

**INFLUENCE OF GEOCHEMICAL PROCESSES ON NUTRIENT
SPIRALING WITHIN THE RECIRCULATION ZONES OF THE
COLORADO RIVER IN THE GRAND CANYON**

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ABSTRACT

The objective of this study is to characterize the biogeochemical environments of reattachment-bar return current channels within recirculation zones along the Colorado River below Glen Canyon Dam. In confined, debris-fan dominated rivers, return current channels (RCCs) provide backwater habitat for several endangered species. To understand how different flow regimes affect biogeochemical cycling along the Colorado River, we examined ground-water compositions collected from 62 PVC wells at depths of 3 and 6 meters within four reattachment bars at different flow rates and during rising and falling flows. This dam-regulated system has extremely low dissolved nitrate (NO_3^- -N) and orthophosphate (PO_4^{+}) concentrations which decrease downstream from 0.47 ± 0.22 mg/l and 3.88 ± 0.21 $\mu\text{g/l}$, respectively, 15 km below the dam, to 0.36 ± 0.11 and 1.64 ± 0.33 82 km (194L) downstream. These nutrients are lost from Colorado River water to riparian systems, particularly RCCs.

Compositions of water in reattachment bars vary, however, they are significantly different from river waters. Ground-water under the RCCs are significantly different from ground-water under the sandier parts of the bars. Dissolved-oxygen (DO) measurements decrease across the bar from 8.6 ± 1.7 mg/l in the river to 1.14 ± 0.97 mg/l under the RCC. Nitrate and nitrite (NO_2^-) concentrations decrease from 0.4 and 0.04 mg/l, respectively in the main current of the river to close to or below detection limits (bdl) for water collected from sediments

underneath the RCC. Ammonium concentrations ($[\text{NH}_4^+]$) vary in the river from bdl to .35 mg/l and increase across the bar to as much as 25.0 mg/l within water collected from sediments within the RCCs. Sequential phosphorous extractions of RCC sediments indicate that RCC sediments are the largest sources of P in the bar complex. Sorbed phosphate was the only detectable fraction. Aggradation of RCCs with silts and clays contribute to a cumulative sequestering of phosphate moving downstream of Glen Canyon Dam. Implementation of Interim Flow criteria has dampened the connection between RCC ground water and mainstream flow and precluded removal of material by scouring. The nutrient enrichment caused by flow regulation contributes to the high productivity of these habitats.

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Many people deserve thanks for participating in this study. We relied heavily on student and professional volunteers. Without the efforts of many dedicated and happy souls, who persevered across climatic extremes, this study would not have been possible.

We would especially like to thank Larry Stevens, Dave Wegner, Kelly Smith, Chris Black, Chris Genious, Wendy Mayer, Kemp Webb, Wally Wilson, Stacy Griffith, the sediment guys, and everyone at the Glen Canyon Environmental Studies for their intellectual and financial support.

INTRODUCTION

Overview of Project

Glen Canyon Dam and the impounded Lake Powell are a key storage facility for the Colorado River Storage Project. Flow regimes below the dam strongly affect the distribution and extent of alluvial deposits and riparian environments within Grand Canyon National Park. Since completion of the dam in March of 1963, significant changes in downstream resources have occurred. Water temperature, turbidity, and composition are now controlled by hypolimnic withdrawal at the dam. A yearly hydrograph once dominated by a seasonal pulse from snow melt is now regulated by Bureau of Reclamation for the Colorado River Storage Project and power generation. The result of these two concerns is clear, cold, and dampened flows that have allowed for a redistribution of sediment resources, an increase in riparian vegetation, the advancement of introduced species, and the endangerment of native species such as the Humpback Chub (Water Science and Technology Board, 1991).

Post-dam riparian marsh development has been significant (Stevens et al., 1995). This report presents the results of studies designed to describe and interpret biogeochemical conditions in reattachment bars in the Grand Canyon.

Previous Work

In December of 1982 the Bureau of Reclamation initiated a broad topic multi-agency study (Phase I) to address concerns about possible negative effects of the operation of Glen Canyon Dam on downstream environmental and recreational resources. Phase I studies included water quality measurements made on the main stem from 1984 to 1986. Among the findings was no apparent downstream trend in mean nitrate concentrations and a downstream increase in dissolved orthophosphate. Phase I studies also noted an increase in riparian vegetation. The results of these studies are included in the GCES Final Report (U.S. Department of Interior, 1987).

Increased public concern during Phase I led the Secretary of the Interior to direct the Bureau of Reclamation to prepare an environmental impact statement to reevaluate the GCD operations. This led to the initiation of Phase II. As part of Phase II, the Bureau conducted a series of research flows designed to determine the impact of different flow regimes on sediment resources. The focus of interest was on erosional processes (bank failure, cut-bank retreat) near the water's edge. The researchers concluded that GCD discharge patterns, both long- and short-term, affect bar topography (Beus and Avery, 1992).

Implementation of Interim Flow Criteria occurred directly after the research flows and during the preparation of an Environmental Impact Statement. These criteria mandated a decrease in peak discharge from

33,000 cfs to 20,000 cfs, decreased daily fluctuations, and slower ramping rates. We conducted this study under Interim Flow Criteria.

Purpose of Study

Prior to the construction of GCD, large seasonal pulses of snow melt prevented the establishment of fluvial marshes. The reduction in flooding allowed an increase in riparian productivity (Turner and Karpiscak, 1980). Both wet and dry marshes have developed on fine grained deposits (Stevens et. al., 1995). In bedrock-channel rivers, geomorphology controls fine-grained deposition (Schmidt and Rubin, 1995). A large proportion of fine-grained deposition occurs in eddies where flow velocities are low. Eddy deposits include a fine to medium-grained sand bar off the main channel, separated from the shore by a scour feature generated by recirculating flow. Post-dam flows have been insufficient to keep the channel complex scoured, allowing for the formation of wet fluvial marshes in these areas (Stevens et. al., 1995). Historically, these areas have provided reproductive habitat for native fish.

Oxidation-reduction (redox) reactions impact mineralization of accumulating organic material cycling within the alluvial deposits. Further cycling of organic matter by biogeochemical reactions controls bioavailability, gaseous export of carbon and nitrogen, and hydrologic flux of nutrients. Rates of reactions and processes are controlled by the delivery of water and oxygen. Current management policy consisting of

daily fluctuating flows affects flow paths of nutrients through the reattachment bar complex.

The Bureau of Reclamation has prepared an Environmental Impact Statement on the impacts of GCD operations on resources in Glen, Marble, and Grand Canyons. Implementation of adaptive management practices for GCD requires monitoring of sand-bar conditions to assess how these actions affect linkages between sediment resources and channel flow. The concept of adaptive management, as stated in the EIS, "is based on the need for operational flexibility to respond to future monitoring and research findings and variable biological and physical findings." Adaptive management is a common element of all GCD management alternatives and long-term monitoring for downstream resources.

We have monitored the interstitial and surface water associated with recirculation-zone alluvial deposits at four sites. We designed this study to recognize spatial and temporal variations in the biogeochemistry of ground water associated with reattachment bars and return current channels in the Grand Canyon, Arizona. This information is needed for the development of energy and nutrient pathway models and assessment impacts of variable discharge regimes.

In addition to modeling reaction pathways for geochemical processes, we have undertaken a hydrogeologic investigation of Colorado River reattachment bars in the Grand Canyon. We have designed this study to investigate the interaction between ground water in the reattachment bars

and surface water in the Colorado River, which will allow us to determine nutrient and hydrologic fluxes between rivers and bars.

Objectives

The principal objectives of the biogeochemical study are:

- (1) description and interpretation of oxidation-reduction conditions within the alluvial deposits of the recirculation zones;
- (2) documentation of changes in water chemistry as it flows through the alluvium and RCCs; and
- (3) construction of a geochemical model describing the relationship between geochemical processes within the alluvial deposits and the biogeochemistry of the main stem.

The principal objectives of the hydrogeologic study are:

- (1) characterize the spatial and stage dependent hydraulic conductivity values of RCC sediments (permeability);
- (2) document dynamic hydraulic gradients across RCCs at rising and falling river stage;
- (3) calculate actual velocities of ground water flow ;

(4) develop a water budget for unconfined aquifers within the reattachment bars; and

(5) determine the availability of ground water for phreatophyte usage by modeling water table-response to rising and falling river stage.

Study Area Description

Canyon constrictions produce areas of recirculating flow. These zones are areas of alluvial deposition. In-stream deposits are integral to the chemistry of surface water flowing above, by, and through the alluvium (Grimm and Fisher, 1984, Valett et. al., 1990, Sterba, 1992). Main channel current separates from the shore where a channel constriction expands and reattaches downstream. A recirculation zone (eddy) forms in between (Figure 1). Current pours into the eddy just upstream of the reattachment point and reenters the main current just downstream of the separation point. As the current is turned upstream, current velocities increase. Increased velocity precludes deposition and permits the formation of the return current channel (RCC) (Figure 1). A smaller secondary eddy can form at the upstream end of the recirculation zone. Within these eddies, current slows enough for sediment to fall out of suspension. These deposits are the reattachment bar and the separation deposit or the constriction/expansion complex.

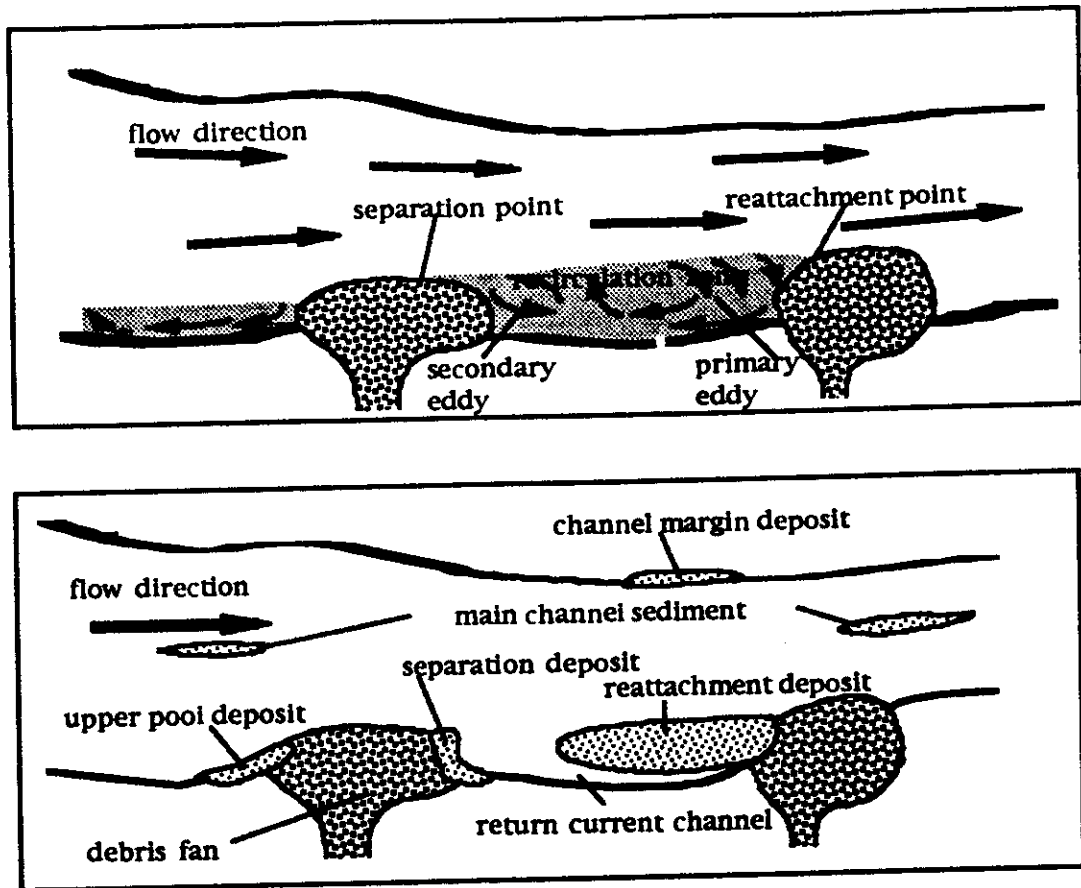


Figure 1. All of the study sites are reattachment bars. These bars form as current leaves a constriction, such as a debris fan. A recirculation zone is formed when current separates from the channel boundary and then reattaches downstream. Fine grain deposits are formed in areas of recirculation and stranded as flows recede.

Recirculation zones retain fine sediments (Schmidt and Graf, 1990) and significant organic debris. Moreover, reattachment bars and RCCs formed during higher stage discharges are now untouched by scouring flows. The removal of disturbance from this system has permitted the establishment of several types of riparian communities. From a mass balance approach, nutrient pools associated with constriction/expansion complexes have increased in size.

As large flows recede, significant organic debris and fine sediments can accumulate in the RCC (Boyle and Watson 1991, Schmidt 1990), providing conditions that are necessary for reduction and mineralization of organic matter. Flood-stage recirculation zones leave deposits that are stranded and unaffected by low flows. However, interstitial water remains and in some cases, standing water exists in return channels. The isolation of these deposits, and the associated increase in residence time, permits significant warming of RCC surface water and interaction with sediment. Moreover, even when these areas lack standing water, a fluctuating water table will saturate sediments enough to produce reduced conditions. The role of these reduction zones in nutrient path dynamics is critical.

RESEARCH METHODS

Field Investigations

Field investigations concentrated on ground water and surface water characterization at four sampling locations (Figure 2). We also sampled and analyzed sediments above the water table at all four sites. Concurrent hydrogeologic investigations concentrated on measuring ground water flow and nutrient transport parameters at the same four locations.

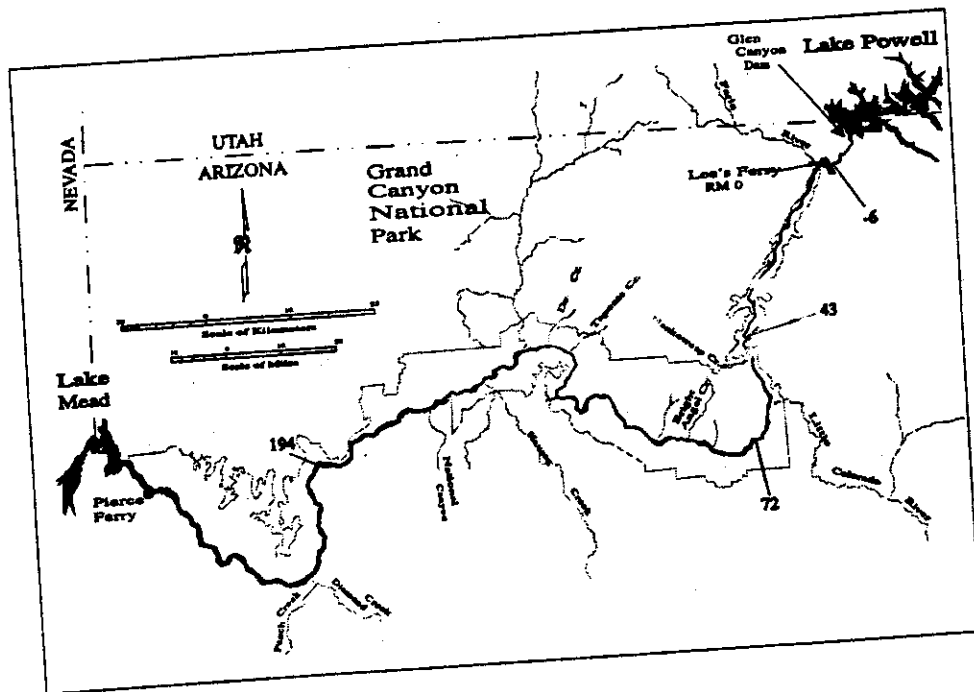


Figure 2. Locations of the four study sites downstream of Glen Canyon Dam in northwestern Arizona. Numbers represent river miles from Lee's Ferry, Arizona.

Site Selection

To describe biogeochemical conditions of alluvial deposits associated with emerging riparian marshes along the Colorado River below Glen Canyon dam, we chose four reattachment bars; one in Glen Canyon (-6r), one in Marble Canyon (43.21), and two in the Grand Canyon (721 and 1941). The four sites were spaced along the river to discern tributary influences. Reattachment bars are the most common alluvial deposits associated with critical backwater habitat and the emerging riparian marshes. We chose the Glen Canyon site due to its accessibility for day trips. We chose the other three sites because of their proximity to established research sites or, as in the case of Cardenas Marsh, its proximity to the confluence of the Colorado and Little Colorado Rivers.

Well Installation and Placement

All wells were installed early in 1993 using a jetting technique. After digging a hole through the unsaturated zone, we set a two-inch diameter PVC casing in the hole by hand. A one-inch diameter PVC jetting tool was then advanced simultaneously with the casing into the bar using river water pumped through the jetting tool. Once we reached the desired depth, we removed the jetting tool and placed a one-inch diameter well assembly inside the casing. The casing had 18 inches of .001 inch width screen located 12 inches off the bottom. Once the well assembly was in

place, we removed the casing, allowing sediments to slump against the well assembly. We then developed each well with a tool fashioned from PVC.

Each well site consisted of two wells of different depths (3 and 6 m), arranged across the reattachment bar and the return current channel in a grid. Each cluster was identified by a letter (A,B,C) and a number (1,2,3 or 100,200,300). The letters correspond to placement on the bar (A wells are away from the main current and usually in a RCC, C wells are close to the river). The numbers increase downstream. Stage gages were installed at the upstream and downstream ends of the reattachment bars.

Sample Collection

Sample collection began in April of 1993, after large winter floods and continued through January 1995. Logistical constraints forced us to sample site -6r on a delayed schedule starting in July 1993 and ending in April 1994. Ground-water samples were taken from each well after purging three well volumes. Surface-water samples were taken from the main current at a point near the reattachment point, the reattachment eddy, and from standing water above stranded return current channels. Each water sample was filtered through a 0.2 μm . Samples were placed in acid-washed polyethylene bottles that had been rinsed three times with filtered sample. One 250-ml sample was not preserved and used for anion analysis. We acidified one of two 125-ml bottles to pH 2 with ultrex HNO_3 to preserve cations. The other 125-ml bottle was preserved with phenal

mercuric acetate for nutrient analysis. Samples were transported in ice chests and stored in a laboratory refrigerator at 4 degrees C until analysis.

We collected soil samples from the unsaturated zone at each cluster. Soil samples from site -6r were refrigerated immediately after collection for phosphorous extraction and analysis.

On-Site Analysis

On-site analysis included temperature, specific conductance, pH, nitrate-nitrite, ammonium, and at least one of the following; Eh, dissolved oxygen with a electrode, or dissolved oxygen with by modified Winkler titration.

Temperature and specific conductance was measured with an Orion electrical conductivity meter and pH was measured with an Orion SA 250 temperature-compensating meter equipped with an Orion Ross combination pH electrode and thermistor electrode. We used the same meter equipped with an Orion ammonium ion selective electrode to measure reduced nitrogen. We measured nitrate and nitrite concentrations on a Hach D2000 UV-VIS spectrophotometer using a cadmium reduction method developed by Hach. In order to qualify reduced conditions we measured Eh with an Orion Ross platinum electrode. The poor poise of the water sampled required an alternative measure of redox state. We made dissolved-oxygen measurements with an Orion dissolved-oxygen probe until it broke. We then used a modified Winkler

titration until the end of the project. Several samples were analyzed with both techniques for comparison purposes.

On-site hydrogeologic investigations included pneumatic-slug tests, synoptic water-level measurements, and surveys to determine elevations of stage gages and wellheads.

We conducted pneumatic-slug tests using an INSITU pneumatic well head, pressure transducer, and HERMIT 2-channel datalogger. We chose slug tests because the well screens only partially-penetrated the aquifer making them inappropriate for pumping tests. We used slug tests with a pneumatic slug because the small diameter of the wells precluded withdrawal of an actual slug. We made synoptic water level measurements using a SOLINST water-level probe, precise to one hundredth of a foot.

Laboratory Analysis

Water Analysis

We analyzed un-acidified samples for chloride and sulfate, using a Dionex DX100 ion chromatograph. We measured orthophosphate in water and extracts using a Lachat QuickChem AE automated ion analyzer. The recommended analytical procedures were taken directly from the Lachat reference manual.

For the first two trips, we measured alkalinity by titration using a Technicon Auto-Analyzer calibrated to deliver 2 ml/min to a 100 ml sample on a stir plate. We adjusted the concentration of the titrant (0.01-0.008 N reagent grade HCl) prior to analysis in order to produce titration curves that could accurately estimate concentrations of alkalinity in the sample. We took titration readings from the initial lab pH to below a pH of 4 with a Ross combination electrode and Orion Research Model 701A/digital Ionalyzer pH meter. The meter was connected to a OmniScribe chart recorder set at 5 cm/min for recording the titration curves. For the last two data trips, including the last three visits to site -6r, we determined alkalinity by measuring inorganic carbon with a Dohrman DC-180 carbon analyzer. We measured sample duplicates with both techniques to insure the reproducibility.

We measured base cation concentrations (Ca^{2+} , Mg^{2+} , Na^{+} , and K^{+}) with a Perkin Elmer 560 atomic adsorption spectrophotometer with an air/acetylene flame. Recommended analytical procedures are in the Perkin Elmer reference manual.

We prepared all the samples, standards, blanks, and replicates using standard laboratory practices and ran them through the same procedure for each type of analysis. To insure precision of methods, we routinely measured EPA standards for base cation and inorganic anion concentrations.

Hydrogeologic Analysis

We used the Bouwer and Rice method (1976) for unconfined aquifers to analyze the pneumatic-slug tests. We plotted the synoptic water levels with a computer software graphing package to establish stage-gradient relationships, and contoured synoptic water levels with the computer software package SURFER (Golden, 1994).

Soil Analyses

To understand the origin of dissolved orthophosphate in beach ground waters, we examined the forms of phosphorous in samples of six soil profiles at site -6r. We performed sequential phosphorous extractions on replicates of each sample using the techniques of Page et al. (1982).

Clay mineral assemblages were analyzed by x-ray diffraction on a Siemens diffractometer using the standard techniques of Moore and Reynolds (1987).

Data Analyses

To evaluate the accuracy of our analysis we used WATEQF. WATEQF (Truesdell and Jones, 1974; Plummer et al., 1976) is a thermochemical model developed by the U.S. Geological Survey. WATEQF solves simultaneous equations that describe equilibrium chemical reactions occurring in a given water starting from the chemical analysis of that water. The model calculates activity products and compares the ion-activity products (IAP) with the equilibrium constant solubility products (K_t) for the minerals and solid compounds contained in the data base. The ratio of IAP to K_t defines the extent of saturation of the solution with respect to a given mineral or solid compound. The natural log of the ratio is called the disequilibrium saturation index (SI).

A positive SI indicates the mineral phase is supersaturated in the solution, a negative SI indicates the mineral has a tendency to continue to dissolve into solution, and a near-zero SI (between -1 and 1) indicates that the solution is in equilibrium with that solid phase (Drever, 1988).

Limitations exist in using and interpreting results from WATEQF. First, equilibrium among aqueous species is assumed. Second, the computations will reflect inaccuracies in the thermochemical data

contained in the data-base. Third, species present in the solution, but not included in the model, may cause misleading results. Forth, complete and accurate chemical analyses are required as model input if meaningful results are to be obtained. And fifth, WATEQF does not consider adsorptive processes. WATEQF does produce important quality-control data. It will compare measured electrical conductivity conductivity calculated from the chemical analysis (a conductivity balance). It will also calculate the difference between the total equivalents/L of anions and cations and express the normalized difference as a percent error (charge balance). Assuming electrostatic neutrality in the water, an ideal water analysis would have a charge balance equal to zero. In practice, a charge balance of $0 \pm 12-15\%$ is generally acceptable (Hem, 1989).

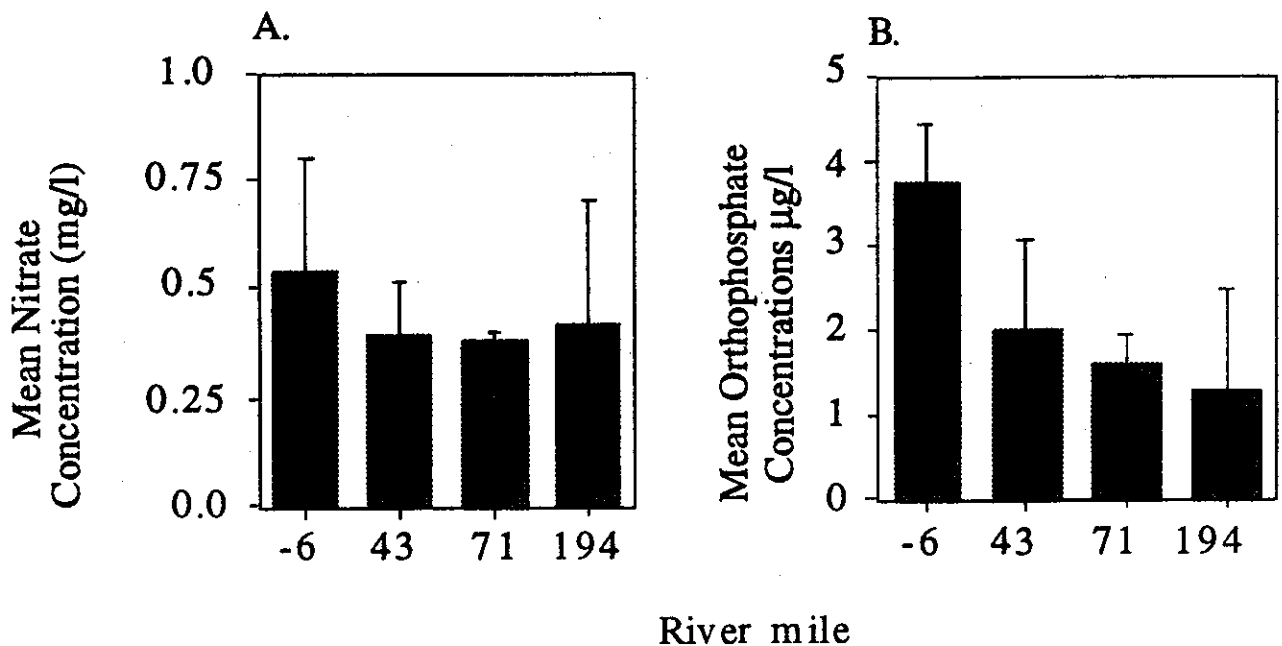
RESULTS

Water Analysis

In-Stream Trends

Mean main stream nitrite ($[\text{NO}_2^-]$) and nitrate ($[\text{NO}_3^-]$) concentrations varied from 0.3 to 0.45 mg/l and exhibited no downstream trend (Figure 3, A.). Ammonium concentrations ($[\text{NH}_4^+]$) varied from 0 (BDL) to 0.35 mg/l. Phase I water quality studies (Maddux et al., 1988) reported $[\text{NH}_4^+]$ to be less than $[\text{NO}_2^-]$ and $[\text{NO}_3^-]$ concentrations. Mean orthophosphate concentrations ($[\text{PO}_4]$) in this

Figure 3. Main stream nitrate and orthophosphate concentrations for 5 trips on the Colorado River were averaged and are plotted below. Nitrate concentrations exhibit no noticeable trend. Orthophosphate concentrations are low and exhibit a downstream decrease. Samples were collected between April, 1993 and January, 1995.



study varied from 3.11 ± 1.56 $\mu\text{g/l}$ (standard deviation) at site -6r to 1.24 ± 1.3 $\mu\text{g/l}$ at site 194l mile (Figure 3, B.). This trend is noticeably different from Phase I reports of a downstream increase in dissolved $[\text{PO}_4]$ with values as high as 171 $\mu\text{g/l}$. The standard deviation for $[\text{PO}_4]$ becomes more important downstream and can be explained by tributary influences.

Mile -6R Water Composition

Surface Water

Surface water in the return current channel is usually warmer than the surface water in the eddy or in the main current. This water also has higher dissolved oxygen concentrations (DO) (Figure 4) and slightly higher pH when measured after mid-day (note Table 4). Surface water in the return current channel and in the main channel has low $[\text{NH}_4^+]$ (<1 mg/l), high DO (> 5 mg/l), similar to high $[\text{N-NO}_3^-]$, and low $[\text{PO}_4]$ (<5 $\mu\text{g/L}$) relative to ground water in the bar or under the RCC (Figure 5). River $[\text{N-NO}_3^-]$ are generally much higher than all ground water. Sulfate ($[\text{SO}_4^-]$) concentrations for surface water in the RCC are similar to concentrations in the main channel.

$[\text{NH}_4^+]$ are highest for surface water in the spring and fall (Figure 4). DO is highest in the spring and summer (Figure 4). $[\text{N-NO}_3^-]$ are highest in fall while $[\text{PO}_4]$ exhibit no seasonal trend (Figure 5).

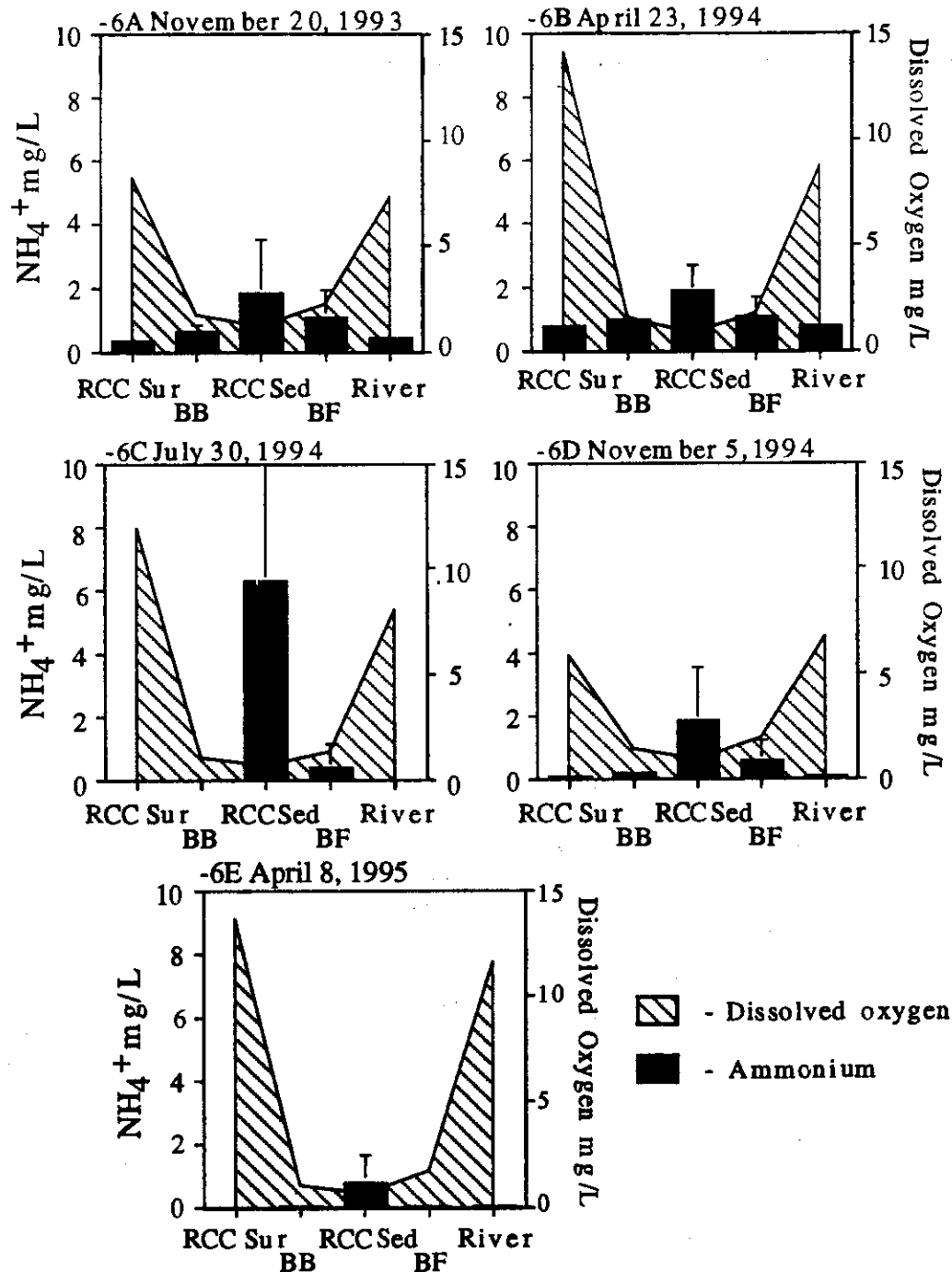


Figure 4. Ammonium and dissolved oxygen concentrations from Hidden Slough (-6). RCC indicates samples taken from the return current channel. MB indicates samples taken from the mid-beach. BF indicates samples taken from the beach face. Samples taken from the main channel or active eddy are indicated with R. Error bars are standard deviations about the mean.

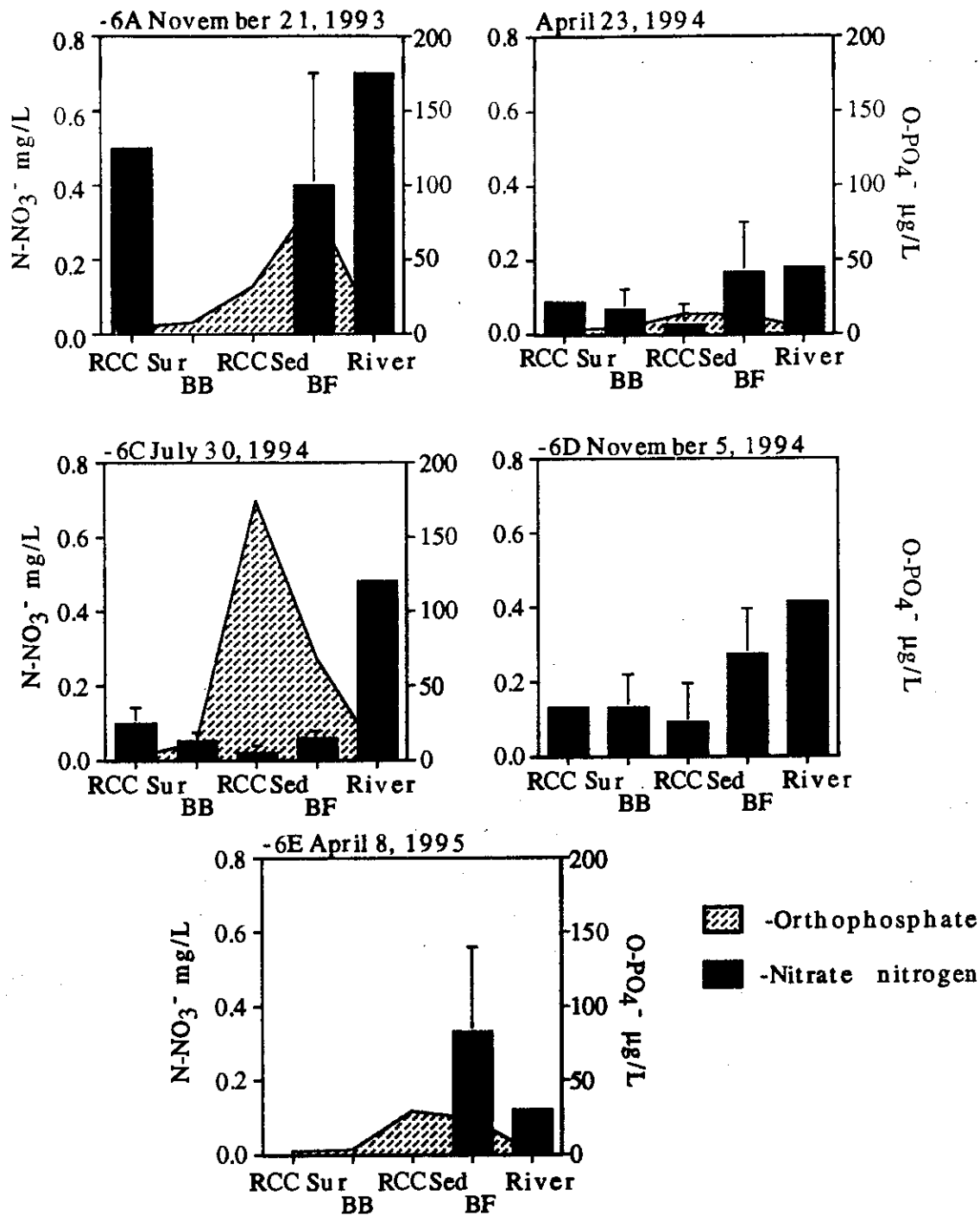


Figure 5. Nitrate and orthophosphate concentrations from Hidden Slough (-6). RCC indicates samples taken from the return current channel. MB indicates samples taken from the mid-beach. BF indicates samples taken from the beach face. Samples taken from the main channel are indicated with R. Error bars are standard deviations about the mean.

Ground Water

Chemical analyses of ground water in the bar at site -6R show consistent trends for (DO), $[N-NO_3^-]$, $[PO_4]$, and $[NH_4^+]$. Ground water from the return current channel sediments, at 3 to 7m in depth, have the lowest DO, low $[N-NO_3^-]$, and more $[PO_4]$ than any surface water. DO, $[N-NO_3^-]$, and $[PO_4]$ increase across the bar moving toward the main channel (Figures 4 and 5). DO and $[N-NO_3^-]$ in the beach face approach river concentrations. $[PO_4]$ is highest in the mid-beach or beach face. This site has the lowest ground water $[NH_4^+]$ of all four sites.

$[PO_4]$ are highest for ground water in the RCC sediments with much lower concentrations in the spring and fall (Figure 5). $[N-NO_3^-]$ are highest in the fall, corresponding to the highest concentrations in the surface water (Figure 5).

Thus, there is a general gradient of increasing DO and $[N-NO_3^-]$ and decreasing $[NH_4^+]$ from the return channel sediments toward the river. The highest $[NH_4^+]$ $[PO_4]$ concentrations are in ground water while $[N-NO_3^-]$ are higher in surface water. Nutrient concentrations are highest, both in surface and ground water, in the fall months and lowest in the spring.

Mile 43L Water Compositions

Surface Water

Surface water in the RCC is usually warmer than the surface water in the eddy or in the main current. This is especially true for spring and

summer. This site has a well connected RCC, with daily inundation occurring at the time of each visit. DO concentrations for RCC surface water are similar or slightly lower than surface water from the main channel (Figure 6). Except for winter, RCC surface water has a slightly higher pH. $[\text{NH}_4^+]$ for surface water in the return current channel are low (.1 mg/L, Figure 6). $[\text{NH}_4^+]$ for the main channel are higher than RCC surface water for one of the two visits that we were able to measure $[\text{NH}_4^+]$. $[\text{N-NO}_3^-]$ are highest in the main channel (>.2 mg/L) while RCC surface water $[\text{NO}_3^-]$ are generally lower and for spring summer and fall are approaching ground water concentrations (Figure 7). Surface water in the RCC and in the main channel has high DO and low $[\text{PO}_4]$ (< 5 $\mu\text{g/L}$).

$[\text{N-NO}_3^-]$ vary seasonally with the lowest concentrations (.2 mg/L) occurring in January 1994 and 1995 and the highest concentrations occurring in October (Figure 7). $[\text{PO}_4]$ are low for all seasons (< 5 $\mu\text{g/L}$) in the main channel while $[\text{PO}_4]$ in the RCC were 10 times higher in October 1994 than the four visits (Figure 7).

Ground Water

Chemical analyses of ground water for the beach at mile 43 show similar trends to those observed at mile -6. However, well water samples from the RCC sediments show seasonal variations in $[\text{NH}_4^+]$ (Figure 6). $[\text{NH}_4^+]$ are almost ten times higher in October (>5 mg/l) than in July (>.6 mg/l). $[\text{NH}_4^+]$ are extremely variable with the largest concentrations occurring in the upstream end of the RCC in the shallow well, 1AS (Table 7 and 8). As at -6 mile, $[\text{N-NO}_3^-]$ is low across the reattachment bar (<1.5

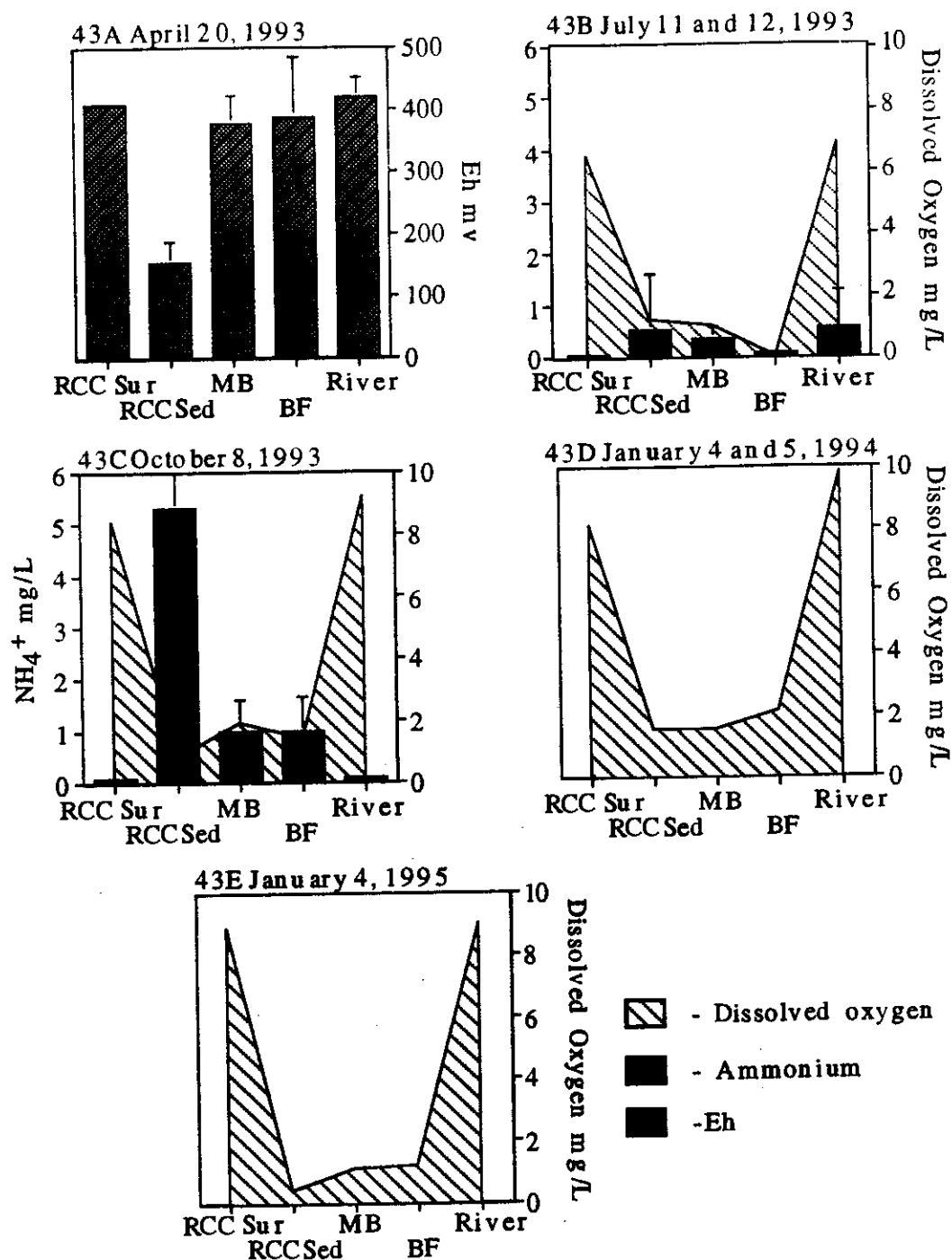


Figure 6. Ammonium and dissolved oxygen concentrations from 43.2L. RCC indicates water samples taken from the return current channel surface (sur) or sediments (sed). MB indicates samples taken from the mid-beach. BF indicates samples taken from the beach face. Samples taken from the main channel or active eddy are indicated with R. Error bars are standard deviations.

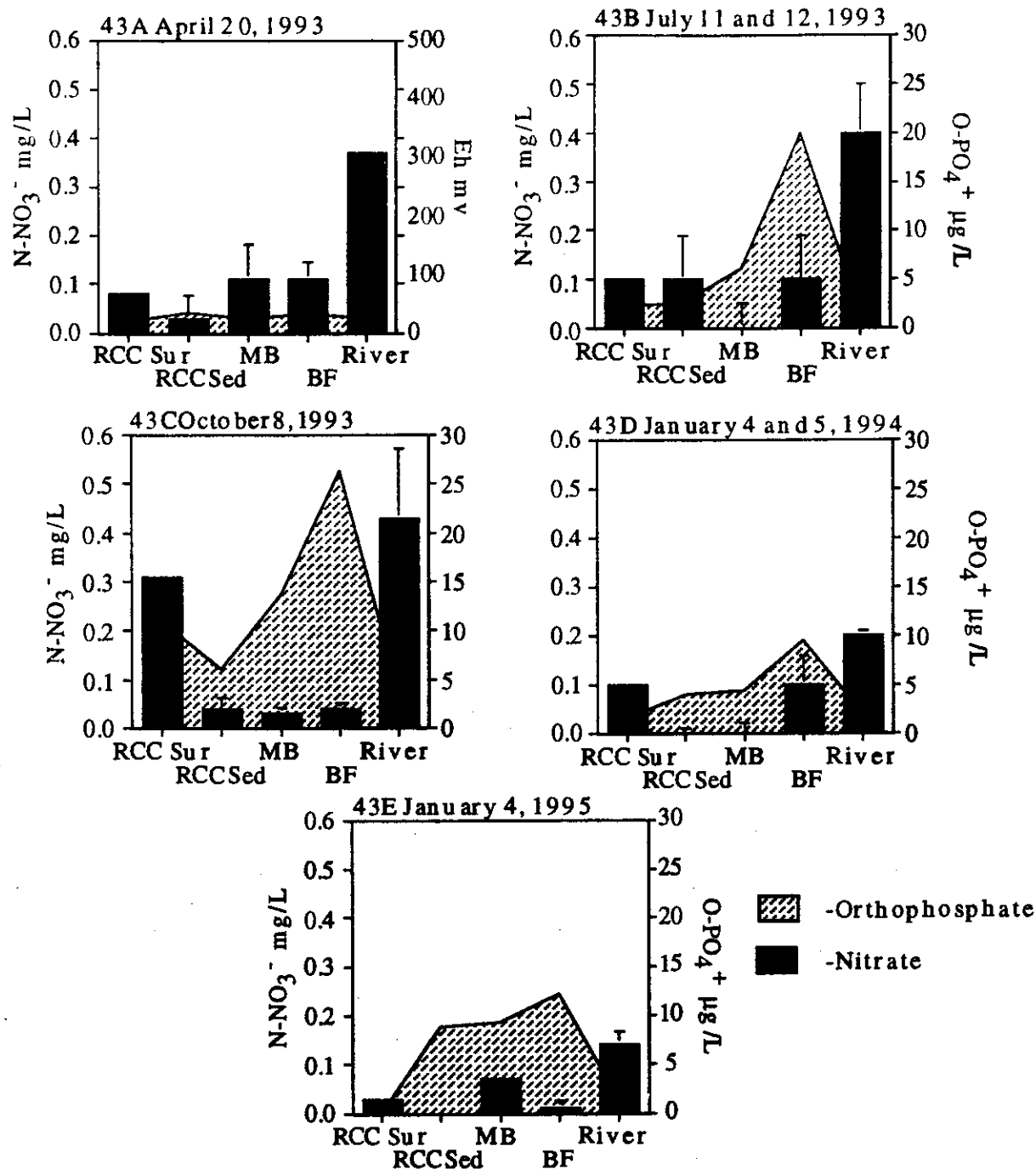


Figure 7. Nitrate and orthophosphate concentrations from 43.2L. RCC indicates samples taken from the return current channel surface (sur) or sediments (sed). MB indicates samples taken from the mid-beach. BF indicates samples taken from the beachface. Samples taken from the main channel or active eddy are indicated with R.

mg/L) with the highest concentrations occurring in the beach-face and mid-beach (Figure 7). $[PO_4]$ are variable (Tables 6 through 10) and highest in the beach face (Figure 7). DO concentrations are low across the reattachment bar and increase to saturated conditions in the river.

The highest $[PO_4]$ occurs in the fall and summer in the beach face. $[PO_4]$ concentrations are highest in the beach face throughout most of the year with the exception of April 1993 when concentrations are very low ($<2 \mu\text{g/l}$) across the bar. $[N-NO_3^-]$ are highest in the spring and summer and lowest in the fall and winter.

Thus, like -6 there is a general gradient of increasing DO and $[N-NO_3^-]$ and decreasing $[NH_4^+]$ from the return channel sediments toward the river (Figures 6 and 7). Orthophosphate concentrations are higher in the ground water and $[N-NO_3^-]$ is higher in the surface water. Unlike -6, seasonal variations in nutrient concentrations exist (Figure 6 and 7).

Mile 72L Water Compositions

Surface Water

Surface water in the RCC was only available for sampling and analysis in July of 1993 and collected early in the day to preclude disturbance. The DO concentration for that sample was less than for the main channel and only slightly higher than ground water. $[NH_4^+]$ are low ($<.05 \text{ mg/L}$) and similar for surface water in the RCC and the main channel. $[N-NO_3^-]$ are highest in the main channel ($>.3 \text{ mg/L}$). $[PO_4]$ are low ($< 5 \mu\text{g/L}$) for all surface water.

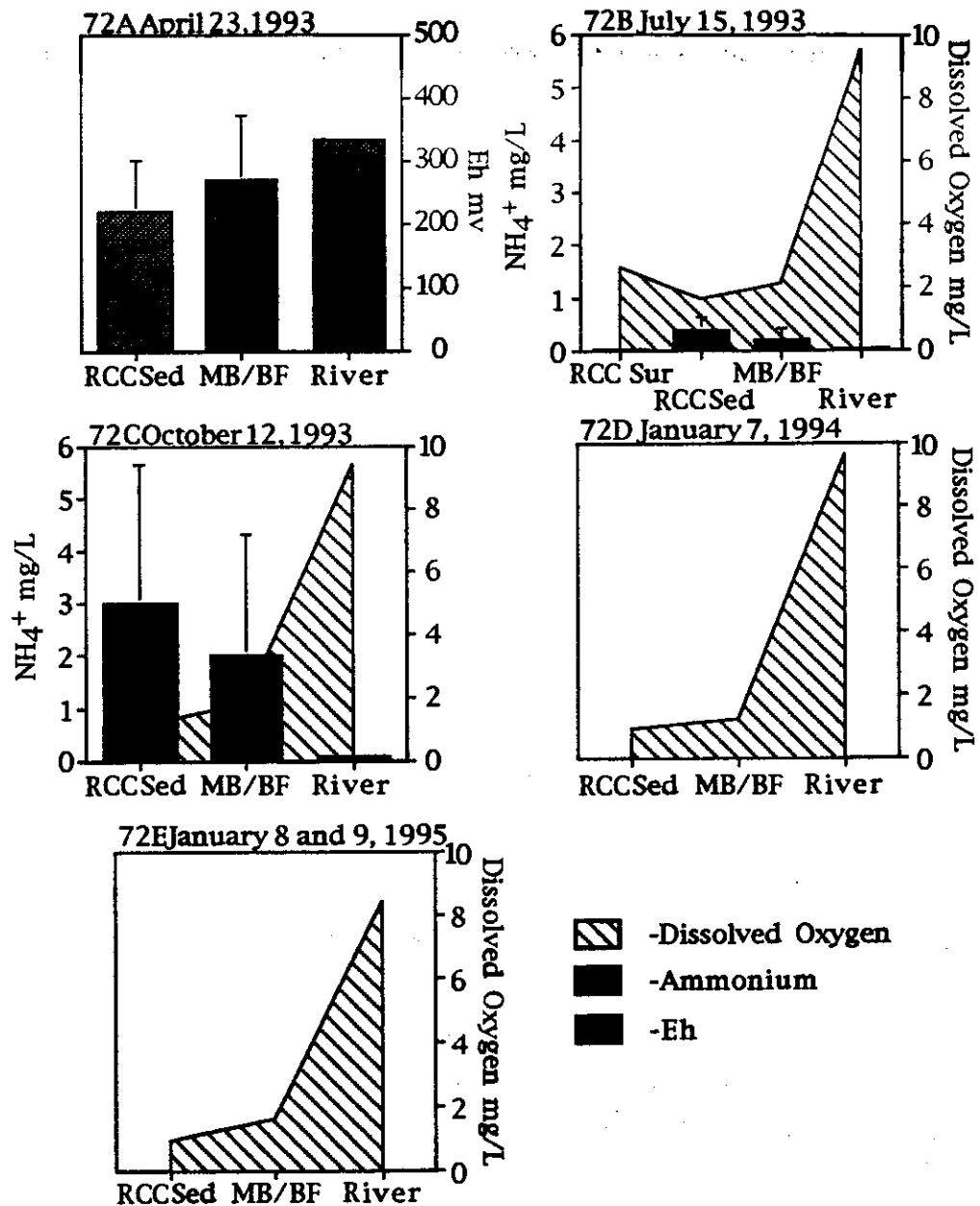


Figure 8. Ammonium and dissolved oxygen concentrations from Cardenas Marsh (72L). RCC indicates samples taken from the return current channel. MB/BF indicates samples taken from an area along the shore line. Samples taken from the main channel or active eddy are indicated with R.

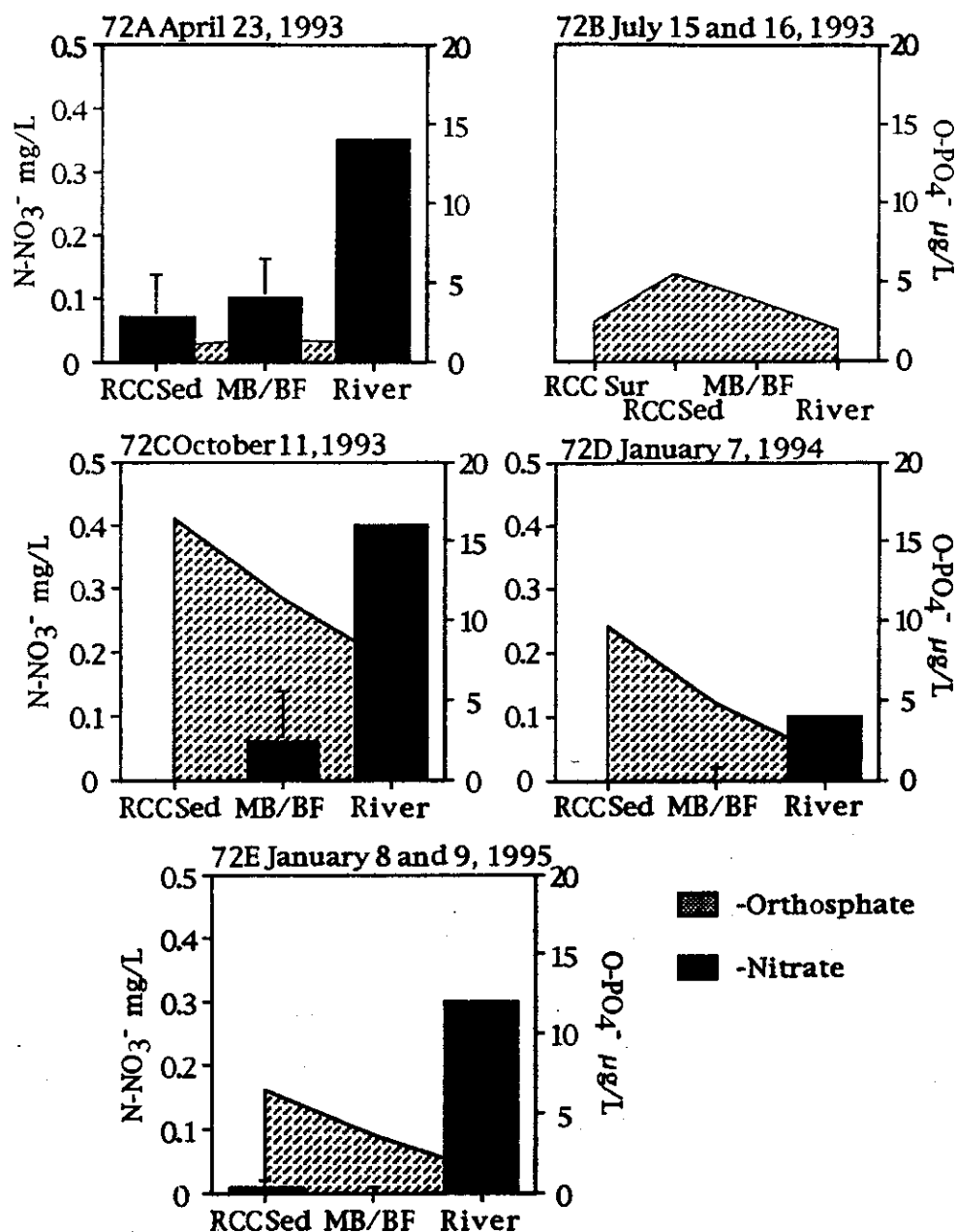


Figure 9. Nitrate and orthophosphate concentrations from Cardenas Marsh (72L). RCC indicates samples taken from the return current channel surface (sur) or sediments (sed). MB/BF indicates samples taken from an area along the shoreline. Samples taken from the main channel or active eddy are indicated with R.

Surface water $[N-NO_3^-]$ are lowest (.1 mg/L) in the winter of 1994, and the highest concentrations occurred in October (Figure 9). $[PO_4]$ are low for all seasons ($< 5 \mu\text{g/L}$) in the main channel (Figure 9).

Ground Water

Chemical analyses of waters for mile 72 reveal some of the same trends in ground water compositions observed at -6 and 43 mile: decreasing amounts of $[NH_4^+]$ and increasing $[N-NO_3^-]$, moving from the return current channel sediments toward the river. Winter $[N-NO_3^-]$ almost undetectable. DO concentrations are low ($< 2.5 \text{ mg/l}$) in ground water throughout the bar and exhibit little seasonal variation (Figure 8). DO data is not available for April 1993. Instead, uncorrected Eh values are plotted as a crude measure of oxidation state of the water and increase from return current channel sediments to the beach face. The highest Eh values occur in the river.

$[PO_4]$ varies seasonally with the highest concentrations occurring in October ($15 \mu\text{g/L}$) as at 43 and in the return current channel sediment ground waters. The lowest $[PO_4]$ concentrations occur in the spring.

Mile 194 Water Compositions

Surface Water

Surface water in the RCC was only available for sampling and analysis in July of 1993 and collected early in the day to preclude disturbance. The DO concentration for that sample was less than for the

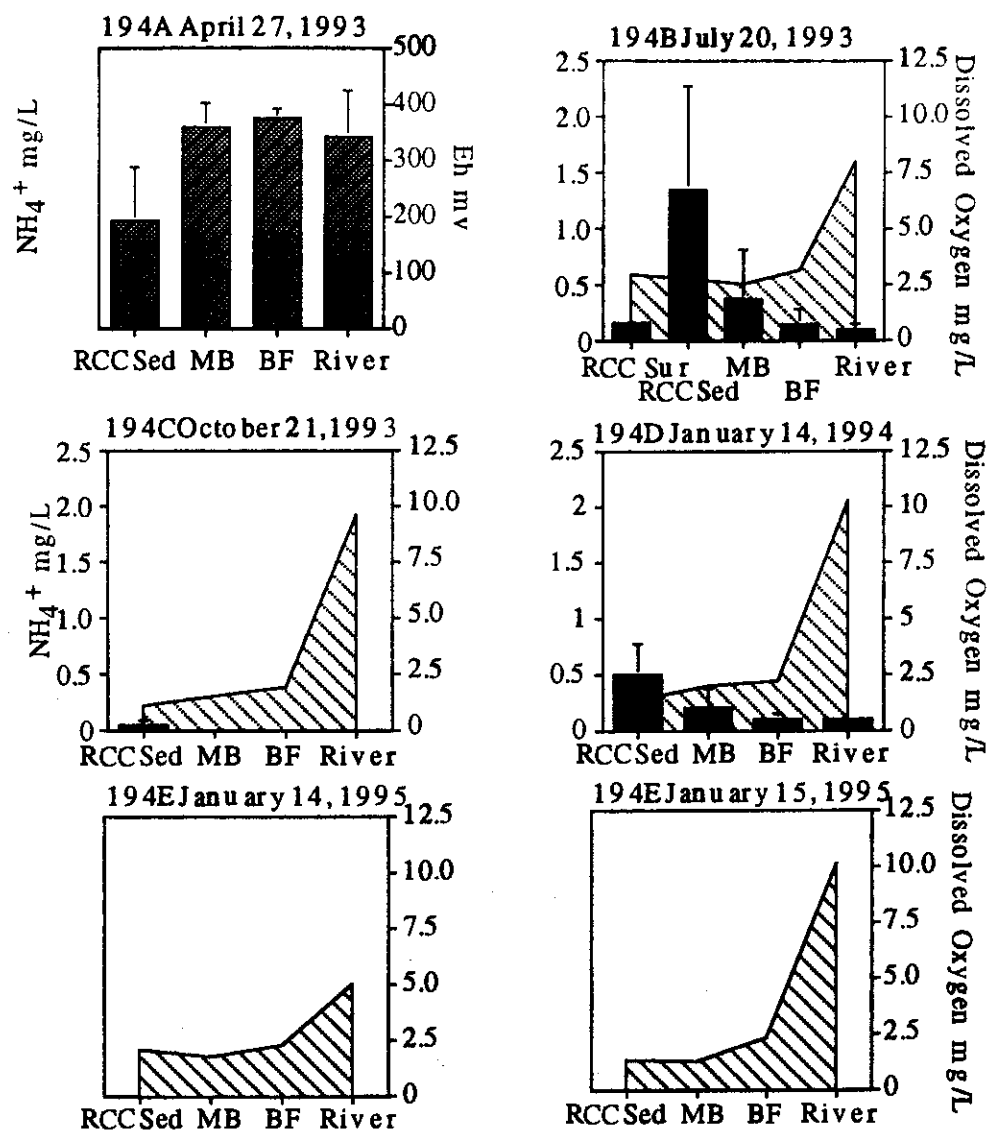


Figure 10. Ammonium and dissolved oxygen concentrations from 194L. RCC indicates water samples taken from the return current channel. MB indicates samples taken from the mid-beach. BF indicates samples taken from the beach face. Samples taken from the main channel or active eddy are indicated with R. Error bars are standard deviations about the mean.

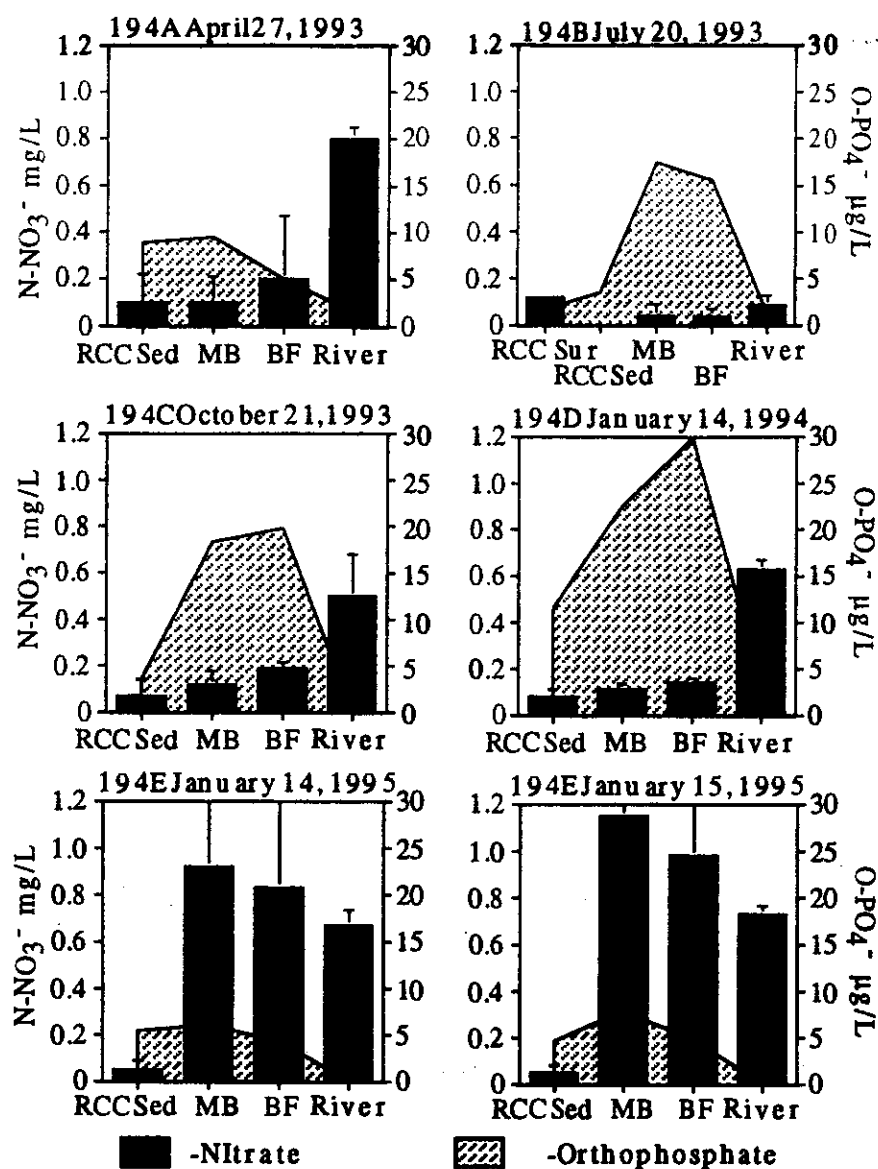


Figure 11. Nitrate and orthophosphate concentrations from 194L RCC indicates samples taken from the return current channel sediments (sed) or surface (sur). MB indicates samples taken from the mid-beach. BF indicates sample taken from the beach face. Samples taken from the main channel are indicated with R. Error bars are standard deviations.

main channel and only slightly higher than ground water. $[\text{NH}_4^+]$ for the main channel are low ($<.1$ mg/L). Analysis for the RCC surface water revealed twice as much ammonium (.16 mg/L) than in the main channel (Figure 11). $[\text{N-NO}_3^-]$ are generally highest in the main channel (.6 to .8 mg/L). $[\text{PO}_4]$ are low (< 4 $\mu\text{g/L}$) for all surface water.

Surface water $[\text{N-NO}_3^-]$ are lowest (.1 mg/L) in the winter of 1994, and the highest concentrations occurred in the spring (Figure 11). $[\text{PO}_4]$ are low for all seasons ($< 54\mu\text{g/L}$) in the main channel (Figure 11).

Ground Water

Compositions of waters from the beach at mile 194 reflect the same trends observed at the other beaches. DO concentrations are low across the reattachment bar, with the exception of well 200AS in the winter of 1995. We were able to remove roots from the well. $[\text{N-NO}_3^-]$ increases in ground water from the return current channel to the beach face in April and October of 1993. In January 1994 and July 1993, however, these ground water concentrations are very low ($>.05$ mg/l) and display no noticeable trends across the bar. A noticeable exception to this trend is noticeable beginning in January of 1994. The $[\text{N-NO}_3^-]$ for well 300BD was 1.73 mg/L. This high concentration increased to 5 mg/L by January of 1995 and spread to well 300CD. These high concentrations are the cause of the large standard deviations in Figure 11. $[\text{PO}_4]$ is generally highest in the mid-beach and beach face ground water. In April 1993, the $[\text{PO}_4]$ concentrations were equally high in the return current channel and mid-beach sediments and decreased at the beach face. The highest

orthophosphate occurred in January of 1994 and lowest values, like at the other bars are in April 1993.

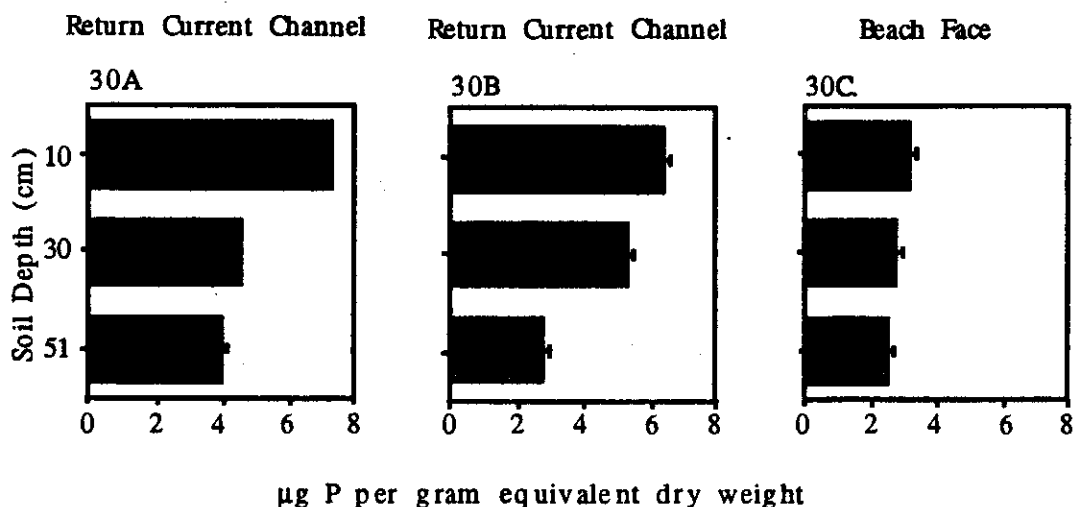
Hydrogeologic Analysis

Objective 3 from our original proposal included a quantitative model. The development of this model was contingent upon hydrogeologic data from another Grand Canyon researcher. This data has not been forthcoming, so we have undertaken a hydrogeologic examination as part of a Master's thesis for a student at Northern Arizona University. However, the model discussed in objective 3 is not ready for this report.

The slug-test analyses indicate a spatial variability in hydraulic-conductivity measurements corresponding to the Schmidt and Graf (1987) model for eddy-driven deposition of Colorado River reattachment bars. Hydraulic conductivity measurements are lowest in the wells located in the return current channels, corresponding to the locations of the finest sediments on the reattachment bars. The highest measurements of hydraulic conductivity are for the wells located in the beach face, corresponding to the locations of the coarsest sediments on the reattachment bars. The slug-test analyses further show that hydraulic-conductivity measurements vary as river stage varies. Hydraulic-conductivity values are greater during rising river stages and lesser during falling river stages. Variations between rising and falling stage hydraulic-conductivity measurements are less than ten per cent (Petroutson and Springer, 1995).

Synoptic water-level measurements indicate a variable gradient across the reattachment bar at rising and falling river stage. For transects parallel to the river at river mile 194, for rising river stage and peak river stage, the gradient is from the upstream wells toward the downstream wells. At falling stage and low river stage, the gradient is from the downstream wells toward the upstream wells. For transects perpendicular to the river, gradient is always towards the river from back beach, except at high water when the water table is level from the back beach to the beach face. The gradient becomes progressively steeper as river stage falls, until it reaches a maximum at low water. The synoptic water-level measurements also indicate a time delay in static water-level response in the wells to rising river stage. This response in the wells becomes greater

Figure 12. The distribution of adsorbed phosphorous with depth is plotted. Samples are from Hidden Slough. RCC sediments (30A and 30B) retain the highest amounts of adsorbed P.



toward the back beach from the beach face along transects perpendicular to the river.

Soil Analysis

Extractable P

To understand the origin of the dissolved PO_4 in beach ground water, we examined the forms of P in samples of six soil profiles at -6 mile beach. We performed sequential P extractions on replicates of each sample using the techniques of Page et al. (1982). This technique differentiates the increasingly insoluble forms of P in soils and sediments.

The most labile ("soluble") form of P is the non-occluded Fe- and Al-bound P. The next fraction is the carbonate sorbed P. The next most labile form is reductant soluble P, and the most insoluble form is acid-extractable P. The non-occluded P corresponds to exchangeable and loosely held P in Fe and Al phosphate minerals. The reductant soluble P is that co-precipitated within Fe oxides and oxyhydroxides. The acid-extractable P is essentially P in apatite. The carbonate-sorbed P is an artifact of the extraction procedure and represents a fraction of the non-occluded P.

In all of the over seventy samples extracted, no detectable P was present in the form of reductant-soluble or acid-soluble P. All of the available P was in the form of non-occluded P. The distribution of this labile P with depth is plotted in the six accompanying graphs. The average values of extractable P vary with depth and across the beach. The

standard deviations of these values are very low (see error bars). In the two cross-beach transects (from 10A to 10B to 10 C and from 30A to 30B to 30C), the amount of available P decreases throughout the profile with proximity to the river. In general, there is a significant decrease in available P with increasing depth in the soil.

X-ray Diffraction Analysis of Clays

Soil pits were dug in order to facilitate well emplacement and where possible discrete samples were taken from soil horizons. Soil samples were analyzed using X-ray diffraction. Percentages and types of clays are remarkably similar for the two study sites below the confluence with the Little Colorado River. Clay minerals present are smectite, illite, and kaolinite. Diffraction curves from each beach and from any depth were similar enough to one another to fit a single modeled curve that indicated relative concentrations of %50, %25, %25, respectively. Clay minerals present at -6 are similar with the exception that there is no smectite above the depth of 61 cm.

CONCLUSIONS AND INTERPRETATIONS

The return current channels along the reattachment bars in the Grand Canyon are distinctive environments, physically, chemically, and geologically. Other workers have demonstrated that the RCCs have the highest primary productivities and accumulations of organic matter of all bar environments (Stevens et al., 1991). As flows recede during fluctuating flows, RCCs are stranded from the main current, and left with standing water. Fine-grained clastic and organic material settle out in these backwaters as the stranded waters evaporate. For example, at mile 194, we observed a thick mat of vegetation buried under 60 cm of clayey silt brought in by the LCR winter floods of 1993. Additionally, daily fluctuating flows inundate RCCs where vegetation winnow out fine sediments (Stevens et al., 1995). This infilling of the RCC with fine-grained clastics and organics is an effect of dam-regulated flows that leads to a dewatering and sedimentation of the RCC. These changes in the RCC represent changes in the size and distribution of various nutrient (N,C,P) pools for the Colorado River.

Nitrogen Dynamics

Nitrogen cycling, particularly denitrification, in riparian marshes such as the RCCs, has been the subject of much attention especially, in areas where changing ecosystems are of concern (Groffman, 1994). Denitrification is the biological reduction of nitrogen by facultative

anaerobes and is the most energetically favored form of anaerobic metabolism (Groffman, 1994). The three main controllers of denitrification are DO, $[\text{NO}_3^-]$, and C. The mass of inorganic nitrogen in wetland sediments is usually an order of magnitude lower than nitrogen in plant biomass and several orders of magnitude less than sediment total nitrogen (Groffman, 1994; Bowden, 1987). Therefore our measurements constrain only a small pool of nitrogen. However, tight coupling between nitrification and denitrification ensures a source of oxidized species for reduction (Groffman, 1994, Bradley et al., 1992). Thus, large denitrification rates have been shown to occur even where the instantaneous dissolved $[\text{NO}_3^-]$ are low as in the RCCs. Also, low concentrations of reducible chemical species can be offset by a large hydrologic flux. Significant denitrification has been documented in fine wetland sands for a shallow unconfined aquifer (Hiscock, 1991, Trudell et al., 1986) and can be accelerated in environments with fluctuating water tables (Groffman, 1994). Our DO, Eh, and NH_4^+ data are evidence that the RCC sediments provide a reducing environment, presumably caused by the decomposition of buried organics such as the buried organic mat at site 194L. Reduced environments, coupled with the increased availability of carbon and ammonium, which we have identified, indicate that denitrification in these bars is an important component of the nitrogen cycle. This process provides a nitrogen sink for the Colorado River and, potentially, a large net loss of nitrogen to the atmosphere.

Seasonal variations in N and P species concentrations are readily explained by evapotranspiration, differential biological uptake and

decomposition release rates. Chloride concentrations are higher during the summer months. Assuming that chloride behaves conservatively, these higher concentrations are a good indicator that in situ processes are impacting nitrogen concentrations. Higher DO concentrations in the summer months also points to increased productivity. Higher N uptake in the summer removes more N from beach ground waters. Increases in nitrogen transformation rates would increase the export of nitrogen as reduced gaseous species. Increasing rates of decompositional microbial activity in the warmer weather would also increase the delivery of NH_4^+ to ground waters.

Phosphorous Dynamics

Low phosphate concentrations can limit overall primary productivity in aquatic ecosystems and are controlled by biotic and abiotic processes (Meyer, 1979). Most of the phosphorus of fresh waters is in the particulate phase of living biota. Phosphate pathways are impacted when controlling processes are altered. Phosphate can be removed from the water column by biological uptake, adsorption, specific sorption, and precipitation reactions. Therefore, the concentration of orthophosphate is usually very low in the trophogenic zone of fresh water. Losses of phosphorus are replaced by decomposition; desorption processes in sediments; excretions from macrophytes, algae, animals and bacteria; and by phosphorus contained in precipitation (Wetzel and Likens, 1991). Phosphorus mobilized by the decomposition of organic matter within sediments can be adsorbed on to iron-oxhydroxides under aerobic

conditions (Boström et. al., 1988) such as those found around root zones and sediment that is stranded by falling flows. Adsorption-desorption processes in an oxidized surface layer at the sediment-water interface have been shown to control phosphorous flux (Jensen et al., 1995, Olila and Reddy, 1995). The P in bar sediments is all in this form.

We found that adsorbed, leachable organic phosphate is the only measurable form of P in the bar sediments. Concentrations in ground water decrease from the RCC across the reattachment bar. Dissolved orthophosphate increases along the same line. Because reduced redox potential decreases sorption capacity (Holtan et al., 1988), the regular, diurnal fluctuations in river flow under the current river management system leach the labile phosphate from the sediments close to the river.

We also found that RCC sediments that were above the water table at the time of collection, contained twice the adsorbed phosphorous as did reattachment bar sediments collected above the water table. Phosphorus is depleted in the river by mile 43. This decrease in available P can be explained in two ways. First, it could be taken up biologically by *Cladophora*, a filamentous-green algae which exists in great numbers in Glen and Marble Canyon but not farther downstream (Blinn et al., 1995). Secondly, we believe that there is a net loss of P as phosphorous occluded sediments settle out in RCCs with active sedimentation and other slow water areas.

Interim flows, mandated by The Grand Canyon Protection Act of 1992, require relatively low daily fluctuating flows with dampened

seasonal fluctuations. These flows have resulted in aggradation of the RCC (Kaplinski et al., 1995). Much of this sedimentation is in the form of fine-grained silts brought in by daily inundating flows or by non-scouring flood flows, such as the winter floods of 1993. One result of this fine-grained sedimentation is phosphorous storage and phosphorous availability for primary productivity. Phosphorous storage may be problematic when aggradation in the RCC raises the level of storage above the range of fluctuating flows, eliminating the conditions where sorption capacities are reduced.

Fluctuating flows could pose another problem by producing an area that undergoes an alternation between oxidizing and reducing conditions. The importance of an oxidized microlayer in denitrification and in the release of phosphorous has been discussed by Groffman (1995) and Holtan et al. (1988), respectively. Oxidizing conditions can increase the rates of mineralization and the availability of oxidized species available for denitrifying. With respect to phosphorous, desorbed phosphate ions will migrate upward along a concentration gradient until oxidizing conditions will increase sorption capacity (Boström et al., 1988). However, diffusion may not occur with measurable hydrologic velocities. Root zones can provide the oxidized conditions necessary to increase sediment sorption capacities (Table 20). Fluctuating flows; the associated channel infilling; and the accumulation of organic matter could accelerate the export of nitrogen and increase the storage capacity of RCC sediments for phosphorous.

Interpretation of Clay Analysis

The absence of smectite in the upper soil horizons (> 61cm) at -6, as compared to the other study sites, indicates a significant variation in depositional material or authogenic processes. Because GCD prevents any silt or clay from the upper basin from passing through, site -6L is sediment starved. However, the beaches further downstream all are similar to each other in clay compositions that include smectite. This trend can be explained in two ways. First, 61 cm marks the depth between pre-dam and post-dam deposition. This would indicate a definite impact by GCD on beach make-up. Second, authogenic processes occurring below the water table could explain the profile. Smectite can be leached from areas above the saturated zone and deposited in the saturated zone. However, fluctuating water levels periodically inundate the bar rendering this explanation unlikely.

Hydrogeology

Preliminary results of the slug tests for hydraulic-conductivity measurements from this study have been presented at the 1995 Arizona-Nevada Academy of Science. Further results were presented at the 1995 GSA Meeting in New Orleans (Petroutson and Springer, 1995). The complete hydrogeologic characterization and modeling study will be presented in a Master's thesis at Northern Arizona University by Bill Petroutson in 1996.

Summary

- A. In-stream ortho-phosphate concentrations are very low ($< 5\mu\text{g/l}$) and decrease downstream from site -6L (Figure 1).
- B. Dissolved ortho-phosphate concentrations in ground water vary widely across the bar and generally increase from RCC to river while extractable non-occluded P in sediments decrease along the same line (Figures 4 through 12).
- C. Speciation of nitrogen and dissolved oxygen measurements or ground water reflect a changing redox environment with higher $[\text{NO}_3^-]$ and lower $[\text{NH}_4^+]$ moving from the RCC toward the river. The most abundant source of NH_4^+ is the highly reduced RCC sediments (Figure 4 through 11).
- D. Hydraulic conductivities vary across the bar complex with the lowest measurements corresponding to the locations of the finest sediments on the reattachment bars.
- E. Hydraulic conductivity varies with river stage. Hydraulic gradients switch direction as stage falls. Ground water flows downstream at high stage but reverses direction at the lowest stages. Hydraulic gradients across the bars uniform flow toward the river and away from the RCC.

MANAGEMENT CONSIDERATIONS

1) Our research indicates that on-going changes in the return current channel are acting to remove nutrients from the system, either by direct export (nitrogen) or by sequestration (phosphorus). One of the goals of Habitat Maintenance Flows should be to remove the accumulated sediments and organic matter. This will redistribute nutrient-rich sediments and minimize the reducing conditions which promote the export of nitrogen gases.

2) Long-term monitoring and adaptive management plans should include biogeochemical monitoring of lateral hyporheic zones in order to quantify the importance of the processes we have outlined. This is especially important before and after Habitat Maintenance Flows to determine whether nutrients will continue to be removed.

FUTURE MONITORING AND RESEARCH

1) Continue system-wide and seasonal monitoring and research on biogeochemical components to improve our understanding of the linkages between lateral riparian/hyporheic zones with main stem biogeochemistry and productivity. Increased productivity within the RCC (Stevens et. al., 1995) must come at the expense of main stem productivity. How great the cost is to main stream productivity has yet to be determined. This monitoring should include soil gas measurements to quantify nitrogen export and the decoupling of nitrogen cycling between channel flow and

hyporheic ground water. Future monitoring should include dissolved organic carbon, which we believe can be a significant component of dissolved nutrient flux.

2) Development of analysis of flood impacts on biogeochemical conditions with reattachment bar complexes. Part of the adaptive management policies includes periodic Habitat Maintenance Flows intended to redistribute sediments. Additionally, natural flood events can occur such as the Little Colorado River floods of 1993. The effects of flows larger than those of 1993 are likely to be quite different. Monitoring of the biogeochemical conditions within riparian ground water should continue until flood effects on RCC environments can be predicted.

3) Development of a river ecosystem model detailing energy and nutrient flow through various components. This model should integrate water quality data with benthic, planktonic, fisheries, and riparian productivity components. The development of this model can begin to incorporate existing physical and biological monitoring data, as well as flood-related data. A knowledge of energy and nutrient pathways, how they change through time, and when the changes adversely impact primary productivity within critical components of the system will allow dam managers to better predict the need for Habitat Maintenance Flows.

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APPENDIX

Table 1. Data from Hidden Slough (-6R)

Date: November 21, 1993

Notes: Concentrations are mg/l unless otherwise noted

Sample	T(C)	Sp cond.		pH	DO	NH4+	[N-NO3]	[PO4]		[HCO3]	[SO4]
		μ s						μ g/l			
RC surface	5.2	868		8.12	8.25	0.36	0.50	4.1		163.7	236.3
Back beach	12.7	1119		7.54	1.76	0.66	0.04	6.4		301.8	256.5
BB std. dev.	0.64	69.4		0.076	0.593	0.179	0.034	4.92		51.88	25.06
RCC sediment:	11.8	1086		7.45	1.19	1.86	0.01	30.6		361.9	180.2
RCC std. dev.	0.63	136.9		0.152	0.292	1.664	0.007	27.93		84.44	59.84
Beach Face	10.0	908		7.88	2.23	1.09	0.27	88.6		220.5	205.3
BF std. dev.	0.77	73		0.052	1.21	0.885	0.392	127.79		70.12	30.49
River	9.9	869		8.20	7.30	0.45	0.70	3.7		160.3	242.1
10AS	13.1	1188		7.51	1.60	0.73	0.06	3.3		296.0	288.3
10AD	13.4	1169		7.54	1.01	0.41	0.02	2.0		373.0	230.9
10BS	12.4	1060		7.46	2.05	0.66	0.01	7.3		289.6	243.4
10BD	12	1058		7.64	2.38	0.84	0.08	13.0		248.7	263.2
10CS	9.5	915		7.84	1.97	2.24	0.06	277.5		203.7	214.4
10CD	10.7	1008		7.84	1.58	1.34	0.03	55.9		322.4	162.2
30AS	11.7	1183		7.28	0.99	2.46	0.01	57.1		448.2	146.0
30AD	11.2	1052		7.53	1.19	3.93	0.02	52.2		398.5	128.0
30BS	12.7	1201		7.38	0.97	0.38	0.01	5.0		350.6	262.8
30BD	11.7	906		7.62	1.60	0.66	0.00	8.0		250.2	184.0
30CS	9.1	858		7.95	4.00	0.36	0.85	13.3		162.6	233.9
30CD	10.5	850		7.87	1.35	0.43	0.13	7.5		193.4	210.7
RC	5.2	868		8.12	8.25	0.36	0.50	4.1		163.7	236.3
RIVER	9.9	869		8.20	7.3	0.45	0.70	3.7		160.3	242.1

Table 2. Data from Hidden Slough (-6R)

Date: April 23,1994

Notes: Concentrations are mg/l unless otherwise noted
RIVER IS RISING.

Sample	T(C)	Sp cond.		DO	NH4+	[N-NO3]	[PO4] µg/l	[HCO3]	[SO4]
		µs	pH						
RC surface	20.2	838	8.99	14.10	0.81	0.09	2.8	142.5	229.6
Back Beach	17.4	1018	7.56	1.55	0.96	0.07	4.4	307.3	240.7
BB sd.	1.56	110.1	0.056	0.480	0.122	0.054	2.26	66.13	18.06
RC sediments	14.0	1023	7.38	0.78	1.86	0.03	13.8	354.3	184.1
RC sd.	0.39	70.4	0.099	0.206	0.777	0.053	20.47	83.59	43.56
Beach Face	15.5	873	7.86	1.84	1.15	0.17	13.5	223.6	201.9
BF sd.	2.54	20.4	0.075	1.193	0.554	0.135	13.61	90.95	53.36
River	10.9	862	8.33	8.70	0.75	0.18	4.1	164.7	220.2
10AS	15.6	1135	7.53	1.30	0.83	0.13	3.46	363.8	234.2
10AD	17.5	1086	7.50	1.1	1.09	0.00	2.63	356.7	251.8
10BS	19.4	908	7.56	2.2	1.02	0.08	3.79	285.2	218.4
10BD	17.2	941	7.63	1.6	0.89	0.07	7.70	223.7	258.4
10CS	16.9	860	7.78	1.2	1.62	0.07	5.54	200.5	227.2
10CD	13.2	889	7.78	0.5	1.89	0.05	37.10	385.1	107.1
30AS	13.6	1082	7.33	1	2.33	0.00	44.46	442.0	135.7
30AD	14.4	1060	7.51	0.8	2.64	0.00	4.35	408.8	161.4
30BS	14.2	923	7.28	0.5	0.91	0.02	2.76	273.1	231.9
30BD	13.7	1026	7.39	0.8	1.57	0.11	3.53	293.4	207.4
30CS	15.3	900	7.94	3.7	0.79	0.31	13.26	182.5	230.9
30CD	19.0	856	7.90	2	0.75	0.33	5.63	170.3	215.2
RC	20.2	838	8.99	14.1	0.81	0.09	2.80	142.5	229.6
RIVER	10.9	862	8.33	8.7	0.75	0.18	4.14	164.7	220.2
30CD dup	13.0	858	7.90	1.8	0.73	0.11	5.83	179.7	229.3

Table 3. Data from Hidden Slough (-6R)

Date: July 30, 1994

Notes: The first sample set was collected at low water while the second sample s was collected at high water. Concentrations are mg/l unless noted otherw

Sample	T(C)	Sp cond		pH	DO	NH4+	[N-NO3]	PO4		[HCO3]	[SO4]
		μ s						μ g/l			
RC surface	18.0	811	8.52	11.90	0.00	0.00	0.10	2.2		NA	203.0
RCS std. dev.	1.91	12.7	0.375	2.814	0.001	0.045	0.045	1.59		NA	5.72
Back beach	17.4	1227.9	7.44	1.05	0.01	0.05	0.05	11.5		281.8	233.1
BB std. dev.	2.04	339.3	0.181	0.268	0.006	0.025	0.025	3.38		80.9	36.05
RCC sediment	17.9	936	7.47	0.62	6.31	0.02	0.02	174.2		354.3	136.5
RCC std. dev.	0.70	73.5	0.140	0.226	10.439	0.018	0.018	136.67		83.6	88.03
Beach Face	16.7	1007	7.60	1.33	0.41	0.06	0.06	68.1		234.6	206.4
BF std. dev.	0.74	189.0	0.212	0.677	0.738	0.018	0.018	92.33		92.2	124.02
River	9.2	825	8.16	8.10	0.00	0.48	0.48	4.6		164.7	204.0
River std.dev	0.49	10.6	0.028	0.453	0.001	0.006	0.006	0.00		0.00	1.18
10AS	16.4	1070	7.51	1.10	0.01	0.06	0.06	10.8		363.8	254.2
10AD	18.1	1162	7.42	0.90	0.01	0.02	0.02	11.2		356.7	270.7
10BS	21.1	1435	7.14	1.08	0.01	0.08	0.08	7.5		285.2	214.7
10BD	16.5	957	7.55	1.02	0.00	0.08	0.08	9.2		223.7	186.6
10CS	16.5	842	7.58	0.91	0.06	0.06	0.06	236.2		200.5	NA
10CD	16.4	957	7.58	1.31	0.89	0.04	0.04	138.0		385.1	190.6
30AS	17.0	959	7.26	0.26	1.99	0.01	0.01	279.3		442.0	116.0
30AD	17.6	1032	7.45	0.59	22.12	0.01	0.01	168.9		408.8	8.9
30BS	19.1	838	7.62	0.95	0.00	0.03	0.03	15.8		273.1	209.3
30BD	18.5	877	7.37	0.54	0.10	0.01	0.01	11.8		293.4	202.7
30CS	16.8	1304	7.21	1.41	0.00	0.06	0.06	12.7		182.5	328.1
30CD	15.8	897	7.65	2.59	0.01	NA	NA	2.3		170.3	0.0
SLOUGH	19.3	820	8.25	9.91	0.00	0.07	0.07	3.3		NA	207.1
RIVER	9.5	817	8.18	8.42	0.00	0.47	0.47	NA		164.7	203.2
10AS2	15.6	1079	7.57	1.05	0.00	0.05	0.05	11.8		179.7	257.9
10AD2	15	1176	7.49	0.56	0.01	0.02	0.02	18.8		NA	275.7
10BS2	19.4	1980	7.18	1.51	0.02	0.07	0.07	12.8		NA	217.7
10BD2	17.2	964	7.63	1.20	0.00	0.06	0.06	10.0		NA	187.7
10CS2	16.6	844	7.87	0.96	0.13	0.04	0.04	NA		NA	193.2
10CD2	16.0	970	7.80	0.74	2.18	0.04	0.04	NA		NA	189.7
30AS2	17.7	953	7.34	0.69	1.99	0.02	0.02	341.3		NA	116.5
30AD2	17.3	1040	7.55	0.51	24.18	0.01	0.01	228.3		NA	11.8
30BS2	18.2	883	7.66	0.90	0.00	0.06	0.06	NA		NA	217.0
30BD2	17.4	904	7.5	0.49	0.13	0.01	0.01	NA		NA	210.0
30CS2	17.80	1335	7.34	1.40	0.00	0.07	0.07	15.0		NA	315.2
30CD2	17.7	910	7.74	1.32	0.00	0.09	0.09	4.2		NA	227.7
SLOUGH2	16.6	802	8.8	13.89	0.00	0.14	0.14	1.0		NA	199.0
RIVER2	8.80	832	8.14	7.78	0.00	0.48	0.48	4.6		NA	204.8

Table 4. Data from Hidden Slough (-6R)**Date: November 5, 1994****Notes: LOW WATER**

Sample	T(C)	Sp cond.		pH	DO	NH4+	[N-NO2]	[N-NO3]
		μ s						
RC surface	8.0	338		8.02	5.80	0.11	0.03	0.13
Back beach	14.1	1072		7.41	1.43	0.18	0.00	0.13
BB std. dev.	1.09	113.8		0.092	0.155	0.069	0.000	0.089
RCC sediment	14.3	1064		7.24	0.89	1.84	0.01	0.09
RCC std. dev.	0.66	310.8		0.212	0.657	1.673	0.017	0.104
Beach Face	12.1	870		7.60	1.91	0.60	0.02	0.27
BF std. dev.	0.91	105.1		0.133	0.092	0.629	0.020	0.124
River	8.7	547		8.06	6.75	0.10	0.02	0.41
10AS	15.1	1067		7.48	1.20	0.11	0.00	0.19
10AD	14.9	1234		7.42	1.50	0.26	0.00	0.00
10BS	12.8	987		7.28	1.48	0.21	0.00	0.18
10BD	13.6	999		7.47	1.54	0.14	0.00	0.16
10CS	11.2	821		7.66	1.85	0.86	0.01	0.26
10CD	12.4	1025		7.69	2.03	1.37	0.00	0.10
30AS	14.5	926		7.18	0.70	2.60	0.00	0.00
30AD	14.8	928		7.50	1.20	3.81	0.02	0.19
30BS	14.4	1528		6.99	0.07	0.15	0.00	0.00
30BD	13.3	872		7.28	1.59	0.79	0.04	0.17
30CS	11.5	795		7.40	1.94	0.10	0.05	0.35
30CD	13.2	837		7.64	1.83	0.08	0.02	0.37
RC	8.0	338		8.02	5.80	0.11	0.03	0.13
RIVER	8.7	755		8.10	7.70	0.08	0.00	0.69

Table 5. Data from Hidden Slough (-6R)

Date: April 8, 1995

Notes:

Sample	T(C)	Sp cond.		DO(ml)	NH4+	[N-NO2]	[N-NO3]	PO4	
		μ s	pH					μ g/l	[HCO3]
RC surface	20.4	870.	8.82	13.65	0.01	0.07	-0.01	1.3	159.2
Back beach	13.1	1198	7.38	1.03	0.06	0.06	-0.01	2.5	333.6
BB std. dev.	0.46	262.9	0.138	0.419	0.059	0.013	0.008	3.35	70.01
RCC sediment	13.1	996	7.48	0.62	0.78	0.07	-0.01	28.7	382.2
RCC std. dev.	1.19	148.3	0.153	0.225	0.841	0.016	0.003	28.35	151.75
Beach Face	11.7	846	7.83	1.70	0.02	0.07	0.33	24.1	217.1
BF std. dev.	1.17	65.3	0.11	0.798	0.012	0.013	0.230	43.29	68.25
River	15.3	870	8.61	11.63	0.02	0.07	0.12	1.0	156.8
10AS	13.1	1081	7.41	1.30	0.02	0.07	-0.01	0.2	283.0
10AD	13.9	1422	7.36	0.55	0.13	0.05	-0.02	6.6	381.8
10BS	12.4	1382	7.14	1.00	0.03	0.06	-0.02	1.7	423.2
10BD	13.1	905	7.62	1.25	0.04	0.07	0.00	1.7	246.4
10CS	10.8	869	7.98	1.80	0.02	0.06	0.04	4.4	208.1
10CD	11.3	909	7.74	0.55	0.02	0.08	0.52	89.0	316.1
30AS	13.2	984	7.44	0.55	1.06	0.09	-0.01	58.0	522.3
30AD	13.0	952	7.63	0.65	1.84	0.08	-0.01	47.9	NA
30BS	11.6	1201	7.28	0.36	0.04	0.06	0.00	3.9	403.3
30BD	14.5	848	7.56	0.90	0.17	0.06	0.00	4.8	221.0
30CS	13.4	851	7.83	2.06	0.02	0.07	0.51	0.0	175.7
30CD	11.2	755	7.77	2.37	0.04	0.05	0.26	3.1	168.3
SLOUGH	20.4	870	8.82	13.65	0.01	0.07	-0.01	1.3	159.2
RIVER	10.2	870	8.40	9.60	0.02	0.06	0.25	0.6	154.3

Table 6. Data from 43.2L

Date: April 20, 1993

Notes: Concentrations are mg/l unless otherwise noted

Sample	T(C)	Sp. cond.		pH	Eh	[N-NO3]	[PO4]		HCO3	[SO4]
		μ s					μ g/l			
RC surface	24.5	1385		8.28	411.2	0.08	1.2		181.3	283.5
RC sediments	16.6	1140		7.40	155.6	0.03	2.1		309.3	236.1
RC sd.	0.81	96.5		0.19	30.75	0.047	0.55		113.1	17.42
Mid-beach	16.7	1055		7.62	377.6	0.11	1.5		197.6	258.0
MB sd.	1.36	70.6		0.15	45.98	0.071	0.68		37.0	3.60
Beach Face	16.6	1041		7.77	387.4	0.11	1.9		265.6	222.8
BF sd.	0.86	64.5		0.26	97.49	0.035	0.58		72.4	56.83
River	17.2	970		8.06	420.5	0.37	1.5		201.2	254.3
River sd.	0.28	14.1		0.09	32.53	0.000	0.26		26.3	1.89
1AS	17.2	1100		7.73	131.5	0.00	2.7		200.2	253.1
1AD	15.0	1080		7.39	120.5	0.00	2.0		260.1	238.7
1BS	14.3	990		7.73	335.0	0.00	1.7		152.6	258.2
1BD	17.0	1020		7.75	379.5	0.11	1.8		207.0	251.1
1CS	17.5	990		7.89	380.5	0.10	2.5		230.2	214.9
1CD	18.0	940		7.89	369.0	0.08	0.9		300.4	113.4
2AS	16.7	1300		7.15	203.9	0.00	2.8		513.4	213.9
2AD	17.0	1210		7.29	145.5	0.01	1.4		358.4	222.0
2BS	18.0	1160		7.35	376.8	0.17	1.3		259.5	259.7
2BD	18.0	1120		7.67	320.5	0.08	1.8		167.9	260.6
2CS	14.6	1280		7.55	373.7	0.12	1.4		281.4	307.4
2CD	15.5	945		8.13	409.8	0.07	2.2		384.6	189.9
3AS	16.5	1040		7.44	154.5	0.07	2.0		239.3	258.4
3AD	17.0	1110		7.39	177.5	0.11	1.6		284.5	230.4
3BS	16.5	990		7.54	444.5	0.08	2.1		201.5	257.9
3BSS	Dry well, no sample									
3BD	16.5	1050		7.65	409.5	0.20	0.2		197.2	260.7
3CS	17.0	980		7.55	406.8	0.15	1.8		207.6	257.9
3CD	17.0	1110		7.63	384.8	0.14	2.5		189.3	253.3
RC	24.5	1385		8.28	411.2	0.08	1.2		181.3	283.5
EVH	17.0	980		7.99	443.5	0.37	1.7		182.5	253.0
EM	17.4	960		8.12	397.5	0.37	1.4		219.8	255.7

Table 7. Data from 43.2L

Date: July 11 and 12, 1993

Notes: DO done with a probe Concentrations are mg/l unless otherwise noted

Sample	T(C)	Sp cond.		pH	DO	NH4+	[N-NO3]	[PO4]		[HCO3]	[SO4]
		μ s						μ g/l			
RC surface	28.2	943		8.14	6.48	0.07	0.10	2.3		173.8	247.2
RC sediments	18.0	1070		7.5	1.2	0.55	0.1	2.4		286.5	201.5
RC sd.	0.86	282.0		0.28	1.20	1.072	0.09	2.22		284.84	97.60
Mid-beach	19.6	1108		7.5	1.0	0.37	0.0	6.0		387.1	119.3
mid sd.	1.97	174		0.15	1.55	0.224	0.05	4.89		172.14	104.12
Beach Face	22.0	945		7.5	0.0	0.10	0.1	20.0		285.4	151.0
BF sd.	1.21	85.0		0.21	0.00	0.088	0.09	25.78		133.57	113.77
River	14.3	916		7.9	6.9	0.58	0.4	1.5		157.9	233.0
River sd.	0.42	1		0.04	2.07	0.698	0.10	0.57		0.22	3.49
1AS	18.1	1645		6.98	0.00	2.73	0.00	6.9		867.2	2.5
1AD	16.9	950		7.59	0.00	0.04	0.10	1.8		168.2	244.7
1BS	22.8	1061		7.5	0.71	0.24	0.03	3.8		236.1	233.9
1BD	20.6	866		7.7	1.10	0.29	0.03	8.9		223.4	152.0
1CS	22.2	870		7.76	0.00	0.23	0.07	53.9		291.7	107.6
1CD	20	810		7.73	0.00	0.16	0.02	9.3		335.5	40.5
2AS	18.1	973		7.54	3.26	0.27	0.07	2.0		197.5	232.5
2AD	17.1	954		7.62	1.31	0.13	0.10	1.2		161.9	245.0
2BS	18.2	1252		7.24	0.00	0.19	0.13	3.1		502.4	36.5
2BD	17.1	1346		7.48	0.00	0.66	0.00	14.6		650.7	1.6
2CS	23	1010		7.21	0.00	0.02	0.25	1.8		191.1	250.4
2CD	22.7	972		7.5	0.00	0.02	0.12	52.2		524.1	6.4
3AS	19	959		7.62	1.20	0.05	0.27	1.2		161.1	241.3
3AD	18.8	938		7.81	1.41	0.07	0.09	1.5		163.0	242.9
3BS	19.4	992		7.6	4.00	0.66	0.00	1.7		438.1	51.3
3BD	19.6	1129		7.51	0.00	0.20	0.00	3.9		272.1	240.3
3CS	23	1016		7.63	0.00	0.04	0.02	1.2		202.7	251.6
3CD	21.1	993		7.42	0.00	0.12	0.00	1.6		167.3	249.6
1AD dup	NA	NA		7.63	0.75	0.07	0.03	1.6		164.3	237.0
RC	28.2	943		8.14	6.48	0.07	0.10	2.3		173.8	247.2
EVH	14	916		7.95	8.32	0.09	0.36	1.1		158.0	235.5
EM	14.6	915		7.9	5.39	1.08	0.50	1.9		157.7	230.6

Table 8. Data from 43.2L.

Date: October 8, 1993

Notes: Samples were collected at high water, some wells (-2) were sampled again at low water.

Sample	T(C)	Sp cond.		pH	DO	NH4+	[N-NO3]	[PO4]		[HCO3]	[SO4]
		µs						µg/l			
RC surface	11.4	976		8.2	8.4	0.1	0.31	11.0		146.6	268.6
RC sediment	17.2	1367		7.2	0.8	5.3	0.04	6.0		469.1	125.4
RC std. dev.	1.03	180.7		0.11	0.50	9.99	0.022	3.76		183.43	75.22
Mid-beach	18.9	1293		7.5	1.9	1.0	0.03	13.7		384.2	179.8
MB sd	0.68	336.1		0.21	1.86	0.58	0.011	12.53		228.31	98.36
Beach Face	18.8	1115		7.6	1.4	1.0	0.04	26.3		355.8	170.9
BF std. dev.	0.79	161.3		0.26	0.35	0.65	0.01	23.73		99.05	81.31
River	11.8	924		8.0	9.2	0.1	0.43	3.8		166.8	247.2
River sd.	0.78	0.7		0.02	0.71	0.00	0.144	0.09		5.23	0.33
1AS	18.2	1684		7.01	0.0	25.63	BDL	6.43		775.66	5.54
1AD	16.8	1182		7.29	0.5	1.09	BDL	5.55		512.90	68.92
1BS	19.2	1043		7.45	1.6	0.59	0.02	6.86		253.12	233.04
1BD	18.5	1081		7.67	1.8	1.51	0.02	16.00		174.27	184.98
1CS	19.2	1227		7.57	0.9	1.94	0.03	35.53		438.48	182.98
1CD	18.7	890		7.82	1.5	1.33	0.04	18.33		301.69	127.46
2AS	16.6	1420		7.22	0.9	2.30	BDL	3.26		506.66	167.09
2AD	16.6	1368		7.23	0.6	2.03	BDL	13.25		441.08	165.99
2BS	19.2	1994		7.02	1.8	0.31	0.04	7.54		605.52	281.36
2BD	18.7	1566		7.36	0.4	2.10	BDL	43.24		754.41	8.35
2CS	19.5	1120		7.42	2.6	0.17	0.04	7.46		277.60	263.63
2CD	18.5	1082		7.87	1.4	0.80	0.02	67.09		577.97	6.78
3AS	18.1	1338		7.18	1.3	0.45	0.03	3.18		341.57	210.65
3AD	17.0	1209		7.31	1.3	0.31	0.06	4.56		237.00	134.23
3BS	20.0	1332		7.42	6.4	0.88	BDL	13.85		565.47	45.44
3BD	19.1	1093		7.48	1.0	0.73	0.02	4.68		130.67	225.52
3CS	20.2	1299		7.26	1.8	0.12	0.06	8.63		271.15	293.32
3CD	18.3	1056		7.57	1.4	0.43	0.03	5.84		334.23	158.94
1BS-2	18.5	1033		7.53	1.2	0.78	0.04	7.22		247.43	230.19
1BD-2	17.7	1201		7.68	1.3	1.36	0.04	10.16		342.36	229.43
1CS-2	18.3	1260		7.65	0.7	1.73	0.03	53.19		322.10	188.54
1CD-2	17.6	989		7.83	1.2	1.11	0.05	14.32		322.83	145.60
RC	11.4	976		8.17	8.4	0.12	0.31	10.99		146.56	268.65
EVH	11.2	924		8.04	8.7	0.07	0.33	3.72		170.46	246.99
EM	12.3	923		8.01	9.7	0.07	0.53	3.85		163.06	247.47

Table 9. Data from 43.2L

Date: January 4 and 5, 1994

Notes: Ammonia probe failure

Concentrations are mg/l unless otherwise noted

Sample	T(C)	Sp cond.		pH	DO	[NO3]	[PO4]		[HCO3]	[SO4]
		μ s					μ g/l			
RC surface	7.9	818.0		7.2	8.1	0.1	1.5		116.3	194.4
RC sediments	10.5	1399.5		7.1	1.5	0.0	3.9		482.5	122.9
RC std. dev.	1.95	323.57		0.25	1.09	0.01	1.87		242.70	108.06
Mld-beach	12.5	1660.7		7.2	1.5	0.0	4.4		437.8	145.8
MB sd	2.85	867.55		0.28	0.69	0.02	2.80		234.08	115.17
Beach Face	11.2	1056.0		7.4	2.1	0.1	9.4		292.8	124.8
BF std. dev.	1.81	165.02		0.35	0.33	0.06	14.81		83.75	114.37
River	8.8	799.5		7.4	9.8	0.2	1.9		111.2	191.4
River std.dev.	0.07	0.71		0.05	0.07	0.01	0.13		4.95	2.80
1AS	10.1	1757		6.62	0.0	BDL	7.59		867.72	0.92
1AD	8	1532		6.94	0.7	BDL	4.04		584.58	2.62
1BS	12.0	938		8.73	2.3	0.03	2.99		188.79	254.30
1BD	7.2	1804		7.48	2.4	0.03	3.88		281.81	208.70
1CS	10.8	1250		7.85	2.1	0.03	39.20		376.44	50.86
1CD	8.9	810		7.88	1.9	0.03	3.14		271.23	20.18
2AS	8.6	1631		7.13	2.6	BDL	2.94		528.66	179.07
2AD	11.7	888		7.26	2.7	0.04	2.83		185.89	212.02
2BS	13.1	2580		6.95	1.0	0.00	4.16		685.23	173.73
2BD	13.1	2390		7.26	0.7	BDL	10.00		709.63	1.09
2CS	9.5	1030		7.18	2.8	0.03	2.00		230.37	252.24
2CD	12.8	1230		7.35	2.2	BDL	8.57		418.51	2.34
3AS	12	1195		7.08	0.9	BDL	2.72		270.74	252.73
3AD	12.8	1414		7.30	1.8	0.03	3.35		457.55	89.97
3BS	13.8	1233		7.32	1.3	BDL	2.79		532.22	1.12
3BD	15.7	1241		7.34	1.4	0.05	2.73		229.28	234.89
3CS	12	1043		7.09	2.2	0.16	1.51		224.89	248.18
3CD	13.4	973		7.20	1.8	0.07	2.24		235.41	175.13
RC	7.9	818		7.15	8.1	0.10	1.53		118.28	194.39
EVH	8.7	800		7.42	9.8	0.22	1.95		107.87	189.41
EM	8.8	799		7.35	9.7	0.21	1.77		114.66	193.37

Table 10. Data from 43.2L

Date: January 4, 1995

Notes: Ammonia probe failure

Sample	T(C)	Sp cond.		DO	[NO ₂]	[NO ₃]	[PO ₄] µg/L
		µs	pH				
RCC surface	7.9	818	7.8	8.85	0.01	0.03	0.0
RC sediments	10.5	1400	7.2	0.43	0.01	0.00	8.8
RC std. dev.	1.95	323.57	0.08	0.528	0.008	0.000	3.01
Mid-beach	12.5	1661	7.4	1.11	0.01	0.01	9.2
mid std. dev.	2.85	667.5	0.18	0.970	0.007	0.027	12.32
Beach Face	11.2	1056	7.7	1.18	0.01	0.01	12.1
BF std. dev.	1.81	165.0	0.25	0.399	0.003	0.015	15.64
River	8.8	800	8.0	9.0	0.1	0.14	1.3
River std.dev.	0.07	0.7	0.34	0.071	0.068	0.028	1.51
1AS	10.1	1757	7.12	0.00	0.00	0.00	7.59
1AD	8	1532	7.28	0.00	BDL	0.00	NA
1BS	12.0	936	7.68	1.10	0.01	0.00	3.70
1BD	7.2	1604	7.51	3.00	0.01	0.07	4.05
1CS	10.8	1250	7.95	0.97	0.01	0.00	42.42
1CD	8.9	810	8.03	1.10	0.01	0.00	5.20
2AS	8.6	1631	7.22	0.22	0.00	0.00	7.25
2AD	11.7	868	7.38	1.35	0.02	0.00	13.14
2BS	13.1	2560	7.14	1.00	0.01	0.00	4.83
2BD	13.1	2390	7.32	0.70	0.00	0.00	34.32
2CS	9.5	1030	7.49	1.60	0.01	0.03	3.79
2CD	12.8	1230	7.70	0.65	0.02	0.00	15.64
3AS	12	1195	7.23	0.25	0.01	0.00	10.54
3AD	12.8	1414	7.26	0.75	0.01	0.00	5.57
3BS	13.6	1233	7.49	0.35	0.00	0.00	3.31
3BD	15.7	1241	7.43	0.50	0.01	0.00	5.10
3CS	12	1043	7.46	1.70	0.01	0.02	3.54
3CD	13.4	973	7.53	1.05	0.01	0.00	2.01
RC	7.9	818	7.76	8.85	0.01	0.03	0.00
RIVER	8.8	799	8.22	9.08	0.11	0.12	2.37
EDDY	8.7	800	7.74	8.98	0.01	0.16	0.24

Table 11. Data from Cardenas Marsh (72.2L)

Date: April 23, 1993

Notes:

Sample	T(C)	Sp cond		Eh(mv)	[N-NO3]	[PO4]		
		μ s	pH			μ /L	[HCO3]	[SO4]
RC sediments	17.3	1248	7.46	220	0.07	0.9	372.3	204.6
RC sd.	2.07	152.3	0.259	82.0	0.067	0.43	130.51	27.67
MB/BF	15.0	1116	7.73	269	0.10	1.3	488.7	163.4
mid sd.	2.76	252.5	0.152	102.6	0.062	0.35	239.08	60.22
RIVER	3.5	940	8.08	334	0.35	1.10	2.1	240.5
IAS	14.5	1200	7.68	317.0	0.04	0.89	327.49	199.6
IAD	19.0	1215	7.55	318.0	0.14	0.75	447.67	194.9
IBS	13.5	1015	7.84	398.0	0.11	1.07	474.71	187.8
IBS dup	13.1	1005	7.76	358.0	0.14	1.30	NA	NA
IBD	13.5	890	7.63	154.0	0.00	1.68	722.28	124.9
IIAS	20.0	1475	7.38	172.5	0.01	0.60	465.10	169.3
IIAD	17.0	1105	7.53	197.0	0.08	0.80	252.98	223.8
IIBS	18.5	1645	7.50	322.0	0.06	1.65	783.57	103.5
IIBD	11.5	985	7.92	203.0	0.13	0.91	245.77	207.9
IIIAS	17.5	1390	6.98	113.0	0.00	1.80	535.40	191.7
IIAD	15.5	1105	7.65	200.0	0.16	0.74	204.91	248.5
IIIBS	17.0	1210	7.60	140.0	0.07	1.39	508.36	107.3
IIBD	18.0	1060	7.83	308.0	0.19	0.79	197.70	249.1
RIVER	3.5	940	8.08	334.0	0.35	1.10	98.14	240.5
Field Blank							0.00	-2.4

Table 12. Data from Cardenas Marsh (72.2L)

Date: July 15 and 16, 1993

Notes: IAS, IAD, IIAD, IIAS, IIBS, and IIBD are filled with sediment and have to be redeveloped. IAD, after redeveloping has 13" of sediment and recharges slowly.

Nitrite and Nitrate numbers are suspect due to bad reagents!

Sample	T(C)	Sp cond.		pH	DO	NH4+	[PO4]		
		μ s					μ g/L	[HCO3]	[SO4]
RC	21.4	1211		8.38	2.6	0.03	2.344	163.05	384.79
RC sediments	17.3	1460.5		7.3	1.6	0.4	5.4	586.44	49.0
RC sd.	2.36	386.39		0.18	1.67	0.22	3.28	157.03	50.61
MB/BF	17.2	1296.2		7.4	2.1	0.2	3.7	457.16	136.1
MB/BF sd.	2.24	414.73		0.27	1.82	0.21	1.21	233.15	65.6
River	16.60	964.00		7.87	9.49	0.04	1.88	163.48	282.9
IAS	16.5	1333		7.40	1.1	0.2	2.8	665.40	2.65
IAD	21.8	1686		7.16	0.6	0.6	4.0	763.00	9.77
IBS	20.9	1187		7.50	2.13	0.1	2.7	397.58	157.11
IBD	14.9	1525		7.05	1.06	0.3	4.8	683.20	BDL
IIAS	17.3	1175		7.41	0.5	0.2	7.8	501.87	76.63
IIAD	16.7	1266		7.26	0.2	0.6	11.0	633.89	0.28
IIBS	18.8	2037		7.03	0.1	0.6	5.3	912.81	46.27
IIBD	16.3	1015		7.61	0.7	0.2	4.0	359.29	229.55
IIIAS	16.4	2145		6.94	3.23	0.4	3.5	639.48	114.62
IIAD	14.9	1158		7.36	4.23	0.2	3.3	315.01	89.95
IIIBS	16.7	1005		7.57	4.69	0.1	3.6	186.48	127.66
IIIBD	15.6	1008		7.58	3.76	0.1	2.0	203.64	119.70
RIVER	16.6	964		7.87	9.49	0.0	1.9	163.48	282.87
RC	21.4	1211		8.38	2.6	0.0	2.3	163.05	384.79

Table 13. Data from Cardenas Marsh (72.2L)

Date: October 11, 1993

Notes: A flash flood in Cardenas Creek has changed the dynamics within the and washed away the IB wells. Concentrations are given as mg/l.

Sample	T(C)	Sp cond.		pH	DO	[NH4]	[N-NO3]	[PO4]		[HCO3]	[SO4]
		μ s						μ g/l			
RC sediment	16.5	1400		7.3	1.1	3.0	0.00	16.4		505.0	89.2
RC std. dev.	1.2	249		0.22	1.51	2.67	0.000	19.57		118.34	76.74
MB/BF	15.3	1375		7.5	1.8	2.0	0.06	11.3		391.6	149.7
middles sd	0.66	483		0.31	1.71	2.31	0.08	8.21		212.68	107.60
River	12.6	989.0		8.2	9.4	0.1	0.4	7.3		172.6	223.3
IAS	17.8	1305		7.4	4.2	0.63	0.00	5.86		608.98	BDL
IAi	18.8	1475		7.5	0.4	1.43	0.00	4.63		539.39	BDL
IAD	16.9	1822		7.1	2.0	8.03	0.00	58.80		612.28	5.5
IIAS	15.8	1207		7.5	0.5	1.50	0.00	6.82		382.65	161.2
IHAD	15.3	1211		7.3	0.4	5.22	0.00	17.62		541.63	25.2
IIBS	16.0	2090		7.0	0.0	5.47	0.18	6.68		701.24	14.5
IIBD	15.3	1169		7.7	4.1	1.24	0.02	8.38		359.13	136.6
IIIAS	16.4	1620		6.8	0.0	2.80	0.00	16.95		550.17	80.3
IIHAD	14.8	1160		7.3	0.3	1.50	0.00	3.83		299.64	173.9
IIIBS	15.3	1212		7.6	1.6	0.43	0.02	6.66		240.42	275.2
IIIBD	14.4	1030		7.6	1.4	1.02	0.02	23.58		265.48	172.6
RIVER	12.6	989		8.2	9.4	0.11	0.40	7.30		172.58	223.3

Table 14. Data from Cardenas Marsh (72.2L).

Date: January 7, 1994

Notes: Concentrations are mg/l unlessw otherwise noted

Sample	Sp cond.			DO	[NO3]	[PO4]		
	T(C)	µs	pH			µg/l	[HCO3]	[SO4]
RC sediments	11.0	1391.0	7.3	0.9	0.0	9.56	550.14	59.0
RC sd.	0.99	232.00	0.18	0.52	0.00	11.06	192.63	98.4
MB/BF	10.8	1299.3	7.5	1.2	0.0	4.8	473.8	100.5
MB/BF sd.	1.03	411.39	0.37	0.78	0.02	2.78	263.57	63.6
RIVER	9.0	879.0	8.1	9.6	0.1	1.5	131.3	227.6
IAS	11.0	1404	7.39	1.4	0	5.3	634.90	1.4
IAI	9.8	1504	7.49	0.8	0	5.3	677.10	0.1
IAD	11.3	1810	7.33	1.1	0	3.8	768.09	1.2
IIAS	11.6	1210	7.47	1.2	0	3.1	360.45	170.2
IIAD	12.5	1264	7.27	0.6	0	34.3	588.44	2.3
IIBS	11.6	1906	6.96	0	0.0	8.8	864.42	6.0
IIBD	11.5	1152	7.61	1.4	0.0	2.8	347.70	144.2
IIIAS	9.7	1442	6.96	0	0	8.5	605.52	6.6
IIAD	11.1	1103	7.39	1.5	0.0	6.6	216.50	231.1
IIIBS	9.4	1148	7.68	1.7	0.0	3.1	391.36	128.8
IIIBD	10.5	991	7.78	1.5	0.0	4.4	291.78	123.0
RIVER	9.0	879	8.10	9.6	0.1	1.5	131.30	227.6

Table 15. Data from Cardenas Marsh (72.2L).

Date: January 8, 1995

Notes:

Sample	Sp cond.		pH	[H+]	DO	[NO2]	[NO3]	[PO4]
	T(C)	Âs						µg/l
RC sediments	13.8	1374	7.3	0.0	0.9	0.0	0.01	6.37
RC sd.	1.70	305.1	0.17	0.00	0.69	0.01	0.01	5.26
MB/BF	11.5	1079	7.4	0.0	1.6	0.0	0.0	3.6
MB/BF sd.	1.24	179.4	0.47	0.00	1.24	0.01	0.01	2.69
RIVER	11.1	872	8.2	0.0	8.4	0.0	0.3	1.4
RIVER sd	0.49	10.6	0.02	0.00	1.63	0.01	NA	NA
IAS	13.3	1417	7.32	4.79E-08	1.30	0.0	NA	NA
IAi	15.1	1493	7.49	3.24E-08	0.20	0.0	NA	NA
IAD	15.6	1910	7.18	6.61E-08	0.00	0.0	NA	NA
IBS	10.1	939	7.79	1.62E-08	4.05	0.0	NA	NA
IIAS	12.1	1096	7.57	2.69E-08	1.30	0.0	NA	NA
IIAD	12.4	1146	7.41	3.89E-08	1.00	0.0	NA	NA
IIBS	11.2	1240	7.12	7.59E-08	0.10	0.0	NA	NA
IIBD	12.3	1077	6.31	4.90E-07	2.45	0.0	NA	NA
IIIAS	11.2	1240	7.17	6.76E-08	0.50	0.0	NA	NA
IIAD	12.2	995	7.56	2.75E-08	2.45	0.0	NA	NA
IIIBS	10.3	941	7.71	1.95E-08	1.95	0.0	NA	NA
IIIBD	10.7	895	7.78	1.66E-08	2.00	0.0	NA	NA
RIVER	10.7	879	8.26	5.50E-09	7.25	0.0	NA	NA

Date: January 9, 1995

IAS	15.7	1480	7.24	5.75E-08	0.75	-0.03	0.01	2.81
IAi	16.9	1620	7.39	4.07E-08	0.4	0.00	0.00	10.32
IAD	15.5	2001	7.18	6.61E-08	0.3	0.01	0.00	2.34
IBS	13.1	1052	7.58	2.63E-08	1.9	0.01	0.03	1.61
IIAS	13.5	1161	7.43	3.72E-08	1.5	0.00	0.02	2.66
IIAD	14.1	1253	7.41	3.89E-08	0.6	0.00	0.00	7.18
IIBS	12.5	1498	7.11	7.76E-08	0.15	0.00	0.00	1.61
IIBD	13.5	1102	7.13	7.41E-08	0.15	0.00	0.01	2.70
IIIAS	12.4	1354	7.03	9.33E-08	0.4	0.00	0.02	16.19
IIAD	13.6	1073	7.5	3.16E-08	1.7	0.00	0.04	3.09
IIIBS	10.7	1090	7.5	3.16E-08	1.55	0.00	0.02	3.86
IIIBD	10.6	960	7.76	1.74E-08	2.15	0.01	0.03	8.09
RIVER	11.4	864	8.23	5.89E-09	9.55	0.01	0.25	1.36

Table 16. Data from 194L.

Date: April 27, 1993

Notes:

Sample	T(C)	Sp cond.	pH	Eh	[N-NO3]	[PO4]	[HCO3]	[SO4]
		μ s				μ g/l		
RC sediments	20.3	1144	7.6	190.4	0.1	8.8	158.9	248.5
RC sd.	1.92	204.5	0.2	94.73	0.12	18.29	149.79	49.96
Mid-beach	21.2	1062	7.9	359.3	0.1	9.4	NA	206.0
midstd. dev.	1.3	330.5	0.3	40.91	0.11	16.00	NA	132.85
Beach Face	22.7	1003	8.0	374.1	0.2	4.9	242.9	192.1
BF sd.	3.23	204.5	0.2	17.37	0.27	4.14	49.06	75.57
River	19.8	1055	8.3	340.9	0.8	1.5	184.7	213.5
River sd.	1.06	21.2	0	82.73	0.05	0.01	3.74	1.26
50AD	20.8	1015	7.39	137.5	0.00	2.304	262.7	208.2
100AS	23.0	1185	7.65	222.5	0.00	2.373	4.1	197.2
100AD	20.5	985	7.89	245.5	0.06	0.312	222.8	215.3
100BS	22.0	1340	7.60	385.1	0.04	2.371	NA	285.5
100BD	21.5	1190	7.66	287.1	0.29	1.332	188.8	200.4
100CS	27.5	1230	7.87	372.1	0.67	2.519	215.4	251.3
100CD	25.3	1100	8.02	390.1	0.47	2.685	187.8	217.1
200AS*	21.0	1550	7.28	111.0	0.22	50.267	266.6	241.7
200AD	21.3	1220	7.76	368.5	0.26	1.856	2.8	278.5
200BS	21.5	1395	7.70	369.5	0.20	2.595	2.6	396.5
200BD	20.5	1140	8.00	339.2	0.18	2.265	231.4	239.7
200CS	20.0	1145	7.68	372.8	0.22	2.399	254.2	248.4
200CD	20.0	905	8.05	346.8	0.08	2.268	203.0	224.6
300AS1*	18.0	960	7.52	131.4	0.00	2.287	4.4	257.5
300AS2*	17.5	1090	7.42	116.4	BDL	2.403	348.6	341.2
300BS	19.0	650	7.99	401.5	0.06	5.756	2.8	60.0
300BD	22.7	655	8.28	373.5	0.00	41.89	242.7	53.9
300CS	20.0	975	7.93	367.5	0.01	6.882	311.1	156.7
300CD	23.5	660	8.19	395.5	0.04	12.505	286.1	54.5
EM	20.5	1070	8.29	399.4	0.76	1.512	187.3	214.4
HM	19.0	1040	8.30	282.4	0.83	1.5	182.0	212.7

Table 17. Data from 194L

Date: July 20 and 21, 1993

Notes: Concentrations are mg/l unless otherwise noted.

Sample	T(C)	Sp cond.		pH	DO	[NH ₄ ⁺]	[NO ₃]	[PO ₄]		
		μs						μg/L	[HCO ₃]	[SO ₄]
RC surface	20.6	967		8.1	2.9	0.16	0.12	1.6	164.3	231.8
RC sediments	18.9	1448		7.3	2.7	1.34	0.00	3.4	413.4	229.7
RCstd. dev.	1.36	442.2		0.1	1.4	0.933	0.011	1.17	176.84	179.86
Mid-beach	20.7	1016.0		7.8	2.5	0.37	0.04	17.4	303.09	157.2
midstd. dev.	2.5	424.3		0.3	0.9	0.444	0.05	24.81	119.39	100.3
Beach face	21.1	1027.2		7.8	3.1	0.15	0.04	15.5	263.88	201.9
BF std. dev.	1.7	406.9		0.2	0.9	0.132	0.03	15.3	74.75	124.5
River	18.5	943.5		8.3	8.0	0.09	0.09	1.1	155.03	228.0
River std.dev	0.4	0.7		0.0	0.2	0.054	0.04	0.2	9.41	0.0
50AD	18.4	1657		7.2	1.2	2.42	0.00	3.90	702.51	9.25
100AS	18.9	1716		7.4	5.7	2.05	0.00	4.12	578.53	225.49
100AD	17.2	919		7.3	3.0	1.47	0.00	2.58	253.96	141.01
100BS	18.2	1403		7.4	2.1	0.18	0.00	3.28	376.42	249.34
100BD	18	1423		7.5	1.2	1.10	0.00	3.35	504.52	128.49
100CS	21.7	1427		7.6	4.8	0.11	0.03	5.17	259.15	356.96
100CD	19.9	1313		7.7	2.7	0.23	0.03	8.23	397.67	228.32
200AS*	21.6	1677		7.1	1.8	2.21	0.00	4.85	474.27	269.47
200AD	19.4	2003		7.4	2.7	0.27	0.00	1.31	286.80	581.79
200BS	21.7	1278		7.6	2.1	0.08	0.03	7.69	263.62	290.28
200BD	19.6	974		7.8	3.0	0.75	0.02	3.41	284.00	174.71
200CS	20.3	1162		7.6	2.7	0.09	0.02	9.21	265.75	252.05
200CD	18.9	1232		7.8	2.4	0.37	0.00	8.07	271.75	271.40
300AS1*	18.5	809		7.5	2.4	0.26	0.03	3.72	246.90	123.41
300AS2*	18.4	1353		7.3	2.4	0.67	0.00	2.98	350.98	257.52
300BS	24.2	515		8.0	3.9	0.08	0.08	20.29	192.06	49.21
300BD	22.4	503		8.2	2.7	0.05	0.11	66.22	197.89	50.95
300CS	23.5	529		7.8	3.0	0.03	0.06	16.64	207.14	49.93
300CD	22.4	500		8.1	3.0	0.04	0.07	45.84	181.83	52.57
EM	18.2	943		8.3	8.1	0.13	0.06	0.98	148.38	228.06
HM	18.8	944		8.3	7.8	0.05	0.11	1.22	161.68	228.00
RC	20.6	967		8.05	2.9	0.16	0.12	1.575	164.29	231.83

Table 18. Data from 194L

Date: October 21, 1993

Notes: 100CS is dry at beginning of sampling

Concentrations are in mg/l unless otherwise noted

Sample	Sp cond.			DO	NH4+	[NO3]	[PO4]		
	T(C)	µs	pH				µg/L	[HCO3]	[SO4]
RC sediments	18.9	1210	6.9	1.01	0.04	0.07	3.57	359.3	171.9
RC sd.	1.03	338.34	0.26	.549	0.038	0.072	5.445	165.92	111.42
Mid-beach	21.6	946	7.1	1.45	0.00	0.12	18.25	291.1	200.1
mid sd.	1.37	255.8	0.18	0.455	0.005	0.060	24.315	105.83	177.54
Beach Face	21.4	1081	7.2	1.87	.00	0.19	19.80	242.5	229.0
BF sd.	1.77	388.9	0.21	0.151	0.000	0.024	12.120	54.58	134.04
River	15.9	967	8.2	9.60	.00	0.50	-0.55	155.9	200.7
River sd.	0.49	3.5	0.13	0.141	0.000	0.184	0.748	28.97	0.86
50AD	17.8	1773	6.8	0.3	0.12	0.00	0.56	629.3	0.0
100AS	18.6	1476	7.2	1.3	0.03	0.00	3.42	495.9	146.7
100AD	18.2	917	7.3	1.1	0.02	0.16	1.45	230.1	148.0
100BS	21.6	1201	6.9	0.7	0.00	0.15	0.49	471.7	550.3
100BD	20.2	1201	7.3	1.1	0.01	0.02	1.06	369.1	137.1
100CS	19.7	1287	7.1	2	0.00	0.18	14.35	229.7	310.7
100CD	20.7	1055	7.5	1.8	0.00	0.21	17.93	352.8	237.2
200AS*	20.1	NA	6.6	0.4	0.05	0.01	15.20	454.7	373.8
200AD	20.6	1070	6.7	0.9	0.01	0.08	BDL	204.9	221.7
200BS	20.8	1023	7	1.6	0.00	0.20	5.63	211.3	187.3
200BD	20.9	931	7.1	1.7	0.01	0.12	9.54	222.6	163.9
200CS	20.6	1488	7.1	1.8	0.00	0.21	13.35	211.2	338.1
200CD	20.1	1402	7.3	1.8	0.00	0.15	16.21	229.5	358.7
300AS1*	18.7	992	6.8	1.2	0.01	0.16	3.44	244.6	156.2
300AS2*	18.5	1032	6.8	1.9	0.03	0.11	1.86	255.3	156.6
300BS	24	775	6.9	1.9	0.00	0.11	30.17	244.8	105.1
300BD	22.3	544	7.3	1.7	0.00	0.14	62.61	227.2	57.0
300CS	24	756	6.9	2.1	0.00	0.19	12.72	217.8	78.1
300CD	23.2	499	7.1	1.7	0.00	0.21	44.23	214.3	51.2
EM(eddy)	16.2	964	8.1	9.5	0.00	0.63	BDL	135.4	201.3
HM(river)	15.5	969	8.2	9.7	0.00	0.37	BDL	176.4	200.1
100 CD dup	21.5	1289	7.4	1.6	0.00	0.20	20.8	337.9	211.5
Blank	20.4	0.002	na		0.00		BDL	2.3	-0.2

Table 19. Data from 194L.

Date: January 13,14, and 15, 1994

Notes: Concentrations are mg/l unless otherwise noted.

Sample	T(C)	Sp cond.	pH	DO	NH4+	[NO3]	[PO4]	[HCO3]	[SO4]
		μs					$\mu\text{g/l}$		
RC sediments	13.1	1301	7.7	1.26	0.5	0.08	11.5	430.6	179.4
RC std. dev.	1.35	411.6	0.17	0.624	0.27	0.034	8.06	170.28	100.53
Mid-beach	14.5	1078	7.9	1.93	0.2	0.11	22.4	326.5	179.1
midstd. dev.	1.82	530.4	0.34	0.585	0.17	0.026	21.92	108.00	126.64
Beach Face	14.5	990	7.8	2.13	0.1	0.14	29.8	286.4	211.8
BF std. dev.	2.71	393.6	0.16	0.361	0.05	0.020	17.22	67.10	154.22
River	9.4	867	8.5	10.25	0.1	0.63	3.5	160.1	201.2
River std.dev.	0.14	0.7	0	0.071	0.00	0.040	0.31	0.52	1.35
50AD	14	1841	7.42	0.6	1.06	BDL	16.0	760.3	37.6
100AS	12.4	1180	7.67	1.9	0.45	0.08	5.1	485.0	134.8
100AD	13.1	841	7.78	2.1	0.37	0.13	26.0	242.3	146.9
100BS	12.3	1946	7.46	2.3	0.10	0.12	4.5	467.5	378.4
100BD	14.8	1333	7.7	1.6	0.45	0.07	3.5	456.9	163.6
100CS	12.2	1284	7.74	2.3	0.06	0.13	16.8	294.9	455.1
100CD	14.1	1400	7.82	2.2	0.16	0.15	26.1	402.4	259.7
200AS*	10.4	1502	7.5	1.3	0.50	0.09	14.7	418.1	282.1
200AD	13.9	1794	7.87	1.1	0.42	0.03	10.5	471.3	339.4
200BS	13.3	1150	7.64	2.7	0.09	0.14	14.0	289.7	263.4
200BD	13.8	943	7.86	2	0.36	0.12	15.7	278.8	167.6
200CS	12.1	906	7.65	2.3	0.05	0.12	16.8	271.3	176.3
200CD	13.9	1289	7.91	1.7	0.14	0.14	51.5	305.0	278.0
300AS1*	14.4	1006	7.78	0.4	0.20	0.11	4.3	314.6	171.3
300AS2*	13.2	943	7.78	1.4	0.39	0.07	4.0	322.9	143.4
300BS	15.6	570	8.07	1	0.12	0.10	36.8	246.3	53.1
300BD	17.4	524	8.42	2	0.05	1.98	59.8	219.9	48.2
300BD dup	NA	NA	NA	NA	38.78	1.68	59.4	216.5	47.9
300CS	15	557	7.79	2.6	0.07	0.17	16.0	233.6	55.9
300CD	19.5	504	8.1	1.7	0.06	0.11	51.5	211.4	46.0
100CS-2	7.2	1281	7.65	1.8	0.09	0.13	16.8	311.8	328.6
100CD-2	13.4	1408	7.82	1	0.17	0.10	na	408.4	371.5
200CS-2	13.9	948	7.67	2.2	0.07	0.12	16.5	273.3	163.8
200CD-2	11.7	1280	7.94	1.8	0.13	0.13	54.4	309.5	280.2
300CS-2	11.1	572	7.79	3.8	0.10	0.20	16.7	228.2	54.6
300CD-2	18.9	508	8.04	2	0.09	0.13	54.0	210.2	47.1
EM	9.3	867	8.45	10.3	0.07	0.60	3.7	160.4	202.2
HM	9.5	866	8.45	10.2	0.06	0.66	3.2	159.7	200.3

Table 20. Data from 194L.

Date: January 14, 1995

Sample	T(C)	Sp cond.		DO(ml)	[NO2]	[NO3]	[PO4] µg/L
		µs	pH				
RC sediments	19.7	1415	7.6	2.03	0.0	0.05	5.3
RC std. dev.	1.80	1095.5	0.14	1.766	0.012	0.039	2.97
Mid-beach	20.3	1412	7.7	1.73	0.2	0.92	6.0
midstd. dev.	2.75	1142.2	0.13	0.273	0.48	2.033	3.04
Beach Face	20.9	1598	7.7	2.24	0.2	0.83	4.3
BF std. dev.	2.79	1404.8	0.12	1.137	0.314	1.677	3.13
River	14.9	937	8.2	6.00	0.0	0.71	0.0
River std.dev.	1.70	87	0.10	1.414	0.01	0.066	0.00
50AD	21	3680	7.49	0.70	-0.02	0.00	5.96
100AS	18.5	2030	7.63	0.95	0.01	0.06	4.25
100AD	17.8	913	7.74	1.75	0.00	0.09	4.62
100BS	16	2530	7.66	1.40	0.00	0.08	4.41
100BD	21.5	3170	7.58	1.80	0.01	0.01	10.70
100CS	17.5	3350	7.46	2.00	0.01	0.10	2.82
100CD	22.5	3450	7.70	1.75	0.00	0.13	5.15
200AS*	17.1	943	7.48	5.90	-0.01	0.01	11.39
200AD	20.7	829	7.76	2.00	0.01	0.10	2.18
200BS	18.8	762	7.67	2.00	0.00	0.14	2.55
200BD	19.5	934	7.63	1.80	0.00	0.10	3.48
200CS	18.8	680	7.63	0.70	0.02	0.12	2.76
200CD	19.5	984	7.74	3.90	0.01	0.12	10.36
300AS1*	21.5	772	7.49	1.60	0.01	0.08	5.26
300AS2*	21	736	7.41	1.30	0.01	0.04	3.33
300BS	22.6	550	7.89	1.40	0.01	0.13	7.34
300BD	23.4	524	7.87	2.00	1.18	5.07	7.24
300CS	22.2	590	7.80	3.20	0.11	0.23	2.66
300CD	25	534	7.70	1.90	0.79	4.25	2.25
River	16.1	875	8.30	7.00	0.02	0.76	0.00
Eddy	13.7	998	8.16	5.00	0.01	0.67	0.00

Table 21. Data from 194L.

Date: January 15, 1995

Sample	T(C)	Sp cond.		DO(ml)	[NO2]	[NO3]	[PO4] µg/L
		µs	pH				
RC sediments	22.4	705	7.5	1.26	0.02	0.05	4.6
RC std. dev.	1.83	289.7	0.17	0.634	0.056	0.029	2.39
Mid-beach	25.7	677	7.7	1.20	0.32	1.15	7.8
midstd. dev.	1.82	378.0	0.17	0.586	0.634	2.148	8.97
Beach Face	26.1	599	7.7	2.28	0.29	0.98	4.8
BF std. dev.	1.32	290.2	0.07	0.176	0.503	1.879	2.97
River	14.2	358.0	8.2	10.1	0.0	0.73	0.0
River std.dev.	1.63	18.3848	0.23	0.0919	0.045	0.0339	0
50AD	22.5	455	7.4	0.30	0.12	0.02	2.65
100AS	24	1100	7.69	1.00	-0.02	0.03	4.57
100AD	24.4	916	7.71	1.55	0.01	0.09	2.01
100BS	24.1	1070	7.6	1.00	0.00	0.10	3.72
100BD	27.4	930	7.57	0.75	-0.01	0.08	3.33
100CS	25	920	7.63	1.80	0.01	0.10	8.61
100CD	27	730	7.74	2.15	0.03	0.09	4.80
200AS*	20.5	599	7.35	1.95	0.00	0.04	7.90
300AS2*	20.6	457	7.43	1.50	0.00	0.07	5.84
300BS	24.1	362	7.81	0.98	0.01	0.05	21.24
300BD	27.1	344	7.92	2.06	1.27	4.37	2.87
300CS	24.9	394	7.83	3.22	0.22	0.36	2.96
300CD	27.5	350	7.75	1.95	0.89	3.35	2.77
River	13	345	8.33	10.00	0.01	0.71	0.00
Eddy	15.3	371	8.01	10.13	0.07	0.76	0.00