# ECOLOGICAL STUDIES RELATED TO THE CONSTRUCTION OF THE DEFENSE WASTE PROCESSING FACILITY ON THE SAVANNAH RIVER SITE

FY-1989 AND FY-1990 Annual Report

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SREL--46
DE93 010119

February 1993

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DE-AC09-76SR00-819

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# FOREWORD

The Defense Waste Processing Facility (DWPF) was built on the Savannah River Site (SRS) during the mid-1980's. The Savannah River Ecology Laboratory (SREL) has completed 12 years of ecological studies related to the construction of the DWPF complex. Prior to construction, the 600-acre site (S-Area) contained a Carolina bay and the headwaters of a stream. Research conducted by the SREL has focused primarily on four questions related to these wetlands: 1) Prior to construction, what fauna and flora were present at the DWPF site and at similar, yet undisturbed, alternative sites? 2) By comparing the Carolina bay at the DWPF site (Sun Bay) with an undisturbed control Carolina bay (Rainbow Bay), what effect is construction having on the organisms that inhabited the DWPF site? 3) By comparing control streams with streams on the periphery of the DWPF site, what effect is construction having on the peripheral streams? 4) How effective have efforts been to lessen the impacts of construction, both with respect to erosion control measures and the construction of "refuge ponds" as alternative breeding sites for amphibians that formerly bred at Sun Bay?

Through the long-term census-taking of biota at the DWPF site and Rainbow Bay, SREL has begun to evaluate the impact of construction on the biota and the effectiveness of mitigation efforts. Similarly, the effects of erosion from the DWPF site on the water quality of S-Area peripheral streams are being assessed. This research provides supporting data relevant to the National Environmental Policy Act (NEPA) of 1969, the Endangered Species Act of 1973, Executive Orders 11988 (Floodplain Management) and 11990 (Protection of Wetlands), and United States Department of Energy (DOE) Guidelines for Compliance with Floodplain/Wetland Environmental Review Requirements (10 CFR 1022).

# I. INTRODUCTION AND OVERVIEW

David E. Scott and Joseph H.K. Pechmann

The Savannah River Ecology Laboratory initiated ecological studies related to the construction of the DWPF on the SRS in FY-1979. Two areas have been used for biological surveys and long-term monitoring: the DWPF construction site (S-Area), and two control sites (Rainbow Bay and Tinker Creek). The Rainbow Bay study area and S-Area are located within 5 km of each other on the SRS (Fig I-1), and both once contained Carolina bays which were very similar ecologically (SREL 1980). One goal of the SREL's faunal studies is to compare the natural variation in amphibian populations at the Rainbow Bay control site to the variation observed at the human-altered site (Sun Bay, formerly on the DWPF construction site). Amphibian populations exhibit large year-to-year variation in population size and breeding success (Vitt 1981, Vitt et al. 1982), thus long-term studies are necessary to separate natural variation from variation due to human perturbations.

Pre-construction biological surveys included data on vegetation, birds, mammals, amphibians, reptiles, fish, and several invertebrate groups (SREL 1979, 1980). No species on the Federal Endangered or Threatened lists were found on either site, but several plants and animals of threatened or special-concern status in South Carolina were present (SREL 1980, Vitt 1981).

DWPF construction began in FY-1984. Continuing studies are directed towards assessing its impacts on the biota. Primary emphasis is being placed on evaluating the effectiveness of mitigation measures undertaken by the DOE.

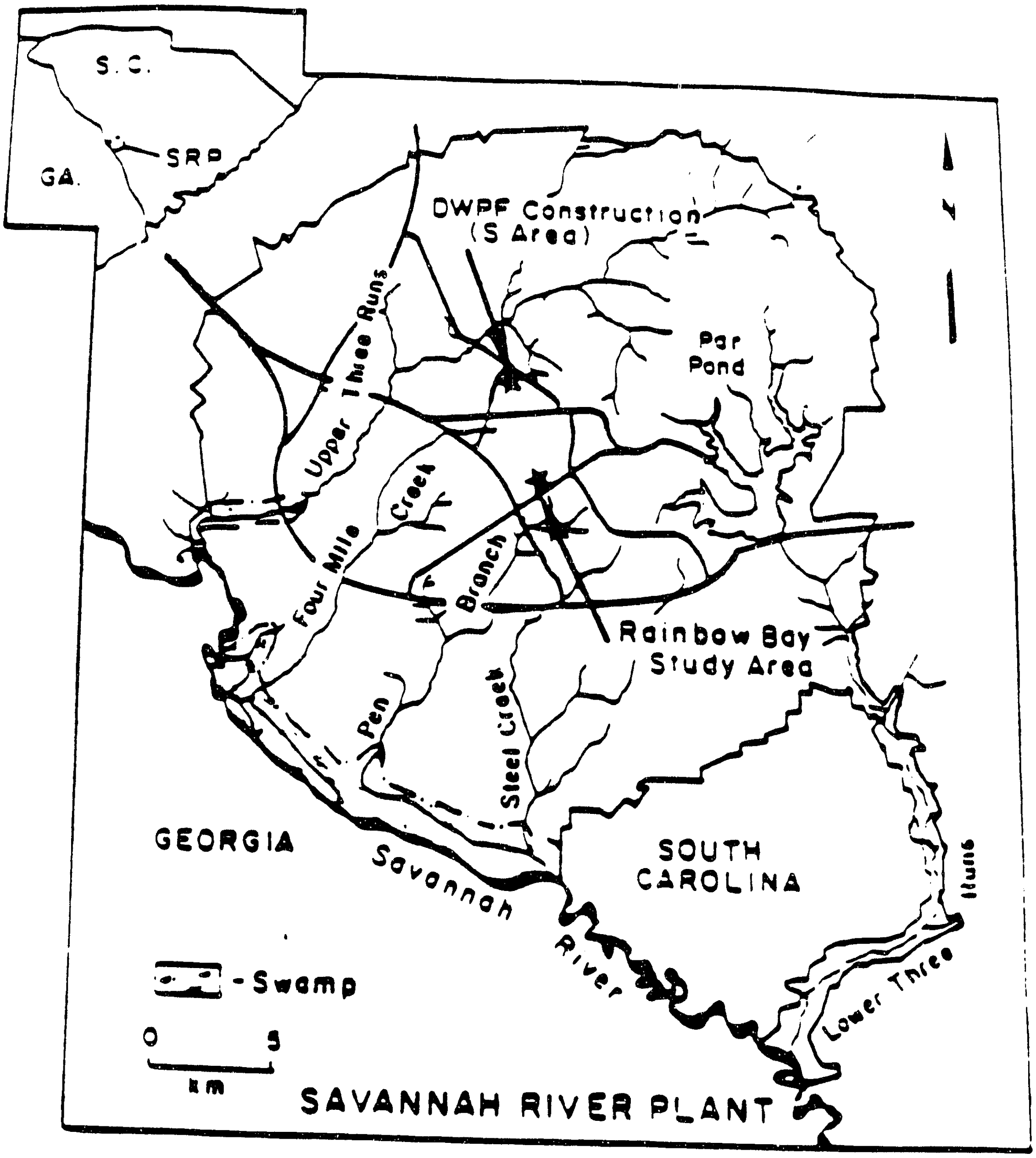


Figure I-1 Locations of the DWPF construction site (S-Area) and the Rainbow Bay Study Area (control site) on the Savannah River Site.

SREL began baseline water quality monitoring on S-Area peripheral streams in November 1982 (prior to construction) to quantify natural variation in water quality parameters. Sampling has continued to the present on the streams that drain the DWPF site (Upper Three Runs Creek, McQueen Branch, and Crouch Branch; Figure II-1) and on a nearby, unimpacted blackwater stream, Tinker Creek. Erosion resulting from DWPF construction potentially could affect the productivity and biotic diversity of McQueen Branch, Crouch Branch, and Upper Three Runs Creek. Results of a baseline survey of macroinvertebrates in these streams were reported in Pechmann et al. (1984). Chapter II of this report contains the FY-1989 and FY-1990 water quality results, and an assessment of the effectiveness of erosion control measures which have been implemented during the DWPF construction (U.S. DOE 1982).

In FY-1984, the DWPF construction eliminated Sun Bay in S-Area. Carolina bays are extremely productive, natural wetlands (Sharitz and Gibbons 1982) which serve as important breeding sites for many species of amphibians (Bennett et al. 1979, Gibbons and Semlitsch 1982, Sharitz and Gibbons 1982). Amphibians are the most prevalent group of vertebrates on both the Rainbow Bay control site and the DWPF site (SREL 1980). A major objective of the SREL studies has been to evaluate the effects of the loss of Sun Bay on the breeding success of amphibians in S-Area (Pechmann et al. 1985). In an experimental attempt to mitigate the loss of the natural breeding habitat in S-Area (i.e., Sun Bay), four refuge ponds were constructed. Only three of these are currently in operation, because of the loss of one due to unanticipated construction activities. The effectiveness of the refuge ponds as alternative breeding sites is discussed in Chapter III.

The long-term nature of the Rainbow Bay study (currently 12 years) has allowed the natural variation in numbers of immigrating breeding adults and of emigrating juveniles at the control site to be documented. Hydroperiod, or the number of days a site holds water during a year, is a critical determinant of amphibian breeding success and persistence. Chapter IV addresses fluctuations in amphibian populations for three salamander and one frog species, and discusses the difficulty in distinguishing these natural fluctuations from human impacts.

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## II. WATER QUALITY MONITORING OF PERIPHERAL STREAMS

Joanne H. McGregor and David E. Scott

### INTRODUCTION

The Savannah River Ecology Laboratory initiated a water quality monitoring program in November 1982 to assess the potential impact of the DWPF construction activities on peripheral streams. Upper Three Runs (UTR) Creek, which receives S- and Z-area drainage, is the only major stream on the Savannah River Site that has not been impacted significantly by thermal discharge.

In FY- 1983 before construction began, baseline information was collected on the natural water quality characteristics of all streams that could be impacted: UTR Creek, Crouch Branch, McQueen Branch, and Tinker Creek, a major upstream tributary of UTR. Rough grading of the construction site began on 15 September 1983 (Pechmann et al. 1984). Data gathered after ground-breaking through September 1987 have been used to evaluate impacts during construction and the initial effectiveness of erosion control measures Data collected from October 1987 to the present are used to assess post-construction stream recovery and the continued effectiveness of erosion control measures.

### METHODS

#### Site Selection

The four streams mentioned above are part of the DWPF watershed (Fig. II-1). McQueen Branch is the principle drainage tributary from the construction area. Crouch Branch receives the outflow from DWPF sediment basin 1. These tributaries are the two primary streams leaving S- and H-area, and are the streams most likely to be impacted by construction activity. Both Crouch Branch and McQueen Branch flow into UTR Creek and impacts on them could potentially affect water quality in UTR

DWPF WATER QUALITY MONITORING SITES

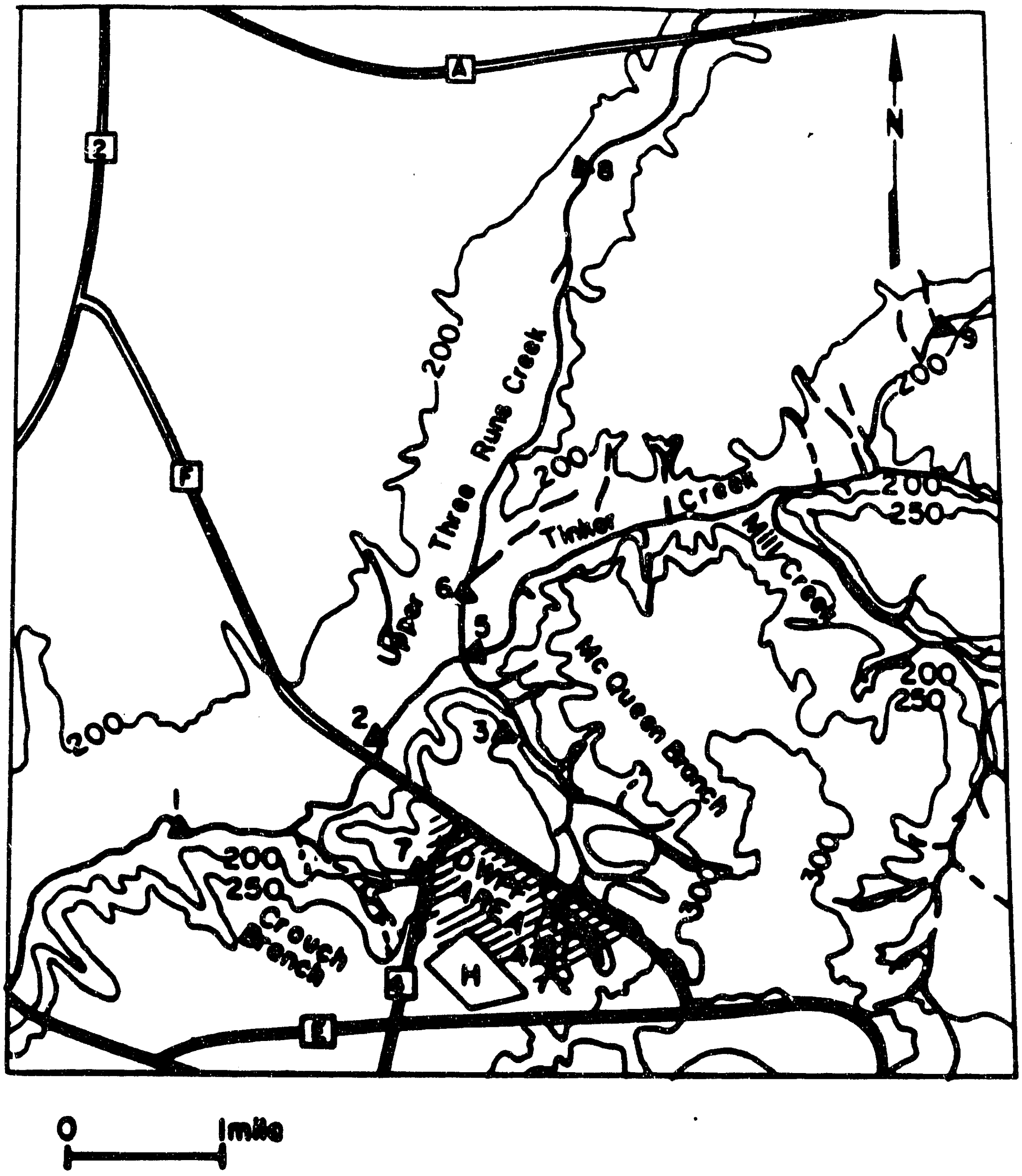


Figure II-1. DWPF Water Quality monitoring sites.

Creek. Tinker Creek also flows into UTR just above the confluence of McQueen Branch and UTR. Similar in size to UTR Creek, Tinker serves as an unimpacted control stream within the watershed.

The SREL monitoring program previously focused on 10 sample sites in the UTR watershed; however, only nine sites are sampled currently (Fig. II-1). Two sites are located on McQueen Branch. Site 3 is located approximately 2 km downstream of the construction area, and site 4 is located on the south side of road F. A third site on this Creek was sampled between November 1984 and September 1986 (Scott et al. 1988). Site 7 is located on Crouch Branch at Road 4 approximately 122 m downstream from the outflow of sedimentation basin 1. Site 7 was sampled twice in FY-1982 and deactivated until FY-1986 after which it was sampled regularly. Sites 1 and 2 are located on UTR Creek below the confluence with McQueen Branch, and two more sites (sites 6 and 8) are located on UTR Creek above this confluence. Two sites (sites 5 and 9) are monitored on Tinker Creek upstream from the construction area.

## Sampling

From the second to the seventh year of sampling (November 1983 - September 1989), water quality monitoring was conducted monthly. During FY- 1983 (November 1982 - September 1983), sampling was conducted more frequently than in later years and with an emphasis on sampling during and after rainfall for the purpose of establishing existing water quality characteristics. Due to budgetary cuts, monitoring ceased between October 1989 and February 1990; however, monthly sampling resumed in March 1990. Thus, the first year (FY- 1983) includes data for 11 months and during the last year (FY- 1990) streams were sampled for seven months. Water quality measures from the intervening years are based on 12 months.

SREL personnel measured the following water quality variables: total suspended solids (TSS), percent ash, turbidity, and specific conductance. Total suspended solids is a measure of the dry weight of nonfilterable residue in each sample. Percent ash is a measure of the inorganic component of the TSS. The ratio of inorganic to organic matter may change relative to the specific stream inputs, i.e. leaf litter vs. erosion clays. Turbidity is based on measurements of refracted light and indicates the relative amount of undissolved particles in a stream sample. Specific conductance measures the ability of a sample to carry an electrical current and depends mostly on the level of dissolved salts (ions) present in the water. Stream profiles and flow measures were added to the routine sampling in October 1985 at three sites: 3 and 4 (McQueen Branch), and 9 (Tinker Creek).

Until February 1985, specific conductance was measured with a field conductivity bridge. Samples since February 1985 were analyzed in the laboratory using a Sybron PM-10CB conductivity bridge or an Orion Research Conductivity Meter Model 101 (25 C). Turbidity was determined in the laboratory using a nephelometer which measured in Nephelometric Turbidity Units (NTU) (reduced sampling during the first year). Samples were analyzed for TSS and ash weight using EPA approved methods (US EPA, 1983). A rain gauge was placed adjacent to the DWPF construction site and monitored daily. Stream velocities (centimeters per second) were measured using a Marsh-McBirney Portable Flow Meter.

In FY- 1986 four plots were established on McQueen Branch to inventory the particle size composition and to observe composition changes over time. Based on the analysis of 2 years of such data a recommendation to terminate that portion of the DWPF monitoring project was made (Scott et al. 1988) and adopted.

## Data Analysis

For the statistical analysis of the water quality data, sampling sites were grouped into six watershed locations: the two McQueen Branch sites (3 and 4; McQueen), the two Tinker Creek sites (5 and 9; Tinker), the two UTR Creek sites above McQueen Branch (6 and 8; UTR- above), the UTR Creek site below McQueen Branch (2; UTR- below), and the Crouch Branch site (7; Crouch). General patterns observed in the data suggested further grouping of data based on rainfall one day prior to sampling. Data were grouped into three classes based on rainfall during the previous day: rainfall $\leqq$ 0.1 cm (no rain), 0.1 cm $<$ rainfall $\leqq$ 1.0 cm (low rain), and rainfall $>$ 1.0 cm (high rain, see Scott et al. 1988). Data were also categorized based on the stages of the construction project: before (FY- 1983), during (FY-1984 to FY-1987), and after (FY-1988 to FY-1990) construction.

Analysis of variance (ANOVA) was used to assess the impact of DWPF construction on S- and Z-area stream water quality. In order to decrease variance and increase normality in the data, log transformations were performed on TSS, turbidity, specific conductivity, TSS load per day per km$^2$, and rainfall. The transformations were made by adding 1.0 to each observation and then taking the natural log of the sum. The transformed variables and percent ash measurements were used in ANOVA models to test for effects of DWPF construction activities in each rainfall class (no, low, and high rain).

Within the ANOVA models, a number of hypotheses were tested for each rainfall class. For each water quality variable (e.g., log TSS), analyses determined whether or not there was a significant location effect (i.e., Did the locations differ in their level of a given variable averaged across all construction periods?), a significant construction period effect (i.e., Did the construction periods differ in their level of a given variable averaged across all locations?), and a significant location-by-construction interaction (i.e., Did the variable levels at some locations respond differently over the construction periods than at other locations?). This last test, the test of a location-by-construction interaction, is the primary test of whether construction activity has affected water quality in the DWPF peripheral streams.

This interaction test is depicted graphically in Figure II-2. In the example, a comparison of stream 1 vs. stream 2 reveals that stream 2 has higher levels of the measured variable, but both streams respond the same over the three construction periods, i.e., there is no location-by-construction interaction effect because the lines are parallel. However, when stream 1 is compared to stream 3, stream response is not the same during the construction periods; stream 3 increases more in the after construction period than stream 1, i.e., there is an interaction effect because the lines are not parallel.

Using the ANOVA models, specific comparisons were made between control locations (UTR- above and Tinker) and impacted locations (McQueen, Crouch, UTR- middle, and UTR- below). These tests (statistical contrasts) were limited to particular comparisons of interest: UTR- above vs. UTR- middle, UTR- above vs. UTR- below, Tinker vs. McQueen, and Tinker vs. Crouch. Comparisons were made over three time intervals (before vs. after, before vs. during, and during vs. after construction). Data were analyzed using SAS version 5.18 statistical package (SAS Institute Inc. 1985a, b).

Due to small sample sizes all Crouch Branch samples and all turbidity samples taken in the before-construction period were omitted from the statistical analysis.

In the following results and discussion section graphical representations of the data accompany and illustrate statistical outcomes and trends. In addition, Appendix A lists numeric summaries of the water quality data by fiscal year and rainfall class.

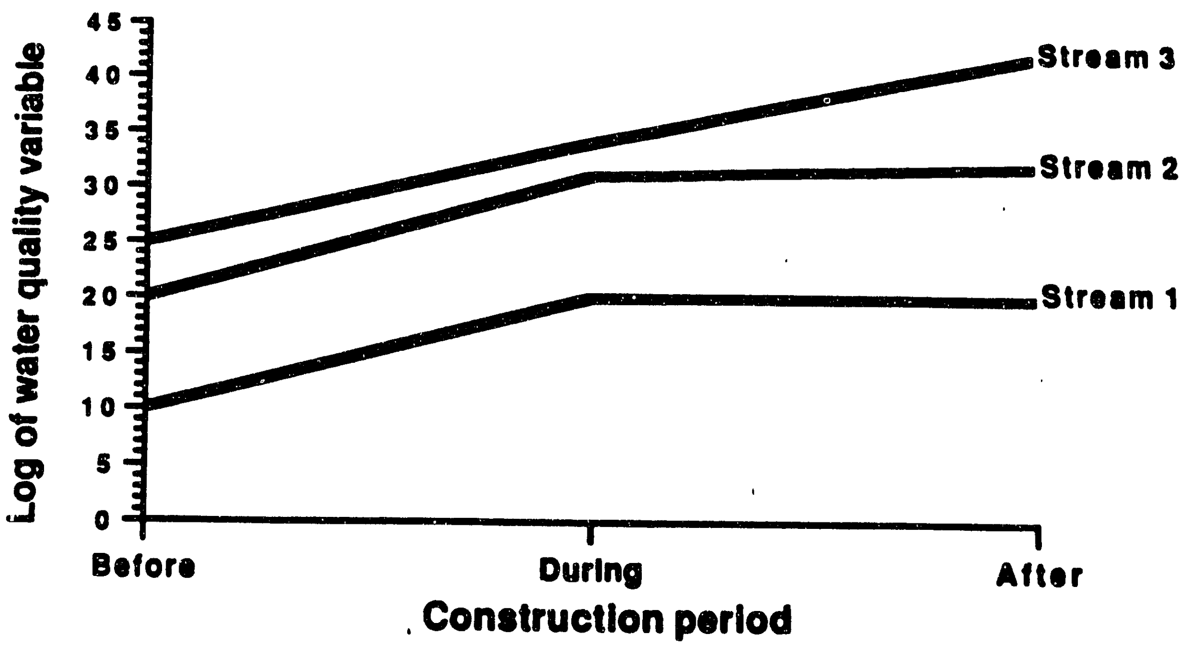


Figure II-2. Log variable by construction period (ANOVA interaction test example schematic representation).

# RESULTS AND DISCUSSION

## Introduction

Log TSS values for each location were plotted against log rainfall levels one day prior to sampling for each construction period (Fig. II-3). These graphs illustrate several points. First, levels of TSS increase as rainfall increases, for all locations across all time periods. Second, TSS levels are generally higher during (DC) and after (AC) construction than before (BC) DWPF construction, even in the no rain class. These observations hold for streams that receive drainage directly from S- and Z-areas (Crouch Branch and McQueen Branch) as well as control locations (UTR- above and Tinker Creek). In addition, the smaller streams were higher than the larger streams in TSS irrespective of the construction period. Given these relationships, the location-by-construction period interaction term was used to test the effect of DWPF construction on stream water quality (as described in methods). Results of the ANOVA contrasts are listed and discussed by stream, beginning with the primary impact streams, McQueen Branch and Crouch Branch, and concluding with UTR Creek.

## McQueen Branch

Water quality variables (i.e. TSS, turbidity, specific conductance, and percent ash) in McQueen Branch were compared to levels in the control stream, Tinker Creek, (Fig. II-4). Data from the BC period illustrate that TSS and turbidity levels rise more sharply as rainfall increases and percent ash levels are higher overall in McQueen Branch than in Tinker Creek. This difference is apparently a function of stream order; as a smaller steam, McQueen Branch is "flashier." The degree to which the flashiness of McQueen Branch was influenced by DWPF construction activity was assessed using the specific statistical contrast tests.

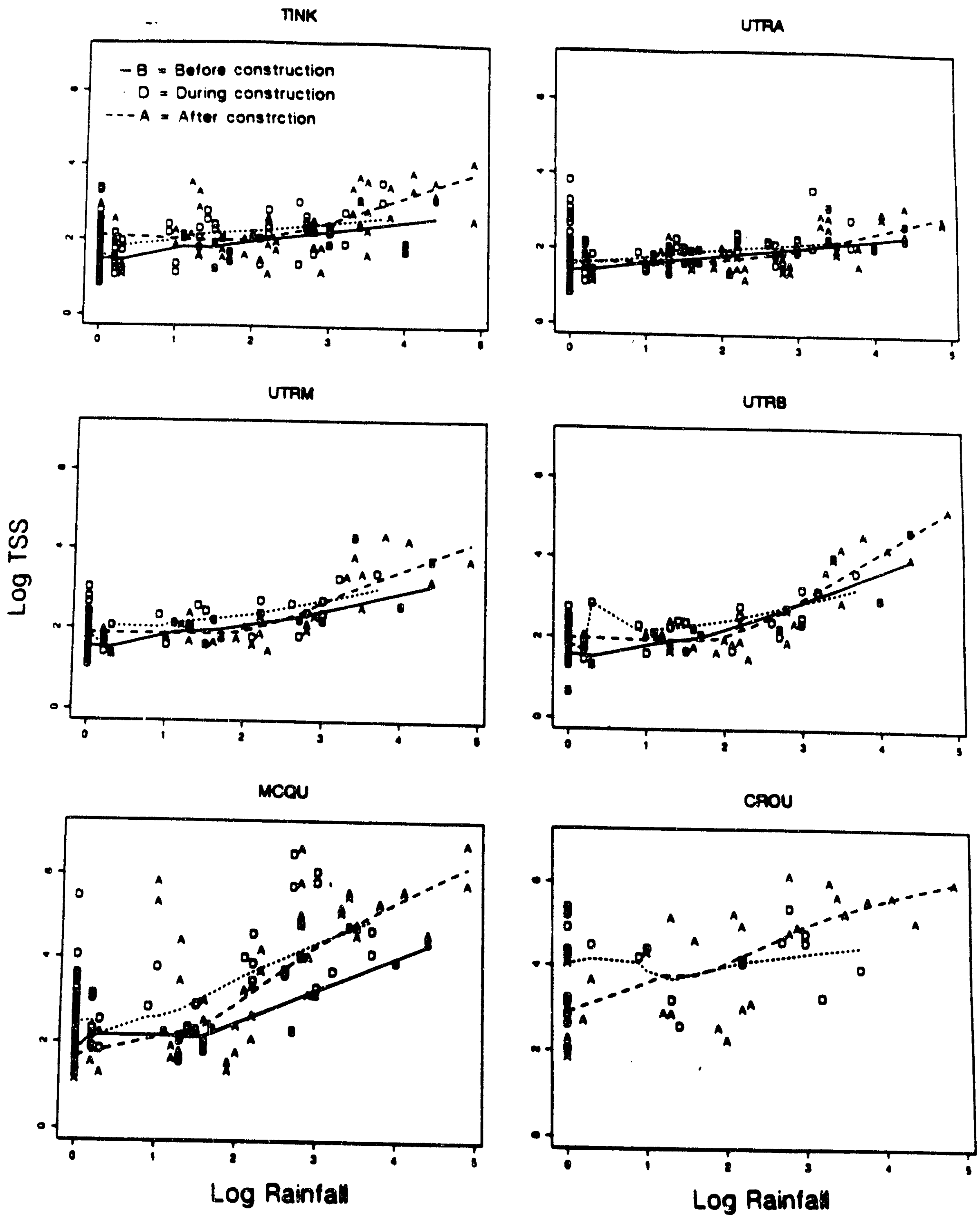


**Figure II-3. Log TSS by log rainfall for each location.**

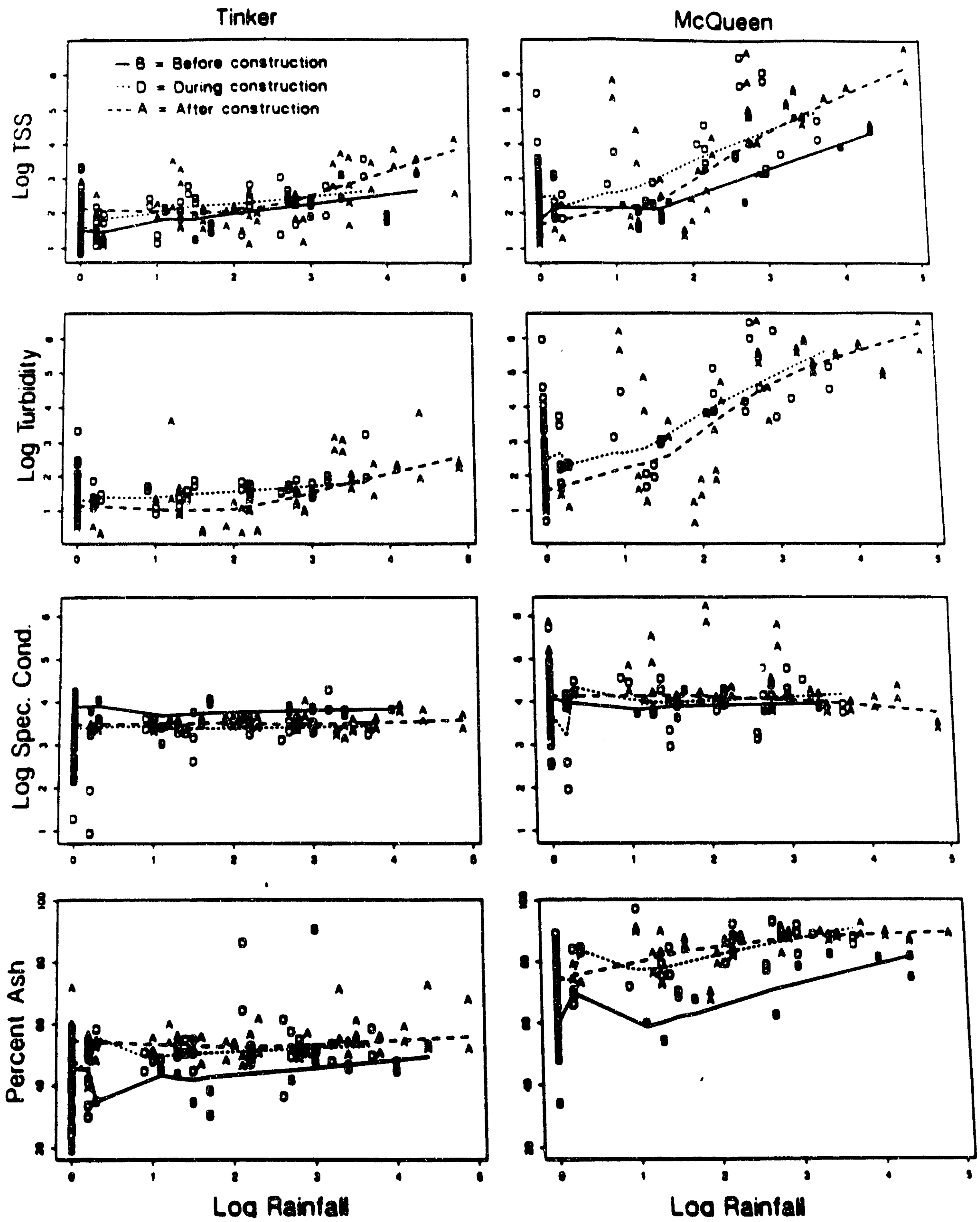


**Figure II-4. Log TSS, log turbidity, log specific conductance, and percent ash by log rainfall, for Tinker and McQueen.**

**TSS**: **No rain** - TSS levels rose moderately in Tinker Creek over the three construction periods. Levels in McQueen Branch were higher than the control BC, increased significantly more DC ($p \leqq 0.0001$), leaving AC levels significantly higher than BC levels when compared to Tinker Creek ($p \leqq 0.005$).

**Low rain** - TSS levels increased sharply over the three construction periods in McQueen Branch compared to a slight increase in Tinker; however, no differences were significant.

**High rain** - TSS levels rose very slightly in Tinker Creek over the construction periods, and more sharply in McQueen Branch, leaving AC levels significantly higher than BC in McQueen Branch as compared to Tinker Creek ($p \leqq 0.01$).

**TURBIDITY**: **No Rain** - Turbidity levels were higher BC and AC in McQueen Branch than Tinker Creek. Both creeks showed increases DC; however McQueen Branch rose more sharply and then decreased significantly more AC than Tinker Creek ($p \leqq 0.02$).

**Low and High rain** - Tinker Creek shows virtually no increase in turbidity over time, while McQueen Branch levels are higher AC than DC. This change in turbidity is statistically non-significant when compared to Tinker.

**SPECIFIC CONDUCTANCE**: **No rain** - McQueen Branch specific conductance was higher BC, fell significantly more than Tinker Creek DC ($p \leqq 0.005$), and was significantly higher AC than BC when compared to Tinker Creek ($p \leqq 0.001$).

**Low and High rain** - Specific conductance was higher BC in McQueen Branch than in Tinker. Levels decreased DC and rose slightly AC in Tinker, while levels increased moderately in McQueen Branch DC and AC. Levels AC were significantly higher than BC in McQueen Branch when compared to Tinker ($p \leqq 0.002$ Low rain; $p \leqq 0.03$ High rain).

**PERCENT ASH:** **No rain** - Percent ash levels increased moderately in Tinker Creek over the three construction periods. Levels in McQueen Branch were higher BC and rose significantly more than Tinker Creek DC ($p \leqq 0.001$). Levels AC remained higher in McQueen Branch than in Tinker Creek.

**Low rain** - Percent ash levels increased in Tinker Creek DC and decreased slightly AC. Levels in McQueen Branch were higher than Tinker Creek over all time periods. Levels AC were significantly higher than BC in McQueen Branch when compared with similar changes in Tinker Creek ($p \leqq 0.04$).

**High rain** - Levels of percent ash in Tinker Creek decreased DC and increased slightly AC. Levels in McQueen Branch were higher BC and increased significantly DC ($p \leqq 0.01$). Levels in McQueen AC were significantly higher than BC when compared to Tinker ($p \leqq 0.03$).

**TSS LOAD**: The log TSS load per day per $km^2$ is graphed against log rainfall for Tinker site 9 and each site on McQueen Branch (sites 3 and 4; Fig. II-5). No data is available for the BC period.

**No rain** - TSS load for Tinker Creek rose moderately AC compared to levels DC. Load levels in McQueen Branch were higher DC and then decreased significantly AC when compared to Tinker Creek ($p \leqq 0.002$ site 4; $p \leqq 0.01$ site 3).

**Low and High rain** - TSS load in Tinker Creek and McQueen Branch decreased from the DC to the AC period under low-rain conditions. Under high rain conditions both creeks showed increases AC over the DC period. No changes in either group were significant.

The results listed above provide evidence that McQueen Branch clearly has been affected by DWPF construction-site runoff over the eight year sampling period.

These effects are most evident in the TSS, specific conductance, and percent ash variables. Based on the nature of McQueen Branch as a primary runoff stream during periods of rainfall, erosion from the construction site would most likely appear in the low and high rain classes. Accordingly, TSS, specific conductance and percent ash levels were significantly higher than controls AC than BC for low- and high- rain classes. During construction levels were also significantly higher than controls in the no rain class. Rainfall prior to the 24 hours before sampling (the period used to classify rainfall groups) may account for the increased levels of TSS and percent ash in McQueen Branch for that rainfall class. Although levels remained high AC, in some cases the water quality variables decreased significantly from the DC to the AC periods. This decrease in TSS, TSS load, and turbidity might be attributed to erosion control measures at the construction site or to decreased land disturbances at the site as construction was completed. In either case some recovery of the tributary is evident in the AC period.

## CROUCH BRANCH

Crouch Branch is the second primary impact site below the DWPF construction area. Like McQueen Branch, it is a small tributary that readily fills under high rainfall conditions. Little data is available for this site BC; however, DC and AC data are used to test the location-by-construction period interaction between Crouch Branch and Tinker Creek for each water quality variable (Fig. II-6).

**TSS**: **No rain** - While Tinker Creek showed a slight increase DC to AC, Crouch Branch TSS was considerably higher DC and decreased significantly AC when compared to Tinker Creek ($p \leqq 0.0001$). AC levels remained higher in Crouch Branch than in Tinker Creek.

**Low rain** - Data showed a non-significant increase in Crouch Branch TSS AC over DC levels; Tinker Creek levels rose only slightly.

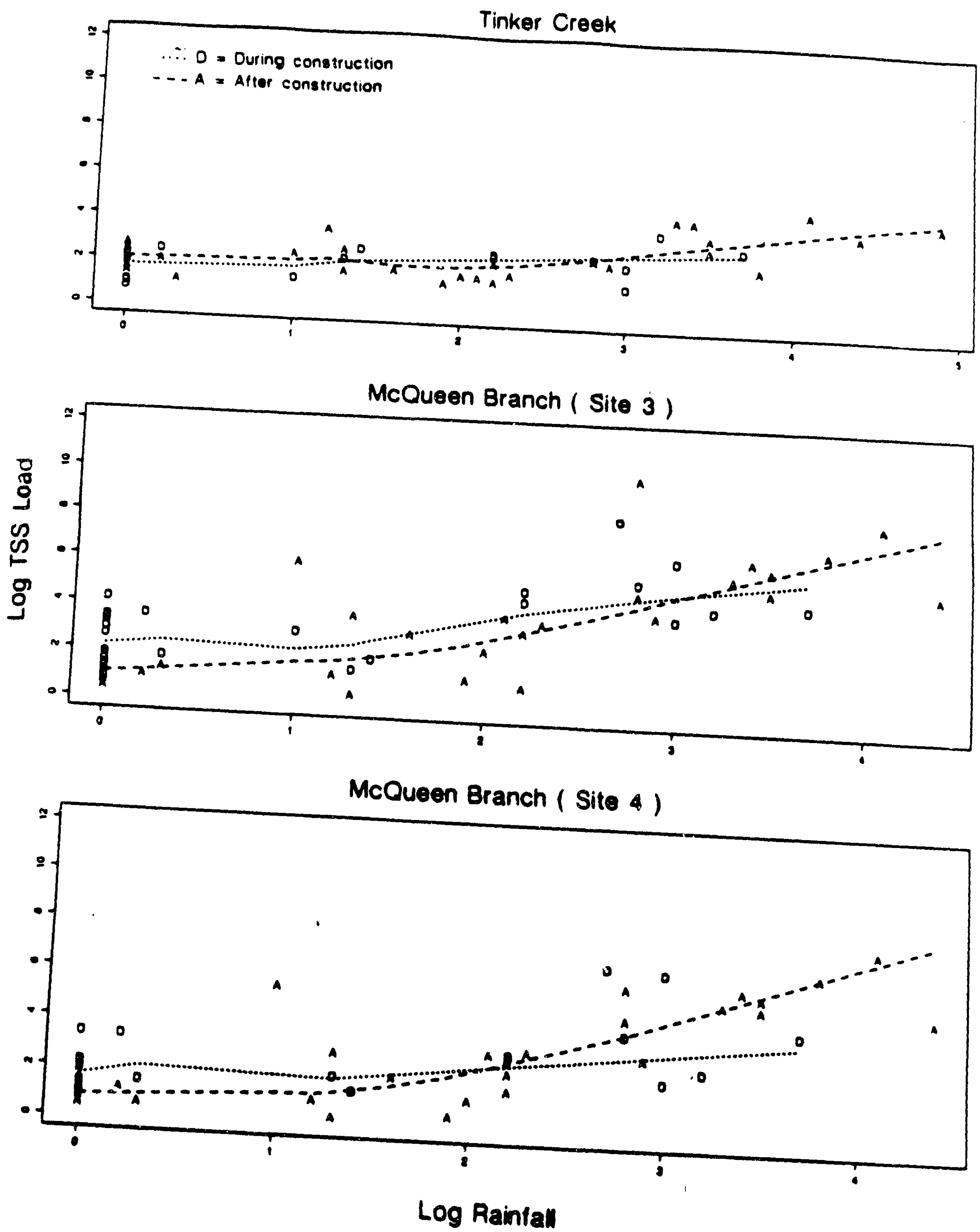


**Figure II-5. Log Tss load by log rainfall, for McQueen Branch (sites 4 and 3) and Tinker Creek (site 9).**

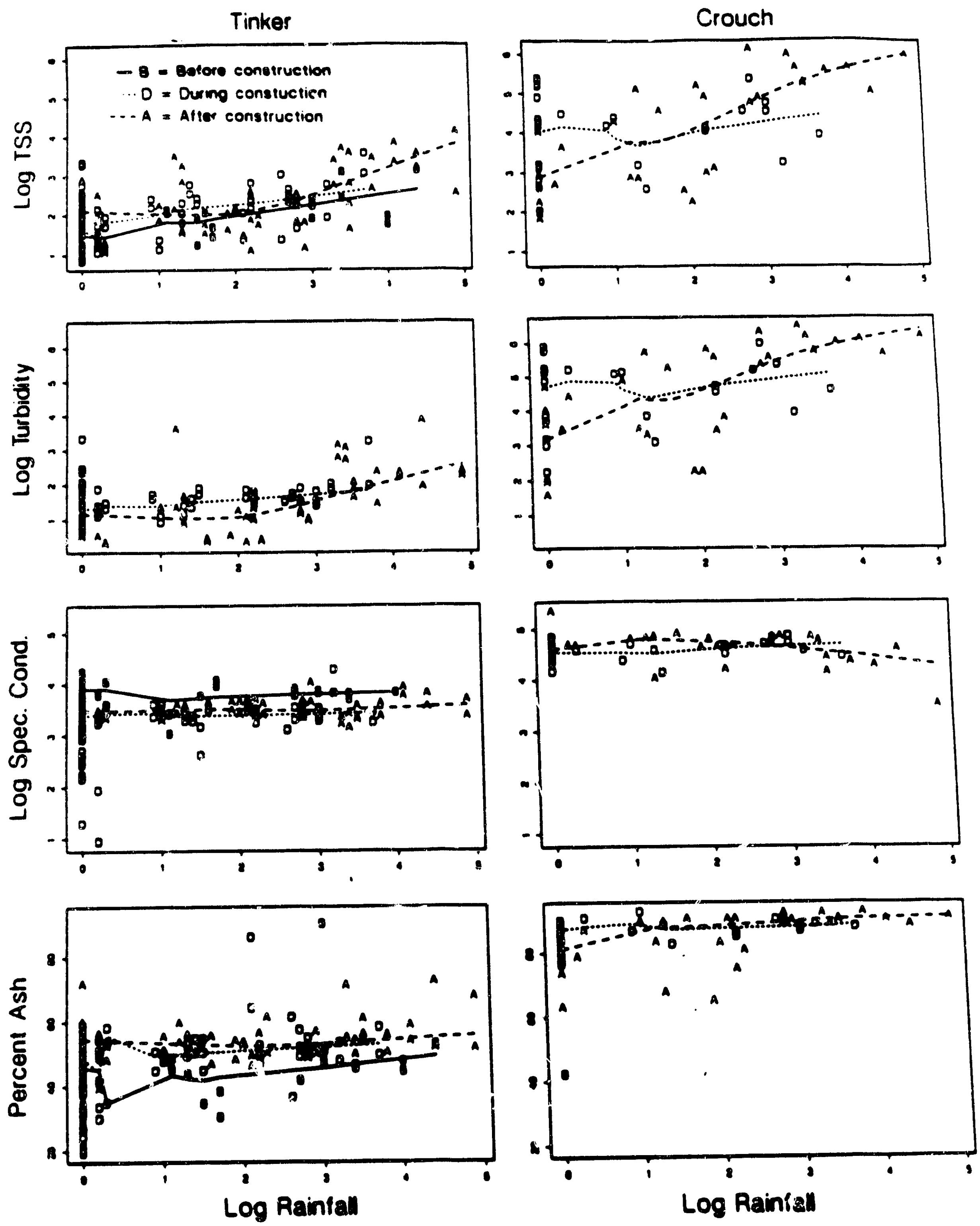


**Figure II-6. Log TSS, long turbidity, log specific conductivity, and percent ash by log rainfall, for Tinker and Crouch.**

**High rain** - Tinker Creek TSS levels rose slightly from the DC to AC periods. Crouch Branch had higher levels DC and rose significantly more AC than Tinker Creek ($p \leqq 0.01$).

**TURBIDITY**: **No rain** - Tinker Creek turbidity levels were relatively unchanged from the DC to the AC period. Crouch Branch levels were considerably higher than Tinker Creek DC and decreased significantly AC ($p \leqq 0.001$).

**Low rain** - Turbidity in Crouch Branch increased AC from DC levels, while Tinker Creek remained stable; however, the change was not statistically significant.

**High rain** - Once again Tinker Creek turbidity levels remained constant, while Crouch Branch levels increased significantly in comparison ($p \leqq 0.02$).

**SPECIFIC CONDUCTANCE**: **No, Low, and High rain** - Tinker Creek showed a slight increase in specific conductance between the DC and AC periods. For the no- and low- rain classes, Crouch Branch also showed an increase. Under high- rain conditions Crouch Branch showed a slight decrease in specific conductance AC than DC. No changes were statistically significant.

**PERCENT ASH**: **No rain** - Percent ash levels increased in Tinker between the DC and AC periods. Crouch Branch decreased significantly AC from DC levels compared to Tinker ($p \leqq 0.001$).

**Low rain** - Tinker Creek showed relatively little change from DC to the AC period, while Crouch Branch decreased AC. No change was significant.

**High rain** - Crouch Branch percent ash level was considerably higher DC than Tinker Creek. Levels in both creeks increased slightly AC from DC levels. Changes were non-significant.

Because few data are available for Crouch Branch before construction began, and because Crouch Branch is the smallest stream in the DWPF watershed, conclusions about overall changes in the stream are difficult to draw. However, the data do provide considerable evidence that Crouch Branch has been affected adversely by DWPF construction. First, for the high- rain class AC levels were significantly higher than controls for TSS and turbidity. Secondly, DC and AC levels in Crouch Branch are higher than every other sampled location in the watershed for each parameter measured in every rain class. Thirdly, significant decreases in TSS, turbidity, and percent ash levels AC are evident in the no- rain class. Without the erosion input that occurs with low and high rainfall, Crouch Branch appears to show better water quality levels. Because it lies below a sedimentation basin, Crouch Branch water quality is a good measure of the effectiveness of the basin's performance. As the basin fills with sediment it becomes less able to hold construction area runoff under rainy conditions, and consequently higher silt levels will occur in the stream below. The significantly elevated levels of TSS and turbidity in Crouch Branch may reflect this condition.

## Upper Three Runs Creek

A principle concern of this monitoring program is to assess the potential impacts of DWPF construction on water quality in UTR Creek. Two contrast pairs were made: UTR- above vs UTR- middle (effects below the McQueen Branch and Tinker Creek confluences) and UTR- above vs UTR- below (effects below the confluence of Crouch Branch) (Figs. II-7 and II-8).

**TSS: No and Low rain** - Trends in the three UTR Creek locations were similar. TSS levels rose DC and fell AC; however, UTR- middle and UTR- below levels were higher than UTR- above levels for all periods. No changes were significant.

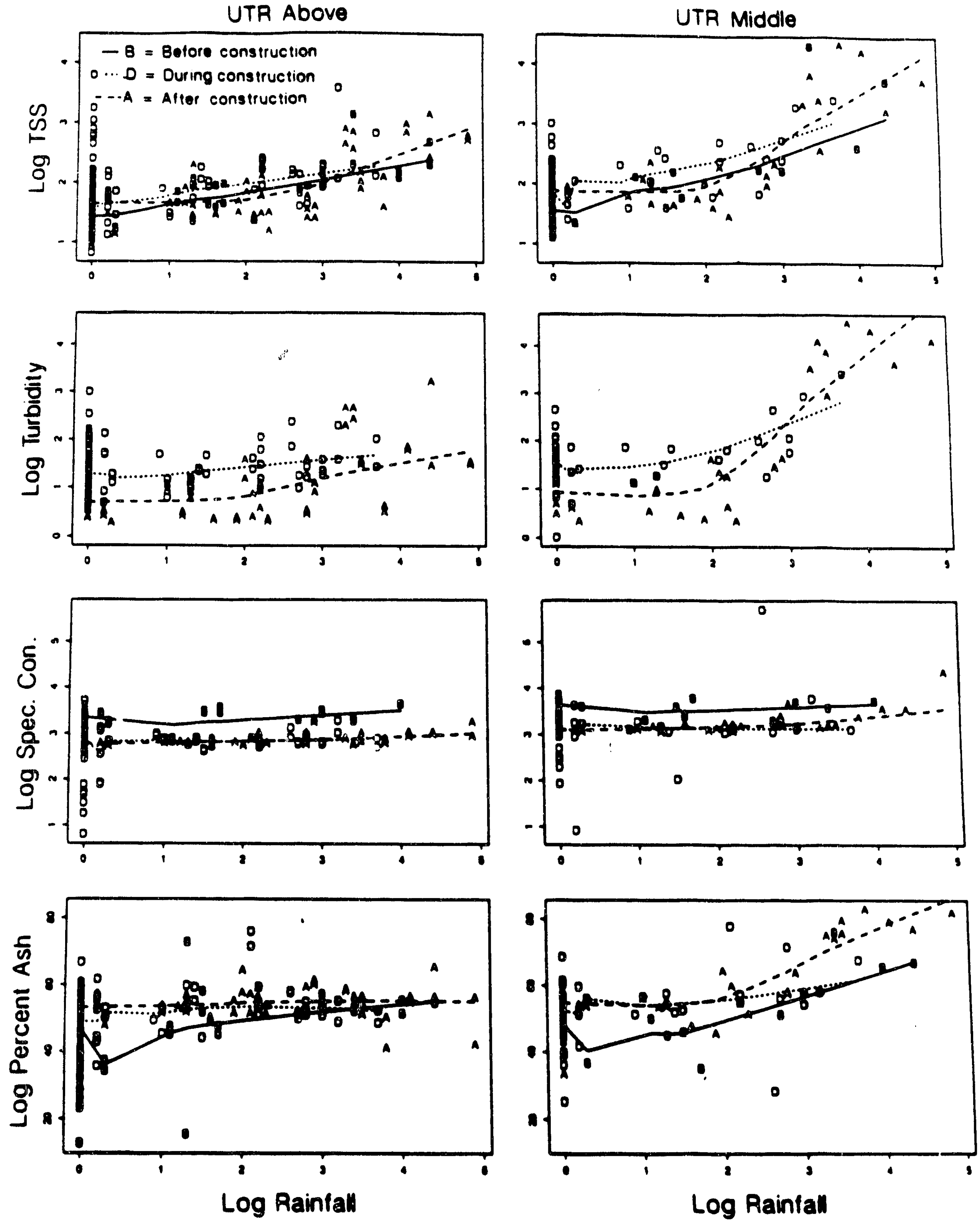


**Figure II-7. Log TSS, log turbidity, log specific conductivity, and percent ash by log rainfall, for UTR- above and UTR- middle.**

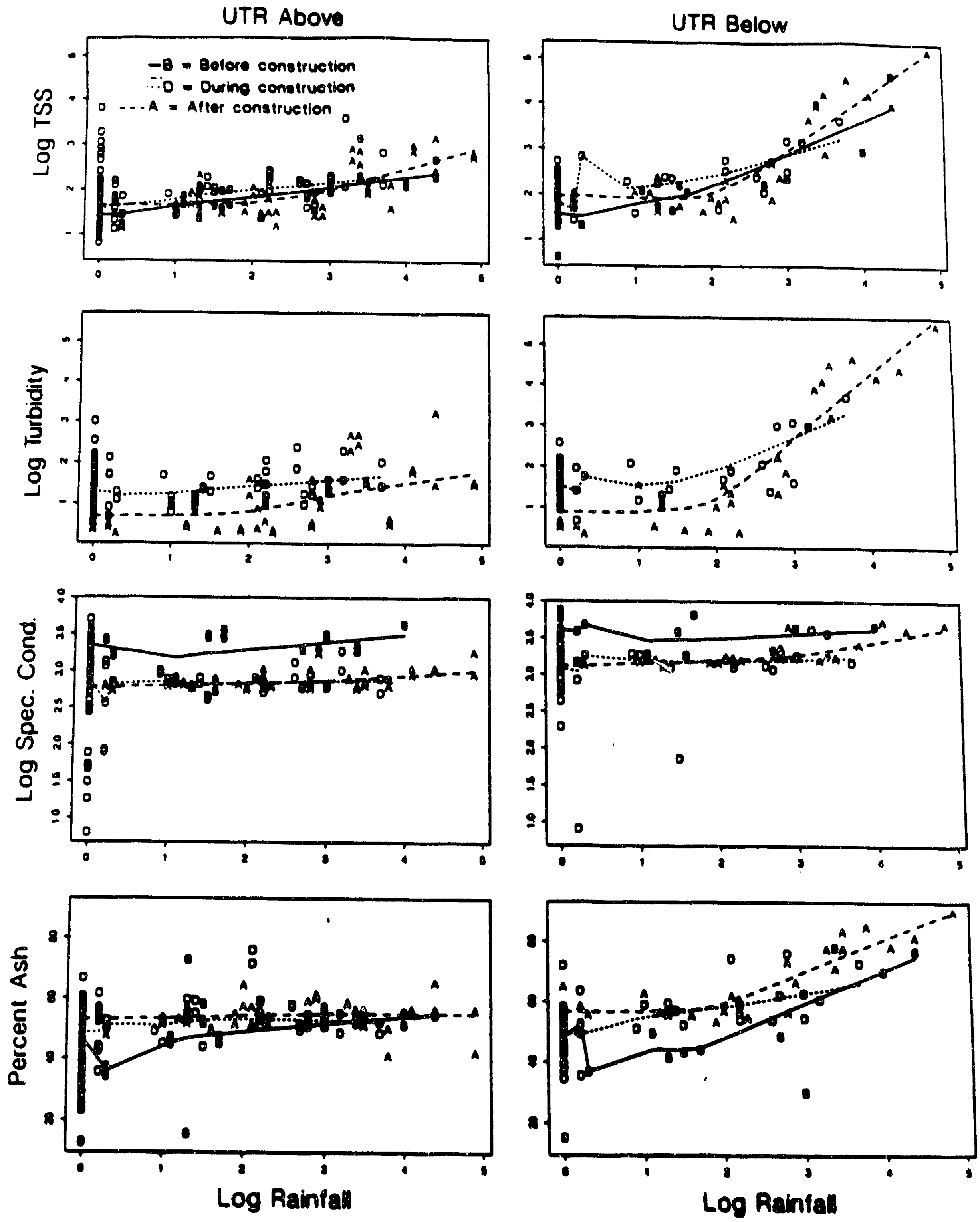


**Figure II-8.** Log TSS, log turbidity, log specific conductivity, and percent ash by log rainfall, for UTR- above and UTR- below.

**High rain** - UTR- above showed little change in TSS level over the three construction periods. UTR- middle and -below showed a sharp decrease DC and a sharp increase to AC levels higher than BC levels for each location. Changes were non-significant.

__TURBIDITY__: **No and Low rain** - All locations on UTR Creek showed a non-significant decrease in turbidity AC from DC levels.

**High rain** - Turbidity levels increased sharply in UTR- middle and -below DC to AC, while levels in UTR- above remained constant. This increase was also non-significant.

__SPECIFIC CONDUCTANCE__: No and Low rain - For all locations on UTR Creek, specific conductance decreased BC to DC and increased slightly AC. Levels AC were below levels BC. No changes were statistically significant.

**High rain** - UTR- above and -below decreased from BC to DC and increased AC. UTR- middle showed an increase DC followed by a decrease AC to BC levels. Again, changes were non-significant.

__PERCENT ASH__

__UTR- Middle__: **No rain** - Both locations (UTR- above and UTR- middle) showed increasing percent ash levels over the three periods. UTR- middle was higher BC and UTR- above was higher AC. No changes were significant.

**Low rain** - Both UTR- above and -middle increased DC and decreased in percent ash levels AC. Levels AC were higher DC than BC levels at both locations. Changes were non-significant.

**High rain** - While UTR- above decreased slightly DC and rose to slightly higher than BC leves AC, UTR- middle decreased sharply DC and rose sharply to a considerably higher AC percent ash level than BC. The increase was non-significant.

**UTR Below: No rain** - UTR- above and -below followed parallel patterns of increase during the three periods.

**Low rain** - The two locations, UTR- above and below, increased DC and decreased AC. Both ended with percent ash levels above BC levels.

**High rain** - UTR- above decreased slightly DC and rose only slightly AC. UTR below increased significantly more DC ($p \leqq 0.03$) and AC levels were significantly higher ($p \leqq 0.003$) than BC when compared to UTR- above.

The data collected over the eight years of this study show an increase in TSS, turbidity, and percent ash levels in UTR Creek; however, this increase can not be attributed to inputs from McQueen Branch and Crouch Branch alone. Comparisons of UTR Creek above the construction site to two locations below did not provide evidence that the S- and Z-area construction raised TSS or other parameter levels in UTR Creek. One possible explanation for the observed decrease in water quality in UTR Creek is the effects of additive inputs. Possible contributors to increased TSS levels besides DWPF construction might be: increases in off-plant construction activities upstream on UTR Creek, increases due to clogged road drainage, flash flooding, or other unnoted disturbances along the creek drainage. A combination of such activities in conjunction with the S- and Z-area input, may have contributed to this alteration in water quality over time. For non-point pollutants, such as erosion, multiple effects are difficult to identify and accurately assess; however, based on this study, water quality in UTR Creek has not been significantly affected by the construction site input from McQueen Branch or Crouch Branch.

## SUMMARY

FY- 1990 concludes eight years of water quality monitoring in the DWPF watershed. Based on the data collected in that period several conclusions can be drawn:

1. TSS levels at all locations have risen during the sample period and have generally remained at higher levels than before construction began.

2. The small tributaries below the construction site, Crouch Branch and McQueen Branch, have been significantly affected by erosion inputs since construction began. In both cases effects are most clearly evident under low and high rainfall conditions.

3. Statistical evidence over the eight year period does not reveal that the DWPF construction-site runoff has impacted UTR Creek significa[illegible].

## CONCLUSION

In a 1986 article Kenneth L. Dickson, former president of the Society of Environmental Toxicology and chemistry, suggested that rather than toxic chemicals, non-point pollutants such as siltation are causing the greatest harm to the aquatic environment (Dickson 1986). He states that one source of silt contamination arises from "poor erosion control practices at construction sites." Based on data from the DWPF watershed samples between 1982 and 1990, it appears that although extensive impact to UTR Creek has been minimized, elevated TSS and other parameter levels continue to persist in tributaries below construction-site sedimentation basins. Further attention to erosion control measures, such as dredging clogged sediment basins, is recommended to improve conditions for these aquatic tributaries.

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# III. REFUGE PONDS: AN EXPERIMENT IN MITIGATION

Joseph H. K. Pechmann, Ruth A. Estes and David E. Scott

## INTRODUCTION

When the interests of development clash with the legal protection of wetlands, an increasingly common compromise is to allow the draining and filling of wetlands as long as artificial replacement wetlands are built for mitigation (Kusler and Kentula, 1990). However, it remains an open question whether these artificial wetlands are ecological equivalents of those that they replaced (Kentula et al., 1992). Many wetlands are important amphibian breeding sites, and there is little information on whether successful mitigation of this aspect is achieved.

A Carolina bay (Sun Bay) located on the DWPF site was cleared and filled during FY-1984 as part of DWPF site preparation. Four artificial ponds were constructed on the periphery of S-Area in an experimental attempt to mitigate the impact of the DWPF construction. Colonization and succession of amphibians are being studied at these "refuge ponds" in order to examine the responses of fauna to DWPF construction, and to determine the potential of the ponds for mitigating these impacts. Examination of colonization and succession in newly created or disturbed habitats provides valuable information on ecosystem structure and function as well as the responses of biota to disturbance (e.g. Odum 1969, Simberloff and Wilson 1969, Vitousek and Reiners 1975, Connell 1978, Paine and Levin 1981, Wilbur and Alford 1985). The DWPF project has provided a unique opportunity to investigate this phenomenon.

Amphibians comprised more than 95% of the total non-avian vertebrate fauna at the DWPF site prior to construction (Vitt 1981). Most of the amphibian species found there are primarily terrestrial but must migrate to aquatic habitats to breed. Sun Bay was formerly used by amphibians for breeding and larval development, as are many Carolina bays (Bennett et al. 1979, SREL 1980, Vitt 1981, Gibbons and

Semlitsch 1982, Sharitz and Gibbons 1982). At least 13 species of amphibians bred at Sun Bay (4 salamanders, 9 frogs or toads). Many amphibian species are philopatric, i.e., they return to the same breeding site year after year (Twitty 1959, Shoop 1965, Oldham 1967, Madison and Shoop 1970, Patterson 1978, Semlitsch 1981, Vitt 1981, Vitt et al. 1982). The sensory mechanisms utilized by amphibians to locate their breeding sites have been extensively studied (Twitty 1961, Oldham 1967, Landreth and Ferguson 1967, Taylor and Adler 1973, Hershey and Forester 1979, McGregor and Teska 1989), but remain poorly understood.

Some individuals of some species may migrate one km from their natal pond (unpublished data); however, migration distances are species-specific. Ambystomatid salamanders may not migrate as far from a pond as some newt species (Semlitsch 1983b). Mean migration distances of ambystomatids are much less than one km, and range from 47 - 252 m (Semlitsch 1983b).

It was clear that significant direct amphibian mortality would occur from DWPF construction activities. However, the indirect effects of construction on the amphibian community were uncertain. Would surviving individuals be able to locate Sun Bay after it had been drained and filled,and the surrounding vegetation and topography had been drastically altered? If they did return, would they remain at the former location of Sun Bay although the bay no longer existed? Or would they migrate out in search of another breeding site? Do amphibians have the ability to locate alternative breeding sites by means other than random encounters?

The purpose of this study is to determine whether the artificial refuge ponds built on the periphery of the DWPF site can provide alternative breeding sites for amphibians, thereby mitigating the loss of Sun Bay. These experimental ponds were completed during the latter part of FY-1983. Amphibians moving to and from the ponds are censused by means of terrestrial drift fence with pitfall traps. The former site of Sun Bay is also being assessed for amphibian presence and abundance.

The specific objectives of this study were, first, to examine how quickly, and to what extent, these refuge ponds were colonized by breeding adult amphibians, especially individuals marked at Sun Bay during SREL surveys there, and especially species known to be philopatric to their home pond. It is well known that amphibians will breed in human-made ponds under certain conditions, so the key question here was what would happen under the conditions of construction. The second objective was to determine if the refuge ponds we built provided adequate habitat for successful breeding and juvenile recruitment, and, in the long run, if a similar amphibian community became established at the refuge ponds compared to that which was found at the former Sun Bay. Unfortunately, we could not do a formal mathematical analysis of community similarity. Although we have 4 years of pre-construction data from Sun Bay, it's not pre-disturbance data, because the pond was partially drained for engineering surveys before we started work there, and this changed the amphibian community (Vitt 1981, Vitt et al. 1982, Pechmann et al. 1984, Scott et al. 1986).

The philosophy of the study was to simply create ponds, let them fill with rainwater, and allow colonization and succession to take their course. We did not attempt to mitigate any other aspects of the lost wetland other than its role as an amphibian breeding site.

This report summarizes results to FY-1990, with emphasis on the FY-1989 and FY-1990 results. Results from FY-1984 to FY-1988 have been reported previously (Pechmann et al. 1984, Pechmann et al. 1985, Scott et al. 1986, 1988). Data are compared to those collected from the Rainbow Bay control site during FY-1989 and FY-1990 as well as in previous years.

# METHODS

## Refuge Pond Design

Four refuge ponds (A, B, C, and D) were completed on 20 June 1983 on the periphery of the DWPF construction site, 3 months before construction began (Fig. III-1). Ponds were built between 300 m and 600 m from Sun Bay, which was as close as permitted by DWPF construction plans (including Z-Area). When possible, sites were chosen where water tended to collect naturally, as evidenced by the presence of hydric plants such as mosses. A paved two-lane road lies between Sun Bay and three of the refuge ponds and a powerline right-of-way containing a dirt road lies between the bay and the fourth pond (Fig III-1). The effect of these barriers on amphibian movements is unknown, but it was probably no greater than that of the widespread clearing and grading from construction activities.

Each pond is circular, approximately 16 m in diameter, and has a maximum depth of approximately 1 m. This is 200$m^2$ area each or 800 for 4 ponds. The wetland they replaced was 10,000$m^2$, so this should be viewed as an experimental "pilot project", not mitigation *per se*.

Ponds were originally lined with hard-packed clay so they would collect and hold rainwater. Carolina bays are underlaid by an impervious clay lens (Bryant and McCracken 1964; Schalles 1979), and typically receive no water input other than rain (Sharitz and Gibbons 1982). Refuge pond water retention was poor during FY-1984 in spite of high rainfall (Pechmann et al. 1984). To rectify this problem fish-grade plastic (CPE) pond liners were installed on 19 November 1984. An overflow pipe was also installed in each pond. After installation of these liners the refuge ponds became permanent ponds. Because the plastic liners initially provided an inert substrate, leaf litter was added to the ponds during February and March 1985. These leaves supplied cover, nutrients, and organic matter for biota.

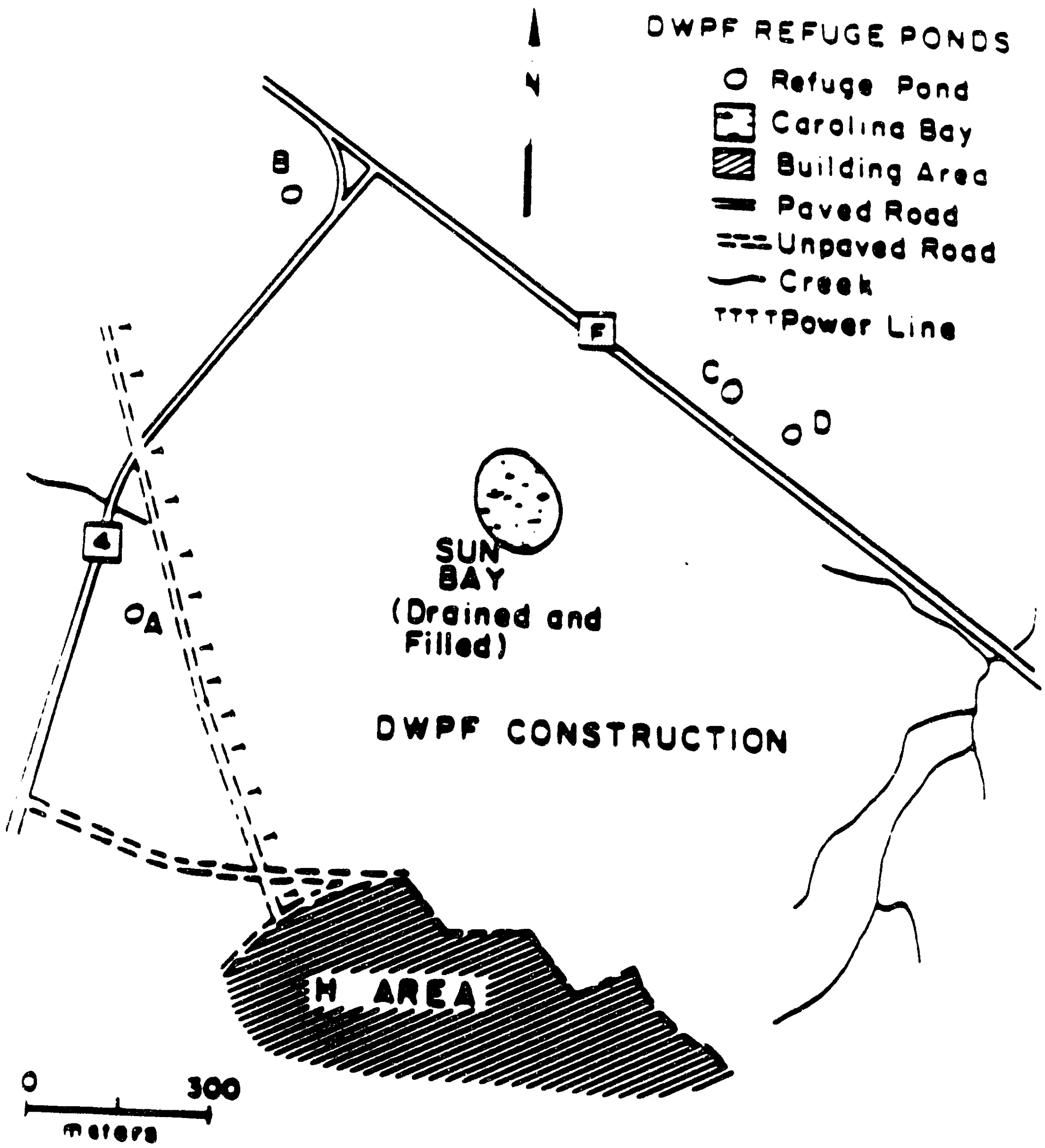


Figure III-1. Locations of DWPF refuge ponds.

At the request of DOE, Refuge Pond C (Fig. III-1) was dismantled on 7 June 1985 to accommodate expansion of the planned Z-Area.

Refuge Ponds A and B were each pumped to one-third of their normal depth from 28-29 September 1987 (Pond A from 63 cm to 22 cm, Pond B from 89 cm to 29 cm). Both ponds were dried completely by pumping and hand bailing from 19 October 1987 to 22 October 1987, then allowed to refill with rain beginning 27 October 1987. These manipulations were an attempt to make the hydrologic cycle of these ponds more similar to those of Rainbow Bay and the former Sun Bay.

## Sampling Techniques

Amphibian populations were monitored using terrestrial drift fences with pitfall traps (Fig. III-2; SREL 1980, Gibbons and Semlitsch 1982). A drift fence with pitfall traps was constructed encircling each refuge pond on 20-21 June 1983. Traps were checked daily and all animals released on the opposite side of the fence, the presumed direction of movement. Data on each amphibian captured were recorded and the majority marked by toe-clipping (see Appendix C for common names). Amphibian populations at the Rainbow Bay control site were monitored in a similar fashion (See Chapter IV for other analyses of these data). By using this technique, the numbers of adults that entered a site to breed, as well as the numbers of juveniles and adults that emigrated from a site, were measured. The drift fence technique works much better for some species than for others. Practically all ambystomatid salamanders are captured, for example, but some salamanders and many treefrogs climb over the fence and some frogs can jump over it. For most species, however, large numbers of juveniles are captured by the drift fence, as juveniles are less adept at fence trespass.

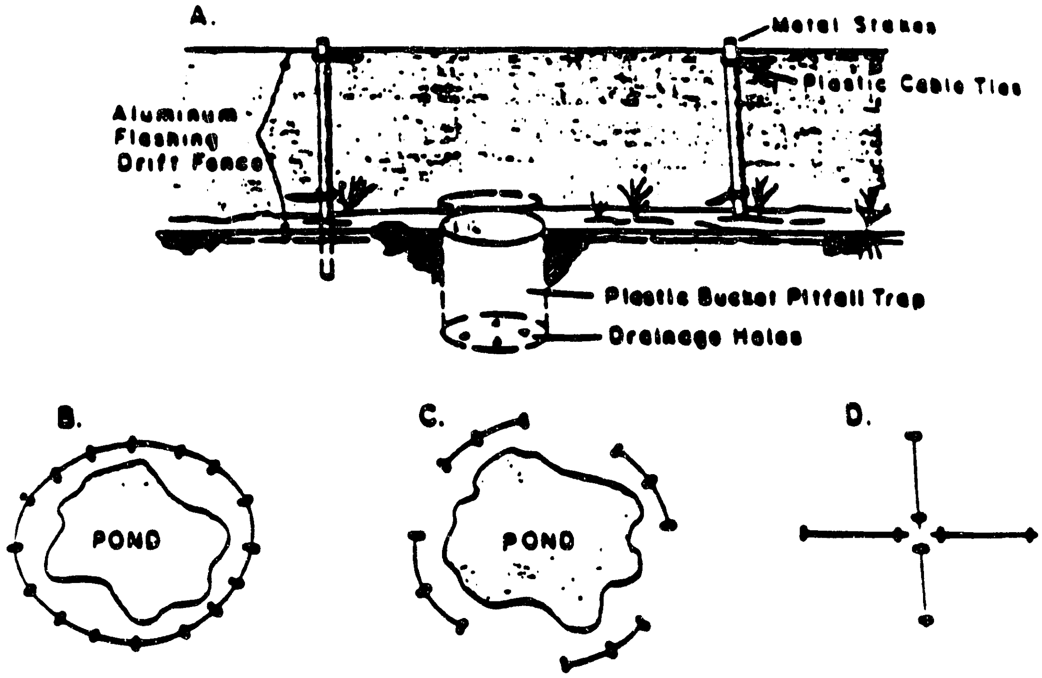


Figure III-2. Design of terrestrial drift fences with pitfall traps used in SREL's DWPF studies (from Gibbons and Semlitsch 1982).

Drift fences with pitfall traps were also used to monitor amphibian breeding migrations to the former site of Sun Bay. Four-liter pitfall traps were employed at all Sun Bay fences instead of the 40-liter traps used elsewhere to facilitate rapid removal in the event of interference with construction. During FY-1984, one temporary 50-m drift fence on the northwest side was used to sample Sun Bay from 13 December 1983 to 11 May 1984. Two temporary 50-m fences were erected during FY-1985 on 17 December 1984: one on the northwest side of the former bay, and the other on the northeast. These remained in place until 3 July 1985. During FY-1986 the former site of Sun Bay was sampled in the same manner as in FY-1985. Both the northwest and the northeast fence were rebuilt on 21 November 1985. The fence on the northwest side remained in place until August 29, 1986, when it was removed because of DWPF construction activities. The fence on the northeast side remained in place and was used for sampling throughout FY-1986 and during FY-1987 through 16 September 1987. The Sun Bay site was not sampled after FY-1987 because captures of amphibians at Sun Bay had dwindled to near zero by that time. Differences among sampling methods cloud among-year comparisons of amphibian populations at Sun Bay, but were unavoidable due to the extensive construction activities.

In addition to the drift fences, amphibians at Sun Bay were sampled with minnow traps during FY-1984 before the site was completely drained. Minnow traps were also used to sample the refuge ponds from 10 January 1987 to 15 April 1987.

## RESULTS

### Biotic Environment

Vegetation succession has occurred at all the refuge ponds, and the old-field grasses and forbs that originally colonized the bare area around each pond are being replaced with pine trees. There are annual blooms of filamentous green algae in the ponds. Emergent sedges (*Scirpus cyperinus*) have taken root in the shallow water along the shores. Aquatic insects, including large predaceous Odonata nymphs, are common in the ponds. Crows, sandpipers, and other birds often feed in the water around the edges of the ponds.

## Frogs and Toads

Some species of frogs and toads colonized the refuge ponds almost immediately, and have continued to be present in fair numbers during their breeding seasons every year of the study (Table III-1). These included *Bufo terrestris, Hyla crucifer, Gastrophryne carolinensis,* and *Rana utricularia*. Smaller numbers of adults of 9 other species have been captured at the ponds during their breeding seasons. These numbers must be judged keeping in mind that capture efficiencies are low for *Acris gryllus* and all adult *Rana* and *Hyla*, because many *Acris* and *Rana* jump over the drift fence and many *Hyla* climb over it. The most extreme example of this is *Hyla gratiosa*. Adults of this species have never been captured at the drift fences even though they have bred at all 3 remaining ponds every year since 1985 (Table III-2). More *Scaphiopus hobrooki, B. quercicus, H. femoralis, H. chrysoscelis, Pseudacris nigrita,* and *R. clamitans* were captured in the first part of the study than the latter part, and the reverse was true for *A. gryllus*.

Only 7 juvenile *Hyla chrysoscelis* and 1 juvenile *Hyla femoralis* metamorphosed and emigrated from the refuge ponds in FY-1984 (see Table V-8 in Pechmann et al. 1984). Observations indicated that the low juvenile recruitment was due in part to the fact that the ponds dried frequently during FY-1984, killing any tadpoles that were present. Substantial production of frog and toad juveniles began in FY-1985 following installation of the pond liners. The highest number of frog and toad juveniles was produced in FY-1985 and the nest highest in FY-1988, with FY-1989 and FY-1990 both being average years (Table III-2).

Through FY-1990 8 species of frogs and toads have produced at least some juveniles at the refuge ponds (Table III-2). *Bufo terrestris, Hyla (Pseudacris) crucifer,*

Table III-1. Number of adult amphibians captured entering the refuge ponds during their breeding season from FY-1984 to FY-1990 (total for all four ponds).

| Species | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 |
|---|---|---|---|---|---|---|---|
| **Salamanders** | | | | | | | |
| *Ambystoma talpoideum* | 6 | 2 | 62 | 59 | 33 | 81 | 204 |
| *Ambystoma tigrinum* | 0 | 0 | 1 | 1 | 0 | 1 | 1 |
| *Notophthalmus viridescens* | 3 | 0 | 9 | 8 | 5 | 6 | 36 |
| *Eurycea quadridigitata* | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| **Frogs and Toads** | | | | | | | |
| *Scaphiopus holbrooki* | 18 | 11 | 7 | 12 | 5 | 2 | 1 |
| *Bufo terrestris* | 34 | 156 | 161 | 53 | 62 | 58 | 62 |
| *Bufo quercicus* | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Acris gryllus* | 0 | 0 | 0 | 0 | 0 | 3 | 9 |
| *Hyla crucifer* | 17 | 27 | 121 | 5 | 28 | 38 | 27 |
| *Hyla femoralis* | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| *Hyla chrysoscelis/versicolor* | 3 | 2 | 1 | 3 | 0 | 0 | 0 |
| *Pseudacris nigrita* | 0 | 2 | 2 | 0 | 0 | 0 | 0 |
| *Pseudacris ornata* | 4 | 4 | 6 | 0 | 10 | 5 | 0 |
| *Gastrophryne carolinensis* | 68 | 69 | 36 | 34 | 29 | 46 | 22 |
| *Rana catesbeiana* | 1 | 0 | 1 | 0 | 0 | 0 | 1 |
| *Rana clamitans* | 13 | 5 | 7 | 0 | 0 | 1 | 1 |
| *Rana utricularia* | 24 | 14 | 98 | 20 | 21 | 19 | 8 |

Table III-2. Number of amphibian juveniles produced at DWPF refuge ponds during FY-1985 to FY-1990. Numbers in parentheses below *Ambystoma talpoideum* entries indicate how many of the total metamorphosed from 1 Jan to mid-May of the following year, and may have been former paedomorphs.

| | Pond A | | | | | | | Pond B | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species** | **1985** | **1986** | **1987** | **1988** | **1989** | **1990** | **Total** | **1985** | **1986** | **1987** | **1988** | **1989** | **1990** | **Total** |
| *Ambystoma talpoideum* | 0 | 9 | 1 | 0 | 0 | 0 | 10 | 0 | 94 | 30 | 138 | 99 | 102 | 463 |
| | | (3) | (0) | | | | (3) | | (62) | (0) | (68) | (57) | (63) | (250) |
| *Notophthalmus viridescens* | 0 | 11 | 41 | 88 | 329 | 56 | 525 | 0 | 0 | 2 | 0 | 0 | 0 | 2 |
| **Total Salamanders** | 0 | 20 | 42 | 88 | 329 | 56 | 535 | 0 | 94 | 32 | 138 | 99 | 102 | 465 |
| *Bufo Terrestris* | 50 | 1 | 0 | 3 | 0 | 2 | 56 | 16 | 1 | 0 | 0 | 0 | 0 | 17 |
| *Acris gryllus* | 0 | 0 | 5 | 0 | 1 | 0 | 6 | 0 | 0 | 0 | 0 | 15 | 6 | 21 |
| *Hyla crucifer* | 306 | 0 | 0 | 97 | 0 | 1 | 404 | 85 | 3 | 0 | 147 | 6 | 0 | 241 |
| *Hyla gratiosa* | 24 | 10 | 31 | 2 | 3 | 6 | 76 | 100 | 15 | 17 | 16 | 138 | 35 | 321 |
| *Rana catesbeiana* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 0 | 0 | 0 | 9 |
| *Pseudacris ornata* | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 6 | 1 | 0 | 7 |
| *Hyla chrysoscelis/versicolor* | 59 | 0 | 2 | 0 | 0 | 1 | 62 | 77 | 0 | 2 | 0 | 0 | 0 | 79 |
| *Rana utricularia* | 19 | 1 | 21 | 287 | 18 | 75 | 421 | 646 | 6 | 0 | 72 | 5 | 177 | 906 |
| **Total Frogs and Toads** | 458 | 12 | 59 | 390 | 22 | 85 | 1026 | 924 | 25 | 28 | 241 | 165 | 218 | 1601 |

Table III-2. (Con't) Number of amphibian juveniles produced at DWPF refuge ponds during FY-1985 to FY-1990. Numbers in parentheses below *Ambystoma talpoideum* entries indicate how many of the total metamorphosed from 1 Jan to mid-May of the following year, and may have been former paedomorphs.

| | Pond C* | Pond D | | | | | | | Total (all ponds) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | 1985 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | Total | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | Total |
| *Ambystoma talpoideum* | 0 | 0 | 36 | 314 | 100 | 199 | 14 | 663 | 0 | 139 | 345 | 238 | 298 | 116 | 1136 |
| | | | (31) | (115) | (44) | (121) | (9) | (320) | | (96) | (115) | (112) | (178) | (72) | (573) |
| *Notophthalmus viridescens* | 0 | 0 | 8 | 1 | 58 | 44 | 68 | 179 | 0 | 19 | 44 | 146 | 373 | 124 | 706 |
| **Total Salamanders** | 0 | 0 | 44 | 315 | 158 | 243 | 82 | 842 | 0 | 158 | 389 | 384 | 671 | 240 | 1842 |
| *Bufo terrestris* | 0 | 0 | 14 | 0 | 298 | 210 | 19 | 541 | 66 | 16 | 0 | 301 | 210 | 21 | 614 |
| *Acris gryllus* | 0 | 0 | 0 | 13 | 31 | 54 | 48 | 146 | 0 | 0 | 18 | 31 | 70 | 54 | 173 |
| *Hyla crucifer* | 313 | 640 | 1 | 1 | 8 | 3 | 54 | 707 | 1344 | 4 | 1 | 252 | 9 | 55 | 1665 |
| *Hyla gratiosa* | 0 | 41 | 98 | 5 | 65 | 23 | 126 | 358 | 165 | 123 | 53 | 83 | 164 | 167 | 755 |
| *Rana catesbeiana* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 0 | 0 | 0 | 9 |
| *Pseudacris ornata* | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 7 | 2 | 0 | 9 |
| *Hyla chrysoscelis/versicolor* | 0 | 6 | 1 | 0 | 1 | 1 | 6 | 15 | 142 | 1 | 4 | 1 | 1 | 7 | 156 |
| *Rana utricularia* | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 7 | 665 | 14 | 21 | 359 | 23 | 252 | 1334 |
| **Total Frogs and Toads** | 313 | 687 | 121 | 19 | 403 | 292 | 253 | 1775 | 2382 | 158 | 106 | 1034 | 479 | 556 | 4715 |

*Eliminated 7 June 1985

*H. gratiosa,* and *Rana utricularia* have been relatively successful at the ponds, whereas *R. catesbeiana* and *P. ornata* have produced only a few juveniles. *Hyla chrysoscelis* was successful primarily at the beginning of the study, as nearly all of its juvenile production was in FY-1985. In contrast, *Acris gryllus* was most successful in the latter part of the study. No juvenile *Acris* were produced until FY-1987, but since then *Acris* has produced a cohort every year.

There were large differences among ponds in the number of juveniles produced of each species (Table III-2). For example, more than twice as many *Rana utricularia* have come from Pond B than from Pond A, and there have been only a few from Pond D. On the other hand, most *Bufo terrestris* and *Acris gryllus* juveniles have been produced at Pond D.

## Salamanders

FY-1986 was the first year that there was any appreciable colonization of the refuge ponds by salamanders. Numbers of adult *Notophthalmus viridescens* and, especially, *Ambystoma talpoideum* that entered the refuge ponds during their FY-1986 breeding seasons were much higher than in any previous year (Table III-1). These higher numbers of adults generally persisted from FY-1987 to FY-1989, and numbers increased sharply again in FY-1990 (Table III-1). About half of the *Ambystoma talpoideum* caught at the refuge ponds during the first 4 years of the study had been marked at Sun Bay during SREL surveys prior to construction. By the last year of the study, most of the *Ambystoma talpoideum* breeding at the refuge ponds were ones that had been born at them, with nearly all returning to their individual home pond.

Juvenile salamanders were not produced at the refuge ponds until FY-1986 (Table III-2), the first year of extensive colonization by adult salamanders (Table III-1). Several hundred metamorphosed salamanders were produced each year from FY-1987 to FY-1990 (Table III-2), but only two species of salamanders have produced juveniles at the ponds to date: the mole salamander, *Ambystoma talpoideum*, and the red-spotted newt, *Notophthalmus viridescens*.

If a site does not dry, mole salamander and red-spotted newt larvae can forego metamorphosis and become paedomorphic, that is, remain in the pond and become sexually mature while retaining the larval body form (Semlitsch 1984). Minnow trapping during FY-1987 confirmed that some individuals of both these species follow this life history path at the refuge ponds (Table III-3). Some of the paedomorphic mole salamanders, including a number of those captured in the minnow traps during FY-1987, metamorphosed and emigrated from the ponds following their first reproduction. Overwintering larvae cannot be distinguished from paedomorphic individuals except by dissection, but it is likely that many of the individuals caught in the aquatic traps or that emigrated immediately following the breeding season were sexually mature. *A. talpoideum* that metamorphosed and emigrated from 1 January to mid-May were included with the previous year's juvenile totals in Table III-2, even though they were a mix of overwintering juveniles and former paedomorphs. The numbers of these included in each total appears in parentheses.

Over the course of time Pond A became strictly a *Notophthalmus* pond in terms of salamanders (Table III-2). Only a few *A. talpoideum* juveniles came from there, all during the first two years of salamander breeding. The reverse happened at Pond B, and Pond D is the only one at which both species now coexist. As near as we can tell, these differences among ponds resulted from the stochastic effects of initial colonization. More *Notophthalmus* than *A. talpoideum* bred in Pond A initially, while the opposite happened in Pond B. Apparently a sufficient number of both species colonized Pond D for both to become established.

Table III-3. Paedomorphic and formerly paedomorphic salamanders captured at the DWPF refuge ponds during FY-1987. Number of individuals captured in aquatic funnel traps from 10 January-15 April 1987, number of those captured in aquatic traps that later metamorphosed and emigrated, and number of individuals first captured when they metamorphosed and emigrated (total for all three ponds).

| Species | Aquatic traps | Recapture emigrants | First capture emigrants |
|---|---|---|---|
| *Ambystoma talpoideum* | 39 | 15 | 64 |
| *Notophthalmus viridescens* | 40 | 0 | 0 |

## Sun Bay and Rainbow Bay

Pre-construction data for Sun Bay was presented in SREL (1980), Vitt (1981), Vitt et al. (1982), Pechmann et al. (1984), and Scott et al. (1986). Many more adult amphibians were captured at Sun bay during their breeding seasons in FY-1984, the year it was drained, than in any subsequent year (Table III-4). In FY-1987, the last year Sun Bay was sampled, only 2 were captured.

More adult salamanders were caught at Sun Bay (Table III-4) than at the refuge ponds (Table III-1) during FY-1984, despite the less efficient sampling at Sun Bay. More salamanders were caught at the refuge ponds than at Sun Bay in every subsequent year that Sun Bay was monitored, although numbers are not directly comparable because sampling effort was greater at the refuge ponds. More frogs and toads of all species except *Pseudacris ornata* were caught at the refuge ponds than at Sun Bay each year that both locations were monitored, but again, sampling effort differed (Tables III-1 and III-4).

Numbers and diversity of amphibians at the Rainbow Bay control site have generally exceeded those at the refuge ponds. Drift fence captures at Rainbow Bay during FY-1989 and FY-1990 are shown in Table III-5, and Rainbow data are discussed further in Chapter IV. Juvenile production at Rainbow Bay in FY-1989 and FY-1990 was reduced by early pond drying due to drought (Table III-5, Chapter IV), whereas the refuge ponds did not dry during this time because of their pond liners.

## DISCUSSION

During FY-1984, the first complete year of our study and of DWPF construction, salamanders continued to return to Sun Bay despite the ongoing construction. The few adult salamanders that entered the refuge ponds during FY-1984 left within a few days (Pechmann et al. 1984). During FY-1985 only one adult salamander was caught at the former site of Sun Bay, and three at the refuge ponds. Lack of opportunities to migrate due to low rainfall during FY-1985 probably contributed to

Table III-4. Number of adult amphibians captured during their breeding season at the former site of Sun Bay from FY-1984 to FY-1987.

| Species | 1984 | 1985 | 1986 | 1987 |
|---|---|---|---|---|
| **Salamanders** | | | | |
| *Ambystoma talpoideum* | 32 | 1 | 9 | 1 |
| *Ambystoma opacum* | 1 | 0 | 0 | 0 |
| *Notophthalmus viridescens* | 17 | 0 | 0 | 0 |
| **Frogs and Toads** | | | | |
| *Scaphiopus holbrooki* | 8 | 1 | 3 | 0 |
| *Bufo terrestris* | 9 | 6 | 0 | 0 |
| *Hyla crucifer* | 6 | 1 | 0 | 0 |
| *Pseudacris ornata* | 10 | 0 | 0 | 0 |
| *Gastrophryne carolinensis* | 2 | 4 | 0 | 0 |
| *Rana clamitans* | 2 | 0 | 0 | 0 |
| *Rana utricularia* | 12 | 0 | 1 | 1 |

Table III-5. Movement of all species of amphibians captured (original and recaptured) in drift fences with pitfall traps at Rainbow Bay during FY-1989 and FY-1990. No juveniles of any species were produced in FY-1989.

| Species | 1989 Immigrating Adults | | | 1990 Immigrating Adults | | |
|---|---|---|---|---|---|---|
| | Male | Female | Juveniles | Male | Female | Juveniles |
| **Salamanders** | | | | | | |
| *Ambystoma talpoideum* | 234 | 227 | 0 | 558 | 681 | 0 |
| *Ambystoma opacum* | 785 | 450 | 0 | 608 | 594 | 201 |
| *Ambystoma tigrinum* | 0 | 0 | 0 | 10 | 10 | 0 |
| *Notophthalmus viridescens* | 473 | 607 | 0 | 389 | 725 | 0 |
| *Plethodon glutinosus* | 2 | 8 | 0 | 60 | 42 | 2 |
| *Eurycea bislineata* | 0 | 0 | 0 | 2 | 1 | 0 |
| *Eurycea quadridigitata* | 15 | 14 | 0 | 10 | 3 | 0 |
| **Frogs and Toads** | | | | | | |
| *Scaphiopus holbrooki* | 8 | 0 | 0 | 129 | 38 | 3456 |
| *Bufo terrestris* | 52 | 23 | 0 | 46 | 22 | 1 |
| *Acris gryllus* | 1 | 0 | 0 | 1 | 0 | 0 |
| *Hyla chrysoscelis/versicolor* | 2 | 0 | 0 | 0 | 0 | 0 |
| *Hyla crucifer* | 43 | 41 | 0 | 57 | 92 | 1 |
| *Pseudacris nigrita* | 1 | 4 | 0 | 1 | 0 | 0 |
| *Pseudacris ornata* | 29 | 13 | 0 | 100 | 104 | 13 |
| *Gastrophryne carolinensis* | 82 | 89 | 0 | 27 | 51 | 2596 |
| *Rana catesbeiana* | 0 | 0 | 0 | 0 | 0 | 0 |
| *Rana clamitans* | 1 | 1 | 0 | 0 | 2 | 0 |
| *Rana utricularia* | 1 | 1 | 0 | 21 | 7 | 0 |

the low number of captures both at these sites and at the Rainbow Bay control site (Pechmann et al. 1985, Pechmann and Semlitsch 1986).

Although much of FY-1986 was also comparatively dry, heavy rains during late November and early December provided salamanders with adequate opportunities to migrate to breeding sites. Record numbers of three salamander species entered Rainbow Bay during FY-1986. Large numbers of two of these species, *Ambystoma talpoideum* and *Notophthalmus viridescens*, also entered the refuge ponds. *Ambystoma talpoideum* and *N. viridescens* normally return to breed at the site where they were born (Semlitsch 1981, D. E. Gill, personal communication). Apparently some individuals of these species responded to the elimination of Sun Bay and other disturbances from construction by migrating to the refuge ponds rather than returning to Sun Bay. *Ambystoma talpoideum* populations philopatric to the individual refuge ponds have now been established from the Sun Bay populations.

Preliminary results indicate that the refuge ponds provide adequate salamander breeding habitat. Both *A. talpoideum* and *N. viridescens* have bred in the refuge ponds since FY-1986, and at least some of their larvae successfully developed through metamorphosis each year. The presence of paedomorphic adults provides additional evidence that the refuge ponds provide favorable habitat for salamanders.

Several species of frogs and toads had colonized the refuge ponds during the first two years of the study (Pechmann et al. 1984, Pechmann et al. 1985). These anuran species may be less philopatric than the salamander species that formerly bred at Sun Bay (personal observations), although differences in speed of travel, response to construction, and other factors might also have contributed to their more rapid colonization.

Lack of seasonal pond drying at the refuge ponds may have reduced or eliminated colonization and juvenile production by some species, and promoted it in others. *Pseudacris ornata* seem to prefer to breed in newly-filled temporary ponds, and therefore may not have colonized the refuge ponds extensively. Lack of pond drying may have hindered their reproductive success as well as that of *Scaphiopus holbrooki* and *Gastrophyne carolinensis*, which also usually breed in newly-filled ponds. The largest total numbers of frog and toad juveniles produced were in FY-1985, the year that the liners were installed and the ponds began to hold water for more than short periods, and FY-1988, the year that two of them were artificially dried. Drying reduces the numbers of insect and salamander predators, and may increase nutrients by allowing soil oxidation. On the other hand, *Acris gryllus* prefers more permanent ponds and became more common at the refuge ponds than at Rainbow Bay, which usually dries seasonally.

Refuge ponds should have a hydrologic cycle similar to that of the original breeding site for maximal success. Ponds that hold water for a shorter or longer period of time each year on the average, or dry more or less frequently than the breeding site they replaced, might support a different amphibian community and a lower density and diversity of amphibians (Scott et al. 1986). Our experience with the DWPF refuge ponds has demonstrated that building a perched water table system such as that found in Carolina bays (Schalles 1979) is not an easy task. The original pond design did not hold water well enough, but adding pond liners turned them into permanent ponds. Future mitigation efforts should include attempts to mimic more carefully the natural wetland system through construction of larger ponds, alteration of pond depth and configuration, and experimentation with other types of drainage mechanisms. Such approaches must be coupled with continued surveillance of amphibian colonization patterns, as well as the physical and hydrologic aspects of the ponds, in order to evaluate the success of this type of mitigation.

The refuge pond concept appears to have much potential for mitigating the loss or degradation of amphibian breeding habitat on the SRS as well as at other locations. However, results to date indicate that they may provide only partial mitigation. Several species of amphibians that were formerly common at Sun Bay have not yet successfully colonized the refuge ponds, notably *Ambystoma opacum* and *Ambystoma tigrinum* (Semlitsch 1983a). Breeding population sizes at Sun Bay of these two unsuccessful salamander species were less than 100, compared to over 1000 for the successful salamanders, so we think that the probability that surviving individuals would find and use the refuge ponds was simply much lower. A few *Ambystoma tigrinum* were caught at the refuge ponds, but we never got a male and a female in the same pond at the same time. If mitigation was being undertaken primarily for the benefit of a rare or endangered species, our results suggest that there is no guarantee that they would become established in the new habitat.

Finally, community structure diverged among the three replicate ponds, probably in part due to chance historical effects during initial colonization. Thus, chance alone may result in the establishment of a different amphibian community in artificial wetlands than that which was found in the one they replaced.

Building replacement wetlands as mitigation for the elimination or degradation of natural wetlands is required in many areas under certain conditions. However, there are very little data to indicate whether or not this is a useful exercise. Studies such as ours will be useful to the Department of Energy as well as other groups in planning how to better manage wetland ecosystems and minimize the impacts of man upon them.

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NOTE: This chapter was published in the 23 August 1991 issue of the journal Science, Vol. 253, pages 892-895, and appears here with only minor changes. The U.S. Government retained a license to publish or reproduce this article for U.S. Government purposes, such as this report.

# IV. Declining Amphibian Populations: The Problem of Separating Human Impacts from Natural Fluctuations

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## INTRODUCTION

Evaluation of the reported declines of amphibian populations, some possibly to extinction (1), has been hampered by the dearth of long-term census data on amphibians. Conclusions of National Research Council workshop participants about the status of amphibian populations (1) were based primarily on numerous anecdotal observations. These observations have convinced many that there is a general decline worldwide, although not all species and regions appear to be affected (1, 2). In many individual cases, however, it may be difficult to distinguish declines resulting from human activities from natural population fluctuations

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without long-term data on the natural variation in both real and apparent catchable population sizes (2).

We have monitored amphibian populations at one ephemeral pond, Rainbow Bay, continuously for the past 12 years, the period during which most of the reported declines occurred (1). Although data from any one site cannot be extrapolated to other sites, Rainbow Bay nonetheless provides an important test site for the amphibian decline question because of the extensive data available. The study illustrates how misinterpretations could be made at other locations with less complete data, and the importance of knowing natural population dynamics to interpret human impacts.

## STUDY SITE AND METHODS

Rainbow Bay is a Carolina bay (3, 4) located on the U.S. Department of Energy's 780-$km^2$ Savannah River Site (4) in the upper coastal plain sandhills region in South Carolina. The pond is approximately 1 ha with a maximum water depth of 1.04 m and usually fills during the winter and dries each spring or summer (5). Rainbow Bay and the adjacent terrestrial habitats were protected from most human impacts during our 12-year study, but were altered in the past (6). Anthropogenic factors have been implicated in many of the reported declines and extinctions of amphibian populations, yet others have occurred in protected, seemingly pristine areas (1). Thus, Rainbow Bay's current protected status does not make it an exception with respect to its potential for amphibian declines.

Amphibians migrating to and from the pond have been censused since 21 September 1978 with use of a terrestrial drift fence with pitfall traps that completely surrounds the pond (7). Traps are checked daily, and data to 31 August 1990 are reported here. Upon capture, all amphibians are identified, marked by clipping toes, and released on the opposite side of the fence from where captured.

Five species of salamanders and 11 species of frogs and toads are known to have bred at Rainbow Bay (5). We report data for *Ambystoma opacum* (marbled salamander), *A. talpoideum* (mole salamander), *A. tigri ıum tigrinum* (eastern tiger salamander), and *Pseudacris ornata* (ornate chorus frog) These species were chosen because demographic interpretation of the drift fence data is most straightforward for them (8). The four are primarily terrestrial and fossorial except for the aquatic larval stage (9). Reproductive *A. opacum* migrate to breeding ponds from September to November, whereas breeding migrations of the other three species occur primarily from November to March. Adults spend a few days to weeks at the pond before returning to terrestrial habitats (10). Juveniles metamorphose and emigrate from the pond during the following spring and summer. Age at first reproduction varies considerably, but some individuals of all four species reproduce at one year of age (11, 12, 13).

These species usually return to their natal pond to breed, i.e., they are philopatric (13, 14). Four smaller breeding sites occur within 1 km of Rainbow Bay, and low rates of dispersal connect populations of these species to form metapopulations (15). Immigration and emigration are usually minor components of the population dynamics of these philopatric species, but may be important in long-term persistence (15).

Because individuals of the four species cannot trespass the drift fence, this technique provides a nearly complete census of breeding adults and juvenile recruitment. Terrestrial immatures and adults that skip breeding are not censused, however. Breeding populations had approximately 1:1 or male-biased sex ratios each year; therefore, only data for females are presented. We tested for evidence of a decline in numbers of breeding females or of metamorphosing juveniles.

## RESULTS

Female breeding population sizes fluctuated over three orders of magnitude among years, and juvenile recruitment over five (Fig. IV-1). Each species was common in some years but uncommon or absent in others. Year-to-year variation and short-term trends make it difficult to discern long-term trends. Breeding populations declined over some time periods, but increased over others (Fig. IV-1). Fluctuations in breeding population sizes were not significantly correlated among species (16).

Breeding population sizes vary more than adult population sizes. Adults migrate to ponds only during warm night rains within their breeding season and may skip breeding in years of low rainfall (13, 17). For example, breeding populations of *A. talpoideum, A. tigrinum*, and *P. ornata* were reduced in the driest years (1981, 1985, 1988, 1989; Figs. IV-1, IV-2A), relative to years that immediately preceded or followed them, except for *P. ornata* in 1980 (Fig. IV-1; 11). We used breeding season rainfall as a covariate to remove rainfall-related variance, and tested for partial rank correlations of female breeding population sizes with year, i.e., for trends over time (Fig. IV-1). T he only significant partial correlation with year was for *A. opacum*, and this correlation was positive. No female *A. opacum* were present the first 2 years, and only two during the third, but 594 females bred in 1990 (Fig. IV-1C). There was a significant correlation between the number of breeding females and rainfall for *A. talpoideum* and *A. tigrinum* (Figs. IV-1, IV-2A).

## FIGURE LEGEND

**Fig. IV-1**. Female breeding population sizes (solid bars, left ordinates) and numbers of metamorphosing juveniles (crosshatched bars, right ordinates) at Rainbow Bay each year. Females that entered the pond from September to December were counted with the following calendar year because they contributed to the following year's cohort of juveniles. Kendall's partial rank correlation between the number of breeding females and year, correcting for breeding season rainfall (Fig. IV-2A), was calculated to test for population trends over time: *A. opacum*, tau-b = 0.85, $P <$ 0.002; *A. talpoideum*, tau-b = 0.17, $P$ = 0.46; *A. tigrinum*, tau-b = -0.40, $P$ = 0.12; *P. ornata*, tau-b = -0.16, $P$ = 0.47; $P$ values were calculated from the quantile estimates of S. Maghsoodloo [*J. Statist. Comput. Simul.* **4**, 155 (1975)], $n$ = 11 for *A. opacum*, $n$ = 12 for others. Data for 1979 were eliminated for *A. opacum* because rainfall data were incomplete. Kendall's rank correlations between the number of breeding females and breeding season rainfall were: *A. opacum*, tau-b = 0.16, $P$ = 0.48; *A. talpoideum*, tau-b = 0.52, $P$ = 0.02; *A. tigrinum*, tau-b = 0.47, $P$ = 0.03, *P. ornata*, tau-b = 0.27, $P$ = 0.22; $n$ = 11 for *A. opacum*, $n$ = 12 for others. Year and breeding season rainfall were not significantly correlated; Kendall's rank correlation: *A. opacum*, tau-b = -0.24, $P$ = 0.31, $n$ = 11; other species (Fig. IV-2A), tau-b = -0.21, $P$ = 0.34, $n$ = 12.

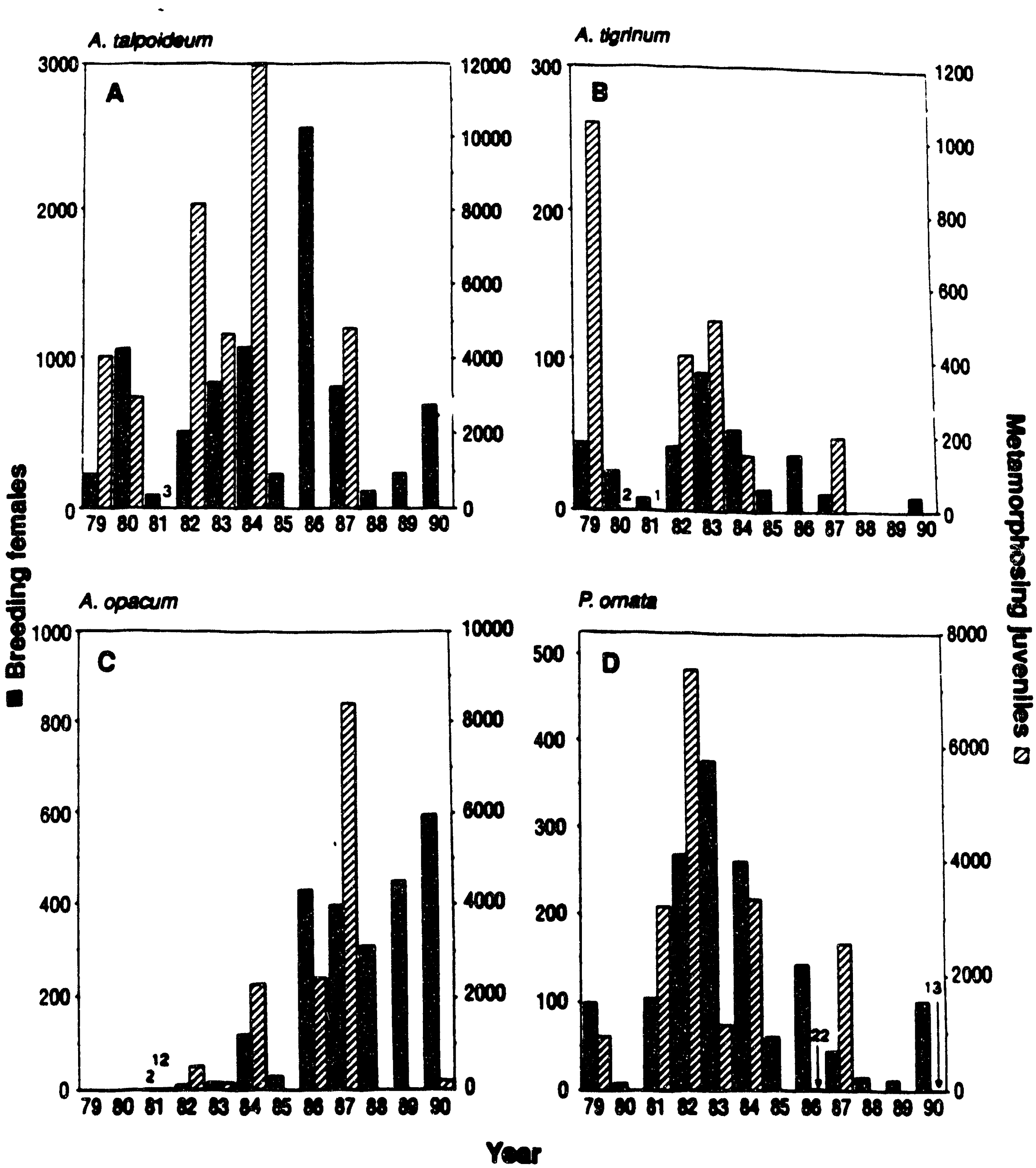
A. talpoideum
A
A. tigrinum
B
A. opacum
C
P. ornata
D
■ Breeding females
Metamorphosing juveniles ▨
Year
79 80 81 82 83 84 85 86 87 88 89 90
3
2
1
12
2
22
13

Figure IV-1.

**Fig. IV-2A.** Rainfall at Rainbow Bay during the November to March breeding migration season of *A. talpoideum, A. tigrinum*, and *P. ornata* (solid bars, left ordinate), with November and December included in the following calendar year, and the number of days Rainbow Bay contained standing water each calendar year until first drying (open bars, right ordinate). Rainfall and pond hydroperiod were significantly correlated; Kendall's rank correlation: tau-b = 0.70, $P$ = 0.002.

**IV-2B**. Rainfall at Blackville, SC, located 35 km east-northeast of Rainbow Bay, from November to March as in IV-2A, 1931 to 1990 (compiled from data provided by NOAA, National Climatic Data Center, Asheville, NC).

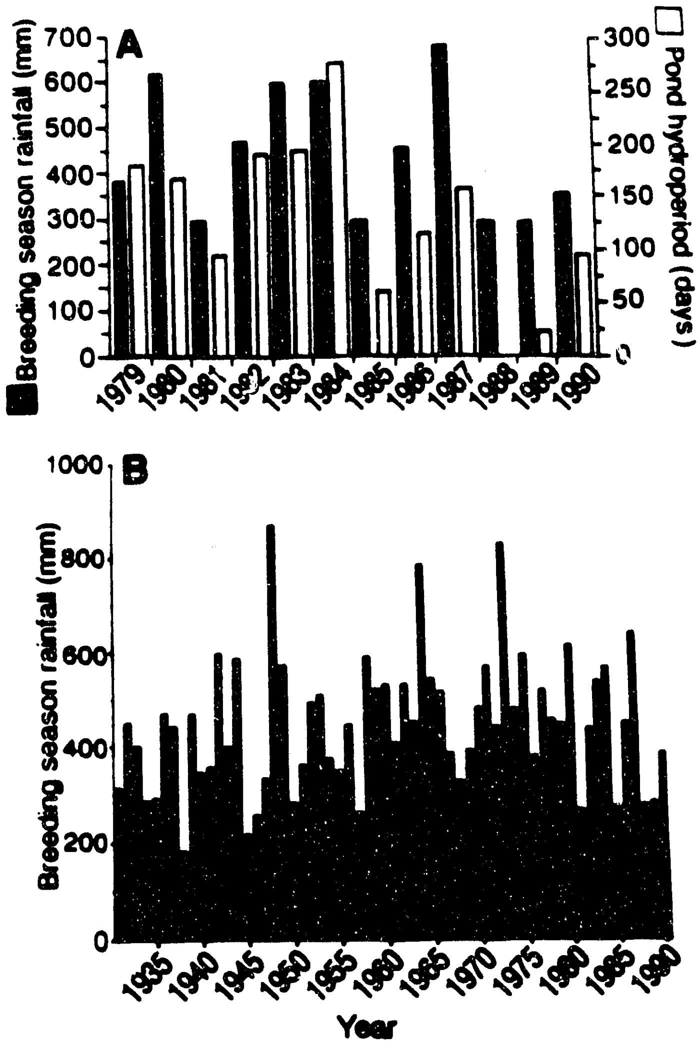


Figure IV-2A and 2B.

Juvenile recruitment of all species was episodic; thousands metamorphosed in some years, few or none in others (Fig. IV-1). Recruitment per female was significantly positively correlated among species for four of six pairwise comparisons (18). Successful recruitment characterized the first 6 years of the study, whereas recruitment failures were far more frequent from 1985 to 1990. From 1979 to 1984, one complete recruitment failure occurred for *P. ornata* (11), with two nearly complete failures for *A. tigrinum* and one for *A. talpoideum*. In contrast, during the last 6 years *A. talpoideum* and *A. tigrinum* had no recruitment in 5 years, and *A. opacum* and *P. ornata* had none in 3 years.

Drought was largely responsible for these recruitment failures. Except for 1980, failures occurred in the 6 years in which Rainbow Bay held water for the fewest number of days, five of which were in the last 6 years (Figs. IV-1 and IV-2A). In 1985 and 1989, the pond dried before any larvae had reached the minimum size for metamorphosis (19), and in 1988 the pond never filled. Evaluation of partial correlations between juvenile recruitment and year, to assess trends over time after correcting for pond hydroperiod and the number of breeding females, was precluded by correlations among the predictor variables (20). Consequently, we calculated simple rank correlations between per capita recruitment and year for each species. Only *A. talpoideum* showed a significant correlation, which was negative, indicating a decline (22). These simple correlations are not very informative, however, because of the confounding correlations and the large number of zero recruitment years, which had tie ranks.

Pond hydroperiod was positively correlated with the breeding population sizes of *A. talpoideum, A. tigrinum*, and *P. ornata* (23). These correlations suggest one reason that these populations have persisted through frequent drought-related recruitment failures. Breeding can be costly in terms of decreased adult survival (11, 13, 24). In dry years, females risk the mortality associated with breeding, yet all larvae perish from early pond drying. Selection may favor a tendency to breed in wet years, with rainfall serving as one predictive cue related to pond hydroperiod. Female breeding population sizes of *A. talpoideum* and *A. tigrinum* were correlated with breeding season rainfall (Figs. IV-1, IV-2A), which in turn was correlated with hydroperiod (Fig. IV-2A). In addition to the potential for selection, lack of rainfall may reduce opportunities to migrate to breeding sites (17) and to forage, decreasing energy stores available for egg production.

## DISCUSSION

We conclude that there have been no declines in these four populations at Rainbow Bay that cannot readily be explained as natural fluctuations related in part to drought. Although one climate model predicts that increases in atmospheric greenhouse gases will result in decreased rainfall in the southeastern United States (25), we are not aware of any evidence that the droughts during our study had an anthropogenic cause. Data from a nearby site show that similar dry periods have occurred in the past, notably in the 1930's (Fig. IV-2B). Our results do suggest that amphibian populations may be useful bioindicators of possible global climate changes.

The fluctuations in our study populations were not controlled only by rainfall, as predation, competition, disturbance (including drought), and other factors may also influence the dynamics of amphibian populations (26, 27). For example, larvae are more likely to attain the minimum size for metamorphosis before a pond dries if larval densities are low or are reduced by predation (27). Intraspecific density-dependence alone may cause wild or even chaotic population fluctuations in amphibians, because of their high intrinsic rate of increase and the time lag between recruitment and maturity (28). Population dynamics can be affected by factors in both the aquatic and terrestrial stages of the life cycle, but little is known about factors affecting the terrestrial stage of pond breeding amphibians (29).

Our data illustrate some cautionary tales for evaluating declines in amphibian populations. Many short-term or two-point subsets of our data easily might have been interpreted as human-caused declines, whereas those same data were interpreted as natural fluctuations in the context of the complete data set. For example, the 30-fold decrease from 1983 to 1989 in the number of breeding female *P. ornata* appears different by itself than following the general increase from 1980 to 1983 (Fig. IV-1D). Large populations may be more likely to be noticed or used by researchers. Anecdotal data therefore may be biased towards observing peak populations that eventually will decline, rather than the reverse.

Alternatively, one easily might mistake a true human-caused population decline as a natural fluctuation, or natural fluctuations might mask a decline. For example, if an unknown human impact had reduced juvenile recruitment at Rainbow Bay over the last six years, we might not have detected it because of the drought related decrease and high variance among years. The persistence of populations despite frequent natural recruitment failures does not necessarily imply that they would persist in the event of similar human caused mortality. Also, natural fluctuations and anthropogenic effects acting together could result in local extinction more easily than either alone. Habitat fragmentation may make populations less resilient to natural downturns, for example.

The observation that animal population sizes, and especially juvenile recruitment, can fluctuate by orders of magnitude is not new. The extent to which amphibian populations can fluctuate has not been well documented, however Hairston (30) concluded that fluctuations in salamander numbers are minor compared to other groups of animals. This conclusion may have resulted from the fact that researchers have not followed a variety of salamander populations for a sufficient time. Hairston cites Rainbow Bay data for *A. tigrinum* for 1979 to 1982 (24), and for *A. talpoideum* from 1979 to 1984 (21). The additional data reported here increase the variation in breeding female *A. tigrinum* from a factor of 5.5- to 90-fold, and that in breeding female *A. talpoideum* from 12.4- to 30-fold. Only part of this variation is in actual population sizes, because adults can skip breeding years. If the annual variation in our data were due primarily to adults that skipped breeding then our data would show that a putative decline could represent nothing more than a catchability artifact. Many amphibian species can be observed easily only at their breeding site, so this problem of interpretation may be a common one.

Fluctuations in breeding population sizes at Rainbow Bay were not synchronous among species. Elsewhere, declining and stable species have been observed to co occur, and sometimes are related phylogenetically (1). Together, these observations suggest that using "indicator species" to assess amphibian declines must be done carefully. In contrast, per capita recruitment was generally synchronous among species at Rainbow Bay; recruitment increased in wet years. This suggests that population increases or decreases may represent natural fluctuations even when several species show similar trends.

*Ambystoma opacum* was not present at Rainbow Bay during the first 2 years of the study (Fig. IV-1C). The regrowth of forests around Rainbow Bay over the last 37 years (6) may have permitted recent colonization or recolonization by *A. opacum*, a woodland species. Alternatively, *A. opacum* occurred at Rainbow Bay in the recent past, but reached a nadir as our study began, similar to *A. tigrinum* in 1988 and 1989. At the extreme, local extinction may have occurred at this nadir, necessitating recolonization from another pond.

Harte and Hoffman (31) provided some of the few published data on the amphibian decline available for comparison with our results. A Colorado population of *A. tigrinum nebulosum* was censused from 1982 to 1988. During this period, the adult population declined while juvenile recruitment was episodic. These data bear a striking resemblance to our data for the eastern subspecies over the same time period (Fig. IV-1B). Harte and Hoffman noted that their census data could be indicative of either natural fluctuations or egg mortality resulting from anthropogenic acidification of ponds during snowmelt, and they presented experimental evidence for the latter hypothesis (31).

The pH of Rainbow Bay was not measured until 1987; 1987 to 1991 pH measurements varied from 5.3 to 6.1 (32), which is within the range that Harte and Hoffman observed egg mortality in *A. t. nebulosum*. It is unlikely, however, that the population dynamics of *A. t. tigrinum* at Rainbow Bay were pH related. Carolina bays are naturally acidic (median pH = 4.6, $n$ = 49 sites), in part because of dissolved organic acids, and there has been no long-term decrease in pH at two Savannah River Site bays sampled several times over the time period of our study (4, 33). We have not observed high mortality or pH-related developmental abnormalities described by Harte and Hoffman in *A. t. tigrinum* eggs at ponds with pH values similar to Rainbow Bay's. There is also no seasonal snow melt to cause episodic acidification at Rainbow Bay.

We conclude that there is no evidence that the declines in amphibian populations observed in other locations have occurred in populations at Rainbow Bay. Factors responsible for amphibian declines or extinctions elsewhere may not have affected this relatively protected site. Understanding of the causes of declines may be enhanced as much by a clear determination of which populations are not affected as which are. Our data strongly support previous admonitions that it may be difficult to distinguish natural population fluctuations from human caused declines (2) and underscore the need for replicated long-term surveys at numerous sites to separate the many confounding factors (1, 34).

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6. Two shallow drainage ditches were dug through the bay, probably in the 1930's, but currently have little effect on water levels. Aerial photographs taken in 1943 and 1951 show Rainbow Bay completely surrounded by agricultural fields. Farming activities ceased after the land was purchased by the government in 1951. The U.S. Forest Service planted *Pinus elliottii* on the land surrounding Rainbow bay in 1953 and 1958. These plantations were treated with a prescribed burn in 1971. The 1953 plantation was clearcut and burned in 1974 and replanted with *P. taeda* in 1975. A 2,000 $m^2$ area located 60 m southeast of the bay was cleared and partially covered with gravel in April 1988. To our knowledge, Rainbow Bay has not

been significantly affected by the Savannah River Site's nuclear production activities.

7. The 440-m-long drift fence is constructed of 50-cm-high aluminum flashing buried 10-15 cm in well-packed soil. The pitfall traps are 40-L buckets located every 10 m on each side of the fence. See J. W. Gibbons and R. D. Semlitsch [*Brimleyana* **7**, 1 (1981)] for discussion of this technique.

8. Data are less easily interpreted for the other species because of trespass across the drift fence, apparent lack of pond philopatry, failure of adults or metamorphosed juveniles to leave the pond basin and therefore be censused at the fence, or a combination of these factors.

9. Terrestrial home ranges of *A. talpoideum* are located 12 to 280 m from their breeding pond [R. D. Semlitsch, *Can J. Zool.* **59**, 315 (1981)] and those of *A. opacum*, 0 to 450 m [P. K. Williams, dissertation, Indiana University, Bloomington, IN (1973)]. There are no paedomorphs at Rainbow Bay because the pond dries annually.

10. *Ambystoma opacum* court and oviposit terrestrially, either in a dry pond basin or near the edge of the water. Eggs hatch after inundation. Courtship and oviposition in the other three species are aquatic.

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16. Kendall's rank correlation, *n* = 12, all NS at experimentwise (Bonferroni correction) alpha = 0.05: *A. tigrinum* vs. *P. ornata*, tau-b = 0.50; *A. tigrinum* vs. *A. talpoideum*, tau-b = 0.41; *A. tigrinum* vs. *A. opacum*, tau-b = -0.31; *P. ornata* vs. *A. talpoideum*, tau-b = 0.15; *P. ornata* vs. *A. opacum*, tau-b = -0.08; *A. talpoideum* vs. *A. opacum*, tau-b = 0.14.

17. R. D. Semlitsch and J. H. K. Pechmann, *Copeia* **1985**, 86 (1985); J. H. K. Pechmann and R. D. Semlitsch, *Can. J. Zool.* **64**, 1116 (1986); R. D. Semlitsch, *Copeia* **1985**, 477 (1985).

18. Kendall's rank correlation, *indicates significance at experimentwise (Bonferroni correction) alpha = 0.05: *A. talpoideum* vs. *A. opacum*, tau-b = 0.86, *n* = 10; *A. talpoideum* vs. *A. tigrinum*, tau-b = 0.81*, *n* = 10; *A. talpoideum* vs. *P. ornata*, tau-b = 0.50, *n* = 12; *A. opacum* vs. *A. tigrinum*, tau-b = 0.79*, *n* = 8; *A. opacum* vs. *P. ornata*, tau-b = 0.81*, *n* = 10; *A. tigrinum* vs. *P. ornata*, tau-b = 0.49, *n* = 10.

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20. Previous analyses found a correlation between juvenile recruitment and pond hydroperiod in *A. talpoideum* [5, 21].

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22. Kendall's rank correlation: *A. talpoideum*, tau-b = -0.53, *P* = 0.02, *n* = 12; *A. opacum*, tau-b = -0.37, *P* = 0.15, *n* = 10; *A. tigrinum*, tau-b = -0.32, *P* = 0.20, *n* = 10; *P. ornata*, tau-b = -0.25, *P* = 0.26, *n* = 12.

23. Kendall's rank correlation, *n* = 12: *A. talpoideum*, tau-b = 0.45, *P* = 0.04; *A. opacum*, tau-b = -0.26, *P* = 0.24; *A. tigrinum*, tau-b = 0.78, *P* = 0.0005; *P. ornata*, tau-b = 0.45, *P* = 0.04.

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34. We are indebted to the many individuals who helped construct the drift fence and check pitfall traps, especially K. L Brown, A. M. Dancewicz, R. A. Estes, P. E. Johns, J. Kemp, G. C. Knight, J. H. McGregor, G. B. Moran, M. K. Nungesser, K. K. Patterson, R. A. Seigel, C. A. Shoemaker, and C. A. West. We thank P. M. Dixon for statistical advice, A. Clement for drafting, and A. E. DeBiase, P. M. Harris, N. G. Hairston, Sr., C. H. Jagoe, P. J. Morin, M. C. Newman, J. C. Pechmann, B. E. Taylor, D. B. Wake, and H. M. Wilbur for comments on the manuscript.

# APPENDIX A

DWPF Water Quality Data

FY-1983 to FY-1990

(summarized by rainfall class and location)

| VARIABLE | MEAN | STD ERROR OF MEAN | MAXIMUM VALUE | MINIMUM VALUE | N |
|---|---|---|---|---|---|
| ------------------------ NO RAINFALL | FY-1983 | UTR CK ABOVE ------------------------ | | | |
| TSS | 3.42 | 0.24 | 7.20 | 1.53 | 33 |
| LTSS | 1.44 | 0.05 | 2.10 | 0.93 | 33 |
| TURB | 6.00 | 2.00 | 8.00 | 4.00 | 2 |
| LTURB | 1.90 | 0.29 | 2.20 | 1.61 | 2 |
| PTSASH | 44.18 | 1.53 | 56.56 | 12.60 | 33 |
| SCOND | 26.44 | 1.04 | 35.29 | 15.25 | 26 |
| LSCOND | 3.29 | 0.04 | 3.59 | 2.79 | 26 |
| ------------------------ NO RAINFALL | FY-1983 | TINKER CK ------------------------ | | | |
| TSS | 3.82 | 0.36 | 11.14 | 1.81 | 31 |
| LTSS | 1.51 | 0.06 | 2.50 | 1.03 | 31 |
| TURB | 1.00 | | 1.00 | 1.00 | 1 |
| LTURB | 0.69 | | 0.69 | 0.69 | 1 |
| PTSASH | 42.54 | 1.52 | 52.30 | 19.40 | 30 |
| SCOND | 49.55 | 2.04 | 68.64 | 32.81 | 25 |
| LSCOND | 3.90 | 0.04 | 4.24 | 3.52 | 25 |
| ------------------------ NO RAINFALL | FY-1983 | MCQUEEN BR ------------------------ | | | |
| TSS | 5.38 | 0.31 | 8.56 | 3.37 | 22 |
| LTSS | 1.83 | 0.05 | 2.26 | 1.47 | 22 |
| TURB | 5.00 | 0.00 | 5.00 | 5.00 | 2 |
| LTURB | 1.79 | 0.00 | 1.79 | 1.79 | 2 |
| PTSASH | 58.64 | 1.75 | 69.86 | 34.11 | 22 |
| SCOND | 58.89 | 3.90 | 81.59 | 32.38 | 15 |
| LSCOND | 4.06 | 0.07 | 4.41 | 3.51 | 15 |
| ------------------------ NO RAINFALL | FY-1983 | UTR CK MID. ------------------------ | | | |
| TSS | 4.04 | 0.42 | 8.58 | 2.02 | 17 |
| LTSS | 1.57 | 0.07 | 2.26 | 1.11 | 17 |
| TURB | 5.00 | | 5.00 | 5.00 | 1 |
| LTURB | 1.79 | | 1.79 | 1.79 | 1 |
| PTSASH | 47.39 | 1.13 | 52.67 | 36.60 | 15 |
| SCOND | 36.50 | 1.99 | 46.17 | 23.11 | 13 |
| LSCOND | 3.61 | 0.06 | 3.85 | 3.18 | 13 |
| ------------------------ NO RAINFALL | FY-1983 | CROUCH BR ------------------------ | | | |
| TSS | | | | | |
| LTSS | | | | | |
| TURB | | | | | |
| LTURB | | | | | |
| PTSASH | | | | | |
| SCOND | | | | | |
| LSCOND | | | | | |

| VARIABLE | MEAN | STD ERROR OF MEAN | MAXIMUM VALUE | MINIMUM VALUE | N |
|---|---|---|---|---|---|
| ------------ | NO RAINFALL | FY-1983 | UTR BR BELOW | ------------ | |
| TSS | 4.10 | 0.49 | 9.02 | 0.89 | 17 |
| LTSS | 1.56 | 0.09 | 2.30 | 0.64 | 17 |
| TURB | 5.00 | | 5.00 | 5.00 | 1 |
| LTURB | 1.79 | | 1.79 | 1.79 | 1 |
| PTSASH | 45.73 | 2.33 | 55.47 | 15.09 | 16 |
| SCOND | 36.60 | 2.05 | 47.33 | 23.96 | 14 |
| LSCOND | 3.61 | 0.06 | 3.88 | 3.22 | 14 |
| ------------ | NO RAINFALL | FY-1984 | UTR CK ABOVE | ------------ | |
| TSS | 3.14 | 0.31 | 6.35 | 1.79 | 20 |
| LTSS | 1.37 | 0.07 | 1.99 | 1.02 | 20 |
| TURB | 2.87 | 0.41 | 7.00 | 1.00 | 18 |
| LTURB | 1.27 | 0.09 | 2.08 | 0.69 | 18 |
| PTSASH | 39.31 | 1.49 | 49.48 | 24.25 | 18 |
| SCOND | 13.14 | 2.19 | 30.48 | 1.26 | 20 |
| LSCOND | 2.39 | 0.17 | 3.45 | 0.81 | 20 |
| ------------ | NO RAINFALL | FY-1984 | TINKER CK | ------------ | |
| TSS | 3.50 | 0.43 | 6.65 | 1.32 | 18 |
| LTSS | 1.43 | 0.09 | 2.04 | 0.84 | 18 |
| TURB | 4.62 | 1.54 | 27.00 | 1.00 | 16 |
| LTURB | 1.48 | 0.15 | 3.33 | 0.69 | 16 |
| PTSASH | 39.32 | 2.11 | 54.40 | 24.20 | 16 |
| SCOND | 13.96 | 2.10 | 31.34 | 1.54 | 18 |
| LSCOND | 2.48 | 0.18 | 3.48 | 0.93 | 18 |
| ------------ | NO RAINFALL | FY-1984 | MCQUEEN BR | ------------ | |
| TSS | 27.69 | 11.26 | 233.82 | 2.74 | 20 |
| LTSS | 2.75 | 0.22 | 5.46 | 1.32 | 20 |
| TURB | 41.67 | 21.35 | 390.00 | 1.00 | 18 |
| LTURB | 2.66 | 0.34 | 5.97 | 0.69 | 18 |
| PTSASH | 72.51 | 1.70 | 85.02 | 58.12 | 18 |
| SCOND | 36.30 | 14.28 | 305.50 | 6.02 | 20 |
| LSCOND | 3.20 | 0.16 | 5.73 | 1.95 | 20 |
| ------------ | NO RAINFALL | FY-1984 | UTR CK MID. | ------------ | |
| TSS | 4.77 | 0.84 | 9.52 | 2.01 | 10 |
| LTSS | 1.67 | 0.14 | 2.35 | 1.10 | 10 |
| TURB | 3.78 | 0.87 | 9.00 | 0.00 | 9 |
| LTURB | 1.40 | 0.23 | 2.30 | 0.00 | 9 |
| PTSASH | 45.02 | 2.15 | 53.11 | 38.71 | 9 |
| SCOND | 14.74 | 3.49 | 40.18 | 1.50 | 10 |
| LSCOND | 2.52 | 0.24 | 3.72 | 0.91 | 10 |

| VARIABLE | MEAN | STD ERROR OF MEAN | MAXIMUM VALUE | MINIMUM VALUE | N |
|---|---|---|---|---|---|
| ------------------------ NO RAINFALL FY-1984 CROUCH BR ---------------------------- | | | | | |
| TSS | | | | | |
| LTSS | | | | | |
| TURB | | | | | |
| LTURB | | | | | |
| PTSASH | | | | | |
| SCOND | | | | | |
| LSCOND | | | | | |
| ------------------------ NO RAINFALL FY-1984 UTR BR BELOW ---------------------------- | | | | | |
| TSS | 4.95 | 0.75 | 8.82 | 2.86 | 10 |
| LTSS | 1.72 | 0.12 | 2.28 | 1.35 | 10 |
| TURB | 4.01 | 0.53 | 7.00 | 1.00 | 9 |
| LTURB | 1.56 | 0.12 | 2.08 | 0.69 | 9 |
| PTSASH | 42.90 | 2.77 | 58.28 | 34.38 | 9 |
| SCOND | 14.85 | 2.22 | 29.32 | 1.49 | 10 |
| LSCOND | 2.62 | 0.21 | 3.41 | 0.91 | 10 |
| ------------------------ NO RAINFALL FY-1985 UTR CK ABOVE ---------------------------- | | | | | |
| TSS | 6.83 | 1.57 | 24.90 | 1.30 | 16 |
| LTSS | 1.83 | 0.17 | 3.25 | 0.83 | 16 |
| TURB | 3.49 | 0.63 | 11.50 | 1.50 | 16 |
| LTURB | 1.40 | 0.11 | 2.53 | 0.92 | 16 |
| PTSASH | 42.55 | 3.45 | 57.00 | 12.87 | 16 |
| SCOND | 19.71 | 1.64 | 39.37 | 11.85 | 15 |
| LSCOND | 3.00 | 0.07 | 3.70 | 2.55 | 15 |
| ------------------------ NO RAINFALL FY-1985 TINKER CK ---------------------------- | | | | | |
| TSS | 6.84 | 1.40 | 27.60 | 1.40 | 19 |
| LTSS | 1.86 | 0.14 | 3.35 | 0.88 | 19 |
| TURB | 3.72 | 0.54 | 10.80 | 1.20 | 19 |
| LTURB | 1.45 | 0.10 | 2.47 | 0.79 | 19 |
| PTSASH | 48.20 | 1.71 | 59.00 | 32.77 | 19 |
| SCOND | 25.97 | 2.41 | 34.97 | 5.93 | 14 |
| LSCOND | 3.21 | 0.13 | 3.58 | 1.94 | 14 |
| ------------------------ NO RAINFALL FY-1985 MCQUEEN BR ---------------------------- | | | | | |
| TSS | 8.13 | 0.83 | 12.18 | 4.70 | 11 |
| LTSS | 2.17 | 0.09 | 2.58 | 1.74 | 11 |
| TURB | 12.43 | 2.77 | 32.00 | 5.20 | 11 |
| LTURB | 2.44 | 0.16 | 3.50 | 1.82 | 11 |
| PTSASH | 69.84 | 1.62 | 79.30 | 60.73 | 11 |
| SCOND | 58.18 | 8.88 | 121.23 | 22.73 | 10 |
| LSCOND | 3.99 | 0.14 | 4.81 | 3.17 | 10 |

| VARIABLE | MEAN | STD ERROR OF MEAN | MAXIMUM VALUE | MINIMUM VALUE | N |
|---|---|---|---|---|---|
| ------------------------ NO RAINFALL | | FY-1985 | UTR CK MID. ---------------------------- | | |
| TSS | 6.49 | 0.99 | 13.00 | 2.60 | 10 |
| LTSS | 1.94 | 0.13 | 2.64 | 1.28 | 10 |
| TURB | 3.92 | 0.53 | 6.90 | 2.10 | 10 |
| LTURB | 1.55 | 0.10 | 2.07 | 1.13 | 10 |
| PTSASH | 48.33 | 3.14 | 57.00 | 25.09 | 10 |
| SCOND | 19.45 | 0.84 | 21.93 | 13.76 | 9 |
| LSCOND | 3.01 | 0.05 | 3.13 | 2.69 | 9 |
| ------------------------ NO RAINFALL | | FY-1985 | CROUCH BR ---------------------------- | | |
| TSS | 35.00 | 17.71 | 70.00 | 12.80 | 3 |
| LTSS | 3.34 | 0.48 | 4.26 | 2.62 | 3 |
| TURB | 79.77 | 45.59 | 170.00 | 23.30 | 3 |
| LTURB | 4.06 | 0.57 | 5.14 | 3.19 | 3 |
| PTSASH | 85.43 | 1.50 | 88.40 | 83.60 | 3 |
| SCOND | 75.26 | 8.21 | 92.26 | 63.83 | 3 |
| LSCOND | 4.36 | 0.11 | 4.54 | 4.17 | 3 |
| ------------------------ NO RAINFALL | | FY-1985 | UTR BR BELOW ---------------------------- | | |
| TSS | 5.79 | 0.78 | 9.50 | 3.10 | 10 |
| LTSS | 1.86 | 0.11 | 2.35 | 1.41 | 10 |
| TURB | 4.21 | 0.60 | 7.80 | 2.60 | 10 |
| LTURB | 1.60 | 0.11 | 2.17 | 1.28 | 10 |
| PTSASH | 50.19 | 1.36 | 58.00 | 43.80 | 10 |
| SCOND | 20.79 | 0.99 | 24.87 | 14.90 | 9 |
| LSCOND | 3.07 | 0.05 | 3.25 | 2.77 | 9 |
| ------------------------ NO RAINFALL | | FY-1986 | UTR CK ABOVE ---------------------------- | | |
| TSS | 8.93 | 2.39 | 43.90 | 2.90 | 18 |
| LTSS | 2.01 | 0.16 | 3.80 | 1.36 | 18 |
| TURB | 4.03 | 0.96 | 19.00 | 1.30 | 18 |
| LTURB | 1.45 | 0.12 | 2.99 | 0.83 | 18 |
| PTSASH | 54.76 | 1.21 | 66.70 | 44.80 | 18 |
| SCOND | 16.99 | 0.39 | 20.30 | 14.40 | 18 |
| LSCOND | 2.89 | 0.02 | 3.06 | 2.73 | 18 |
| ------------------------ NO RAINFALL | | FY-1986 | TINKER CK ---------------------------- | | |
| TSS | 6.37 | 1.38 | 25.60 | 2.20 | 17 |
| LTSS | 1.82 | 0.14 | 3.28 | 1.16 | 17 |
| TURB | 3.22 | 0.49 | 9.70 | 0.90 | 17 |
| LTURB | 1.36 | 0.10 | 2.37 | 0.64 | 17 |
| PTSASH | 50.28 | 1.90 | 56.70 | 30.30 | 17 |
| SCOND | 33.21 | 1.01 | 41.70 | 26.70 | 17 |
| LSCOND | 3.53 | 0.03 | 3.75 | 3.32 | 17 |

| VARIABLE | MEAN | STD ERROR OF MEAN | MAXIMUM VALUE | MINIMUM VALUE | N |
|---|---|---|---|---|---|
| ------------------------- NO RAINFALL | FY-1986 | MCQUEEN BR ---------------------------- | | | |
| TSS | 16.02 | 3.57 | 35.50 | 5.10 | 9 |
| LTSS | 2.67 | 0.20 | 3.60 | 1.81 | 9 |
| TURB | 19.89 | 6.20 | 56.00 | 6.40 | 9 |
| LTURB | 2.71 | 0.28 | 4.04 | 2.00 | 9 |
| PTSASH | 78.86 | 2.37 | 89.00 | 65.70 | 9 |
| SCOND | 85.50 | 9.91 | 133.20 | 54.00 | 9 |
| LSCOND | 4.41 | 0.11 | 4.90 | 4.01 | 9 |
| ------------------------ NO RAINFALL | FY-1986 | UTR CK MID. ---------------------------- | | | |
| TSS | 8.33 | 2.09 | 19.20 | 3.10 | 8 |
| LTSS | 2.07 | 0.21 | 3.01 | 1.41 | 8 |
| TURB | 4.72 | 1.17 | 13.00 | 1.40 | 9 |
| LTURB | 1.61 | 0.18 | 2.64 | 0.88 | 9 |
| PTSASH | 55.48 | 2.68 | 68.40 | 44.40 | 8 |
| SCOND | 23.82 | 1.00 | 30.00 | 20.80 | 9 |
| LSCOND | 3.21 | 0.04 | 3.43 | 3.08 | 9 |
| ------------------------ NO RAINFALL | FY-1986 | CROUCH BR ---------------------------- | | | |
| TSS | 105.13 | 27.51 | 217.10 | 16.10 | 9 |
| LTSS | 4.28 | 0.34 | 5.38 | 2.84 | 9 |
| TURB | 177.28 | 46.07 | 365.00 | 19.00 | 9 |
| LTURB | 4.79 | 0.35 | 5.90 | 2.99 | 9 |
| PTSASH | 86.40 | 1.67 | 90.00 | 76.40 | 9 |
| SCOND | 97.33 | 4.85 | 125.20 | 76.70 | 9 |
| LSCOND | 4.58 | 0.05 | 4.84 | 4.35 | 9 |
| ------------------------ NO RAINFALL | FY-1986 | UTR BR BELOW ---------------------------- | | | |
| TSS | 7.04 | 1.33 | 14.30 | 3.30 | 9 |
| LTSS | 1.99 | 0.15 | 2.73 | 1.46 | 9 |
| TURB | 4.60 | 1.09 | 12.00 | 2.20 | 9 |
| LTURB | 1.61 | 0.16 | 2.56 | 1.16 | 9 |
| PTSASH | 54.24 | 2.59 | 72.10 | 45.30 | 9 |
| SCOND | 24.68 | 1.24 | 33.20 | 21.70 | 9 |
| LSCOND | 3.24 | 0.04 | 3.53 | 3.12 | 9 |
| ------------------------ NO RAINFALL | FY-1987 | UTR CK ABOVE ---------------------------- | | | |
| TSS | 5.00 | 0.61 | 7.80 | 3.20 | 8 |
| LTSS | 1.76 | 0.10 | 2.17 | 1.44 | 8 |
| TURB | 2.70 | 0.77 | 7.30 | 0.90 | 8 |
| LTURB | 1.19 | 0.18 | 2.12 | 0.64 | 8 |
| PTSASH | 52.68 | 1.67 | 61.50 | 45.50 | 8 |
| SCOND | 16.85 | 0.93 | 21.70 | 14.60 | 8 |
| LSCOND | 2.87 | 0.05 | 3.12 | 2.75 | 8 |

| VARIABLE | MEAN | STD ERROR OF MEAN | MAXIMUM VALUE | MINIMUM VALUE | N |
|---|---|---|---|---|---|
| ------------------------ NO RAINFALL | FY-1987 | TINKER CR ---------------------------- | | | |
| TSS | 4.36 | 0.45 | 6.10 | 2.80 | 8 |
| LTSS | 1.65 | 0.08 | 1.96 | 1.34 | 8 |
| TURB | 2.21 | 0.29 | 3.40 | 1.00 | 8 |
| LTURB | 1.14 | 0.10 | 1.48 | 0.69 | 8 |
| PTSASH | 51.21 | 1.90 | 58.30 | 42.90 | 8 |
| SCOND | 28.86 | 1.55 | 35.50 | 24.30 | 8 |
| LSCOND | 3.39 | 0.05 | 3.59 | 3.23 | 8 |
| ------------------------ NO RAINFALL | FY-1987 | MCQUEEN BR ---------------------------- | | | |
| TSS | 11.13 | 2.36 | 22.00 | 4.30 | 8 |
| LTSS | 2.37 | 0.19 | 3.14 | 1.67 | 8 |
| TURB | 14.13 | 4.86 | 40.50 | 3.20 | 8 |
| LTURB | 2.41 | 0.28 | 3.73 | 1.44 | 8 |
| PTSASH | 80.60 | 1.96 | 85.00 | 70.00 | 8 |
| SCOND | 68.90 | 6.73 | 101.50 | 45.90 | 8 |
| LSCOND | 4.21 | 0.10 | 4.63 | 3.85 | 8 |
| ------------------------ NO RAINFALL | FY-1987 | UTR CK MID. ---------------------------- | | | |
| TSS | 5.20 | 0.74 | 6.80 | 3.70 | 4 |
| LTSS | 1.80 | 0.12 | 2.05 | 1.55 | 4 |
| TURB | 2.98 | 0.89 | 5.40 | 1.30 | 4 |
| LTURB | 1.31 | 0.22 | 1.86 | 0.83 | 4 |
| PTSASH | 57.38 | 1.42 | 60.00 | 54.10 | 4 |
| SCOND | 22.60 | 1.07 | 24.70 | 20.10 | 4 |
| LSCOND | 3.16 | 0.05 | 3.25 | 3.05 | 4 |
| ------------------------ NO RAINFALL | FY-1987 | CROUCH BR ---------------------------- | | | |
| TSS | 91.50 | 50.12 | 180.20 | 6.70 | 3 |
| LTSS | 3.91 | 0.96 | 5.20 | 2.04 | 3 |
| TURB | 179.50 | 95.58 | 350.00 | 8.50 | 3 |
| LTURB | 4.44 | 1.11 | 5.86 | 2.25 | 3 |
| PTSASH | 86.17 | 4.29 | 90.80 | 77.60 | 3 |
| SCOND | 96.57 | 3.44 | 102.40 | 90.50 | 3 |
| LSCOND | 4.58 | 0.04 | 4.64 | 4.52 | 3 |
| ------------------------ NO RAINFALL | FY-1987 | UTR BR BELOW ---------------------------- | | | |
| TSS | 7.75 | 2.72 | 15.90 | 4.70 | 4 |
| LTSS | 2.05 | 0.26 | 2.83 | 1.74 | 4 |
| TURB | 3.60 | 1.10 | 6.10 | 1.60 | 4 |
| LTURB | 1.43 | 0.25 | 1.96 | 0.96 | 4 |
| PTSASH | 55.57 | 4.07 | 63.50 | 50.00 | 3 |
| SCOND | 23.05 | 0.74 | 25.10 | 21.60 | 4 |
| LSCOND | 3.18 | 0.03 | 3.26 | 3.12 | 4 |

| VARIABLE | MEAN | STD ERROR OF MEAN | MAXIMUM VALUE | MINIMUM VALUE | N |
|---|---|---|---|---|---|
| ------------------------ NO RAINFALL | FY-1988 | UTR CK ABOVE ------------------------------ | | | |
| TSS | 4.27 | 0.86 | 7.90 | 2.10 | 6 |
| LTSS | 1.60 | 0.16 | 2.19 | 1.13 | 6 |
| TURB | 1.37 | 0.23 | 2.20 | 0.70 | 6 |
| LTURB | 0.84 | 0.10 | 1.16 | 0.53 | 6 |
| PTSASH | 53.30 | 1.40 | 57.40 | 47.60 | 6 |
| SCOND | 14.70 | 0.33 | 16.10 | 14.00 | 6 |
| LSCOND | 2.75 | 0.02 | 2.84 | 2.71 | 6 |
| ------------------------ NO RAINFALL | FY-1988 | TINKER CK ---------------------------- | | | |
| TSS | 7.82 | 2.30 | 17.50 | 2.50 | 6 |
| LTSS | 2.01 | 0.25 | 2.92 | 1.25 | 6 |
| TURB | 2.63 | 0.59 | 4.50 | 0.80 | 6 |
| LTURB | 1.21 | 0.18 | 1.70 | 0.59 | 6 |
| PTSASH | 57.08 | 2.99 | 71.70 | 52.00 | 6 |
| SCOND | 31.82 | 1.53 | 36.10 | 27.70 | 6 |
| LSCOND | 3.49 | 0.05 | 3.61 | 3.36 | 6 |
| ------------------------ NO RAINFALL | FY-1988 | MCQUEEN BR ---------------------------- | | | |
| TSS | 5.80 | 1.36 | 10.30 | 2.10 | 6 |
| LTSS | 1.82 | 0.20 | 2.42 | 1.13 | 6 |
| TURB | 6.90 | 3.02 | 21.10 | 1.70 | 6 |
| LTURB | 1.77 | 0.32 | 3.09 | 0.99 | 6 |
| PTSASH | 75.37 | 3.14 | 85.40 | 66.70 | 6 |
| SCOND | 137.72 | 46.21 | 349.00 | 58.10 | 6 |
| LSCOND | 4.71 | 0.28 | 5.86 | 4.08 | 6 |
| ------------------------ NO RAINFALL | FY-1988 | UTR CK MID. ---------------------------- | | | |
| TSS | 5.73 | 1.27 | 7.60 | 3.30 | 3 |
| LTSS | 1.87 | 0.21 | 2.15 | 1.46 | 3 |
| TURB | 2.0[illegible] | 0.51 | 2.70 | 1.00 | 3 |
| LTURB | 1.07 | 0.19 | 1.31 | 0.69 | 3 |
| PTSASH | 48.07 | 7.38 | 55.60 | 33.30 | 3 |
| SCOND | 20.80 | 1.07 | 22.90 | 19.40 | 3 |
| LSCOND | 3.08 | 0.05 | 3.17 | 3.01 | 3 |
| ------------------------ NO RAINFALL | FY-1988 | CROUCH BR ---------------------------- | | | |
| TSS | 13.60 | 4.17 | 18.40 | 5.30 | 3 |
| LTSS | 2.57 | 0.36 | 2.97 | 1.84 | 3 |
| TURB | 21.37 | 8.64 | 36.00 | 6.10 | 3 |
| LTURB | 2.90 | 0.49 | 3.61 | 1.96 | 3 |
| PTSASH | 78.10 | 2.42 | 81.90 | 73.60 | 3 |
| SCOND | 106.30 | 12.23 | 120.00 | 81.90 | 3 |
| LSCOND | 4.66 | 0.12 | 4.80 | 4.42 | 3 |

| VARIABLE | MEAN | STD ERROR OF MEAN | MAXIMUM VALUE | MINIMUM VALUE | N |
|---|---|---|---|---|---|
| ------------------------ | NO RAINFALL | FY-1988 | UTR BR BELOW | ---------------------------- | |
| TSS | 5.43 | 0.87 | 6.50 | 3.70 | 3 |
| LTSS | 1.84 | 0.15 | 2.01 | 1.55 | 3 |
| TURB | 1.90 | 0.47 | 2.60 | 1.00 | 3 |
| LTURB | 1.04 | 0.18 | 1.28 | 0.69 | 3 |
| PTSASH | 53.80 | 2.66 | 57.40 | 48.60 | 3 |
| SCOND | 21.47 | 1.08 | 23.50 | 19.80 | 3 |
| LSCOND | 3.11 | 0.05 | 3.20 | 3.03 | 3 |
| ------------------------ | NO RAINFALL | FY-1989 | UTR CK ABOVE | ---------------------------- | |
| TSS | 3.60 | 0.43 | 4.50 | 2.10 | 6 |
| LTSS | 1.50 | 0.10 | 1.70 | 1.13 | 6 |
| TURB | 0.73 | 0.26 | 2.00 | 0.32 | 6 |
| LTURB | 0.50 | 0.13 | 1.10 | 0.28 | 6 |
| PTSASH | 49.87 | 1.71 | 57.50 | 46.50 | 6 |
| SCOND | 14.92 | 0.33 | 16.40 | 14.20 | 6 |
| LSCOND | 2.77 | 0.02 | 2.86 | 2.72 | 6 |
| ------------------------ | NO RAINFALL | FY-1989 | TINKER CK | ---------------------------- | |
| TSS | 5.67 | 1.63 | 12.50 | 1.90 | 6 |
| LTSS | 1.76 | 0.23 | 2.60 | 1.06 | 6 |
| TURB | 1.63 | 0.55 | 3.30 | 0.38 | 6 |
| LTURB | 0.85 | 0.21 | 1.46 | 0.32 | 6 |
| PTSASH | 52.52 | 2.48 | 60.00 | 43.2 | 6 |
| SCOND | 30.68 | 1.44 | 34.80 | 27.10 | 6 |
| LSCOND | 3.45 | 0.05 | 3.58 | 3.34 | 6 |
| ------------------------ | NO RAINFALL | FY-1989 | MCQUEEN BR | ---------------------------- | |
| TSS | 5.25 | 1.13 | 9.10 | 2.60 | 6 |
| LTSS | 1.75 | 0.18 | 2.31 | 1.28 | 6 |
| TURB | 6.90 | 2.41 | 18.00 | 2.00 | 6 |
| LTURB | 1.87 | 0.27 | 2.94 | 1.10 | 6 |
| PTSASH | 76.90 | 2.04 | 83.50 | 73.00 | 6 |
| SCOND | 92.83 | 24.14 | 180.00 | 41.20 | 6 |
| LSCOND | 4.39 | 0.24 | 5.20 | 3.74 | 6 |
| ------------------------ | NO RAINFALL | FY-1989 | UTR CK MID. | ---------------------------- | |
| TSS | 4.23 | 0.94 | 6.00 | 2.80 | 3 |
| LTSS | 1.62 | 0.18 | 1.95 | 1.34 | 3 |
| TURB | 1.07 | 0.57 | 2.20 | 0.40 | 3 |
| LTURB | 0.66 | 0.26 | 1.16 | 0.34 | 3 |
| PTSASH | 53.03 | 0.67 | 53.80 | 51.70 | 3 |
| SCOND | 22.17 | 1.62 | 25.40 | 20.50 | 3 |
| LSCOND | 3.14 | 0.07 | 3.27 | 3.07 | 3 |

| VARIABLE | MEAN | STD ERROR OF MEAN | MAXIMUM VALUE | MINIMUM VALUE | N |
|---|---|---|---|---|---|
| ------------------------ NO RAINFALL | FY-1989 | CROUCH BR ---------------------------- | | | |
| TSS | 32.93 | 14.33 | 55.40 | 6.30 | 3 |
| LTSS | 3.22 | 0.63 | 4.03 | 1.99 | 3 |
| TURB | 66.63 | 30.87 | 110.00 | 6.90 | 3 |
| LTURB | 3.73 | 0.84 | 4.71 | 2.07 | 3 |
| PTSASH | 86.13 | 1.88 | 88.80 | 82.50 | 3 |
| SCOND | 99.60 | 4.33 | 107.00 | 92.00 | 3 |
| LSCOND | 4.61 | 0.04 | 4.68 | 4.53 | 3 |
| ------------------------ NO RAINFALL | FY-1989 | UTR BR BELOW ---------------------------- | | | |
| TSS | 5.33 | 1.39 | 7.40 | 2.70 | 3 |
| LTSS | 1.79 | 0.25 | 2.13 | 1.31 | 3 |
| TURB | 1.48 | 0.92 | 3.30 | 0.43 | 3 |
| LTURB | 0.78 | 0.34 | 1.46 | 0.36 | 3 |
| PTSASH | 58.80 | 3.05 | 64.90 | 55.60 | 3 |
| SCOND | 23.17 | 1.72 | 26.60 | 21.30 | 3 |
| LSCOND | 3.18 | 0.07 | 3.32 | 3.10 | 3 |
| ------------------------ NO RAINFALL | FY-1990 | UTR CK ABOVE ---------------------------- | | | |
| TSS | 4.85 | 0.49 | 6.40 | 3.30 | 6 |
| LTSS | 1.75 | 0.09 | 2.00 | 1.46 | 6 |
| TURB | 1.03 | 0.19 | 1.60 | 0.52 | 6 |
| LTURB | 0.69 | 0.09 | 0.96 | 0.42 | 6 |
| PTSASH | 55.92 | 1.24 | 60.90 | 52.40 | 6 |
| SCOND | 15.30 | 0.35 | 16.40 | 14.40 | 6 |
| LSCOND | 2.79 | 0.02 | 2.86 | 2.73 | 6 |
| ------------------------ NO RAINFALL | FY-1990 | TINKER CK ---------------------------- | | | |
| TSS | 9.93 | 0.93 | 12.20 | 6.40 | 6 |
| LTSS | 2.37 | 0.09 | 2.58 | 2.00 | 6 |
| TURB | 2.32 | 0.32 | 2.80 | 0.72 | 6 |
| LTURB | 1.17 | 0.13 | 1.34 | 0.54 | 6 |
| PTSASH | 52.18 | 2.74 | 56.70 | 39.30 | 6 |
| SCOND | 32.28 | 1.72 | 39.30 | 27.70 | 6 |
| LSCOND | 3.50 | 0.05 | 3.70 | 3.36 | 6 |
| ------------------------ NO RAINFALL | FY-1990 | MCQUEEN BR ---------------------------- | | | |
| TSS | 3.92 | 0.48 | 5.90 | 2.50 | 6 |
| LTSS | 1.57 | 0.09 | 1.93 | 1.25 | 6 |
| TURB | 3.02 | 0.31 | 4.20 | 2.00 | 6 |
| LTURB | 1.38 | 0.08 | 1.65 | 1.10 | 6 |
| PTSASH | 75.58 | 1.75 | 81.80 | 70.50 | 6 |
| SCOND | 54.82 | 4.54 | 75.10 | 45.40 | 6 |
| LSCOND | 4.01 | 0.08 | 4.33 | 3.84 | 6 |

| VARIABLE | MEAN | STD ERROR OF MEAN | MAXIMUM VALUE | MINIMUM VALUE | N |
|---|---|---|---|---|---|
| ------------------------ NO RAINFALL | FY-1990 | UTR CK MID. | ---------------------------- | | |
| TSS | 6.87 | 0.44 | 7.40 | 6.00 | 3 |
| LTSS | 2.06 | 0.06 | 2.12 | 1.95 | 3 |
| TURB | 1.68 | 0.42 | 2.20 | 0.84 | 3 |
| LTURB | 0.96 | 0.17 | 1.16 | 0.61 | 3 |
| PTSASH | 55.13 | 1.51 | 58.10 | 53.20 | 3 |
| SCOND | 20.73 | 0.63 | 21.60 | 19.50 | 3 |
| LSCOND | 3.08 | 0.03 | 3.12 | 3.02 | 3 |
| ------------------------ NO RAINFALL | FY-1990 | CROUCH BR | ---------------------------- | | |
| TSS | 27.00 | 15.82 | 58.50 | 8.70 | 3 |
| LTSS | 3.02 | 0.55 | 4.09 | 2.27 | 3 |
| TURB | 29.97 | 14.76 | 55.00 | 3.90 | 3 |
| LTURB | 3.02 | 0.74 | 4.02 | 1.59 | 3 |
| PTSASH | 74.13 | 5.48 | 80.30 | 63.20 | 3 |
| SCOND | 130.63 | 42.14 | 212.00 | 70.90 | 3 |
| LSCOND | 4.78 | 0.32 | 5.36 | 4.26 | 3 |
| ------------------------ NO RAINFALL | FY-1990 | UTR BR BELOW | ---------------------------- | | |
| TSS | 8.47 | 1.82 | 12.10 | 6.60 | 3 |
| LTSS | 2.21 | 0.18 | 2.57 | 2.03 | 3 |
| TURB | 1.26 | 0.47 | 2.20 | 0.71 | 3 |
| LTURB | 0.78 | 0.20 | 1.16 | 0.54 | 3 |
| PTSASH | 57.23 | 0.67 | 58.50 | 56.20 | 3 |
| SCOND | 21.77 | 0.54 | 22.40 | 20.70 | 3 |
| LSCOND | 3.12 | 0.02 | 3.15 | 3.08 | 3 |
| ------------------------ LOW RAINFALL | FY-1983 | UTR CK ABOVE | ---------------------------- | | |
| TSS | 4.85 | 0.41 | 6.97 | 2.86 | 10 |
| LTSS | 1.74 | 0.07 | 2.08 | 1.35 | 10 |
| TURB | -- | -- | -- | -- | 0 |
| LTURB | -- | -- | -- | -- | 0 |
| PTSASH | 47.73 | 5.67 | 72.64 | 15.38 | 8 |
| SCOND | 23.84 | 3.06 | 34.49 | 14.19 | 8 |
| LSCOND | 3.16 | 0.13 | 3.57 | 2.72 | 8 |
| ------------------------ LOW RAINFALL | FY-1983 | TINKER CK | ---------------------------- | | |
| TSS | 5.20 | 0.63 | 7.41 | 2.45 | 8 |
| LTSS | 1.78 | 0.11 | 2.13 | 1.24 | 8 |
| TURB | -- | -- | -- | -- | 0 |
| LTURB | -- | -- | -- | -- | 0 |
| PTSASH | 42.14 | 3.16 | 54.67 | 30.42 | 7 |
| SCOND | 38.99 | 4.98 | 57.31 | 19.61 | 7 |
| LSCOND | 3.64 | 0.14 | 4.07 | 3.03 | 7 |

| VARIABLE | MEAN | STD ERROR OF MEAN | MAXIMUM VALUE | MINIMUM VALUE | N |
|---|---|---|---|---|---|
| ------------------------ | LOW RAINFALL | FY-1983 | MCQUEEN BR | --------------------------- | |
| TSS | 6.93 | 0.75 | 8.97 | 3.75 | 7 |
| LTSS | 2.04 | 0.10 | 2.30 | 1.56 | 7 |
| TURB | -- | -- | -- | -- | 0 |
| LTURB | -- | -- | -- | -- | 0 |
| PTSASH | 61.00 | 3.19 | 69.10 | 54.12 | 5 |
| SCOND | 50.07 | 5.96 | 70.36 | 36.47 | 5 |
| LSCOND | 3.91 | 0.11 | 4.27 | 3.62 | 5 |
| ------------------------ | LOW RAINFALL | FY-1983 | UTR CK MID. | --------------------------- | |
| TSS | 6.16 | 0.76 | 8.02 | 3.95 | 5 |
| LTSS | 1.94 | 0.11 | 2.20 | 1.60 | 5 |
| TURB | -- | -- | -- | -- | 0 |
| LTURB | -- | -- | -- | -- | 0 |
| PTSASH | 43.81 | 3.16 | 49.73 | 34.88 | 4 |
| SCOND | 33.02 | 3.60 | 42.26 | 26.48 | 4 |
| LSCOND | 3.51 | 0.10 | 3.77 | 3.31 | 4 |
| ------------------------ | LOW RAINFALL | FY-1983 | CROUCH BR | --------------------------- | |
| TSS | | | | | |
| LTSS | | | | | |
| TURB | | | | | |
| LTURB | | | | | |
| PTSASH | | | | | |
| SCOND | | | | | |
| LSCOND | | | | | |
| ------------------------ | LOW RAINFALL | FY-1983 | UTR BR BELOW | --------------------------- | |
| TSS | 6.15 | 0.73 | 8.02 | 4.18 | 5 |
| LTSS | 1.94 | 0.11 | 2.20 | 1.65 | 5 |
| TURB | -- | -- | -- | -- | 0 |
| LTURB | -- | -- | -- | -- | 0 |
| PTSASH | 44.41 | 1.73 | 49.35 | 41.34 | 4 |
| SCOND | 32.64 | 4.63 | 44.71 | 25.31 | 4 |
| LSCOND | 3.49 | 0.13 | 3.82 | 3.27 | 4 |
| ------------------------ | LOW RAINFALL | FY-1984 | UTR CK ABOVE | --------------------------- | |
| TSS | 6.30 | 0.37 | 6.66 | 5.93 | 2 |
| LTSS | 1.99 | 0.05 | 2.04 | 1.94 | 2 |
| TURB | 3.45 | 0.85 | 4.30 | 2.60 | 2 |
| LTURB | 1.47 | 0.19 | 1.67 | 1.28 | 2 |
| PTSASH | 43.92 | 0.07 | 43.99 | 43.84 | 2 |
| SCOND | 12.88 | 0.25 | 13.13 | 12.62 | 2 |
| LSCOND | 2.63 | 0.02 | 2.65 | 2.61 | 2 |

| VARIABLE | MEAN | STD ERROR OF MEAN | MAXIMUM VALUE | MINIMUM VALUE | N |
|---|---|---|---|---|---|
| ------------------------ LOW RAINFALL | | FY-1984 | TINKER CK | ---------------------------- | |
| TSS | 9.47 | 0.73 | 10.19 | 8.74 | 2 |
| LTSS | 2.35 | 0.07 | 2.42 | 2.28 | 2 |
| TURB | 5.10 | 0.50 | 5.60 | 4.60 | 2 |
| LTURB | 1.80 | 0.08 | 1.89 | 1.72 | 2 |
| PTSASH | 47.48 | 2.86 | 50.34 | 44.62 | 2 |
| SCOND | 17.59 | 4.96 | 22.54 | 12.62 | 2 |
| LSCOND | 2.89 | 0.27 | 3.16 | 2.61 | 2 |
| ------------------------ LOW RAINFALL | | FY-1984 | MCQUEEN BR | ---------------------------- | |
| TSS | 16.91 | 0.27 | 17.18 | 16.64 | 2 |
| LTSS | 2.89 | 0.02 | 2.90 | 2.87 | 2 |
| TURB | 19.00 | 1.00 | 20.00 | 18.00 | 2 |
| LTURB | 2.99 | 0.05 | 3.04 | 2.94 | 2 |
| PTSASH | 69.40 | 0.89 | 70.28 | 68.51 | 2 |
| SCOND | 22.68 | 4.43 | 27.12 | 18.25 | 2 |
| LSCOND | 3.15 | 0.19 | 3.34 | 2.96 | 2 |
| ------------------------ LOW RAINFALL | | FY-1984 | UTR CK MID. | ---------------------------- | |
| TSS | 10.51 | -- | 10.51 | 10.51 | 1 |
| LTSS | 2.44 | -- | 2.44 | 2.44 | 1 |
| TURB | 5.20 | -- | 5.20 | 5.20 | 1 |
| LTURB | 1.82 | -- | 1.82 | 1.82 | 1 |
| PTSASH | 52.33 | -- | 52.33 | 52.33 | 1 |
| SCOND | 6.51 | -- | 6.51 | 6.51 | 1 |
| LSCOND | 2.02 | -- | 2.02 | 2.02 | 1 |
| ------------------------ LOW RAINFALL | | FY-1984 | CROUCH BR | ---------------------------- | |
| TSS | | | | | |
| LTSS | | | | | |
| TURB | | | | | |
| LTURB | | | | | |
| PTSASH | | | | | |
| SCOND | | | | | |
| LSCOND | | | | | |
| ------------------------ LOW RAINFALL | | FY-1984 | UTR BR BELOW | ---------------------------- | |
| TSS | 9.64 | -- | 9.64 | 9.64 | 1 |
| LTSS | 2.36 | -- | 2.36 | 2.36 | 1 |
| TURB | 5.80 | -- | 5.80 | 5.80 | 1 |
| LTURB | 1.92 | -- | 1.92 | 1.92 | 1 |
| PTSASH | 52.28 | -- | 52.28 | 52.28 | 1 |
| SCOND | 5.40 | -- | 5.40 | 5.40 | 1 |
| LSCOND | 1.86 | -- | 1.86 | 1.86 | 1 |

| VARIABLE | MEAN | STD ERROR OF MEAN | MAXIMUM VALUE | MINIMUM VALUE | N |
|---|---|---|---|---|---|
| ------------------------ | LOW RAINFALL | FY-1985 | UTR CK ABOVE | ---------------------------- | |
| TSS | 4.73 | 0.92 | 5.70 | 2.90 | 3 |
| LTSS | 1.72 | 0.18 | 1.90 | 1.36 | 3 |
| TURB | 3.80 | 0.42 | 4.40 | 2.99 | 3 |
| LTURB | 1.56 | 0.09 | 1.69 | 1.38 | 3 |
| PTSASH | 65.47 | 8.29 | 75.90 | 49.10 | 3 |
| SCOND | 17.86 | 0.49 | 19.15 | 17.10 | 4 |
| LSCOND | 2.94 | 0.03 | 3.00 | 2.90 | 4 |
| ------------------------ | LOW RAINFALL | FY-1985 | TINKER CK | ---------------------------- | |
| TSS | 6.90 | 1.51 | 10.10 | 2.90 | 4 |
| LTSS | 2.00 | 0.23 | 2.41 | 1.36 | 4 |
| TURB | 4.43 | 0.32 | 5.30 | 3.90 | 4 |
| LTURB | 1.69 | 0.06 | 1.84 | 1.59 | 4 |
| PTSASH | 61.40 | 9.23 | 86.20 | 44.60 | 4 |
| SCOND | 32.93 | 2.08 | 36.84 | 27.82 | 4 |
| LSCOND | 3.52 | 0.06 | 3.63 | 3.36 | 4 |
| ------------------------ | LOW RAINFALL | FY-1985 | MCQUEEN BR | ---------------------------- | |
| TSS | 34.75 | 18.75 | 53.50 | 16.00 | 2 |
| LTSS | 3.42 | 0.58 | 4.00 | 2.83 | 2 |
| TURB | 33.60 | 11.60 | 45.20 | 22.00 | 2 |
| LTURB | 3.48 | 0.35 | 3.83 | 3.14 | 2 |
| PTSASH | 75.65 | 3.75 | 79.40 | 71.90 | 2 |
| SCOND | 68.55 | 25.14 | 93.69 | 43.41 | 2 |
| LSCOND | 4.17 | 0.38 | 4.55 | 3.79 | 2 |
| ------------------------ | LOW RAINFALL | FY-1985 | UTR CK MID. | ---------------------------- | |
| TSS | 7.05 | 2.15 | 9.20 | 4.90 | 2 |
| LTSS | 2.05 | 0.27 | 2.32 | 1.77 | 2 |
| TURB | 4.70 | 0.70 | 5.40 | 4.00 | 2 |
| LTURB | 1.73 | 0.12 | 1.86 | 1.61 | 2 |
| PTSASH | 64.35 | 13.25 | 77.60 | 51.10 | 2 |
| SCOND | 20.46 | 0.73 | 21.19 | 19.73 | 2 |
| LSCOND | 3.07 | 0.03 | 3.10 | 3.03 | 2 |
| ------------------------ | LOW RAINFALL | FY-1985 | CROUCH BR | ---------------------------- | |
| TSS | 65.30 | -- | 65.30 | 65.30 | 1 |
| LTSS | 4.19 | -- | 4.19 | 4.19 | 1 |
| TURB | 158.00 | -- | 158.00 | 158.00 | 1 |
| LTURB | 5.07 | -- | 5.07 | 5.07 | 1 |
| PTSASH | 86.70 | -- | 86.70 | 86.70 | 1 |
| SCOND | 78.71 | -- | 78.71 | 78.71 | 1 |
| LSCOND | 4.38 | -- | 4.38 | 4.38 | 1 |

| VARIABLE | MEAN | STD ERROR OF MEAN | MAXIMUM VALUE | MINIMUM VALUE | N |
|---|---|---|---|---|---|
| ------------------------ LOW RAINFALL | FY-1985 | UTR BR BELOW ------------------------ | | | |
| TSS | 6.55 | 2.25 | 8.80 | 4.30 | 2 |
| LTSS | 1.96 | 0.31 | 2.28 | 1.67 | 2 |
| TURB | 5.75 | 1.25 | 7.00 | 4.50 | 2 |
| LTURB | 1.89 | 0.19 | 2.08 | 1.70 | 2 |
| PTSASH | 62.75 | 11.65 | 74.40 | 51.10 | 2 |
| SCOND | 24.74 | 1.05 | 25.79 | 23.61 | 2 |
| LSCOND | 3.25 | 0.04 | 3.29 | 3.21 | 2 |
| ------------------------ LOW RAINFALL | FY-1986 | UTR CK ABOVE ------------------------ | | | |
| TSS | 10.10 | 0.30 | 10.40 | 9.80 | 2 |
| LTSS | 2.41 | 0.03 | 2.43 | 2.38 | 2 |
| TURB | 5.90 | 0.90 | 6.80 | 5.00 | 2 |
| LTURB | 1.92 | 0.13 | 2.05 | 1.79 | 2 |
| PTSASH | 57.00 | 2.20 | 59.20 | 54.80 | 2 |
| SCOND | 15.75 | 0.15 | 15.90 | 15.60 | 2 |
| LSCOND | 2.82 | 0.01 | 2.83 | 2.81 | 2 |
| ------------------------ LOW RAINFALL | FY-1986 | TINKER CK ------------------------ | | | |
| TSS | 12.50 | 3.10 | 15.60 | 9.40 | 2 |
| LTSS | 2.58 | 0.23 | 2.81 | 2.34 | 2 |
| TURB | 4.75 | 0.15 | 4.90 | 4.60 | 2 |
| LTURB | 1.75 | 0.03 | 1.77 | 1.72 | 2 |
| PTSASH | 50.80 | 1.80 | 52.60 | 49.00 | 2 |
| SCOND | 30.40 | 1.60 | 32.00 | 28.80 | 2 |
| LSCOND | 3.45 | 0.05 | 3.50 | 3.39 | 2 |
| ------------------------ LOW RAINFALL | FY-1986 | MCQUEEN BR ------------------------ | | | |
| TSS | 46.40 | -- | 46.40 | 46.40 | 1 |
| LTSS | 3.86 | -- | 3.86 | 3.86 | 1 |
| TURB | 79.00 | -- | 79.00 | 79.00 | 1 |
| LTURB | 4.38 | -- | 4.38 | 4.38 | 1 |
| PTSASH | 88.40 | -- | 38.40 | 88.40 | 1 |
| SCOND | 66.60 | -- | 66.60 | 66.60 | 1 |
| LSCOND | 4.21 | -- | 4.21 | 4.21 | 1 |
| ------------------------ LOW RAINFALL | FY-1986 | UTR CK MID. ------------------------ | | | |
| TSS | 13.90 | -- | 13.90 | 13.90 | 1 |
| LTSS | 2.70 | -- | 2.70 | 2.70 | 1 |
| TURB | 5.10 | -- | 5.10 | 5.10 | 1 |
| LTURB | 1.81 | -- | 1.81 | 1.81 | 1 |
| PTSASH | 54.70 | -- | 54.70 | 54.70 | 1 |
| SCOND | 22.10 | -- | 22.10 | 22.10 | 1 |
| LSCOND | 3.14 | -- | 3.14 | 3.14 | 1 |

| VARIABLE | MEAN | STD ERROR OF MEAN | MAXIMUM VALUE | MINIMUM VALUE | N |
|---|---|---|---|---|---|
| ------------ LOW RAINFALL | FY-1986 | CROUCH BR ------------ | | | |
| TSS | 62.50 | -- | 62.50 | 62.50 | 1 |
| LTSS | 4.15 | -- | 4.15 | 4.15 | 1 |
| TURB | 110.00 | -- | 110.00 | 110.00 | 1 |
| LTURB | 4.71 | -- | 4.71 | 4.71 | 1 |
| PTSASH | 86.20 | -- | 86.20 | 86.20 | 1 |
| SCOND | 104.60 | -- | 104.60 | 104.60 | 1 |
| LSCOND | 4.66 | -- | 4.66 | 4.66 | 1 |
| ------------ LOW RAINFALL | FY-1986 | UTR BR BELOW ------------ | | | |
| TSS | 14.80 | -- | 14.80 | 14.80 | 1 |
| LTSS | 2.76 | -- | 2.76 | 2.76 | 1 |
| TURB | 5.70 | -- | 5.70 | 5.70 | 1 |
| LTURB | 1.90 | -- | 1.90 | 1.90 | 1 |
| PTSASH | 54.10 | -- | 54.10 | 54.10 | 1 |
| SCOND | 22.50 | -- | 22.50 | 22.50 | 1 |
| LSCOND | 3.16 | -- | 3.16 | 3.16 | 1 |
| ------------ LOW RAINFALL | FY-1987 | UTR CK ABOVE ------------ | | | |
| TSS | 5.95 | 0.75 | 8.80 | 3.10 | 8 |
| LTSS | 1.89 | 0.12 | 2.28 | 1.41 | 8 |
| TURB | 2.36 | 0.25 | 3.40 | 1.20 | 8 |
| LTURB | 1.19 | 0.08 | 1.48 | 0.79 | 8 |
| PTSASH | 53.51 | 1.63 | 59.60 | 45.20 | 8 |
| SCOND | 15.49 | 0.39 | 17.20 | 13.90 | 8 |
| LSCOND | 2.80 | 0.02 | 2.90 | 2.70 | 8 |
| ------------ LOW RAINFALL | FY-1987 | TINKER CK ------------ | | | |
| TSS | 8.13 | 1.52 | 15.00 | 2.10 | 8 |
| LTSS | 2.09 | 0.20 | 2.77 | 1.13 | 8 |
| TURB | 2.74 | 0.28 | 3.90 | 1.50 | 8 |
| LTURB | 1.30 | 0.08 | 1.59 | 0.92 | 8 |
| PTSASH | 50.23 | 0.96 | 54.70 | 46.90 | 8 |
| SCOND | 28.38 | 1.29 | 35.70 | 24.40 | 8 |
| LSCOND | 3.37 | 0.04 | 3.60 | 3.23 | 8 |
| ------------ LOW RAINFALL | FY-1987 | MCQUEEN BR ------------ | | | |
| TSS | 28.67 | 12.24 | 95.10 | 6.80 | 7 |
| LTSS | 2.95 | 0.37 | 4.57 | 2.05 | 7 |
| TURB | 45.81 | 22.71 | 165.00 | 4.40 | 7 |
| LTURB | 3.06 | 0.52 | 5.11 | 1.69 | 7 |
| PTSASH | 84.46 | 3.15 | 97.20 | 75.30 | 7 |
| SCOND | 64.83 | 7.92 | 93.10 | 39.80 | 7 |
| LSCOND | 4.14 | 0.13 | 4.54 | 3.71 | 7 |

| VARIABLE | MEAN | STD ERROR OF MEAN | MAXIMUM VALUE | MINIMUM VALUE | N |
|---|---|---|---|---|---|
| ------------------------ LOW RAINFALL | FY-1987 | UTR CK MID. | ---------------------------- | | |
| TSS | 8.13 | 1.77 | 12.00 | 3.90 | 4 |
| LTSS | 2.15 | 0.21 | 2.56 | 1.59 | 4 |
| TURB | 3.33 | 0.66 | 5.10 | 2.10 | 4 |
| LTURB | 1.43 | 0.15 | 1.81 | 1.13 | 4 |
| PTSASH | 55.65 | 1.33 | 57.40 | 51.70 | 4 |
| SCOND | 22.35 | 1.08 | 25.20 | 20.30 | 4 |
| LSCOND | 3.15 | 0.05 | 3.27 | 3.06 | 4 |
| ------------------------ LOW RAINFALL | FY-1987 | CROUCH BR | ---------------------------- | | |
| TSS | 43.23 | 15.74 | 80.70 | 12.10 | 4 |
| LTSS | 3.55 | 0.42 | 4.40 | 2.57 | 4 |
| TURB | 81.00 | 31.75 | 165.00 | 21.00 | 4 |
| LTURB | 4.14 | 0.44 | 5.11 | 3.09 | 4 |
| PTSASH | 87.33 | 2.24 | 92.90 | 82.60 | 4 |
| SCOND | 89.20 | 9.94 | 108.60 | 61.80 | 4 |
| LSCOND | 4.48 | 0.12 | 4.70 | 4.14 | 4 |
| ------------------------ LOW RAINFALL | FY-1987 | UTR BR BELOW | ---------------------------- | | |
| TSS | 8.45 | 1.64 | 11.50 | 3.90 | 4 |
| LTSS | 2.19 | 0.21 | 2.53 | 1.59 | 4 |
| TURB | 3.55 | 0.81 | 5.90 | 2.30 | 4 |
| LTURB | 1.47 | 0.16 | 1.93 | 1.19 | 4 |
| PTSASH | 58.65 | 0.57 | 59.50 | 57.00 | 4 |
| SCOND | 22.30 | 1.05 | 25.40 | 20.90 | 4 |
| LSCOND | 3.15 | 0.04 | 3.27 | 3.09 | 4 |
| ------------------------ LOW RAINFALL | FY-1988 | UTR CK ABOVE | ---------------------------- | | |
| TSS | 4.51 | 0.40 | 6.70 | 3.30 | 8 |
| LTSS | 1.69 | 0.07 | 2.04 | 1.46 | 8 |
| TURB | 2.00 | 0.30 | 3.90 | 1.20 | 8 |
| LTURB | 1.07 | 0.09 | 1.59 | 0.79 | 8 |
| PTSASH | 55.64 | 1.57 | 64.20 | 51.20 | 8 |
| SCOND | 15.94 | 0.60 | 19.40 | 14.40 | 8 |
| LSCOND | 2.83 | 0.03 | 3.02 | 2.73 | 8 |
| ------------------------ LOW RAINFALL | FY-1988 | TINKER CK | ---------------------------- | | |
| TSS | 5.49 | 0.78 | 8.40 | 2.00 | 8 |
| LTSS | 1.81 | 0.14 | 2.24 | 1.10 | 8 |
| TURB | 2.10 | 0.19 | 2.90 | 1.40 | 8 |
| LTURB | 1.12 | 0.06 | 1.36 | 0.88 | 8 |
| PTSASH | 52.25 | 0.85 | 55.50 | 48.10 | 8 |
| SCOND | 30.48 | 1.34 | 37.40 | 26.20 | 8 |
| LSCOND | 3.44 | 0.04 | 3.65 | 3.30 | 8 |

| VARIABLE | MEAN | STD ERROR OF MEAN | MAXIMUM VALUE | MINIMUM VALUE | N |
|---|---|---|---|---|---|
| ------------------------ LOW RAINFALL | FY-1988 | MCQUEEN BR ---------------------------- | | | |
| TSS | 87.18 | 41.82 | 331.20 | 4.80 | 8 |
| LTSS | 3.63 | 0.51 | 5.81 | 1.76 | 8 |
| TURB | 128.86 | 61.45 | 495.00 | 3.20 | 8 |
| LTURB | 3.89 | 0.59 | 6.21 | 1.44 | 8 |
| PTSASH | 85.91 | 1.48 | 91.10 | 79.20 | 8 |
| SCOND | 192.93 | 58.20 | 510.00 | 50.30 | 8 |
| LSCOND | 4.95 | 0.30 | 6.24 | 3.94 | 8 |
| ------------------------ LOW RAINFALL | FY-1988 | UTR CK MID. ---------------------------- | | | |
| TSS | 5.38 | 0.51 | 6.70 | 4.30 | 4 |
| LTSS | 1.84 | 0.08 | 2.04 | 1.67 | 4 |
| TURB | 2.58 | 0.50 | 4.00 | 1.70 | 4 |
| LTURB | 1.25 | 0.13 | 1.61 | 0.99 | 4 |
| PTSASH | 57.05 | 2.44 | 64.20 | 53.50 | 4 |
| SCOND | 22.13 | 0.53 | 23.70 | 21.50 | 4 |
| LSCOND | 3.14 | 0.02 | 3.21 | 3.11 | 4 |
| ------------------------ LOW RAINFALL | FY-1988 | CROUCH BR ---------------------------- | | | |
| TSS | 96.50 | 35.53 | 167.50 | 8.40 | 4 |
| LTSS | 4.15 | 0.66 | 5.13 | 2.24 | 4 |
| TURB | 175.65 | 66.18 | 300.00 | 8.60 | 4 |
| LTURB | 4.60 | 0.80 | 5.71 | 2.26 | 4 |
| PTSASH | 88.45 | 1.73 | 90.70 | 83.30 | 4 |
| SCOND | 117.60 | 5.41 | 127.00 | 102.00 | 4 |
| LSCOND | 4.77 | 0.05 | 4.85 | 4.63 | 4 |
| ------------------------ LOW RAINFALL | FY-1988 | UTR BR BELOW ---------------------------- | | | |
| TSS | 5.55 | 0.54 | 6.70 | 4.10 | 4 |
| LTSS | 1.87 | 0.09 | 2.04 | 1.63 | 4 |
| TURB | 2.58 | 0.45 | 3.70 | 1.80 | 4 |
| LTURB | 1.25 | 0.12 | 1.55 | 1.03 | 4 |
| PTSASH | 59.10 | 1.56 | 62.70 | 56.10 | 4 |
| SCOND | 22.93 | 0.43 | 24.20 | 22.30 | 4 |
| LSCOND | 3.17 | 0.02 | 3.23 | [illegible].15 | 4 |
| ------------------------ LOW RAINFALL | FY-1989 | UTR CK ABOVE ---------------------------- | | | |
| TSS | 3.6[illegible] | 0.38 | 5.90 | 2.30 | 8 |
| LTSS | 1.30 | 0.08 | 1.93 | 1.19 | 8 |
| TURB | 0.59 | 0.12 | 1.40 | 0.36 | 8 |
| LTURB | 0.45 | 0.06 | 0.88 | 0.31 | 8 |
| PTSASH | 52.21 | 0.92 | 56.90 | 48.50 | 8 |
| SCOND | 16.15 | 0.29 | 17.20 | 15.10 | 8 |
| LSCOND | 2.84 | 0 02 | 2.90 | 2.78 | 8 |

| VARIABLE | MEAN | STD ERROR OF MEAN | MAXIMUM VALUE | MINIMUM VALUE | N |
|---|---|---|---|---|---|
| ------------------------ LOW RAINFALL | | FY-1989 | TINKER CK | ------------------------ | |
| TSS | 8.23 | 3.51 | 32.50 | 3.20 | 8 |
| LTSS | 1.94 | 0.24 | 3.51 | 1.44 | 8 |
| TURB | 5.41 | 4.38 | 36.00 | 0.43 | 8 |
| LTURB | 1.01 | 0.39 | 3.61 | 0.36 | 8 |
| PTSASH | 52.94 | 2.03 | 61.50 | 46.30 | 8 |
| SCOND | 33.33 | 1.15 | 37.50 | 28.90 | 8 |
| LSCOND | 3.53 | 0.03 | 3.65 | 3.40 | 8 |
| ------------------------ LOW RAINFALL | | FY-1989 | MCQUEEN BR | ------------------------ | |
| TSS | 23.78 | 7.01 | 64.10 | 4.00 | 8 |
| LTSS | 2.91 | 0.31 | 4.18 | 1.61 | 8 |
| TURB | 40.80 | 12.11 | 110.00 | 4.00 | 8 |
| LTURB | 3.35 | 0.37 | 4.71 | 1.61 | 8 |
| PTSASH | 85.01 | 1.42 | 88.50 | 76.10 | 8 |
| SCOND | 60.84 | 2.36 | 75.70 | 53.50 | 8 |
| LSCOND | 4.12 | 0.04 | 4.34 | 4.00 | 8 |
| ------------------------ LOW RAINFALL | | FY-1989 | UTR CK MID. | ------------------------ | |
| TSS | 4.55 | 0.81 | 6.90 | 3.20 | 4 |
| LTSS | 1.68 | 0.14 | 2.07 | 1.44 | 4 |
| TURB | 1.12 | 0.56 | 2.80 | 0.41 | 4 |
| LTURB | 0.66 | 0.23 | 1.34 | 0.34 | 4 |
| PTSASH | 52.88 | 2.52 | 59.60 | 47.60 | 4 |
| SCOND | 23.48 | 0.45 | 24.60 | 22.70 | 4 |
| LSCOND | 3.20 | 0.02 | 3.24 | 3.17 | 4 |
| ------------------------ LOW RAINFALL | | FY-1989 | CROUCH BR | ------------------------ | |
| TSS | 79.73 | 39.19 | 183.20 | 16.60 | 4 |
| LTSS | 3.95 | 0.57 | 5.22 | 2.87 | 4 |
| TURB | 148.75 | 70.35 | 330.00 | 31.00 | 4 |
| LTURB | 4.58 | 0.56 | 5.80 | 3.47 | 4 |
| PTSASH | 86.48 | 2.53 | 90.80 | 80.80 | 4 |
| SCOND | 116.75 | 7.51 | 135.00 | 103.00 | 4 |
| LSCOND | 4.76 | 0.06 | 4.91 | 4.64 | 4 |
| ------------------------ LOW RAINFALL | | FY-1989 | UTR BR BELOW | ------------------------ | |
| TSS | 4.93 | 0.68 | 6.60 | 3.30 | 4 |
| LTSS | 1.76 | 0.12 | 2.03 | 1.46 | 4 |
| TURB | 1.39 | 0.77 | 3.70 | 0.51 | 4 |
| LTURB | 0.74 | 0.27 | 1.55 | 0.41 | 4 |
| PTSASH | 57.03 | 1.66 | 61.90 | 54.60 | 4 |
| SCOND | 24.18 | 0.45 | 25.00 | 23.30 | 4 |
| LSCOND | 3.23 | 0.02 | 3.26 | 3.19 | 4 |

| VARIABLE | MEAN | STD ERROR OF MEAN | MAXIMUM VALUE | MINIMUM VALUE | N |
|---|---|---|---|---|---|
| ------------------------- LOW RAINFALL | | FY-1990 | UTR CK ABOVE ---------------------------- | | |
| TSS | 6.48 | 0.92 | 9.20 | 3.50 | 6 |
| LTSS | 1.97 | 0.13 | 2.32 | 1.50 | 6 |
| TURB | 1.20 | 0.30 | 2.20 | 0.41 | 6 |
| LTURB | 0.74 | 0.14 | 1.16 | 0.34 | 6 |
| PTSASH | 54.88 | 0.91 | 57.00 | 51.30 | 6 |
| SCOND | 15.48 | 0.19 | 16.10 | 14.80 | 6 |
| LSCOND | 2.80 | 0.01 | 2.84 | 2.76 | 6 |
| ------------------------- LOW RAINFALL | | FY-1990 | TINKER CK ---------------------------- | | |
| TSS | 12.55 | 3.07 | 25.20 | 4.00 | 6 |
| LTSS | 2.47 | 0.24 | 3.26 | 1.61 | 6 |
| TURB | 2.54 | 0.63 | 4.30 | 0.73 | 6 |
| LTURB | 1.17 | 0.24 | 1.67 | 0.55 | 6 |
| PTSASH | 52.88 | 1.35 | 56.50 | 48.10 | 6 |
| SCOND | 34.47 | 1.58 | 39.90 | 29.50 | 6 |
| LSCOND | 3.56 | 0.04 | 3.71 | 3.42 | 6 |
| ------------------------- LOW RAINFALL | | FY-1990 | MCQUEEN BR ---------------------------- | | |
| TSS | 5.97 | 1.54 | 13.10 | 2.80 | 6 |
| LTSS | 1.84 | 0.19 | 2.64 | 1.34 | 6 |
| TURB | 3.64 | 1.02 | 7.70 | 0.91 | 6 |
| LTURB | 1.41 | 0.22 | 2.16 | 0.65 | 6 |
| PTSASH | 74.80 | 2.65 | 83.70 | 67.50 | 6 |
| SCOND | 58.18 | 3.25 | 67.30 | 46.50 | 6 |
| LSCOND | 4.07 | 0.06 | 4.22 | 3.86 | 6 |
| ------------------------- LOW RAINFALL | | FY-1990 | UTR CK MID. ---------------------------- | | |
| TSS | 7.73 | 1.54 | 9.70 | 4.70 | 3 |
| LTSS | 2.13 | 0.20 | 2.37 | 1.74 | 3 |
| TURB | 1.31 | 0.65 | 2.60 | 0.47 | 3 |
| LTURB | 0.76 | 0.27 | 1.28 | 0.39 | 3 |
| PTSASH | 52.03 | 3.27 | 55.30 | 45.50 | 3 |
| SCOND | 20.53 | 0.26 | 21.00 | 20.10 | 3 |
| LSCOND | 3.07 | 0.01 | 3.09 | 3.05 | 3 |
| ------------------------- LOW RAINFALL | | FY-1990 | CROUCH BR ---------------------------- | | |
| TSS | 15.57 | 2.11 | 18.80 | 11.60 | 3 |
| LTSS | 2.79 | 0.13 | 2.99 | 2.53 | 3 |
| TURB | 21.57 | 6.54 | 30.00 | 8.70 | 3 |
| LTURB | 3.00 | 0.37 | 3.43 | 2.27 | 3 |
| PTSASH | 69.30 | 2.95 | 75.00 | 65.10 | 3 |
| SCOND | 74.70 | 14.00 | 102.00 | 55.70 | 3 |
| LSCOND | 4.29 | 0.18 | 4.63 | 4.04 | 3 |

| VARIABLE | MEAN | STD ERROR OF MEAN | MAXIMUM VALUE | MINIMUM VALUE | N |
|---|---|---|---|---|---|
| ------------------------ LOW RAINFALL | FY-1990 | UTR BR BELOW ------------------------ | | | |
| TSS | 7.67 | 1.85 | 9.90 | 4.00 | 3 |
| LTSS | 2.10 | 0.25 | 2.39 | 1.61 | 3 |
| TURB | 1.68 | 0.57 | 2.40 | 0.55 | 3 |
| LTURB | 0.93 | 0.25 | 1.22 | 0.44 | 3 |
| PTSASH | 55.33 | 1.19 | 57.30 | 53.20 | 3 |
| SCOND | 21.87 | 0.50 | 22.60 | 20.90 | 3 |
| LSCOND | 3.13 | 0.02 | 3.16 | 3.09 | 3 |
| ------------------------ HIGH RAINFALL | FY-1983 | UTR CK ABOVE ------------------------ | | | |
| TSS | 9.36 | 1.62 | 22.20 | 5.26 | 10 |
| LTSS | 2.25 | 0.13 | 3.14 | 1.83 | 10 |
| TURB | -- | -- | -- | -- | 0 |
| LTURB | -- | -- | -- | -- | 0 |
| PTSASH | 53.04 | 0.74 | 57.07 | 49.62 | 10 |
| SCOND | 29.15 | 1.62 | 37.09 | 25.41 | 7 |
| LSCOND | 3.40 | 0.05 | 3.64 | 3.27 | 7 |
| ------------------------ HIGH RAINFALL | FY-1983 | TINKER CK ------------------------ | | | |
| TSS | 11.15 | 2.10 | 21.79 | 4.76 | 9 |
| LTSS | 2.39 | 0.16 | 3.13 | 1.75 | 9 |
| TURB | -- | -- | -- | -- | 0 |
| LTURB | -- | -- | -- | -- | 0 |
| PTSASH | 52.00 | 4.96 | 90.54 | 41.53 | 9 |
| SCOND | 44.37 | 1.05 | 48.26 | 39.63 | 7 |
| LSCOND | 3.81 | 0.02 | 3.90 | 3.70 | 7 |
| ------------------------ HIGH RAINFALL | FY-1983 | MCQUEEN BR ------------------------ | | | |
| TSS | 59.04 | 16.31 | 114.97 | 8.89 | 6 |
| LTSS | 3.81 | 0.38 | 4.75 | 2.29 | 6 |
| TURB | -- | -- | -- | -- | 0 |
| LTURB | -- | -- | -- | -- | 0 |
| PTSASH | 76.81 | 3.06 | 82.34 | 62.59 | 6 |
| SCOND | 51.28 | 6.23 | 63.57 | 43.36 | 3 |
| LSCOND | 3.94 | 0.11 | 4.17 | 3.79 | 3 |
| ------------------------ HIGH RAINFALL | FY-1983 | UTR CK MID. ------------------------ | | | |
| TSS | 28.59 | 12.81 | 73.74 | 8.00 | 5 |
| LTSS | 3.01 | 0.43 | 4.31 | 2.20 | 5 |
| TURB | -- | -- | -- | -- | 0 |
| LTURB | -- | -- | -- | -- | 0 |
| PTSASH | 63.25 | 4.27 | 75.96 | 5.97 | 5 |
| SCOND | 34.80 | 3.19 | 39.69 | 25.84 | 4 |
| LSCOND | 3.56 | 0.10 | 3.71 | 3.29 | 4 |

| VARIABLE | MEAN | STD ERROR OF MEAN | MAXIMUM VALUE | MINIMUM VALUE | N |
|---|---|---|---|---|---|
| ------------------------ HIGH RAINFALL FY-1983 CROUCH BR ---------------------------- | | | | | |
| TSS | | | | | |
| LTSS | | | | | |
| TURB | | | | | |
| LTURB | | | | | |
| PTSASH | | | | | |
| SCOND | | | | | |
| LSCOND | | | | | |
| ------------------------ HIGH RAINFALL FY-1983 UTR BR BELOW ---------------------------- | | | | | |
| TSS | 39.01 | 18.60 | 105.70 | 8.12 | 5 |
| LTSS | 3.24 | 0.48 | 4.67 | 2.21 | 5 |
| TURB | -- | -- | -- | -- | 0 |
| LTURB | -- | -- | -- | -- | 0 |
| PTSASH | 60.64 | 9.35 | 78.03 | 29.90 | 5 |
| SCOND | 34.19 | 2.50 | 38.17 | 27.01 | 4 |
| LSCOND | 3.55 | 0.08 | 3.67 | 3.33 | 4 |
| ------------------------ HIGH RAINFALL FY-1984 UTR CK ABOVE ---------------------------- | | | | | |
| TSS | 8.03 | 0.32 | 8.34 | 7.71 | 2 |
| LTSS | 2.20 | 0.03 | 2.23 | 2.16 | 2 |
| TURB | 7.55 | 2.15 | 9.70 | 5.40 | 2 |
| LTURB | 2.11 | 0.26 | 2.37 | 1.86 | 2 |
| PTSASH | 57.75 | 0.29 | 58.03 | 57.46 | 2 |
| SCOND | 19.47 | 2.18 | 21.65 | 17.28 | 2 |
| LSCOND | 3.01 | 0.11 | 3.12 | 2.91 | 2 |
| ------------------------ HIGH RAINFALL FY-1984 TINKER CK ---------------------------- | | | | | |
| TSS | 11.34 | 8.42 | 19.76 | 2.92 | 2 |
| LTSS | 2.20 | 0.83 | 3.03 | 1.37 | 2 |
| TURB | 3.60 | 0.10 | 3.70 | 3.50 | 2 |
| LTURB | 1.53 | 0.02 | 1.55 | 1.50 | 2 |
| PTSASH | 48.79 | 12.49 | 61.29 | 36.30 | 2 |
| SCOND | 21.38 | 0.09 | 21.47 | 21.30 | 2 |
| LSCOND | 3.11 | <0.01 | 3.11 | 3.10 | 2 |
| ------------------------ HIGH RAINFALL FY-1984 MCQUEEN BR ---------------------------- | | | | | |
| TSS | 37.35 | 2.01 | 39.36 | 35.34 | 2 |
| LTSS | 3.65 | 0.05 | 3.70 | 3.59 | 2 |
| TURB | 54.00 | 8.00 | 62.00 | 46.00 | 2 |
| LTURB | 4.00 | 0.15 | 4.14 | 3.85 | 2 |
| PTSASH | 78.00 | 0.92 | 78.91 | 77.08 | 2 |
| SCOND | 23.52 | 1.69 | 25.21 | 21.83 | 2 |
| LSCOND | 3.20 | 0.07 | 3.27 | 3.13 | 2 |

| VARIABLE | MEAN | STD ERROR OF MEAN | MAXIMUM VALUE | MINIMUM VALUE | N |
|---|---|---|---|---|---|
| ------------------------ HIGH RAINFALL | | FY-1984 | UTR CK MID. ------------------------ | | |
| TSS | 12.89 | -- | 12.89 | 12.89 | 1 |
| LTSS | 2.63 | -- | 2.63 | 2.63 | 1 |
| TURB | 6.40 | -- | 6.40 | 6.40 | 1 |
| LTURB | 2.00 | -- | 2.00 | 2.00 | 1 |
| PTSASH | 28.16 | -- | 28.16 | 28.16 | 1 |
| SCOND | 303.71 | -- | 303.71 | 303.71 | 1 |
| LSCOND | 5.72 | -- | 5.72 | 5.72 | 1 |
| ------------------------ HIGH RAINFALL | | FY-1984 | CROUCH BR ------------------------ | | |
| TSS | | | | | |
| LTSS | | | | | |
| TURB | | | | | |
| LTURB | | | | | |
| PTSASH | | | | | |
| SCOND | | | | | |
| LSCOND | | | | | |
| ------------------------ HIGH RAINFALL | | FY-1984 | UTR BR BELOW ------------------------ | | |
| TSS | 9.82 | -- | 9.82 | 9.82 | 1 |
| LTSS | 2.38 | -- | 2.38 | 2.38 | 1 |
| TURB | 6.90 | -- | 6.90 | 6.90 | 1 |
| LTURB | 2.07 | -- | 2.07 | 2.07 | 1 |
| PTSASH | 53.87 | -- | 53.87 | 53.87 | 1 |
| SCOND | 21.60 | -- | 21.60 | 21.60 | 1 |
| LSCOND | 3.12 | -- | 3.12 | 3.12 | 1 |
| ------------------------ HIGH RAINFALL | | FY-1986 | UTR CK ABOVE ------------------------ | | |
| TSS | 14.30 | 6.96 | 35.10 | 6.10 | 4 |
| LTSS | 2.48 | 0.37 | 3.59 | 1.96 | 4 |
| TURB | 4.60 | 1.49 | 9.00 | 2.60 | 4 |
| LTURB | 1.63 | 0.23 | 2.30 | 1.28 | 4 |
| PTSASH | 52.75 | 1.43 | 55.00 | 48.60 | 4 |
| SCOND | 18.80 | 2.44 | 25.50 | 14.90 | 4 |
| LSCOND | 2.96 | 0.12 | 3.28 | 2.77 | 4 |
| ------------------------ HIGH RAINFALL | | FY-1986 | TINKER CK ------------------------ | | |
| TSS | 9.73 | 1.94 | 14.90 | 5.80 | 4 |
| LTSS | 2.32 | 0.18 | 2.77 | 1.92 | 4 |
| TURB | 4.68 | 0.82 | 6.50 | 3.00 | 4 |
| LTURB | 1.70 | 0.15 | 2.01 | 1.39 | 4 |
| PTSASH | 51.13 | 1.21 | 53.40 | 47.70 | 4 |
| SCOND | 44.03 | 9.82 | 71.50 | 27.40 | 4 |
| LSCOND | 3.74 | 0.21 | 4.28 | 3.35 | 4 |

| VARIABLE | MEAN | STD ERROR OF MEAN | MAXIMUM VALUE | MINIMUM VALUE | N |
|---|---|---|---|---|---|
| ------------------------ | HIGH RAINFALL | FY-1986 | MCQUEEN BR | ---------------------------- | |
| TSS | 32.45 | 6.55 | 39.00 | 25.90 | 2 |
| LTSS | 3.49 | 0.20 | 3.69 | 3.29 | 2 |
| TURB | 53.00 | 14.00 | 67.00 | 39.00 | 2 |
| LTURB | 3.95 | 0.27 | 4.22 | 3.69 | 2 |
| PTSASH | 85.45 | 3.25 | 88.70 | 82.20 | 2 |
| SCOND | 75.10 | 14.40 | 89.50 | 60.70 | 2 |
| LSCOND | 4.31 | 0.19 | 4.51 | 4.12 | 2 |
| ------------------------ | HIGH RAINFALL | FY-1986 | UTR CK MID. | ---------------------------- | |
| TSS | 17.70 | 7.90 | 25.60 | 9.80 | 2 |
| LTSS | 2.83 | 0.45 | 3.28 | 2.38 | 2 |
| TURB | 11.40 | 6.60 | 18.00 | 4.80 | 2 |
| LTURB | 2.35 | 0.59 | 2.94 | 1.76 | 2 |
| PTSASH | 55.95 | 1.85 | 57.80 | 54.10 | 2 |
| SCOND | 31.70 | 10.30 | 42.00 | 21.40 | 2 |
| LSCOND | 3.44 | 0.33 | 3.76 | 3.11 | 2 |
| ------------------------ | HIGH RAINFALL | FY-1986 | CROUCH BR | ---------------------------- | |
| TSS | 59.35 | 34.45 | 93.80 | 24.90 | 2 |
| LTSS | 3.90 | 0.65 | 4.55 | 3.25 | 2 |
| TURB | 130.00 | 80.00 | 210.00 | 50.00 | 2 |
| LTURB | 4.64 | 0.71 | 5.35 | 3.93 | 2 |
| PTSASH | 88.75 | 0.45 | 89.20 | 88.30 | 2 |
| SCOND | 103.70 | 7.80 | 111.50 | 95.90 | 2 |
| LSCOND | 4.65 | 0.07 | 4.72 | 4.57 | 2 |
| ------------------------ | HIGH RAINFALL | FY-1986 | UTR BR BELOW | ---------------------------- | |
| TSS | 16.70 | 5.70 | 22.40 | 11.00 | 2 |
| LTSS | 2.82 | 0.33 | 3.15 | 2.48 | 2 |
| TURB | 11.55 | 7.45 | 19.00 | 4.10 | 2 |
| LTURB | 2.31 | 0.68 | 2.99 | 1.63 | 2 |
| PTSASH | 57.60 | 3.10 | 60.70 | 54.50 | 2 |
| SCOND | 30.35 | 5.95 | 36.30 | 24.40 | 2 |
| LSCOND | 3.43 | 0.19 | 3.62 | 3.23 | 2 |
| ------------------------ | HIGH RAINFALL | FY-1987 | UTR CK ABOVE | ---------------------------- | |
| TSS | 7.88 | 1.33 | 15.90 | 4.00 | 8 |
| LTSS | 2.11 | 0.14 | 2.83 | 1.61 | 8 |
| TURB | 3.41 | 0.52 | 6.50 | 1.70 | 8 |
| LTURB | 1.44 | 0.11 | 2.01 | 0.99 | 8 |
| PTSASH | 51.28 | 0.66 | 54.80 | 48.40 | 8 |
| SCOND | 16.15 | 0.54 | 18.30 | 13.80 | 8 |
| LSCOND | 2.84 | 0.03 | 2.96 | 2.69 | 8 |

| VARIABLE | MEAN | STD ERROR OF MEAN | MAXIMUM VALUE | MINIMUM VALUE | N |
|---|---|---|---|---|---|
| ------------------------ HIGH RAINFALL | | FY-1987 | TINKER CK | --------------------------- | |
| TSS | 13.71 | 3.88 | 34.20 | 4.20 | 7 |
| LTSS | 2.51 | 0.23 | 3.56 | 1.65 | 7 |
| TURB | 7.49 | 2.78 | 24.00 | 3.20 | 7 |
| LTURB | 1.94 | 0.22 | 3.22 | 1.44 | 7 |
| PTSASH | 51.99 | 1.25 | 58.20 | 49.10 | 7 |
| SCOND | 29.86 | 1.54 | 35.60 | 24.50 | 7 |
| LSCOND | 3.42 | 0.05 | 3.60 | 3.24 | 7 |
| ------------------------ HIGH RAINFALL | | FY-1987 | MCQUEEN BR | --------------------------- | |
| TSS | 256.04 | 75.18 | 655.00 | 54.00 | 8 |
| LTSS | 5.20 | 0.33 | 6.49 | 4.01 | 8 |
| TURB | 327.44 | 75.05 | 650.00 | 88.50 | 8 |
| LTURB | 5.56 | 0.28 | 6.48 | 4.49 | 8 |
| PTSASH | 89.70 | 0.96 | 93.20 | 85.40 | 8 |
| SCOND | 75.55 | 10.09 | 118.30 | 41.70 | 8 |
| LSCOND | 4.28 | 0.13 | 4.78 | 3.75 | 8 |
| ------------------------ HIGH RAINFALL | | FY-1987 | UTR CK MID. | --------------------------- | |
| TSS | 14.65 | 5.16 | 29.10 | 5.20 | 4 |
| LTSS | 2.59 | 0.33 | 3.40 | 1.82 | 4 |
| TURB | 12.83 | 5.81 | 29.00 | 2.50 | 4 |
| LTURB | 2.34 | 0.45 | 3.40 | 1.25 | 4 |
| PTSASH | 63.05 | 3.74 | 71.30 | 55.80 | 4 |
| SCOND | 22.50 | 1.26 | 25.90 | 20.10 | 4 |
| LSCOND | 3.15 | 0.05 | 3.29 | 3.05 | 4 |
| ------------------------ HIGH RAINFALL | | FY-1987 | CROUCH BR | --------------------------- | |
| TSS | 119.75 | 34.79 | 215.50 | 50.40 | 4 |
| LTSS | 4.67 | 0.30 | 5.38 | 3.94 | 4 |
| TURB | 216.75 | 60.07 | 390.00 | 97.00 | 4 |
| LTURB | 5.26 | 0.28 | 5.97 | 4.58 | 4 |
| PTSASH | 88.78 | 0.86 | 90.50 | 86.50 | 4 |
| SCOND | 110.55 | 9.58 | 127.20 | 84.30 | 4 |
| LSCOND | 4.70 | 0.09 | 4.85 | 4.45 | 4 |
| ------------------------ HIGH RAINFALL | | FY-1987 | UTR BR BELOW | --------------------------- | |
| TSS | 20.15 | 6.48 | 36.80 | 6.60 | 4 |
| LTSS | 2.89 | 0.34 | 3.63 | 2.03 | 4 |
| TURB | 20.78 | 7.56 | 40.00 | 3.10 | 4 |
| LTURB | 2.80 | 0.49 | 3.71 | 1.41 | 4 |
| PTSASH | 68.40 | 3.56 | 76.10 | 62.10 | 4 |
| SCOND | 23.73 | 1.26 | 26.30 | 20.60 | 4 |
| LSCOND | 3.20 | 0.05 | 3.31 | 3.07 | 4 |

| VARIABLE | MEAN | STD ERROR OF MEAN | MAXIMUM VALUE | MINIMUM VALUE | N |
|---|---|---|---|---|---|
| ------------------------ HIGH RAINFALL | | FY-1988 | UTR CK ABOVE | ------------------------ | |
| TSS | 13.34 | 1.97 | 22.40 | 3.10 | 10 |
| LTSS | 2.54 | 0.18 | 3.15 | 1.41 | 10 |
| TURB | 8.76 | 2.20 | 24.00 | 1.50 | 10 |
| LTURB | 2.04 | 0.24 | 3.22 | 0.92 | 10 |
| PTSASH | 58.07 | 1.08 | 65.20 | 53.80 | 10 |
| SCOND | 19.25 | 1.21 | 26.90 | 14.70 | 10 |
| LSCOND | 2.99 | 0.06 | 3.33 | 2.75 | 10 |
| ------------------------ HIGH RAINFALL | | FY-1988 | TINKER CK | ------------------------ | |
| TSS | 24.28 | 4.44 | 45.00 | 2.20 | 10 |
| LTSS | 2.99 | 0.27 | 3.83 | 1.16 | 10 |
| TURB | 14.34 | 4.05 | 45.00 | 1.60 | 10 |
| LTURB | 2.40 | 0.29 | 3.83 | 0.96 | 10 |
| PTSASH | 57.46 | 2.55 | 72.40 | 49.90 | 10 |
| SCOND | 36.80 | 3.54 | 55.30 | 22.30 | 10 |
| LSCOND | 3.59 | 0.10 | 4.03 | 3.15 | 10 |
| ------------------------ HIGH RAINFALL | | FY-1988 | MCQUEEN BR | ------------------------ | |
| TSS | 162.56 | 30.03 | 273.90 | 22.00 | 10 |
| LTSS | 4.86 | 0.26 | 5.62 | 3.14 | 10 |
| TURB | 237.30 | 39.69 | 395.00 | 35.00 | 10 |
| LTURB | 5.27 | 0.24 | 5.98 | 3.58 | 10 |
| PTSASH | 88.39 | 0.43 | 90.10 | 86.40 | 10 |
| SCOND | 101.16 | 28.62 | 328.00 | 46.70 | 10 |
| LSCOND | 4.40 | 0.20 | 5.80 | 3.86 | 10 |
| ------------------------ HIGH RAINFALL | | FY-1988 | UTR CK MID. | ------------------------ | |
| TSS | 34.22 | 9.90 | 66.90 | 9.10 | 5 |
| LTSS | 3.38 | 0.32 | 4.22 | 2.31 | 5 |
| TURB | 40.92 | 11.91 | 74.00 | 4.10 | 5 |
| LTURB | 3.43 | 0.47 | 4.32 | 1.63 | 5 |
| PTSASH | 73.66 | 2.63 | 78.90 | 63.70 | 5 |
| SCOND | 30.18 | 3.20 | 38.40 | 22.10 | 5 |
| LSCOND | 3.42 | 0.11 | 3.67 | 3.14 | 5 |
| ------------------------ HIGH RAINFALL | | FY-1988 | CROUCH BR | ------------------------ | |
| TSS | 250.94 | 47.84 | 398.30 | 135.40 | 5 |
| LTSS | 5.45 | 0.20 | 5.99 | 4.92 | 5 |
| TURB | 430.00 | 74.10 | 670.00 | 260.00 | 5 |
| LTURB | 6.01 | 0.17 | 6.51 | 5.56 | 5 |
| PTSASH | 90.26 | 0.67 | 92.60 | 88.90 | 5 |
| SCOND | 108.32 | 10.34 | 128.50 | 72.30 | 5 |
| LSCOND | 4.67 | 0.10 | 4.86 | 4.29 | 5 |

| VARIABLE | MEAN | STD ERROR OF MEAN | MAXIMUM VALUE | MINIMUM VALUE | N |
|---|---|---|---|---|---|
| ------------------------ HIGH RAINFALL FY-1988 UTR BR BELOW ---------------------------- | | | | | |
| TSS | 43.46 | 9.73 | 66.60 | 9.50 | 5 |
| LTSS | 3.63 | 0.33 | 4.21 | 2.35 | 5 |
| TURB | 50.88 | 12.37 | 78.50 | 5.40 | 5 |
| LTURB | 3.68 | 0.46 | 4.38 | 1.86 | 5 |
| PTSASH | 74.80 | 2.69 | 81.10 | 66.30 | 5 |
| SCOND | 32.50 | 3.30 | 40.20 | 23.60 | 5 |
| LSCOND | 3.49 | 0.10 | 3.72 | 3.20 | 5 |
| ------------------------ HIGH RAINFALL FY-1989 UTR CK ABOVE ---------------------------- | | | | | |
| TSS | 5.69 | 0.55 | 7.80 | 3.10 | 10 |
| LTSS | 1.87 | 0.09 | 2.17 | 1.41 | 10 |
| TURB | 2.39 | 0.47 | 4.00 | 0.60 | 10 |
| LTURB | 1.12 | 0.16 | 1.61 | 0.47 | 10 |
| PTSASH | 51.95 | 1.51 | 59.20 | 41.00 | 10 |
| SCOND | 16.89 | 0.57 | 19.40 | 14.80 | 10 |
| LSCOND | 2.88 | 0.03 | 3.02 | 2.76 | 10 |
| ------------------------ HIGH RAINFALL FY-1989 TINKER CK ---------------------------- | | | | | |
| TSS | 14.24 | 3.32 | 35.30 | 4.10 | 10 |
| LTSS | 2.54 | 0.20 | 3.59 | 1.63 | 10 |
| TURB | 4.52 | 0.71 | 9.60 | 2.20 | 10 |
| LTURB | 1.64 | 0.12 | 2.36 | 1.16 | 10 |
| PTSASH | 53.53 | 1.10 | 60.90 | 48.70 | 10 |
| SCOND | 30.99 | 1.40 | 38.30 | 26.30 | 10 |
| LSCOND | 3.46 | 0.04 | 3.67 | 3.31 | 10 |
| ------------------------ HIGH RAINFALL FY-1989 MCQUEEN BR ---------------------------- | | | | | |
| TSS | 217.39 | 62.32 | 742.50 | 92.00 | 10 |
| LTSS | 5.16 | 0.20 | 6.61 | 4.53 | 10 |
| TURB | 254.00 | 49.38 | 680.00 | 140.00 | 10 |
| LTURB | 5.43 | 0.14 | 6.52 | 4.95 | 10 |
| PTSASH | 88.73 | 0.84 | 92.50 | 82.60 | 10 |
| SCOND | 54.99 | 5.90 | 95.90 | 41.40 | 10 |
| LSCOND | 3.98 | 0.09 | 4.57 | 3.75 | 10 |
| ------------------------ HIGH RAINFALL FY-1989 UTR CK MID. ---------------------------- | | | | | |
| TSS | 26.00 | 13.14 | 76.00 | 6.10 | 5 |
| LTSS | 2.87 | 0.44 | 4.34 | 1.96 | 5 |
| TURB | 31.90 | 16.27 | 89.00 | 3.20 | 5 |
| LTURB | 2.84 | 0.62 | 4.50 | 1.44 | 5 |
| PTSASH | 70.64 | 5.40 | 82.90 | 57.40 | 5 |
| SCOND | 25.48 | 1.20 | 28.70 | 23.30 | 5 |
| LSCOND | 3.27 | 0.04 | 3.39 | 3.19 | 5 |

| VARIABLE | MEAN | STD ERROR OF MEAN | MAXIMUM VALUE | MINIMUM VALUE | N |
|---|---|---|---|---|---|
| ---------- HIGH RAINFALL | | FY-1989 | CROUCH BR ---------- | | |
| TSS | 246.32 | 59.55 | 466.50 | 119.70 | 5 |
| LTSS | 5.41 | 0.22 | 6.15 | 4.79 | 5 |
| TURB | 362.00 | 58.77 | 560.00 | 210.00 | 5 |
| LTURB | 5.84 | 0.16 | 6.33 | 5.35 | 5 |
| PTSASH | 91.22 | 0.65 | 92.90 | 89.60 | 5 |
| SCOND | 91.32 | 11.19 | 126.00 | 63.40 | 5 |
| LSCOND | 4.50 | 0.12 | 4.84 | 4.17 | 5 |
| ---------- HIGH RAINFALL | | FY-1989 | UTR BR BELOW ---------- | | |
| TSS | 39.16 | 17.33 | 93.60 | 5.50 | 5 |
| LTSS | 3.24 | 0.50 | 4.55 | 1.87 | 5 |
| TURB | 45.82 | 21.33 | 105.00 | 2.80 | 5 |
| LTURB | 3.19 | 0.64 | 4.66 | 1.34 | 5 |
| PTSASH | 75.04 | 5.12 | 85.00 | 56.40 | 5 |
| SCOND | 25.98 | 1.12 | 29.30 | 23.90 | 5 |
| LSCOND | 3.29 | 0.04 | 3.41 | 3.21 | 5 |
| ---------- HIGH RAINFALL | | FY-1990 | UTR CK ABOVE ---------- | | |
| TSS | 14.80 | 0.70 | 15.50 | 14.10 | 2 |
| LTSS | 2.76 | 0.04 | 2.80 | 2.71 | 2 |
| TURB | 3.55 | 0.15 | 3.70 | 3.40 | 2 |
| LTURB | 1.51 | 0.03 | 1.55 | 1.48 | 2 |
| PTSASH | 49.10 | 7.10 | 56.20 | 42.00 | 2 |
| SCOND | 21.60 | 3.50 | 25.10 | 18.10 | 2 |
| LSCOND | 3.11 | 0.16 | 3.26 | 2.95 | 2 |
| ---------- HIGH RAINFALL | | FY-1990 | TINKER CK ---------- | | |
| TSS | 36.25 | 24.35 | 60.60 | 11.90 | 2 |
| LTSS | 3.34 | 0.78 | 4.12 | 2.56 | 2 |
| TURB | 9.05 | 0.75 | 9.80 | 8.30 | 2 |
| LTURB | 2.30 | 0.07 | 2.38 | 2.23 | 2 |
| PTSASH | 59.80 | 8.00 | 67.80 | 51.80 | 2 |
| SCOND | 33.85 | 5.45 | 39.30 | 28.40 | 2 |
| LSCOND | 3.54 | 0.16 | 3.70 | 3.38 | 2 |
| ---------- HIGH RAINFALL | | FY-1990 | MCQUEEN BR ---------- | | |
| TSS | 571.10 | 250.70 | 821.80 | 320.40 | 2 |
| LTSS | 6.24 | 0.47 | 6.71 | 5.77 | 2 |
| TURB | 455.00 | 180.00 | 635.00 | 275.00 | 2 |
| LTURB | 6.04 | 0.42 | 6.46 | 5.62 | 2 |
| PTSASH | 89.15 | 0.25 | 89.40 | 88.90 | 2 |
| SCOND | 30.90 | 2.40 | 33.30 | 28.50 | 2 |
| LSCOND | 3.46 | 0.08 | 3.54 | 3.38 | 2 |

| VARIABLE | MEAN | STD ERROR OF MEAN | MAXIMUM VALUE | MINIMUM VALUE | N |
|---|---|---|---|---|---|
| ------------------------ HIGH RAINFALL FY-1990 UTR CK MID. ---------------------------- | | | | | |
| TSS | 40.20 | -- | 40.20 | 40.20 | 1 |
| LTSS | 3.72 | -- | 3.72 | 3.72 | 1 |
| TURB | 60.00 | -- | 60.00 | 60.00 | 1 |
| LTURB | 4.11 | -- | 4.11 | 4.11 | 1 |
| PTSASH | 81.80 | -- | 81.80 | 81.80 | 1 |
| SCOND | 76.10 | -- | 76.10 | 76.10 | 1 |
| LSCOND | 4.35 | -- | 4.35 | 4.35 | 1 |
| ------------------------ HIGH RAINFALL FY-1990 CROUCH BR ---------------------------- | | | | | |
| TSS | 401.00 | -- | 401.00 | 401.00 | 1 |
| LTSS | 6.00 | -- | 6.00 | 6.00 | 1 |
| TURB | 490.00 | -- | 490.00 | 490.00 | 1 |
| LTURB | 6.20 | -- | 6.20 | 6.20 | 1 |
| PTSASH | 91.30 | -- | 91.30 | 91.30 | 1 |
| SCOND | 32.90 | -- | 32.90 | 32.90 | 1 |
| LSCOND | 3.52 | -- | 3.52 | 3.52 | 1 |
| ------------------------ HIGH RAINFALL FY-1990 UTR BR BELOW ---------------------------- | | | | | |
| TSS | 180.30 | -- | 180.30 | 180.30 | 1 |
| LTSS | 5.20 | -- | 5.20 | 5.20 | 1 |
| TURB | 240.00 | -- | 240.00 | 240.00 | 1 |
| LTURB | 5.48 | -- | 5.48 | 5.48 | 1 |
| PTSASH | 90.20 | -- | 90.20 | 90.20 | 1 |
| SCOND | 38.90 | -- | 38.90 | 38.90 | 1 |
| LSCOND | 3.69 | -- | 3.69 | 3.69 | 1 |

## APPENDIX B

Amphibians Found at
Rainbow Bay, Sun Bay, and the Refuge Ponds

## Salamanders

| | |
|---|---|
| *Ambystoma opacum* | marbled salamander |
| *A. talpoideum* | mole salamander |
| *A. t. tigrinum* | eastern tiger salamander |
| *Eurycea bislineata cirrigera* | southern two-lined salamander |
| *E. longicauda guttolineata* | three-lined salamander |
| *E. quadridigitata* | dwarf salamander |
| *Notophthalmus v. viridescens* | red-spotted newt |
| *Plethodon g. glutinosus* | slimy salamander |
| *Pseudotriton m. montanus* | eastern mud salamander |
| *P. ruber vioscai* | southern red salamander |
| *Siren intermedia* | lesser siren |

## Toads

| | |
|---|---|
| *Bufo terrestris* | southern toad |
| *B. quercicus* | oak toad |
| *Gastrophryne carolinensis* | eastern narrow-mouthed toad |
| *Scaphiopus h. holbrooki* | eastern spadefoot toad |

## Tree frogs

| | |
|---|---|
| *Hyla cinerea* | green treefrog |
| *H. femoralis* | pine woods treefrog |
| *H. gratiosa* | barking treefrog |
| *H. squirella* | squirrel treefrog |
| *H. versicolor* and/or *chrysoscelis* | gray treefrog |

## Other Frogs

| | |
|---|---|
| *Acris g. gryllus* | southern cricket frog |
| *Pseudacris crucifer* | northern spring peeper |
| *P. n. nigrita* | southern chorus frog |
| *P. ornata* | ornate chorus frog |
| *Rana areolata capito* | Carolina gopher frog |
| *R. catesbeiana* | bullfrog |
| *R. c. clamitans* | bronze frog |
| *R. utricularia* | southern leopard frog |

# END

# DATE FILMED

5/24/93