						(test conc. includes diluent SO4 conc. of 76 mg/L)	
Anguilla anguilla		NR-ENZ		176	CaSO4	rejected: biochem response but no toxic resp.	1, 2
European eel						(test conc. includes diluent SO4 conc. of 76 mg/L)	
						original	

Chlorella vulgaris	30	PGR	1872000	**1321**	CaSO4	reference not checked	8598
Green algae							
Chlorella vulgaris	30	PGR	1497000	**1056**	CaSO4	original reference not checked	8598
Green algae							
Gambusia affinis	1	LC50 MOR >	56000000	44688	CaSO4	reject: turbid diluent; corrected from orig. ref.	508
Mosquitofish							
Gambusia affinis	2	LC50 MOR >	56000000	44688	CaSO4	reject: turbid diluent; corrected from orig. ref.	508
Mosquitofish							
Gambusia affinis	4	LC50 MOR >	56000000	44688	CaSO4	reject: turbid diluent; corrected from orig. ref.	508
Mosquitofish							
Lepomis macrochirus	4	MOR	876000	**618**	CaSO4	original reference not checked	8037
Bluegill							
Lepomis macrochirus	4	LC50 MOR	2980000	**2102**	CaSO4	original reference not checked	949
Bluegill							
Nitzschia linearis	5	LC50 MOR	3200000	**2257**	CaSO4	original reference not checked	949
Bold Text Values = acceptable data							

	Table 2 AQUIRE Reference Numbers Cross Reference						
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