

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

FY-1993 ANNUAL REPORT

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FOREWARD

Construction of the Defense Waste Processing Facility (DWPF) on the Savannah River Site (SRS) began during FY-1984. The Savannah River Ecology Laboratory (SREL) has completed 15 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 been evaluating 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 Z-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, thus long-term studies are necessary to separate natural variation from variation due to human perturbations (Pechmann et al. 1991, 1993; Vitt 1981, Vitt et al. 1982).

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) and the gopher frog (*Rana areolata*) is currently being considered for federal listing.

DWPF construction began in FY-1984. Continuing studies are directed towards assessing construction impacts on the biota, and towards modeling the effects of alteration of wetland hydroperiod on the biota. Primary emphasis is being placed on evaluating the effectiveness of mitigation measures undertaken by the DOE. Also, a special automated audio-monitoring technique is being tested at Rainbow Bay (and other SRS habitats). This technique will greatly enhance site assessment for amphibians.

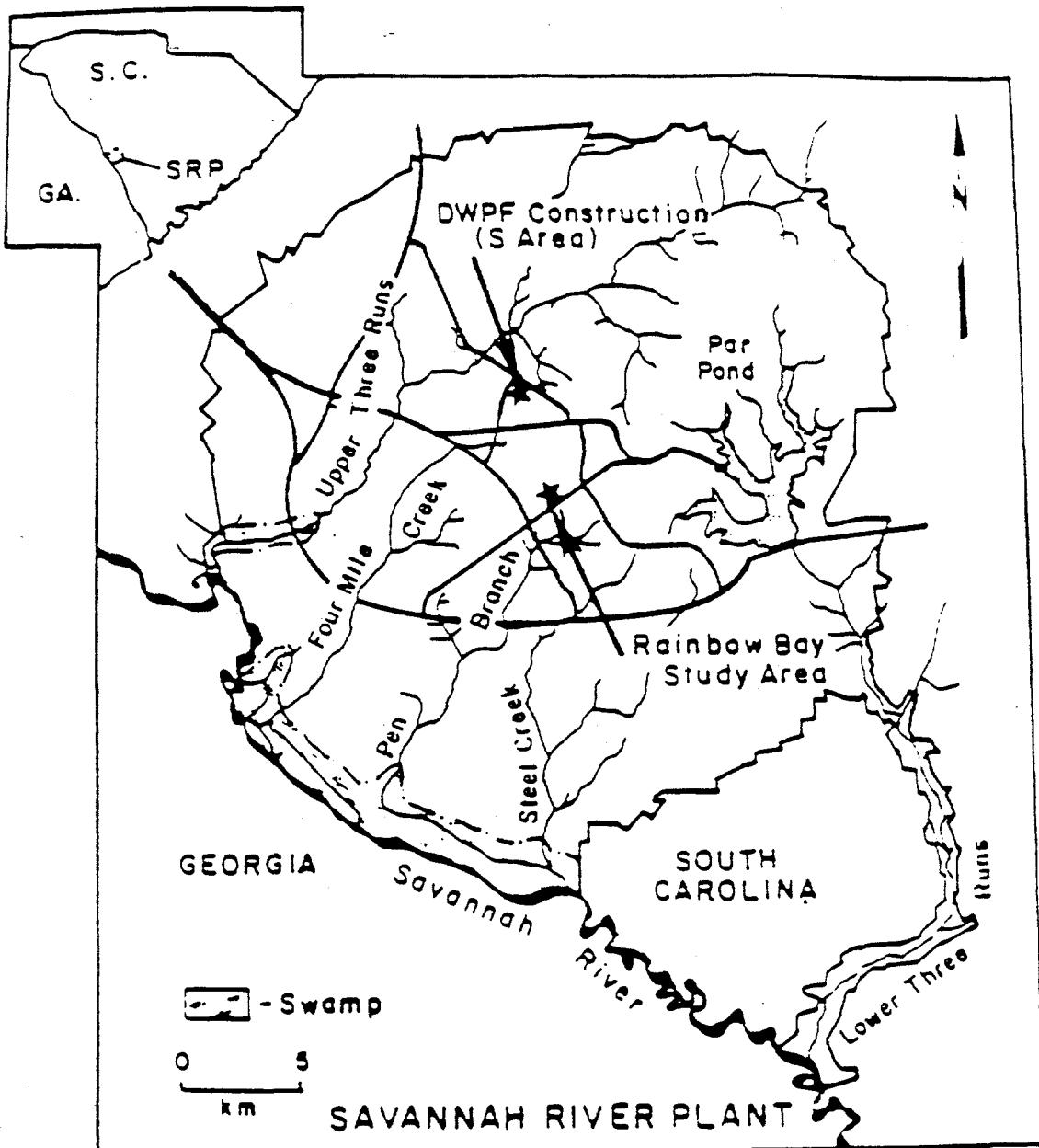


Figure I-1 Locations of the DWPF construction site (S-Area) and the control site (Rainbow Bay) on the Savannah River Site.

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 (U.S. DOE 1982). 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-1993 water quality results which were obtained during the continuing DWPF construction.

In FY-1984, the DWPF construction eliminated Sun Bay in S-Area. Carolina bays are productive, natural wetlands which serve as important breeding sites for many species of amphibians (Bennett et al. 1979, Gibbons and Semlitsch 1981, 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, Scott et al. 1986). 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. A summary of refuge pond captures is presented in Chapter III.

LITERATURE CITED

Bennett, S.H., J.W. Gibbons and J. Glanville. 1979. Terrestrial activity, abundance and diversity of amphibians in differently managed forest types. *Am. Midl. Nat.* 103:412-416.

Gibbons, J.W. and R.D. Semlitsch. 1981. Terrestrial drift fences with pitfall traps: an effective technique for quantitative sampling of animal populations. *Brimleyana* 7:1-16.

Pechmann, J.H.K., R.D. Semlitsch, R.M. Lew and D.T. Mayack. 1984. Ecological Studies Related to the Construction of the Defense Waste Processing Facility on the Savannah River Plant; FY-1983-84 Annual Report. NTIS publ. SREL-17, UC-66e. 166 pp.

Pechmann, J.H.K., D.E. Scott and J.N. Knox. 1985. Ecological Studies Related to Construction of the Defense Waste Processing Facility on the Savannah River Plant. FY-1985 Annual Report. NTIS publ. SREL-19, UC-66e. 77 pp.

Pechmann, J.H.K., D.E. Scott, J.H. McGregor, R.A. Estes and A.C. Chazal. 1993. Ecological Studies Related to Construction of the Defense Waste Processing Facility on the Savannah River Plant. FY-1989 and FY-1990 Annual Report. NTIS publ. SREL-66, UC-66e. 103 pp.

Pechmann, J.H.K., D.E. Scott, R.D. Semlitsch, J.P. Caldwell, L. J. Vitt, and J. W. Gibbons. 1991. Declining amphibian populations: the problem of separating human impacts from natural fluctuations. *Science* 253:892-895.

Savannah River Ecology Laboratory. 1979. Ecological inventory for the Proposed AFR Site. Final Report, January 31, 1979. Report No. EY-76-C-09-0819.

Savannah River Ecology Laboratory. 1980. Annual Report, FY-1980. A biological

inventory of the proposed site of the Defense Waste Processing Facility on the Savannah River Plant in Aiken, South Carolina. NTIS publ. SREL-7 UC-66e. 179 pp.

Scott, D.E., J.H.K. Pechmann, J.N. Knox, R.A. Estes, and A.M. Dancewicz. 1986. Ecological Studies Related to the Construction of the Defense Waste Processing Facility on the Savannah River Plant. FY-1986 Annual Report. Savannah River Ecology Laboratory. NTIS publ. SREL-32 UC-66e. 103 pp.

Sharitz, R.R. and J.W. Gibbons. 1982. The ecology of southeastern shrub bogs (Pocosins) and Carolina bays: a community profile. Fish and Wildlife Service, U.S. Department of the Interior, Washington, D.C. FWS-OBS-82/04. 93 pp.

United States Department of Energy. 1982. Final Environmental Impact Statement, Defense Waste Processing Facility, Savannah River Plant, Aiken, South Carolina. NTIS publ. DOE/EIS-0082 UC-70.

Vitt, L.J. 1981. Annual Report, FY-1981. A biological inventory of the proposed site of the Defense Waste Processing Facility on the Savannah River Plant in Aiken, South Carolina NTIS publ. SREL-8 UC-66e. 86 pp.

Vitt, L.J., R.D. Semlitsch and M.L. Cothran. 1982. Annual Report, FY-1982. A biological inventory of the proposed site of the Defense Waste Processing Facility on the Savannah River Plant in Aiken, South Carolina. NTIS publ. SREL-13 UC-66e. 146 pp.

II. WATER QUALITY MONITORING OF PERIPHERAL STREAMS

Tracy K. Lynch 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 plus additional control sites: 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 initial impacts during construction and the effectiveness of erosion control measures. Data collected from October 1987 to the present are used to assess stream recovery and the continued effectiveness of erosion control measures; major earthmoving and site preparation activities had been completed by this date.

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 Z-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

DWPF WATER QUALITY MONITORING SITES.

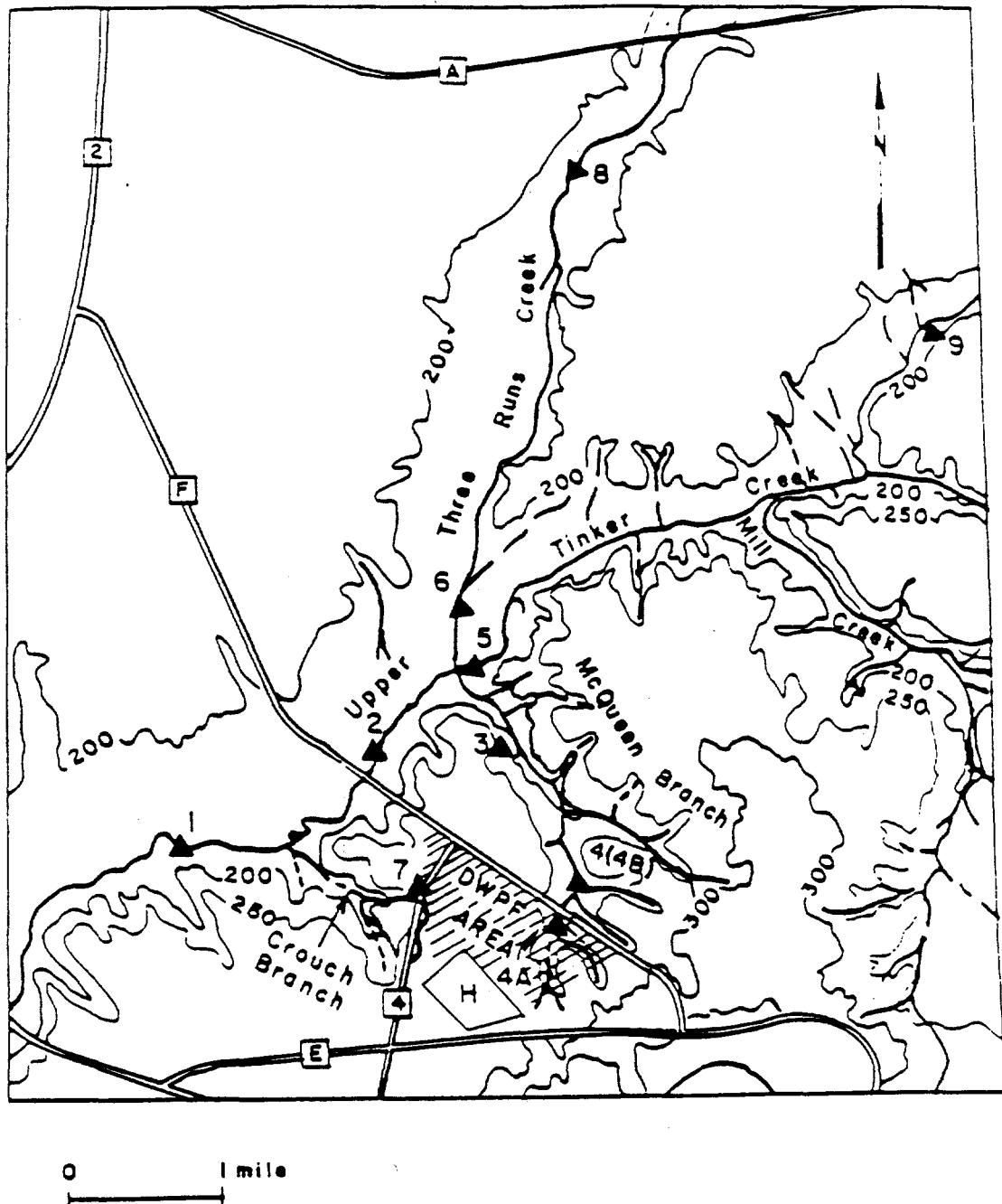


Figure II-1. DWPF Water Quality monitoring sites.

potentially affect water quality in UTR Creek. Tinker Creek also flows into UTR just above the confluence of McQueen Branch and UTR. Similar in size to UTR Creek at their confluence, 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 (3 and 4) 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. The latter four sites (sites 6, 8, 5, and 9) are unimpacted control sites.

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 FY- 1990 streams were sampled for seven months. Water quality measures from the remaining 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, e.g., eroded clays vs. leaf litter. 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). 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 velocity (cm per second) was measured using a Marsh-McBirney portable flow meter. Stream velocity and flow were used to calculate TSS load.

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-middle), the Crouch Branch site (7; Crouch), and the UTR Creek site below Crouch Branch (1; UTR-below). 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 \leq 0.1 cm (No Rain), rainfall $>$ 0.1 cm but \leq 1.0 cm (Low Rain), and rainfall $>$ 1.0 cm (High Rain, see Scott et al. 1988). Data also were categorized based on the stages of the construction project: Before (1983), During (FY-1984 to FY-1987), and After (FY-1988 to FY-1993) Construction (see Introduction).

Analysis of variance (ANOVA) was used to assess the impact of DWPF construction on S- and Z-Area stream water quality. In order to increase homogeneity of variance and normality in the data, log transformations were performed on TSS, turbidity, specific conductivity, TSS load (kg per day per km²), and rainfall data. 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), statistical tests determined whether or not there was a significant location effect (e.g., Did the locations differ in their level of TSS averaged across all construction periods?), a significant construction period effect (e.g., Did the construction periods differ in their level of TSS averaged across all locations?), and a significant location-by-construction interaction (e.g., Did TSS 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 effect, 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). Due to small sample sizes all Crouch Branch samples and all turbidity samples taken in the Before Construction period were omitted from the statistical analyses. Data were analyzed using SAS version 6.07 statistical package (SAS Institute Inc. 1985a, b).

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, Appendix B lists P values of ANOVA main effects, and Appendix C summarizes construction period means.

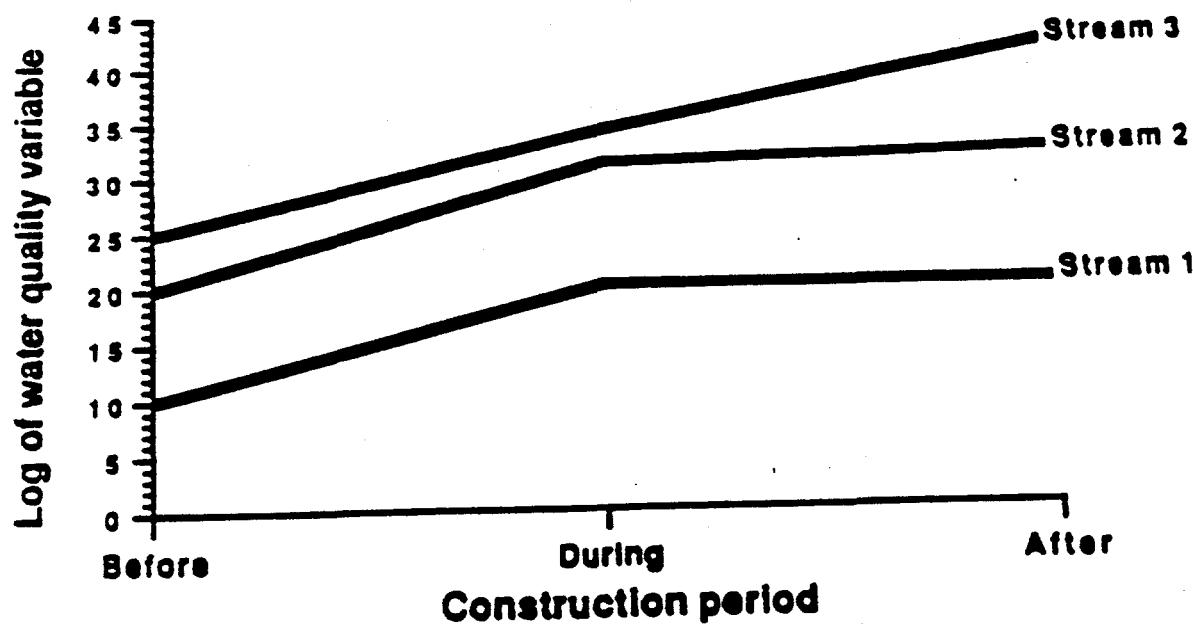


Figure II-2. Water quality variable (log-transformed) plotted for three construction periods (schematic representation of the interaction test in analysis of variance models).

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, TSS levels in the smaller streams were higher than the larger streams irrespective of the construction period.

In both the No Rain and High Rain classes, the main effect of location was significant for TSS, specific conductivity, percent ash, and turbidity. In the Low Rain class the location effect was also significant for all variables except TSS (Appendix B). In general, locations differed in their levels of all water quality variables averaged across construction periods.

The construction periods differed in their level of a given variable averaged over all locations. Construction period significantly affected levels of all water quality variables in the No Rain class. In general, in the No Rain class levels of the water quality variables in the S-Area peripheral streams were elevated in the During Construction Period, and have since declined. In the Low Rain class only specific conductance levels were significantly affected by construction period. In the High Rain class, only turbidity levels were significantly influenced by the construction period; effects on other variables were non-significant, perhaps due to the extreme variation in levels of all variables under high rainfall conditions. For the No Rain class, interpretation of the significant location and construction main effects is confounded by the significant location-by construction interaction.

Given these relationships, the location-by-construction period

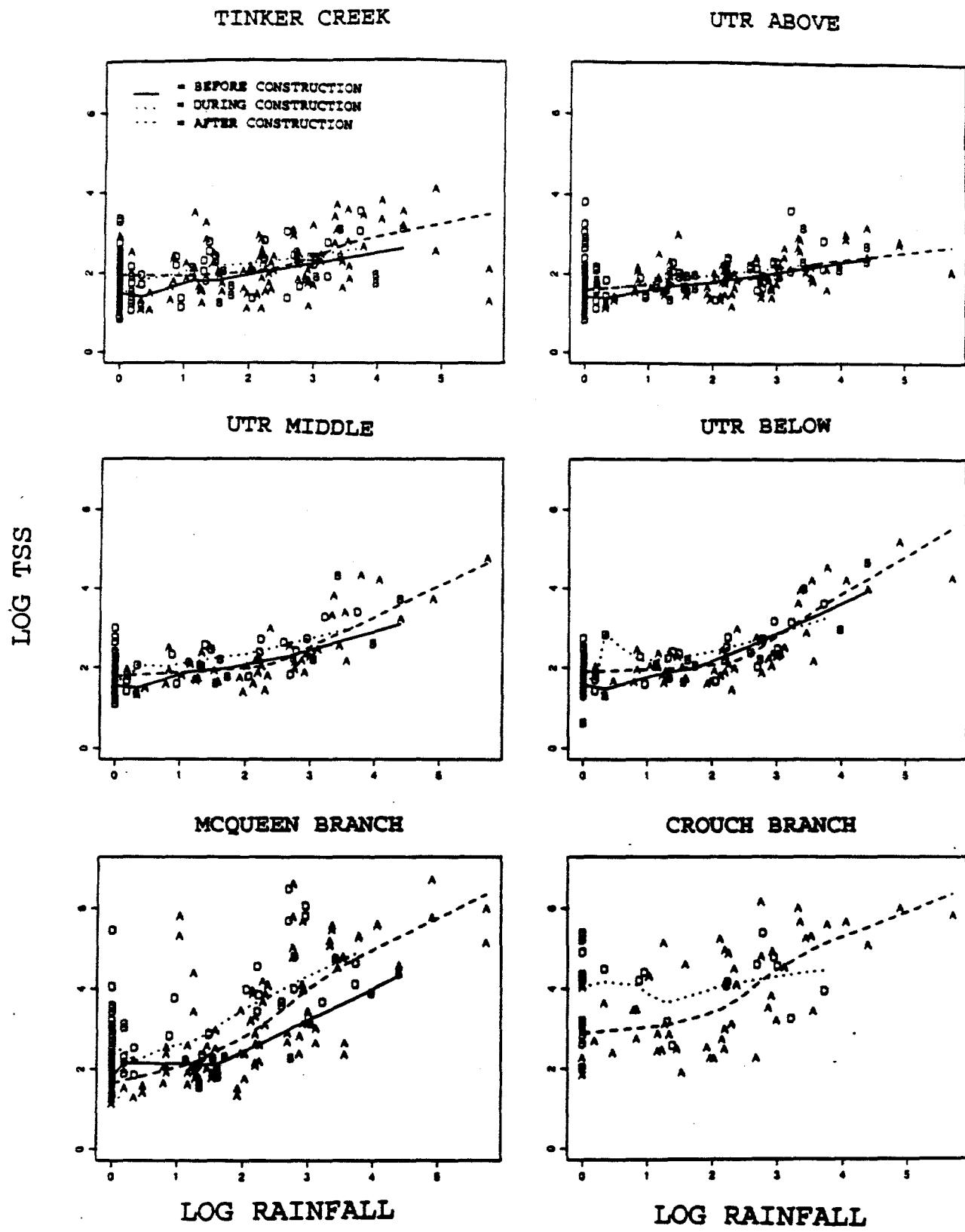


Figure II-3. Log TSS levels plotted versus rainfall for each location.

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. Means for each construction period in each rainfall class are reported in Appendix C.

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). 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 stream, McQueen Branch is "flashier." The degree to which the overall water quality of McQueen Branch was influenced by DWPF construction activity was assessed using the specific statistical contrast tests.

TSS (Fig. II-5): No Rain - TSS levels rose moderately in Tinker Creek over the three construction periods. Levels in McQueen Branch were higher than the control BC, and increased significantly more DC ($p < 0.005$). In the After Construction period, TSS levels in McQueen Branch were reduced significantly compared to the decline observed in Tinker Creek ($p < 0.0001$), and returned to levels similar to McQueen Branch before construction (BC $\bar{x} = 5.38$; AC $\bar{x} = 5.99$).

Low Rain - TSS levels were higher in McQueen Branch than the control for all construction periods. TSS levels increased between BC and DC and declined slightly AC in both McQueen Branch and Tinker Creek. There were no significant differences in the response profiles of the two streams over time.

High Rain - TSS levels rose very slightly in Tinker Creek over the construction periods; levels increased in McQueen Branch DC, but declined slightly AC. Although the increase in TSS from BC to DC was more rapid in McQueen Branch than in Tinker Creek ($p < 0.05$), the decline from DC to AC

TINKER CREEK

MCQUEEN BRANCH

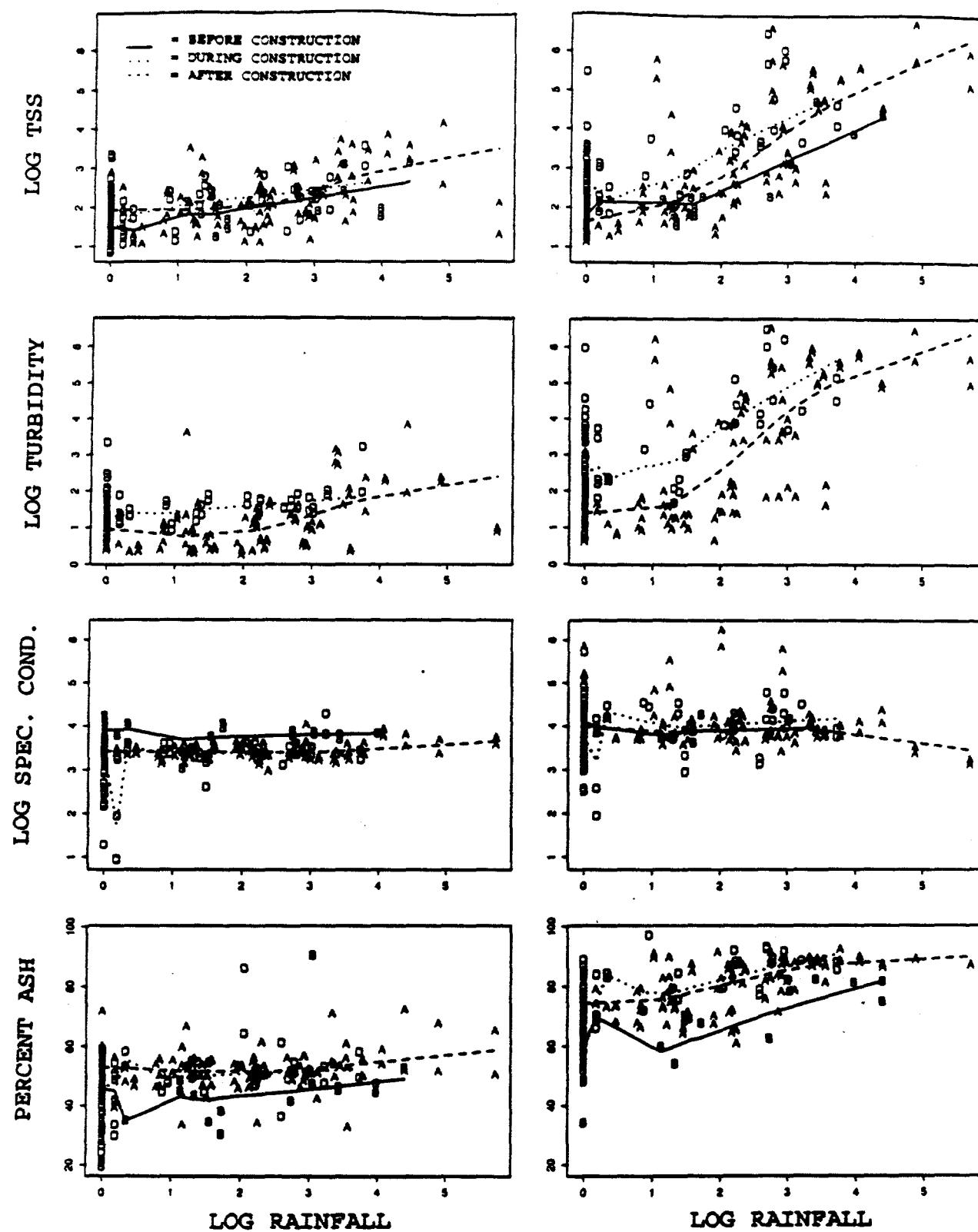


Figure II-4. Log TSS, log turbidity, log specific conductance, and percent ash plotted versus log rainfall for Tinker Creek and McQueen Branch.

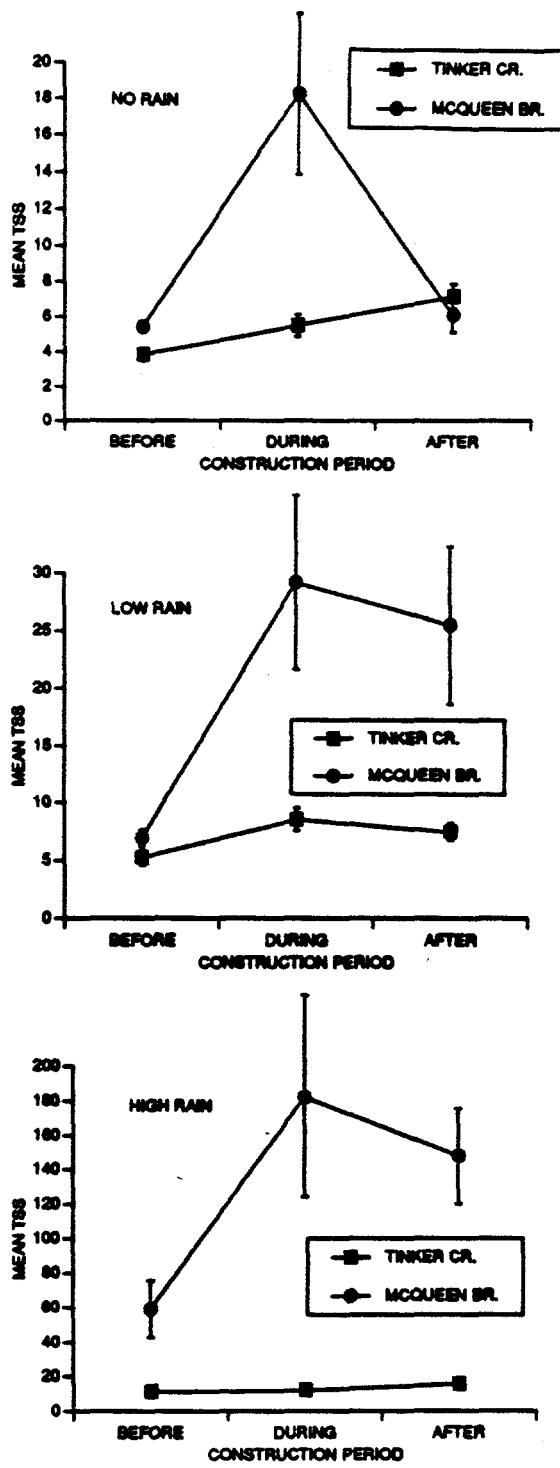


Figure II-5. Comparison of mean TSS levels in Tinker Creek (control) and McQueen Branch during the three construction periods.

tended to be significantly greater ($p < 0.08$). Overall, there was no significant difference in the response profiles of McQueen Branch and Tinker Creek from BC to AC.

TURBIDITY (Fig. II-6): No Rain - Turbidity levels were higher BC and AC in McQueen Branch than Tinker Creek. Both creeks showed increases DC; however McQueen Branch decreased significantly more AC than Tinker Creek ($p < 0.001$).

Low and High Rain - Tinker Creek shows virtually no change in turbidity levels over time; McQueen Branch levels declined in the AC period compared to DC. The slight declines in turbidity in McQueen Branch from DC to AC were no different from the response profile of the control stream for either rainfall class ($p > 0.20$).

SPECIFIC CONDUCTANCE (Fig. II-7): No Rain - McQueen Branch specific conductance was higher than Tinker Creek during all construction periods. Specific conductance levels in Tinker Creek fell from BC to DC, but the response profile in McQueen Branch during the same time interval showed significantly less of a decline ($p < 0.01$). Specific conductance levels in both creeks increased at the same rate from DC to AC. Comparing responses from BC to AC, McQueen Branch and Tinker Creek responded differently ($p < 0.01$), with levels in McQueen increasing as levels in Tinker decreased.

Low Rain - Specific conductance was higher during all construction periods in McQueen Branch than in Tinker Creek. Levels decreased DC and rose slightly AC in Tinker, while levels increased moderately throughout all time periods in McQueen Branch. The specific conductance response profile in McQueen Branch differed significantly from Tinker Creek from BC to AC ($p < 0.03$).

High Rain - McQueen's Branch specific conductance was higher than Tinker Creek for all construction periods. Specific conductance levels in Tinker Creek declined through both time intervals. McQueen Branch levels rose slightly DC and fell slightly AC. There was no significant difference in the

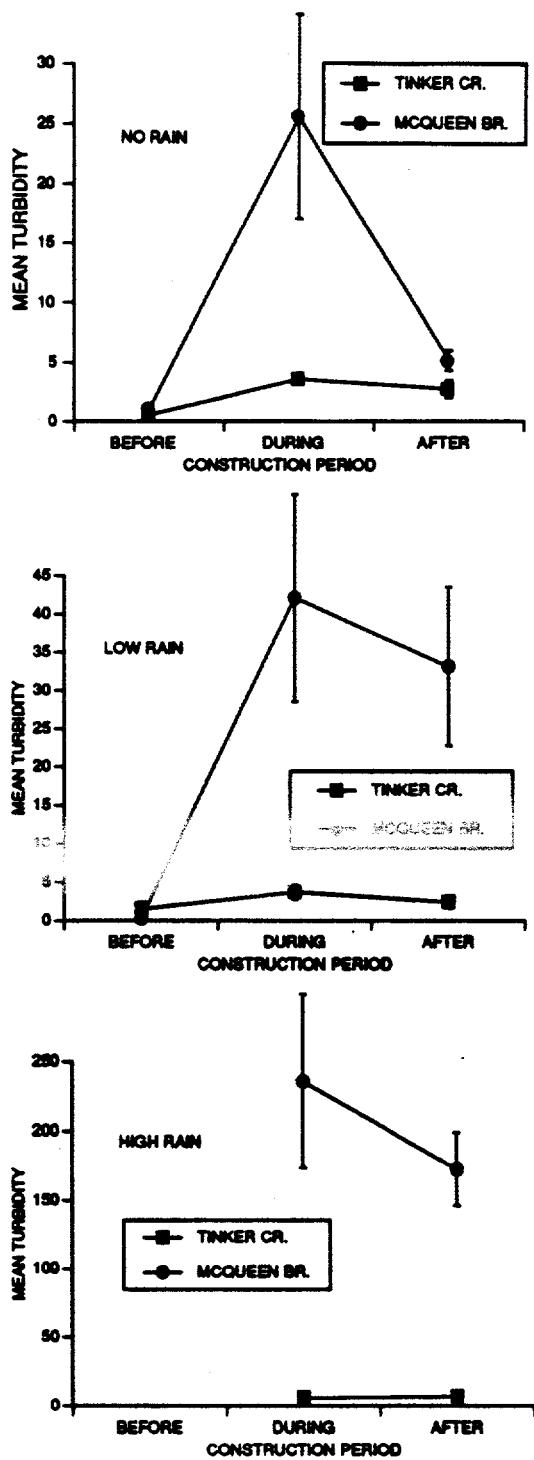


Figure II-6. Comparison of the mean turbidity levels in Tinker Creek (control) and McQueen Branch during the three construction periods.

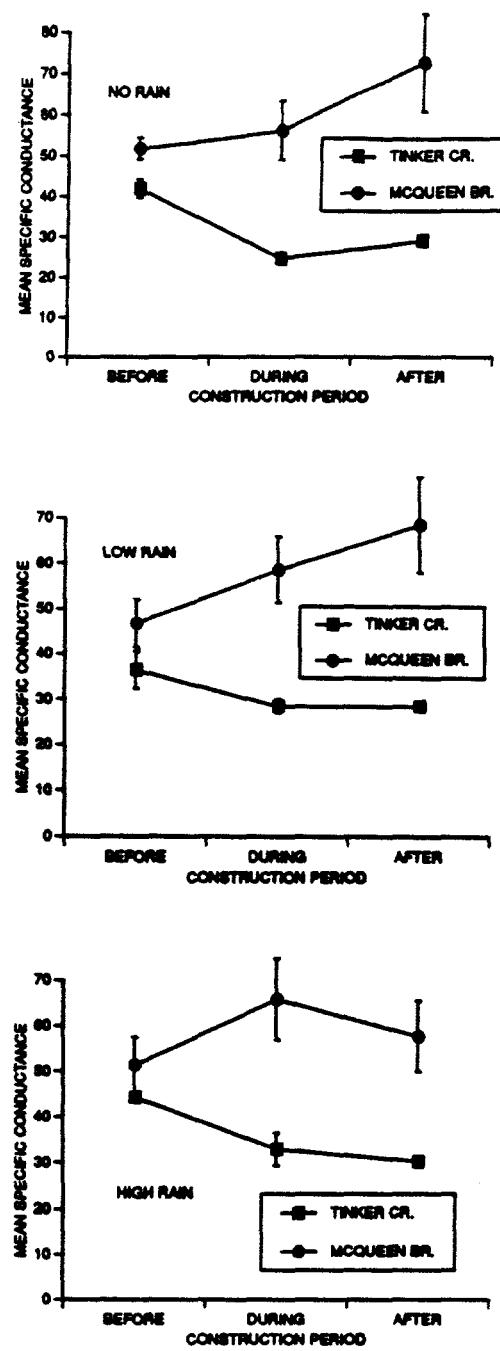


Figure II-7. Comparison of mean specific conductance levels in Tinker Creek (control) and McQueen Branch during three construction periods.

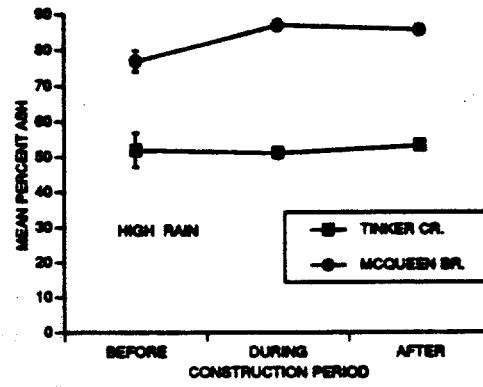
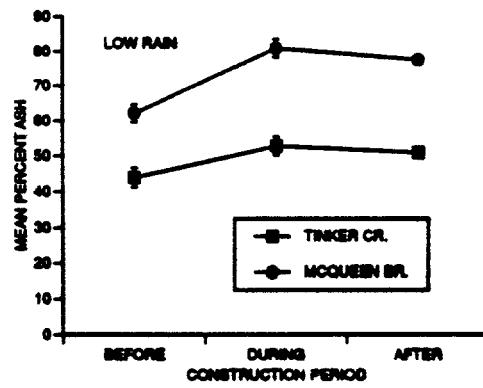
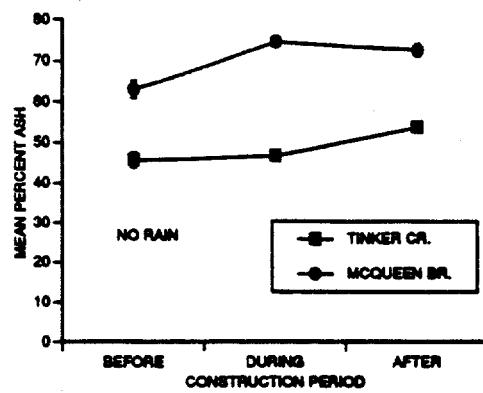


Figure II-8. Comparison of mean percent ash levels in Tinker Creek (control) and McQueen Branch during three construction periods.

overall responses between the two streams.

PERCENT ASH (Fig. II-8): No Rain - Percent ash levels increased moderately in Tinker Creek over the three construction periods. Levels in McQueen Branch began higher than Tinker Creek and rose significantly more in the DC period ($p < 0.001$). Response profiles from DC to AC were also different ($p < 0.001$); percent ash continued to rise in Tinker Creek, but showed a slight decline in McQueen Branch.

Low Rain - Percent ash levels increased DC and decreased slightly AC in both McQueen Branch and Tinker Creek. Levels in McQueen Branch were higher than Tinker Creek over all time periods. There were no significant differences in responses between McQueen Branch and Tinker Creek over construction periods.

High Rain - Levels of percent ash in Tinker Creek decreased DC and increased slightly AC. Levels in McQueen Branch were higher than Tinker Creek BC and increased significantly DC ($p < 0.02$). Both streams had increased percent ash AC when compared to BC levels; the overall increase in McQueen Branch was significantly greater than the increase at Tinker Creek ($p < 0.05$).

The results listed above provide evidence that McQueen Branch clearly was affected by DWPF construction-site runoff between the BC and DC period. These effects are evident in the TSS, specific conductivity and percent ash variables. However, there is also evidence that impacts have been ameliorated in the years since construction was completed. Turbidity and TSS levels under No Rain conditions were similar AC to BC levels (Figure II-5 and II-6). Under Low and High Rain conditions, however, TSS levels appear to remain elevated. Levels of other water quality variables also remained elevated AC in McQueen Branch in most cases; generally there was a slight decrease from DC levels. Given 10 possible comparisons of overall response profiles between BC and AC periods, four showed a significant location-by-construction interaction, indicating that McQueen Branch responded differently between BC and AC periods than Tinker Creek. Six comparisons were significant between the BC and DC periods. Three (of 12 possible, including turbidity) comparisons were

significant between the DC and AC periods and all of these occurred under No Rain conditions. The differences may be attributed to increases in the control stream versus little to no increase (and a decrease in one instance) in McQueen Branch. Some recovery of the tributary seems 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 Rain conditions. Few data are 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-9).

TSS (Fig. II-10): No Rain - Tinker Creek showed a slight increase in TSS from DC to AC. Crouch Branch TSS levels were considerably higher DC and AC although Crouch Branch showed a decrease AC. The difference in TSS level response between DC and AC for the two streams was significant ($p < 0.0001$). AC levels remained higher in Crouch Branch than in Tinker Creek.

Low and High Rain - The TSS response profiles for Crouch Branch and Tinker Creek were similar for both rain classes. In the Low Rain class, TSS levels in Crouch Branch decreased slightly AC compared to DC, as did levels in Tinker Creek. In the High Rain class, TSS levels in both creeks rose from the DC to the AC period. There was no significant location-by-construction period interaction for either rain class.

TURBIDITY (Fig. II-11): No Rain - Both Tinker Creek and Crouch Branch turbidity levels decreased between the DC and AC periods with Crouch Branch decreasing significantly more sharply ($p < 0.0001$) than Tinker Creek. Turbidity levels in Crouch Branch were higher than in the control stream during both time periods.

Low Rain - Turbidity levels in Crouch Branch and Tinker Creek decreased AC from the DC period; the response profiles of the two streams were not significantly different.

High Rain - Tinker Creek turbidity levels remained relatively constant, while Crouch Branch levels increased from the DC to AC period. These responses were not significantly different, however.

SPECIFIC CONDUCTANCE (Fig. II-12): No, Low, and High Rain - Tinker Creek specific conductance levels remained relatively constant from the DC to the AC period under all rainfall conditions. For the No and Low Rain classes, specific conductance levels in Crouch Branch also were constant. Under High Rain conditions levels in Crouch Branch decreased slightly; response profiles of the two creeks were not significantly different.

PERCENT ASH (Fig. II-13): No Rain - Percent ash levels increased in Tinker Creek from the DC to the AC period. Levels in Crouch Branch decreased significantly during that same period compared to Tinker Creek ($p < 0.001$).

Low Rain - Both Tinker Creek and Crouch Branch showed slight decreases in percent ash levels from DC to the AC period; response profiles were no different.

High Rain - Crouch Branch percent ash levels were considerably higher DC and AC 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 in the Before Construction period, 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, levels of TSS, turbidity and percent ash increased in Crouch Branch during the AC period. 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 are evident in the No Rain class during the AC period. 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

TINKER CREEK

CROUCH BRANCH

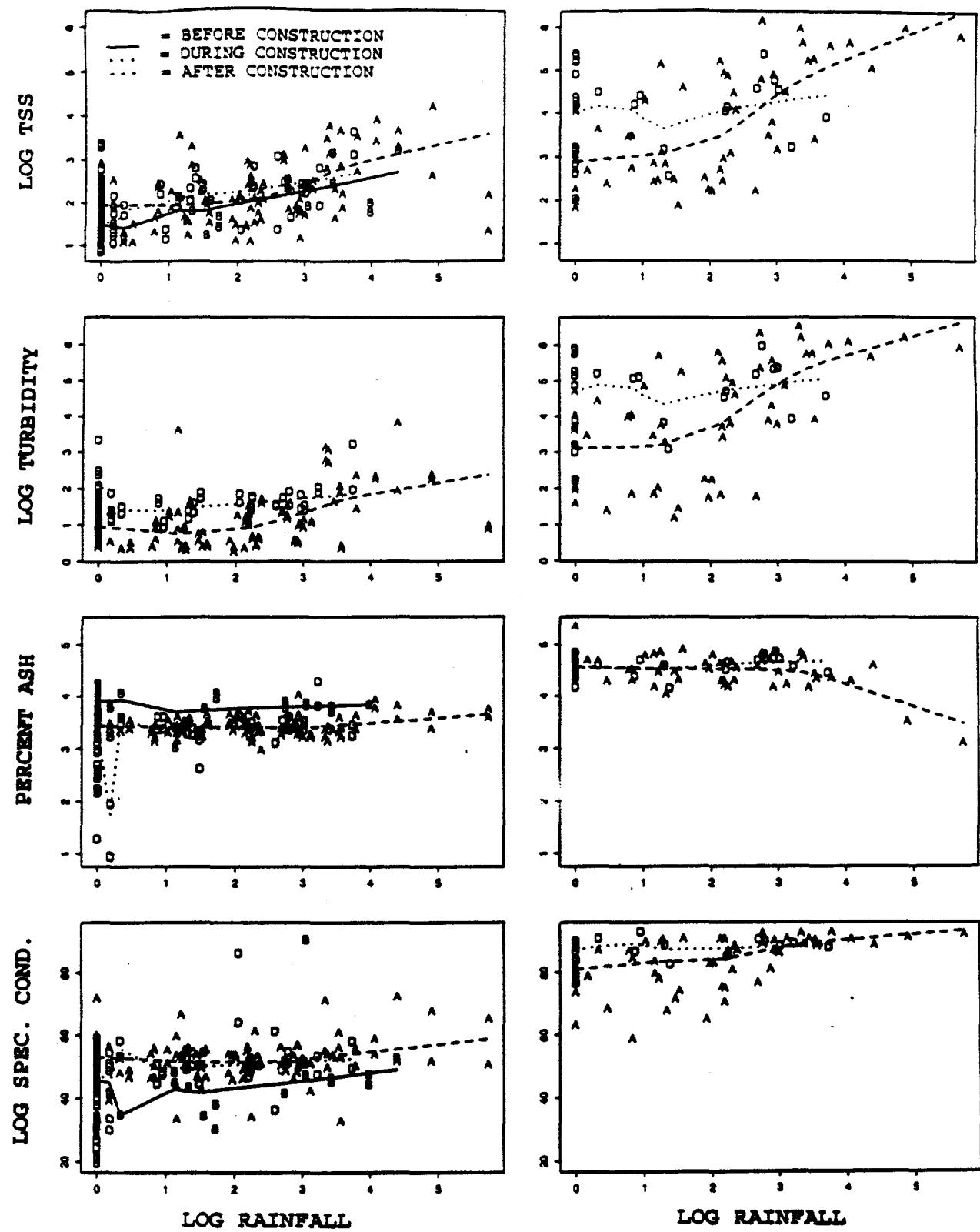


Figure II-9. Log TSS, log turbidity, log specific conductance, and percent ash levels plotted versus rainfall for Tinker Creek and Crouch Branch.

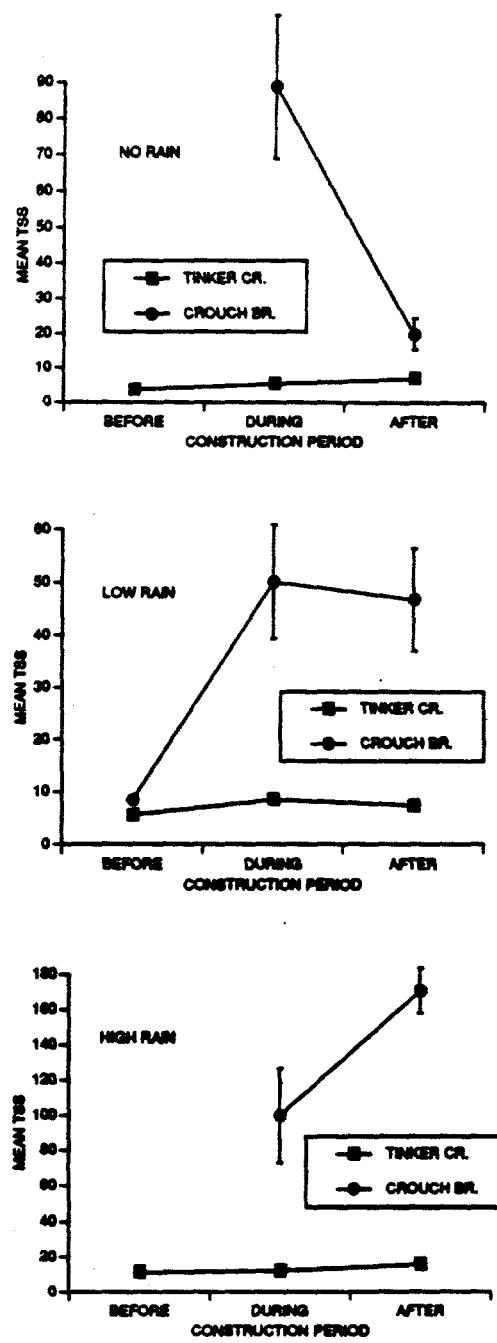


Figure II-10. Comparison of mean TSS levels in Tinker Creek (control) and Crouch Branch during three construction periods.

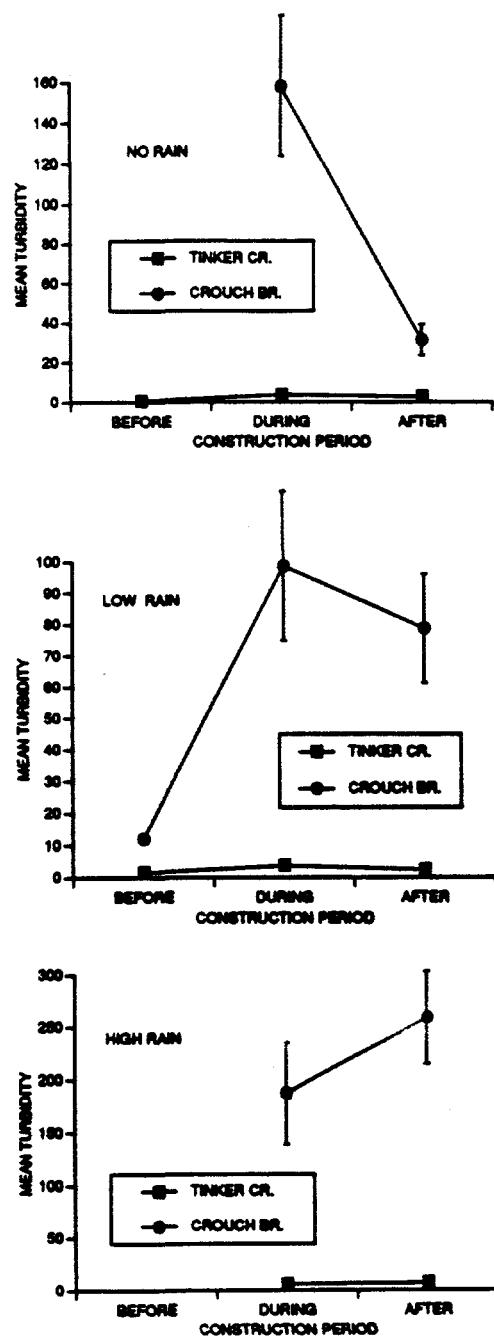


Figure II-11. Comparison of mean turbidity levels in Tinker Creek (control) and Crouch Branch during three construction periods.

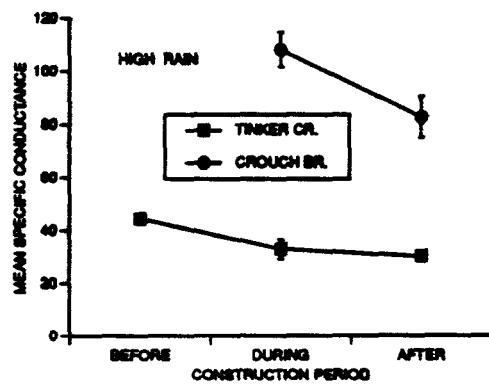
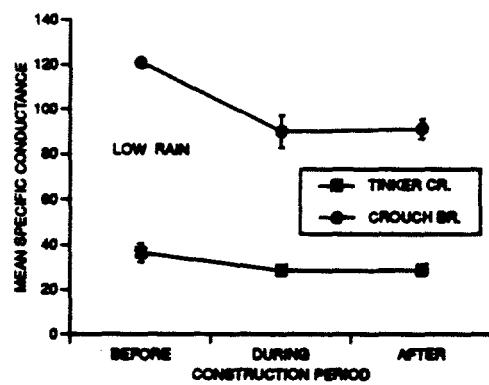
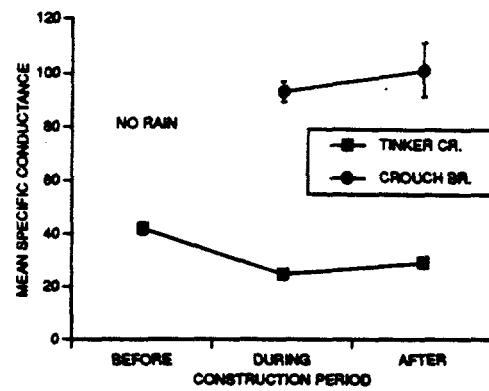


Figure II-12. Comparison of mean specific conductance levels in Tinker Creek (control) and Crouch Branch during three construction periods.

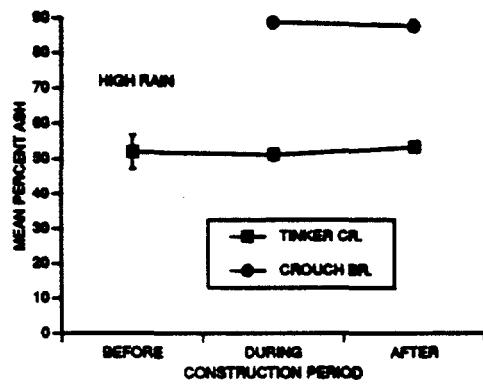
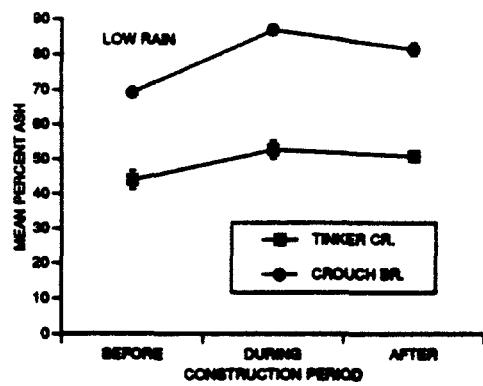
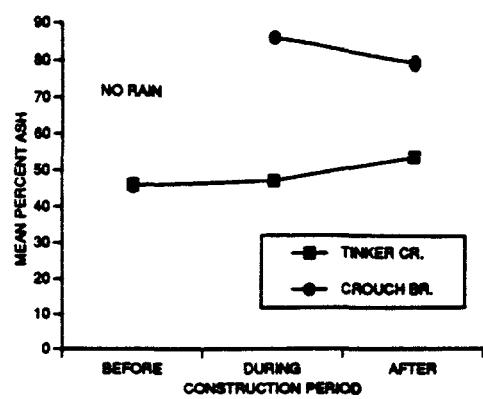


Figure II-13. Comparison of mean percent ash levels in Tinker Creek (control) and Crouch Branch during three construction periods.

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 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-14 and II-15).

TSS (Fig. II-16): No and Low Rain - Trends in the three UTR Creek locations were similar. TSS levels rose DC and fell AC except for after-construction TSS levels in UTR-below which increased slightly in No Rain conditions. Some trends hinted at potential erosional input to UTR; UTR-middle and UTR-below TSS levels were higher than UTR-above levels during all periods, levels were most different in the AC period under baseflow (No Rain) conditions, and the largest difference occurred between UTR-below (which received inputs from McQueen Branch, Crouch Branch, and Tinker Creek) and the control location (UTR-above) during the AC period. In addition, all AC levels were higher than BC levels, but elevated levels also occurred in the control section of the stream (UTR-above). No response profiles were significantly different between the three UTR locations.

High Rain - UTR-above showed little change in TSS level over the three construction periods and had the lowest TSS levels of all three sites during all time periods. UTR-middle and -below showed a decrease DC in TSS levels, but both increased during the AC period to levels comparable to BC at each location. Changes were non-significant.

TURBIDITY (Fig. II-17) 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 in UTR-above and -below from the DC to AC period, while levels in UTR-middle decreased. These responses were also non significant.

SPECIFIC CONDUCTANCE (Fig. II-18): No and Low Rain - For all locations on UTR Creek, specific conductance decreased from the BC to DC period and increased slightly AC. Levels AC were below levels BC. No changes were statistically significant.

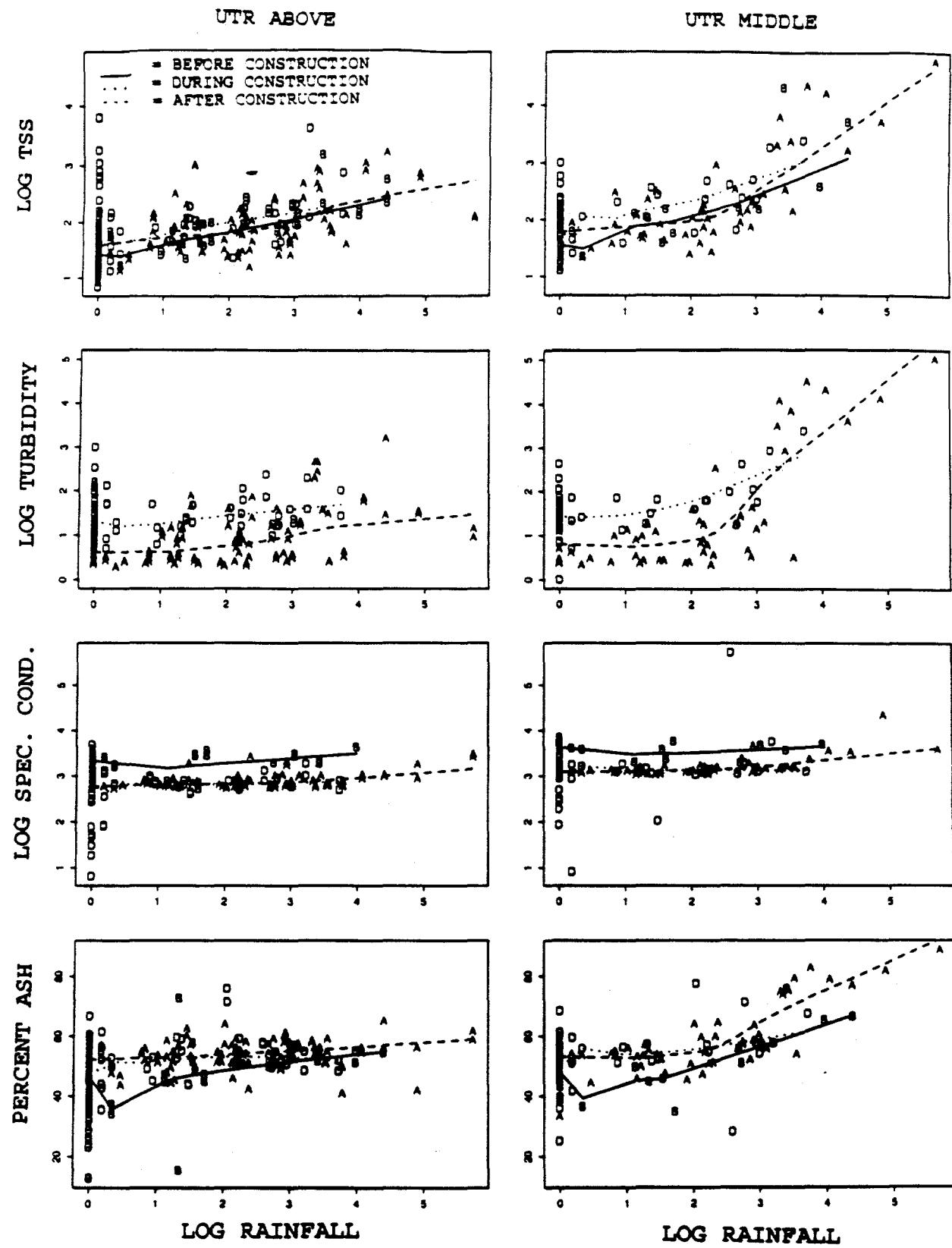


Figure II-14. Log TSS, log turbidity, log specific conductance, and percent ash levels plotted versus rainfall for UTR-above and UTR-middle.

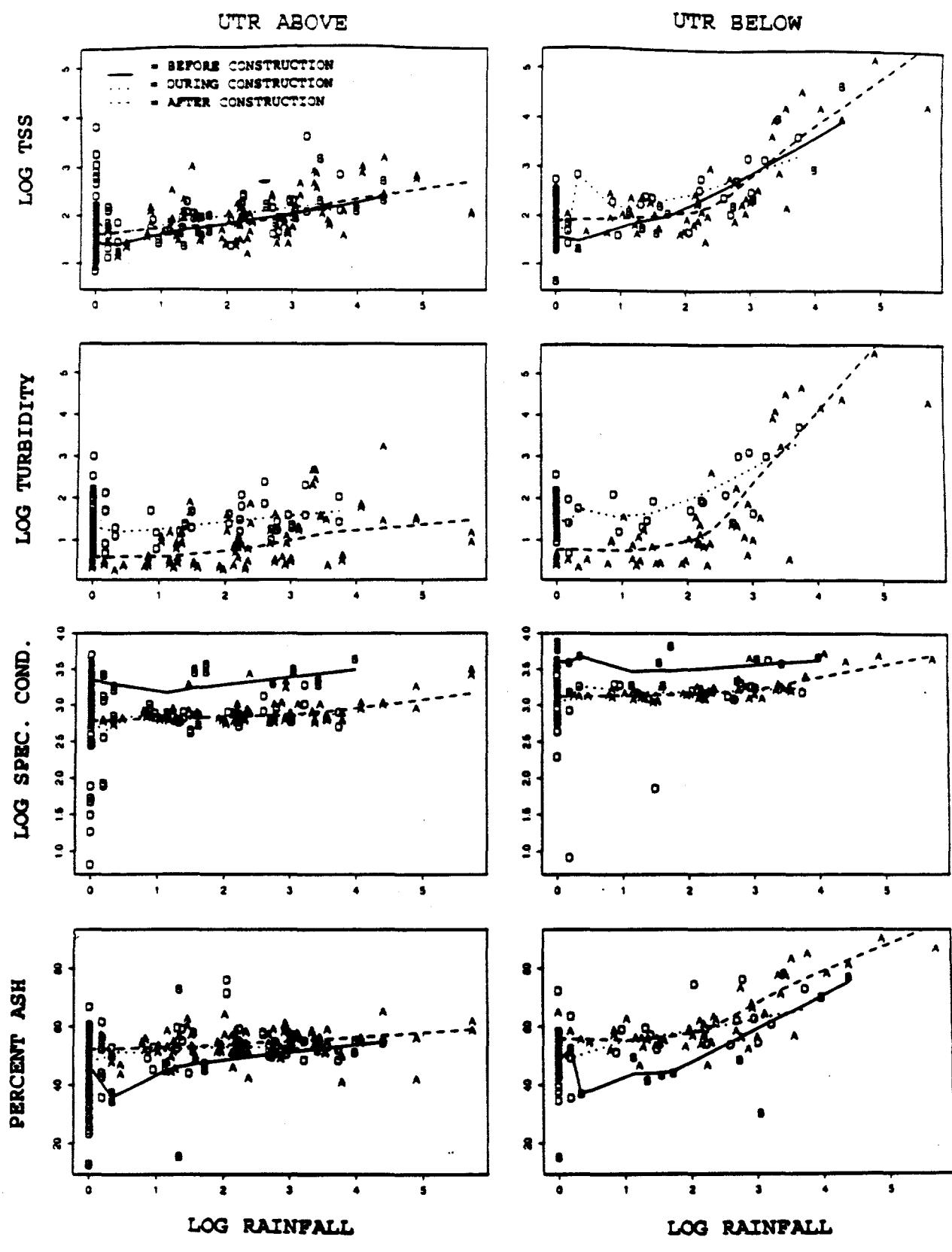


Figure II-15. Log TSS, log turbidity, log specific conductance, and percent ash levels plotted versus rainfall for UTR-above and UTR-below.

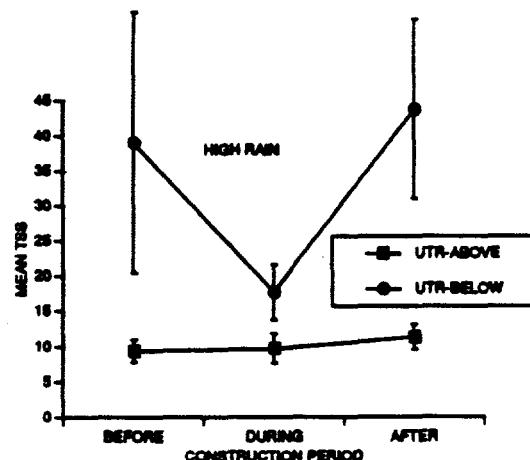
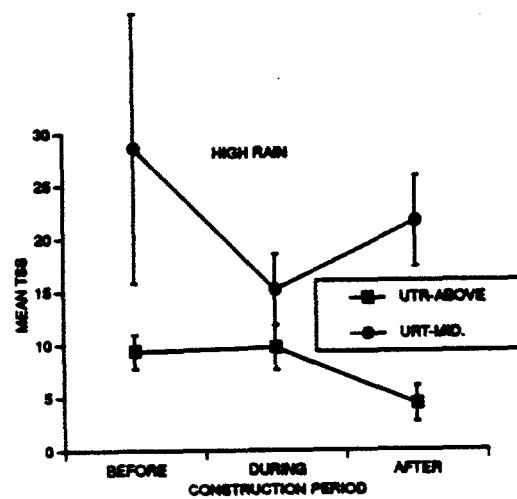
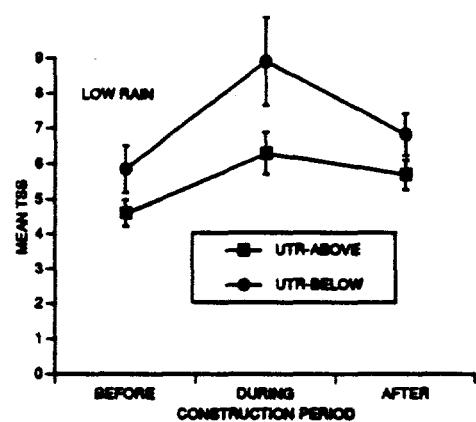
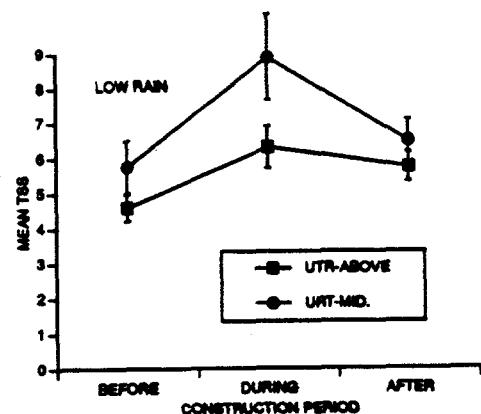
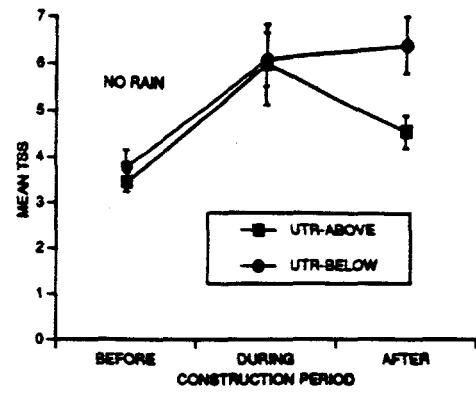
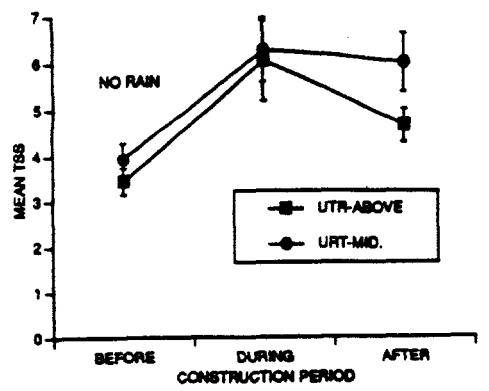


Figure II-16. Comparison of mean TSS levels in Upper Three Runs Creek-above (control) and Upper Three Runs Creek-middle and -below during three construction periods.

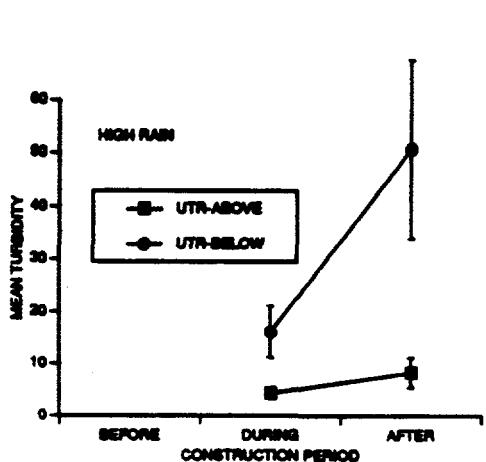
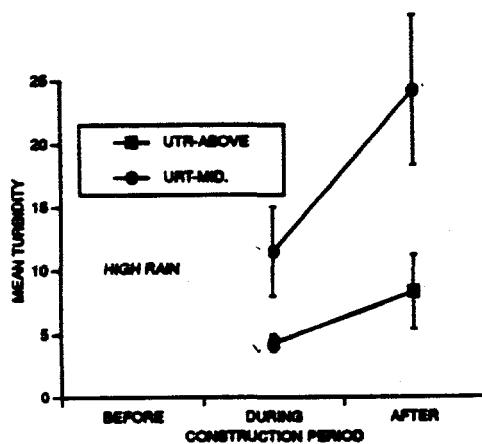
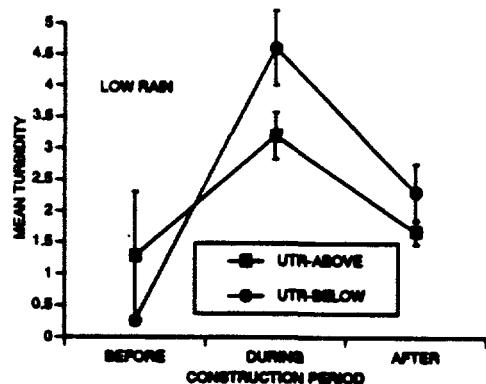
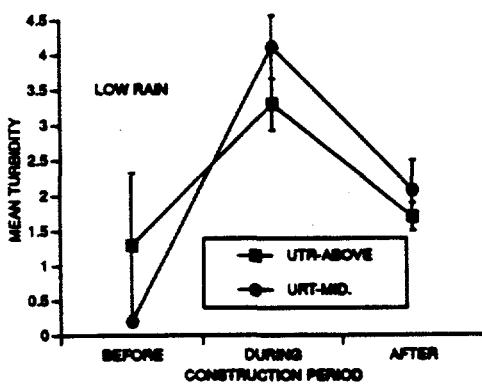
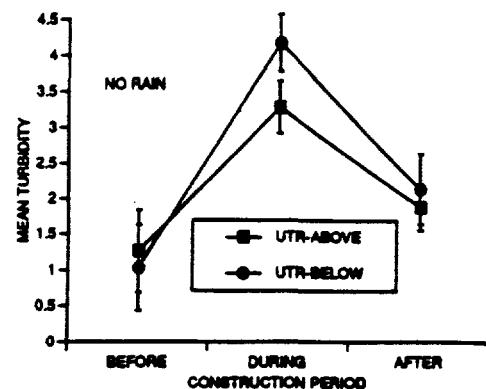
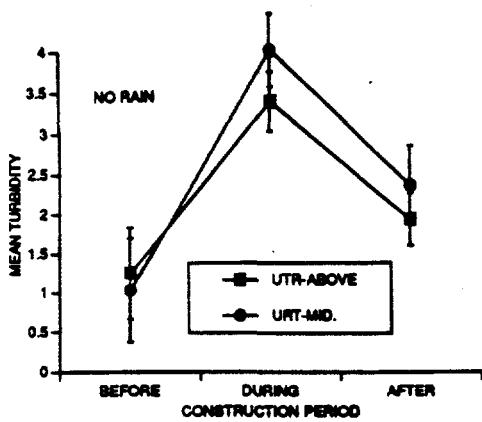


Figure II-17. Comparison of mean turbidity levels in Upper Three Runs Creek-above (control) and Upper Three Runs Creek-middle and -below during three construction periods.

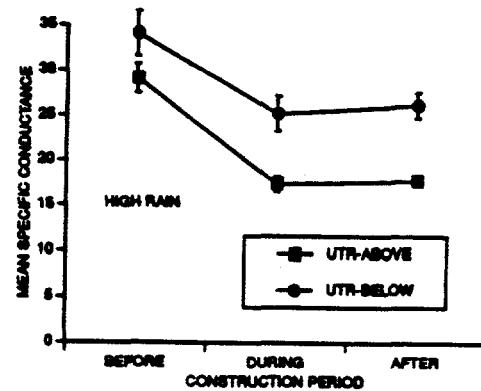
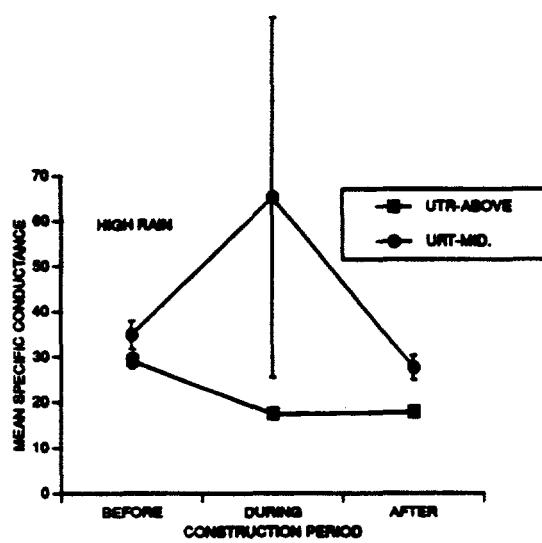
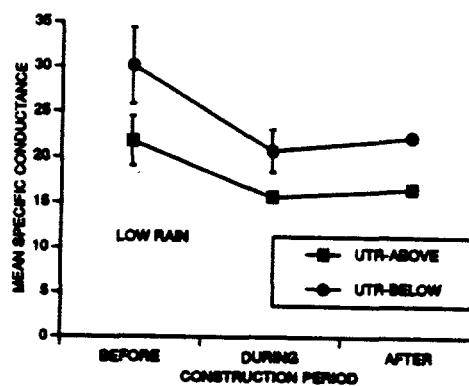
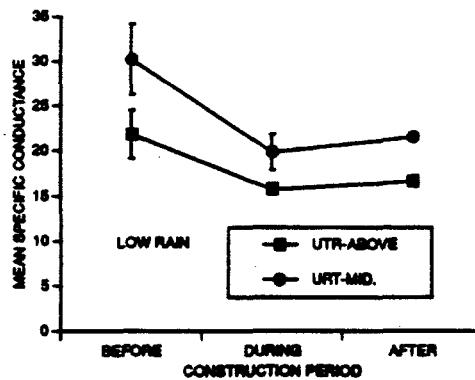
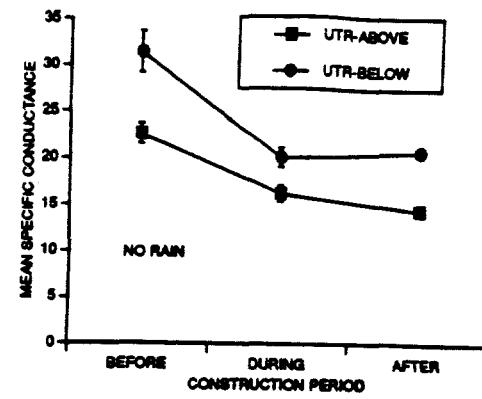
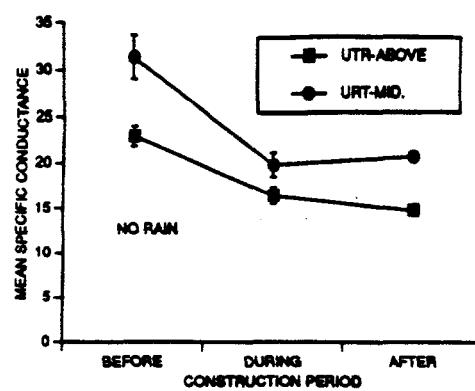


Figure II-18. Comparison of mean specific conductance levels in Upper Three Runs Creek-above (control) and Upper Three Runs Creek-middle and -below during three construction periods.

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. The only significant interaction involved the UTR-above and middle sites during the BC and DC periods.

PERCENT ASH

UTR-Above vs. UTR-Middle (Fig. II-19): No and Low Rain - Both locations (UTR-above and UTR middle) showed increasing percent ash levels over the three periods except levels at UTR-middle decreased slightly between DC and AC. Percent ash at UTR-middle was higher BC and levels at UTR-above were higher AC. No changes were significant.

High Rain - Percent ash levels at both UTR-above and -middle decreased DC and rose during the AC period to levels higher than the BC levels. The changes were non-significant.

UTR-Above vs. UTR-Below: No Rain - Percent ash levels in UTR-above and -below followed parallel patterns of increase during the three periods. Percent ash levels for UTR-above remained below that of UTR-below.

Low Rain - Percent ash levels in UTR-below increased DC and decreased AC while UTR-above increased over all construction periods. Both locations ended with percent ash levels above BC levels.

High Rain - Percent ash levels in UTR-above decreased DC and rose only slightly AC. Levels in UTR-below increased significantly DC ($p < 0.03$) and increased further AC. When compared to UTR-above, both of these changes were significantly different (BC to DC, $p < 0.003$; DC to AC, $p < 0.004$).

The data collected over the eleven years of this study show an increase in TSS, turbidity, and percent ash levels in UTR Creek; however, this increase cannot 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

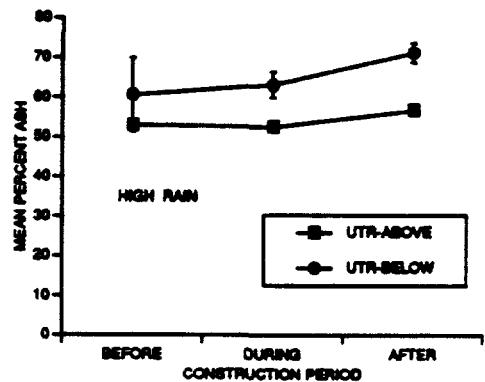
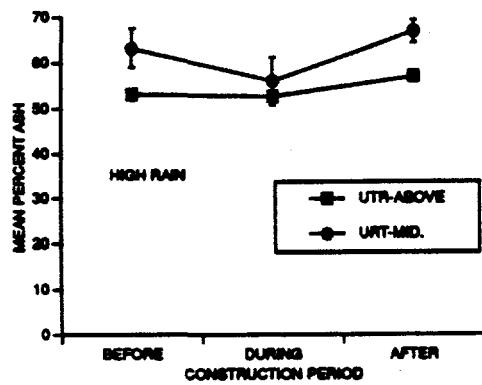
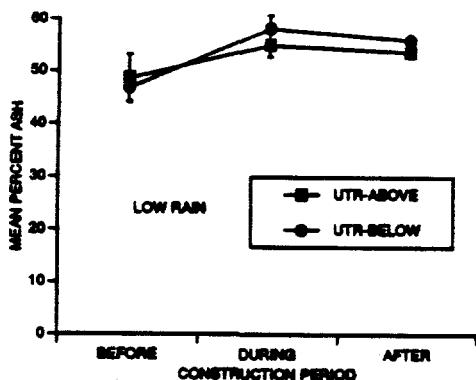
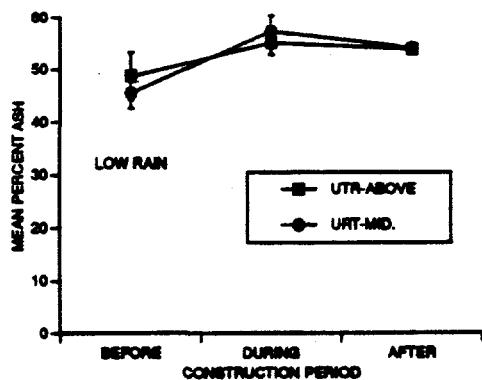
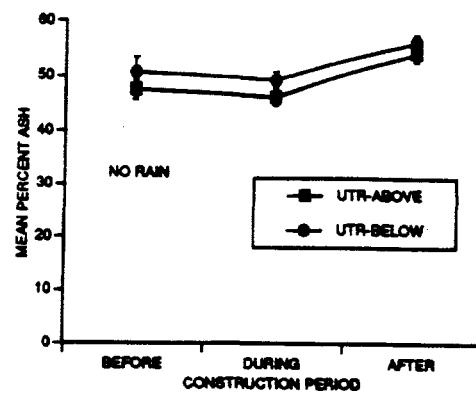
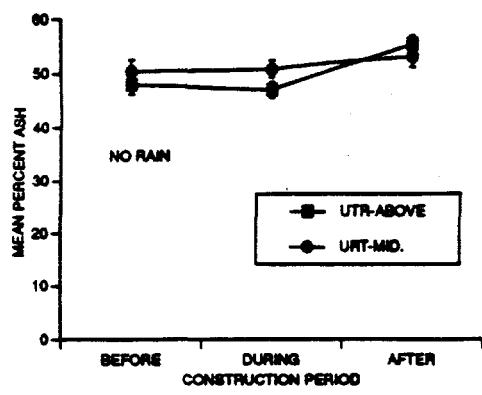


Figure II-19. Comparison of mean percent ash levels in Upper Three Runs Creek-above (control) and Upper Three Runs Creek-middle and -below during three construction periods.

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-1993 concludes eleven 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 during the pre-construction period.
2. The small tributaries below the construction site, Crouch Branch and McQueen Branch, contained significantly elevated TSS levels during the construction period; post-construction period effects are still evident under low and high rainfall conditions.
3. In general, during the after-construction period, levels of the water quality variables have decreased under No Rain conditions but remain elevated under High Rain conditions. This may indicate some recovery under baseflow conditions, but erosional inputs may still occur during periods of heavy rainfall.
4. Statistical evidence over the eleven year period does not reveal that the DWPF construction-site runoff has impacted UTR Creek significantly.

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 1993, 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.

LITERATURE CITED

Chambers, John M., W. S Cleveland, B. Kleiner, and P. A. Tukey, 1983.

Graphical Methods for Data Analysis. Bell Telephone Laboratories Inc. Murray Hill, N.J. 395pp.

Dickson, Kenneth L., 1986. Neglected and forgotten contaminants affecting aquatic life. Environ. Toxicol. and Chem. 5: 939-940.

Pechmann, J. H. K., R. D. Semlitsch, R. M. Lew, and D. T. Mayack, 1984.

Ecological Studies Related to Construction of the Defense Waste Processing Facility on the Savannah River Plant. FY 1983-84 Annual Report. Savannah River Ecology Laboratory NTIS publ. SREL-17-UC-66e, 166pp.

Pechmann, J. H. K., D. E. Scott, H. H. McGregor, R. A. Estes and A. C. Chazal, 1993. Ecological Studies Related to the Construction of the Defense Waste Processing Facility on the Savannah River Site. FY 1989-90 Annual Report. Savannah River Ecology Laboratory NTIS publ. SREL-46-UC-66e, 103pp.

SAS Institute, Inc., 1985a. SAS User's Guide: Basics, Version 5 Edition. SAS Institute Inc., Cary, N.C. 1290pp.

SAS Institute, Inc., 1985b. SAS User's Guide: Statistics, Version 5 Edition. SAS Institute Inc., Cary, N.C. 956pp.

Scott, David E., J. H. K. Pechmann, J. N. Knox, R. A. Estes, and J. H. McGregor, 1988. Ecological Studies Related to the Construction of the Defense Waste Processing Facility on the Savannah River Plant. FY-1987 and FY-1988 Annual Report. Savannah River Ecology

Laboratory. NTIS publ. SREL-43-UC-66e, 108 pp.

United States Environmental Protection Agency, 1983. Methods for chemical analysis of water and wastes. Environmental Monitoring and Support Laboratory. Cincinnati, OH.

APPENDIX A

DWPF Water Quality Data
FY-1983 to FY-1993
(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	--	--	--	--	--
TU RB	--	--	--	--	--
LTU RB	--	--	--	--	--
PTSASH	--	--	--	--	--
SCOND	--	--	--	--	--
LSCOND	--	--	--	--	--

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- NO RAINFALL FY-1983 -----					
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 -----					
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 TI NKER 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					
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 CK 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	30.80	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 CK 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 -----					
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 -----					
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 -----					
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 -----					
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 -----					
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
TU RB	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	2.00	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 CK 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 CK 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 CK 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
----- NO RAINFALL FY-1991 UTR CK ABOVE -----					
TSS	2.91	0.10	3.16	2.71	4
LTSS	1.36	0.03	1.43	1.31	4
TURB	0.52	0.01	0.55	0.48	4
LTURB	0.42	0.01	0.44	0.39	4
PTSASH	49.55	2.56	54.60	43.70	4
SCOND	15.18	0.23	15.70	14.70	4
LSCOND	2.78	0.01	2.82	2.75	4
----- NO RAINFALL FY-1991 TINKER CK -----					
TSS	2.79	0.35	3.47	1.91	4
LTSS	1.32	0.10	1.50	1.07	4
TURB	0.54	0.06	0.67	0.40	4
LTURB	0.43	0.04	0.51	0.34	4
PTSASH	51.33	2.48	58.10	46.60	4
SCOND	29.25	1.30	32.80	26.70	4
LSCOND	3.41	0.04	3.52	3.32	4

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- NO RAINFALL FY-1991 MCQUEEN BR -----					
TSS	3.29	0.24	3.89	2.76	4
LTSS	1.45	0.06	1.59	1.32	4
TURB	1.24	0.12	1.50	0.93	4
LTURB	0.80	0.06	0.92	0.66	4
PTSASH	71.65	1.90	76.10	68.20	4
SCOND	39.65	0.82	41.90	38.40	4
LSCOND	3.70	0.02	3.76	3.67	4
----- NO RAINFALL FY-1991 UTR CK MID. -----					
TSS	3.29	0.11	3.40	3.18	2
LTSS	1.46	0.03	1.48	1.43	2
TURB	0.56	0.07	0.62	0.49	2
LTURB	0.44	0.04	0.48	0.40	2
PTSASH	47.65	3.25	50.90	44.40	2
SCOND	20.95	0.85	21.80	20.10	2
LSCOND	3.09	0.04	3.13	3.05	2
----- NO RAINFALL FY- 1991 CROUCH BR -----					
TSS	11.83	1.81	13.63	10.02	2
LTSS	2.54	0.14	2.68	2.40	2
TURB	5.63	2.58	8.20	3.05	2
LTURB	1.81	0.41	2.22	1.40	2
PTSASH	75.50	7.00	82.50	68.50	2
SCOND	76.95	4.85	81.80	72.10	2
LSCOND	4.35	0.06	4.42	4.29	2
----- NO RAINFALL FY-1991 UTR CK BELOW -----					
TSS	4.10	0.16	4.25	3.94	2
LTSS	1.63	0.03	1.66	1.60	2
TURB	0.66	0.07	0.72	0.59	2
LTURB	0.50	0.04	0.54	0.46	2
PTSASH	55.50	0.90	56.40	54.60	2
SCOND	21.15	0.65	21.80	20.50	2
LSCOND	3.10	0.03	3.13	3.07	2
----- NO RAINFALL FY-1992 UTR CK ABOVE -----					
TSS	3.71	0.46	4.17	3.25	2
LTSS	1.54	0.10	1.64	1.45	2
TURB	0.44	0.04	0.47	0.40	2
LTURB	0.36	0.02	0.39	0.34	2
PTSASH	41.85	1.55	43.40	40.30	2
SCOND	15.15	0.15	15.30	15.00	2
LSCOND	2.78	0.01	2.79	2.77	2

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- NO RAINFALL FY-1992 TINKER CK -----					
TSS	4.55	0.43	4.97	4.12	2
LTSS	1.71	0.08	1.79	1.63	2
TURB	0.53	0.02	0.54	0.51	2
LTURB	0.42	0.01	0.43	0.41	2
PTSAS	47.60	0.50	48.10	47.10	2
SCOND	25.40	2.20	27.60	23.20	2
LSCOND	3.27	0.08	3.35	3.19	2
----- NO RAINFALL FY-1992 MCQUEEN BR -----					
TSS	4.12	0.67	4.79	3.45	2
LTSS	1.62	0.13	1.76	1.49	2
TURB	1.28	0.42	1.70	0.86	2
LTURB	0.81	0.19	0.99	0.62	2
PTSASH	55.95	0.85	56.80	55.10	2
SCOND	53.30	7.50	60.80	45.80	2
LSCOND	3.98	0.14	4.12	3.85	2
----- NO RAINFALL FY-1992 UTR CK MID. -----					
TSS	4.00	--	4.00	4.00	1
LTSS	1.61	--	1.61	1.61	1
TURB	0.46	--	0.46	0.46	1
LTURB	0.38	--	0.38	0.38	1
PTSASH	39.00	--	39.00	39.00	1
SCOND	20.40	--	20.40	20.40	1
LSCOND	3.06	--	3.06	3.06	1
----- NO RAINFALL FY-1992 CROUCH BR -----					
TSS	20.27	--	20.27	20.27	1
LTSS	3.06	--	3.06	3.06	1
TURB	39.00	--	39.00	39.00	1
LTURB	3.69	--	3.69	3.69	1
PTSASH	78.60	--	78.60	78.60	1
SCOND	78.20	--	78.20	78.20	1
LSCOND	4.37	--	4.37	4.37	1
----- NO RAINFALL FY-1992 UTR CK BELOW -----					
TSS	4.51	--	4.51	4.51	1
LTSS	1.71	--	1.71	1.71	1
TURB	0.51	--	0.51	0.51	1
LTURB	0.41	--	0.41	0.41	1
PTSASH	48.60	--	48.60	48.60	1
SCOND	20.80	--	20.80	20.80	1
LSCOND	3.08	--	3.08	3.08	1

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
-----NO RAINFALL FY-1993 UTR CK ABOVE -----					
TSS	6.19	0.81	9.97	3.17	8
LTSS	1.93	0.11	2.40	1.43	8
TURB	4.58	0.45	6.70	3.40	8
LTURB	1.70	0.08	2.04	1.41	8
PTSASH	63.21	3.58	83.90	55.00	8
SCOND	13.85	0.07	14.10	13.60	8
LSCOND	2.70	0.01	2.71	2.68	8
-----NO RAINFALL FY-1993 TINKER CK -----					
TSS	6.94	1.13	13.19	3.45	8
LTSS	2.00	0.14	2.65	1.49	8
TURB	5.19	0.49	7.80	3.60	8
LTURB	1.80	0.08	2.17	1.53	8
PTSAS	55.69	3.10	74.90	49.00	8
SCOND	24.64	0.95	28.70	21.40	8
LSCOND	3.24	0.04	3.39	3.11	8
----- NO RAINFALL FY-1993 MCQUEEN BR -----					
TSS	9.43	3.14	28.07	3.13	8
LTSS	2.11	0.24	3.37	1.42	8
TURB	6.09	0.80	11.00	4.30	8
LTURB	1.92	0.10	2.48	1.67	8
PTSASH	69.61	2.58	82.40	60.50	8
SCOND	41.63	3.93	60.10	30.80	8
LSCOND	3.72	0.09	4.11	3.46	8
----- NO RAINFALL FY-1993 UTR CK MID. -----					
TSS	7.93	1.49	11.17	5.33	4
LTSS	2.15	0.17	2.50	1.85	4
TURB	4.95	0.55	6.40	3.80	4
LTURB	1.77	0.09	2.00	1.57	4
PTSASH	58.33	2.04	64.00	54.30	4
SCOND	18.80	0.94	21.60	17.60	4
LSCOND	2.98	0.05	3.12	2.92	4
----- NO RAINFALL FY-1993 CROUCH BR -----					
TSS	10.42	2.12	16.01	6.17	4
LTSS	2.38	0.18	2.83	1.97	4
TURB	18.10	4.42	27.00	8.40	4
LTURB	2.86	0.26	3.33	2.24	4
PTSASH	82.48	4.50	95.90	76.70	4
SCOND	89.02	21.04	130.70	51.20	4
LSCOND	4.41	0.25	4.88	3.96	4

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- NO RAINFALL FY-1993 UTR CK BELOW -----					
TSS	7.72	0.83	10.12	6.40	4
LTSS	2.15	0.09	2.41	2.00	4
TURB	4.35	1.18	6.20	0.90	4
LTURB	1.56	0.31	1.97	0.64	4
PTSASH	60.30	2.59	67.70	55.80	4
SCOND	18.78	0.28	19.50	18.20	4
LSCOND	2.98	0.01	3.02	2.95	4

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
-----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
-----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	.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	--	--	--	--	--

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- 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
----- 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

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- LOW RAINFALL FY-1984 CROUCH BR -----					
TSS	--	--	--	--	--
LTSS	--	--	--	--	--
TURB	--	--	--	--	--
LTU RB	--	--	--	--	--
PTSASH	--	--	--	--	--
SCOND	--	--	--	--	--
LSCOND	--	--	--	--	--
----- LOW RAINFALL FY-1984 UTR CK 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
----- 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

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- 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
----- 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

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- 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
----- 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 CK 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

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- 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	8.38	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
----- 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 CK 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

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- 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
----- 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

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- LOW RAINFALL FY-1988 UTR CK 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	3.15	4
----- LOW RAINFALL FY-1989 UTR CK ABOVE -----					
TSS	3.60	0.38	5.90	2.30	8
LTSS	1.50	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
----- 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

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- 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 CK 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
----- 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

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- 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
----- LOW RAINFALL FY-1990 UTR CK 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
----- LOW RAINFALL FY-1991 UTR CK ABOVE -----					
TSS	7.78	1.39	19.03	2.91	14
LTSS	2.04	0.14	3.00	1.36	14
TURB	1.63	0.41	5.60	0.35	14
LTURB	0.85	0.12	1.89	0.30	14
PTSASH	53.08	1.37	62.70	45.50	14
SCOND	16.19	0.77	25.80	14.90	14
LSCOND	2.83	0.04	3.29	2.77	14
----- LOW RAINFALL FY-1991 TINKER CK -----					
TSS	7.79	1.31	17.75	2.04	14
LTSS	2.02	0.15	2.93	1.11	14
TURB	1.23	0.25	3.50	0.27	14
LTURB	0.73	0.10	1.50	0.24	14
PTSASH	48.16	1.85	55.60	33.60	14
SCOND	27.41	0.98	32.80	21.70	14
LSCOND	3.34	0.03	3.52	3.12	14

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- LOW RAINFALL FY-1991 MCQUEEN BR -----					
TSS	16.80	4.10	51.24	4.86	14
LTSS	2.62	0.19	3.96	1.77	14
TURB	6.86	3.28	49.0	1.60	14
LTURB	1.64	0.20	3.91	0.96	14
PTSASH	71.97	2.13	91.70	61.00	14
SCOND	42.28	2.12	61.60	30.20	14
LSCOND	3.75	0.05	4.14	3.44	14
----- LOW RAINFALL FY-1991 UTR CK MID. -----					
TSS	6.91	0.98	11.32	3.04	7
LTSS	2.01	0.13	2.51	1.40	7
TURB	1.22	0.20	2.00	0.51	7
LTURB	0.77	0.10	1.10	0.41	7
PTSASH	51.56	1.56	57.30	45.90	7
SCOND	20.34	0.22	21.20	19.70	7
LSCOND	3.06	0.01	3.10	3.03	7
----- LOW RAINFALL FY-1991 CROUCH BR -----					
TSS	29.35	16.62	128.60	8.60	7
LTSS	2.91	0.34	4.86	2.26	7
TURB	37.11	21.50	160.0	2.30	7
LTURB	2.74	0.54	5.08	1.19	7
PTSASH	79.69	2.89	90.60	70.60	7
SCOND	78.70	5.23	99.90	64.20	7
LSCOND	4.37	0.06	4.61	4.18	7
----- LOW RAINFALL FY-1991 UTR CK BELOW -----					
TSS	7.71	0.82	10.39	4.26	7
LTSS	2.13	0.10	2.43	1.66	7
TURB	1.19	0.14	1.50	0.66	7
LTURB	0.77	0.07	0.92	0.51	7
PTSASH	54.13	1.48	59.30	46.70	7
SCOND	20.99	0.27	22.00	19.80	7
LSCOND	3.09	0.01	3.14	3.03	7
----- LOW RAINFALL FY-1992 UTR CK ABOVE -----					
TSS	5.42	0.37	7.72	3.62	14
LTSS	1.84	0.06	2.17	1.53	14
TURB	1.13	0.37	5.40	0.40	14
LTURB	0.64	0.12	1.86	0.34	14
PTSASH	52.50	1.22	58.20	42.40	14
SCOND	17.79	0.95	29.90	15.80	14
LSCOND	2.92	0.04	3.43	2.82	14

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- LOW RAINFALL FY-1992 TINKER CK -----					
TSS	6.63	0.72	10.40	2.73	14
LTSS	1.97	0.10	2.43	1.32	14
TURB	1.42	0.35	4.50	0.37	14
LTURB	0.78	0.12	1.70	0.31	14
PTSASH	52.02	1.50	66.70	42.60	14
SCOND	26.20	0.91	30.40	18.60	14
LSCOND	3.30	0.04	3.45	2.98	14
----- LOW RAINFALL FY-1992 MCQUEEN BR -----					
TSS	18.20	5.47	60.00	4.18	14
LTSS	2.54	0.24	4.11	1.64	14
TURB	23.27	9.78	102.0	1.50	14
LTURB	2.16	0.38	4.63	0.92	14
PTSASH	75.88	1.94	87.20	66.30	14
SCOND	45.40	2.22	68.50	37.70	14
LSCOND	3.82	0.04	4.24	3.66	14
----- LOW RAINFALL FY-1992 UTR CK MID. -----					
TSS	7.82	2.01	18.60	3.85	7
LTSS	2.06	0.19	2.98	1.58	7
TURB	2.50	1.56	11.80	0.45	7
LTURB	0.90	0.29	2.55	0.37	7
PTSASH	55.64	1.91	64.70	49.80	7
SCOND	21.86	0.48	23.70	20.20	7
LSCOND	3.13	0.02	3.21	3.05	7
----- LOW RAINFALL FY-1992 CROUCH BR -----					
TSS	34.26	11.09	87.21	5.63	7
LTSS	3.23	0.35	4.48	1.89	7
TURB	52.04	19.92	140.00	3.30	7
LTURB	3.28	0.55	4.95	1.46	7
PTSASH	79.71	4.03	88.60	58.80	7
SCOND	82.71	3.43	93.40	73.00	7
LSCOND	4.42	0.04	4.55	4.30	7
----- LOW RAINFALL FY-1992 UTR CK BELOW -----					
TSS	8.18	1.90	18.6	4.13	7
LTSS	2.12	0.17	2.98	1.64	7
TURB	2.70	1.65	12.50	0.49	7
LTURB	0.97	0.29	2.60	0.40	7
PTSASH	56.34	2.24	63.40	46.60	7
SCOND	22.60	0.59	24.60	20.20	7
LSCOND	3.16	0.03	3.24	3.05	7

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
-----LOW RAINFALL FY-1993 UTR CK ABOVE-----					
TSS	4.79	0.35	6.21	3.60	8
LTSS	1.74	0.06	1.98	1.53	8
TURB	3.45	0.75	8.50	2.10	8
LTURB	1.42	0.13	2.25	1.13	8
PTSASH	56.34	1.79	64.50	47.60	8
SCOND	17.06	0.60	19.50	14.80	8
LSCOND	2.89	0.03	3.02	2.76	8
-----LOW RAINFALL FY-1993 TINKER CK-----					
TSS	4.38	0.64	7.66	2.12	8
LTSS	1.63	0.12	2.16	1.14	8
TURB	2.85	0.26	4.30	2.10	8
LTURB	1.33	0.06	1.67	1.13	8
PTSAS	47.93	2.41	53.40	32.00	8
SCOND	24.66	0.93	28.40	21.30	8
LSCOND	3.24	0.04	3.38	3.10	8
-----LOW RAINFALL FY-1993 MCQUEEN BR-----					
TSS	6.87	1.28	13.70	3.01	8
LTSS	1.98	0.16	2.69	1.39	8
TURB	12.93	2.74	27.00	4.40	8
LTURB	2.50	0.20	3.33	1.69	8
PTSASH	78.39	1.68	84.60	71.60	8
SCOND	40.74	1.97	46.60	31.20	8
LSCOND	3.72	0.05	3.86	3.47	8
-----LOW RAINFALL FY-1993 UTR CK MID.-----					
TSS	4.58	0.57	5.83	3.08	4
LTSS	1.70	0.11	1.92	1.41	4
TURB	3.55	0.52	4.80	2.60	4
LTURB	1.50	0.11	1.76	1.28	4
PTSASH	54.55	1.25	57.10	52.20	4
SCOND	21.06	1.10	23.50	18.20	4
LSCOND	3.09	0.05	3.20	2.95	4
-----LOW RAINFALL FY-1993 CROUCH BR-----					
TSS	29.98	8.41	52.50	12.90	4
LTSS	3.32	0.28	3.98	2.63	4
TURB	56.25	14.30	91.00	21.00	4
LTURB	3.93	0.30	4.52	3.09	4
PTSASH	85.75	3.44	90.70	75.60	4
SCOND	88.85	16.16	135.00	59.50	4
LSCOND	4.45	0.17	4.91	4.10	4

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- LOW RAINFALL FY-1993 UTR CK BELOW -----					
TSS	4.84	0.66	6.31	3.38	4
LTSS	1.75	0.12	1.99	1.48	4
TURB	4.35	0.93	6.10	2.70	4
LTURB	1.63	0.18	1.96	1.31	4
PTSASH	56.73	1.18	60.10	54.60	4
SCOND	21.78	1.24	24.40	18.50	4
LSCOND	3.12	0.06	3.23	2.97	4

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- 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
----- HIGH RAINFALL FY-1983 CROUCH BR -----					
TSS	--	--	--	--	--
LTSS	--	--	--	--	--
TURB	--	--	--	--	--
LTURB	--	--	--	--	--
PTSASH	--	--	--	--	--
SCOND	--	--	--	--	--
LSCOND	--	--	--	--	--

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- HIGH RAINFALL FY-1983 UTR CK 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
----- 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

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- HIGH RAINFALL FY-1984 CROUCH BR -----					
TSS	--	--	--	--	--
LTSS	--	--	--	--	--
TURB	--	--	--	--	--
LTURB	--	--	--	--	--
PTSASH	--	--	--	--	--
SCOND	--	--	--	--	--
LSCOND	--	--	--	--	--
----- HIGH RAINFALL FY-1984 UTR CK 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
----- 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

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- 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 CK 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
----- 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

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- 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 CK 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
----- 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

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- 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 -----					
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
----- HIGH RAINFALL FY-1988 UTR CK 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

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- 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	42.50	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
----- 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

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- HIGH RAINFALL FY-1989 UTR CK 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
----- 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

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- 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 CK 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
----- HIGH RAINFALL FY-1991 UTR CK ABOVE -----					
TSS	7.02	1.06	10.34	4.14	6
LTSS	2.04	0.13	2.43	1.64	6
TURB	1.44	0.32	2.30	0.49	6
LTURB	0.84	0.14	1.19	0.40	6
PTSASH	58.52	1.03	61.80	54.60	6
SCOND	20.48	3.27	32.10	14.70	6
LSCOND	3.01	0.14	3.50	2.75	6
----- HIGH RAINFALL FY-1991 TINKER CK -----					
TSS	10.00	3.02	20.65	2.70	6
LTSS	2.20	0.28	3.08	1.31	6
TURB	1.69	0.41	3.00	0.60	6
LTURB	0.93	0.15	1.39	0.47	6
PTSASH	54.65	2.54	65.30	48.30	6
SCOND	30.88	2.65	41.80	25.20	6
LSCOND	3.45	0.08	3.76	3.27	6
----- HIGH RAINFALL FY-1991 MCQUEEN BR -----					
TSS	158.85	65.20	402.10	13.69	6
LTSS	4.42	0.58	6.00	2.69	6
TURB	122.03	48.15	290.00	5.20	6
LTURB	4.16	0.60	5.67	1.82	6
PTSASH	82.27	1.89	87.20	75.70	6
SCOND	35.13	4.65	50.50	21.90	6
LSCOND	3.54	0.13	3.94	3.13	6

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- HIGH RAINFALL FY-1991 UTR CK MID -----					
TSS	44.35	35.72	115.70	5.55	3
LTSS	3.06	0.87	4.76	1.88	3
TURB	51.09	49.46	150.00	0.68	3
LTURB	2.27	1.39	5.02	0.52	3
PTSASH	67.77	10.55	88.80	55.80	3
SCOND	25.63	4.73	35.10	20.70	3
LSCOND	3.25	0.17	3.59	3.08	3
----- HIGH RAINFALL FY-1991 CROUCH BR -----					
TSS	130.08	103.99	337.00	8.53	3
LTSS	3.97	1.03	5.82	2.25	3
TURB	152.67	115.35	380.00	5.00	3
LTURB	4.01	1.21	5.94	1.79	3
PTSASH	85.47	4.51	92.20	76.90	3
SCOND	60.30	21.33	95.20	21.60	3
LSCOND	3.95	0.43	4.57	3.12	3
----- HIGH RAINFALL FY-1991 UTR CK BELOW -----					
TSS	30.79	20.15	70.80	6.68	3
LTSS	3.03	0.66	4.27	2.04	3
TURB	25.94	24.04	74.00	0.92	3
LTURB	2.11	1.12	4.32	0.65	3
PTSASH	71.10	8.32	86.80	58.50	3
SCOND	26.50	5.45	37.40	21.00	3
LSCOND	3.28	0.18	3.65	3.09	3
----- HIGH RAINFALL FY-1992 UTR CK ABOVE -----					
TSS	7.06	1.08	13.20	4.75	8
LTSS	2.04	0.12	2.65	1.75	8
TURB	1.14	0.31	2.70	0.48	8
LTURB	0.70	0.13	1.31	0.39	8
PTSASH	55.51	1.16	59.20	49.00	8
SCOND	17.79	0.67	19.90	15.30	8
LSCOND	2.93	0.04	3.04	2.79	8
----- HIGH RAINFALL FY-1992 TINKER CK -----					
TSS	8.98	2.23	23.60	4.40	8
LTSS	2.18	0.18	3.02	1.69	8
TURB	1.23	0.25	2.10	0.40	8
LTURB	0.76	0.12	1.13	0.34	8
PTSASH	47.81	2.53	53.40	32.80	8
SCOND	27.05	1.08	31.50	23.90	8
LSCOND	3.33	0.04	3.48	3.21	8

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- HIGH RAINFALL FY-1992 MCQUEEN BR -----					
TSS	16.69	2.46	30.30	9.62	8
LTSS	2.81	0.13	3.44	2.36	8
TURB	18.09	6.42	53.00	4.00	8
LTURB	2.56	0.33	3.99	1.61	8
PTSASH	82.44	1.98	87.90	71.40	8
SCOND	45.18	2.29	58.30	36.30	8
LSCOND	3.82	0.05	4.08	3.62	8
----- HIGH RAINFALL FY-1992 UTR CK MID -----					
TSS	8.75	0.72	10.80	7.71	4
LTSS	2.27	0.07	2.47	2.16	4
TURB	1.63	0.49	2.70	0.67	4
LTURB	0.91	0.19	1.31	0.51	4
PTSASH	55.63	1.78	60.50	52.20	4
SCOND	23.55	0.61	25.30	22.60	4
LSCOND	3.20	0.02	3.27	3.16	4
----- HIGH RAINFALL FY-1992 CROUCH BR -----					
TSS	44.08	15.40	89.90	23.50	4
LTSS	3.67	0.29	4.51	3.20	4
TURB	67.75	20.80	130.00	43.00	4
LTURB	4.12	0.25	4.88	3.78	4
PTSASH	86.70	2.08	90.80	81.10	4
SCOND	84.83	9.22	110.00	67.70	4
LSCOND	4.44	0.10	4.71	4.23	4
----- HIGH RAINFALL FY-1992 UTR CK BELOW -----					
TSS	9.05	0.82	11.40	7.70	4
LTSS	2.30	0.08	2.52	2.16	4
TURB	1.99	0.59	3.60	0.74	4
LTURB	1.03	0.20	1.53	0.55	4
PTSASH	57.55	2.53	64.50	52.40	4
SCOND	22.88	0.80	24.80	21.10	4
LSCOND	3.17	0.03	3.25	3.10	4
----- HIGH RAINFALL FY-1993 UTR CK ABOVE -----					
TSS	21.46	7.99	75.70	6.53	8
LTSS	2.84	0.25	4.34	2.02	8
TURB	27.30	13.57	120.00	5.00	8
LTURB	2.85	0.34	4.80	1.79	8
PTSASH	65.20	4.15	86.70	54.90	8
SCOND	17.73	0.59	20.00	15.00	8
LSCOND	2.93	0.03	3.04	2.77	8

VARIABLE	MEAN	STD ERR OF ME	MAXIMUM VALUE	MINIMUM VALUE	N
----- HIGH RAINFAL FY-1993 TINKER CK -----					
TSS	10.17	72	19.94	5.66	8
LTSS	2.34	14	3.04	1.90	8
TURB	8.74	06	13.00	4.80	8
LTURB	2.23	12	2.64	1.76	8
PTSASH	51.91	259	62.40	39.10	8
SCOND	24.86	171	34.80	20.70	8
LSCOND	3.24	0.06	3.58	3.08	8
----- HIGH RAINFALL FY-1993 MCQUEEN BR -----					
TSS	93.56	50.26	422.20	8.62	8
LTSS	3.66	0.50	6.05	2.26	8
TURB	122.63	61.06	510.00	13.00	8
LTURB	4.02	0.48	6.24	2.64	8
PTSASH	84.75	2.36	93.70	76.40	8
SCOND	34.21	2.92	45.40	25.00	8
LSCOND	3.54	0.08	3.83	3.26	8
----- HIGH RAINFALL FY-1993 UTR CK MID -----					
TSS	15.31	4.23	27.40	8.81	4
LTSS	2.70	0.24	3.35	2.28	4
TURB	18.75	7.11	40.00	10.00	4
LTURB	2.83	0.30	3.71	2.40	4
PTSASH	66.60	6.22	84.70	57.60	4
SCOND	22.48	2.28	28.00	18.20	4
LSCOND	3.14	0.10	3.37	2.95	4
----- HIGH RAINFALL FY-1993 CROUCH BR -----					
TSS	116.63	68.78	313.90	17.39	4
LTSS	4.18	0.65	5.75	2.91	4
TURB	160.25	90.94	420.00	19.00	4
LTURB	4.51	0.66	6.04	3.00	4
PTSASH	83.53	7.82	94.60	60.70	4
SCOND	52.90	11.46	83.50	32.90	4
LSCOND	3.92	0.21	4.44	3.52	4
----- HIGH RAINFALL FY-1993 UTR CK BELOW -----					
TSS	66.93	53.12	226.00	7.37	4
LTSS	3.31	0.73	5.42	2.12	4
TURB	83.00	65.82	280.00	9.00	4
LTURB	3.50	0.75	5.64	2.30	4
PTSASH	76.55	5.93	90.10	61.20	4
SCOND	22.00	2.12	27.00	18.10	4
LSCOND	3.12	0.09	3.33	2.95	4

APPENDIX B

**PROBABILITY LEVELS FOR TESTS OF MAIN EFFECTS
AND INTERACTION EFFECTS IN ANALYSIS OF VARIANCE MODEL**

P VALUES OF ANOVA MAIN EFFECTS

NO RAIN

Main Effect	Log TSS	Log Specific Conductivity	Log Percent Ash	Log Turbidity
Location	0.0001	0.0001	0.0001	0.0001
Construction	0.0001	0.0001	0.0001	0.0001
Loc*Con	0.0001	0.03	0.0001	0.0001
R ² =	0.47	0.58	0.68	0.61

LOW RAIN*

Main Effect	Log TSS	Log Specific Conductivity	Log Percent Ash	Log Turbidity
Log Rain	0.48	0.003	0.61	0.0007
Location	0.10	0.0001	0.0001	0.0004
Construction	0.84	0.03	0.39	0.07
Log Rain*Loc	0.12	0.99	0.73	0.21
Log Rain*Con	0.23	0.004	0.03	0.96
Loc*Con	0.67	0.27	0.49	0.89
R ² =	0.45	0.78	0.78	0.62

HIGH RAIN*

Main Effect	Log TSS	Log Specific Conductivity	Log Percent Ash	Log Turbidity
Log Rain	0.0001	0.61	0.0001	0.0001
Location	0.0001	0.0001	0.0001	0.0001
Construction	0.08	0.67	0.28	0.04
Log Rain*Loc	0.11	0.0015	0.0001	0.01
Log Rain*Con	0.22	0.83	0.40	0.11
Loc*Con	0.64	0.38	0.10	0.80
R ² =	0.63	0.70	0.82	0.72

* "RAIN" is for amount of precipitation 24 hours prior to sampling.

APPENDIX C

**DWPF Means of Water Quality Variables for each
Construction Period from FY-1983 to FY-1993
(summarized by rainfall class and location)**

MEANS BY CONSTRUCTION PERIOD

- - - - NO RAIN - - TSS - - BEFORE CONSTRUCTION - - -

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	3.42	0.24	33
TINKER CREEK	3.82	0.36	31
MCQUEEN BRANCH	5.38	0.31	22
UTR - MIDDLE	4.04	0.42	17
CROUCH BRANCH	--	--	--
UTR - BELOW	4.10	0.49	17

- - - - NO RAIN - - PERCENT ASH - - BEFORE CONSTRUCTION - - -

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	44.18	1.53	33
TINKER CREEK	42.54	1.52	31
MCQUEEN BRANCH	58.64	1.75	22
UTR - MIDDLE	47.39	1.13	17
CROUCH BRANCH	--	--	--
UTR- BELOW	45.73	2.33	17

- - - - NO RAIN - - SPECIFIC CONDUCTANCE - - BEFORE CONSTRUCTION - - -

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	26.44	1.04	33
TINKER CREEK	49.55	2.04	31
MCQUEEN BRANCH	58.89	3.90	22
UTR - MIDDLE	36.50	1.99	17
CROUCH BRANCH	--	--	--
UTR-BELOW	36.60	2.05	17

MEANS BY CONSTRUCTION PERIOD

- - - - NO RAIN - - TSS - - DURING CONSTRUCTION - - -

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	6.01	0.85	66
TINKER CREEK	5.42	0.61	66
MCQUEEN BRANCH	18.26	4.84	48
UTR-MIDDLE	6.25	0.68	33
CROUCH BRANCH	88.38	19.83	16
UTR - BELOW	6.12	0.58	33

- - - - NO RAIN - - TURBIDITY-- DURING CONSTRUCTION - - -

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	3.36	0.37	66
TINKER CREEK	3.62	0.47	66
MCQUEEN BRANCH	25.62	8.58	48
UTR- MIDDLE	3.99	0.45	33
CROUCH BRANCH	158.22	34.27	16
UTR - BELOW	4.19	0.40	33

- - - - NO RAIN - - PERCENT ASH - - DURING CONSTRUCTION - - -

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	46.60	1.39	66
TINKER CREEK	46.82	1.13	66
MCQUEEN BRANCH	74.52	1.11	48
UTR - MIDDLE	50.38	1.59	33
CROUCH BRANCH	86.16	1.25	16
UTR - BELOW	49.77	1.47	33

- - - - NO RAIN - - SPECIFIC CONDUCTANCE - - DURING CONSTRUCTION - - -

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	16.38	0.89	66
TINKER CREEK	24.74	1.40	66
MCQUEEN BRANCH	55.93	7.17	48
UTR- MIDDLE	19.60	1.30	33
CROUCH BRANCH	93.37	3.80	16
UTR - BELOW	20.31	1.07	33

MEANS BY CONSTRUCTION PERIOD

LOCATION	---- NO RAIN -- TSS -- AFTER CONSTRUCTION ---		
	MEAN	STD. ERR.	N
UTR - ABOVE	4.63	0.35	30
TINKER CREEK	7.03	0.72	30
MCQUEEN BRANCH	5.99	0.96	30
UTR - MIDDLE	5.96	0.62	15
CROUCH BRANCH	19.75	4.40	15
UTR- BELOW	6.47	0.62	15

LOCATION	---- NO RAIN -- TURBIDITY -- AFTER CONSTRUCTION ---		
	MEAN	STD. ERR.	N
UTR - ABOVE	1.91	0.33	30
TINKER CREEK	2.77	0.36	30
MCQUEEN BRANCH	5.15	0.84	30
UTR - MIDDLE	2.33	0.48	15
CROUCH BRANCH	31.57	7.88	15
UTR - BELOW	2.16	0.50	15

LOCATION	---- NO RAIN -- PERCENT ASH -- AFTER CONSTRUCTION ---		
	MEAN	STD. ERR.	N
UTR - ABOVE	55.05	1.51	30
TINKER CREEK	54.04	1.28	30
MCQUEEN BRANCH	72.69	1.42	30
UTR - MIDDLE	52.79	1.94	15
CROUCH BRANCH	80.41	1.87	15
UTR - BELOW	57.05	1.27	15

LOCATION	---- NO RAIN -- SPECIFIC CONDUCTANCE -- AFTER CONSTRUCTION ---		
	MEAN	STD. ERR.	N
UTR - ABOVE	14.67	0.15	30
TINKER CREEK	29.09	0.83	30
MCQUEEN BRANCH	74.29	11.92	30
UTR - MIDDLE	20.45	0.52	15
CROUCH BRANCH	101.71	10.04	15
UTR - BELOW	21.04	0.55	15

MEANS BY CONSTRUCTION PERIOD

- - - - LOW RAIN -- TSS -- BEFORE CONSTRUCTION - - -

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	4.85	0.41	10
TINKER CREEK	5.20	0.63	8
MCQUEEN BRANCH	6.93	0.75	7
UTR - MIDDLE	6.16	0.76	5
CROUCH BRANCH	--	--	--
UTR - BELOW	6.15	0.73	5

- - - - LOW RAIN -- PERCENT ASH -- BEFORE CONSTRUCTION - - -

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	47.73	5.67	10
TINKER CREEK	42.14	3.16	8
MCQUEEN BRANCH	61.00	3.19	7
UTR - MIDDLE	43.81	3.16	5
CROUCH BRANCH	--	--	--
UTR - BELOW	44.41	1.73	5

- - - - LOW RAIN -- SPECIFIC CONDUCTANCE -- BEFORE CONSTRUCTION - - -

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	23.84		3.0610
TINKER CREEK	39.00		4.988
MCQUEEN BRANCH	50.07		5.967
UTR - MIDDLE	33.02		3.605
CROUCH BRANCH	--	--	--
UTR - BELOW	32.64		4.635

MEANS BY CONSTRUCTION PERIOD
-- - - LOW RAIN - - TSS- - DURING CONSTRUCTION - - -

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	6.31	0.60	16
TINKER CREEK	8.53	0.96	16
MCQUEEN BRANCH	29.20		7.6213
UTR- MIDDLE	8.88	1.22	8
CROUCH BRANCH	50.12		10.886
UTR - BELOW	8.92	1.27	8

-- - - LOW RAIN - - TURBIDITY - - DURING CONSTRUCTION - - -

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	3.27	0.37	16
TINKER CREEK	3.71	0.30	16
MCQUEEN BRANCH	42.08	13.65	13
UTR - MIDDLE	4.13	0.45	8
CROUCH BRANCH	98.67	23.80	6
UTR - BELOW	4.65	0.61	8

-- - - LOW RAIN - - PERCENT ASH - - DURING CONSTRUCTION - - -

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	55.09	2.36	16
TINKER CREEK	52.75	2.51	16
MCQUEEN BRANCH	80.81	2.63	13
UTR - MIDDLE	57.29	3.03	8
CROUCH BRANCH	87.03	1.43	6
UTR - BELOW	58.31	2.57	8

-- - - LOW RAIN - - SPECIFIC CONDUCTANCE - - DURING CONSTRUCTION - - -

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	15.79	0.44	16
TINKER CREEK	28.42	1.48	16
MCQUEEN BRANCH	58.57	7.31	13
UTR - MIDDLE	19.87	2.00	8
CROUCH BRANCH	90.02	7.14	6
UTR - BELOW	20.82	2.30	8

MEANS BY CONSTRUCTION PERIOD

- - - - LOW RAIN - - TSS - - AFTER CONSTRUCTION - - -

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	5.73	0.41	56
TINKER CREEK	7.44	0.74	56
MCQUEEN BRANCH	25.48	6.90	56
UTR- MIDDLE	6.47	0.61	28
CROUCH BRANCH	46.72	9.71	28
UTR - BELOW	6.83	0.59	28

- - - - LOW RAIN - - TURBIDITY - - AFTER CONSTRUCTION - - -

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	1.67	0.21	56
TINKER CREEK	2.40	0.63	56
MCQUEEN BRANCH	33.07	10.38	56
UTR - MIDDLE	2.09	0.42	28
CROUCH BRANCH	78.66	17.47	28
UTR - BELOW	2.32	0.47	28

- - - - LOW RAIN - - PERCENT ASH - - AFTER CONSTRUCTION - - -

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	53.85	0.61	56
TINKER CREEK	50.81	0.79	56
MCQUEEN BRANCH	77.54	1.06	56
UTR - MIDDLE	54.06	0.88	28
CROUCH BRANCH	81.55	1.70	28
UTR - BELOW	56.12	0.77	28

- - - -LOW RAIN - - SPECIFIC CONDUCTANCE - - AFTER CONSTRUCTION - - -

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	16.63	0.34	56
TINKER CREEK	28.66	0.63	56
MCQUEEN BRANCH	68.59	10.50	56
UTR - MIDDLE	21.52	0.29	28
CROUCH BRANCH	91.28	4.43	28
UTR- BELOW	22.29	0.31	28

MEANS BY CONSTRUCTION PERIOD

- - - - HIGH RAIN - - TSS - - BEFORE CONSTRUCTION - - -

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	9.36	1.62	10
TINKER CREEK	11.15	2.09	9
MCQUEEN BRANCH	59.04	16.31	6
UTR - MIDDLE	28.59	12.81	5
CROUCH BRANCH	--	--	--
UTR - BELOW	39.01	18.60	5

- - - - HIGH RAIN - - PERCENT ASH - - BEFORE CONSTRUCTION - - -

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	53.04	0.74	10
TINKER CREEK	52.00	4.96	9
MCQUEEN BRANCH	76.81	3.06	6
UTR - MIDDLE	63.25	4.27	5
CROUCH BRANCH	--	--	--
UTR - BELOW	60.64	9.35	5

- - - - HIGH RAIN - - SPECIFIC CONDUCTANCE - - BEFORE CONSTRUCTION - - -

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	29.15	1.62	10
TINKER CREEK	44.37	1.05	9
MCQUEEN BRANCH	51.28	6.23	6
UTR - MIDDLE	34.80	3.19	5
CROUCH BRANCH	--	--	--
UTR- BELOW	34.20	2.50	5

MEANS BY CONSTRUCTION PERIOD

- - - HIGH RAIN - - TSS - - DURING CONSTRUCTION - - -

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	9.73	2.09	14
TINKER CREEK	12.12	2.35	13
MCQUEEN BRANCH	182.33	58.19	12
UTR - MIDDLE	15.27	3.32	7
CROUCH BRANCH	99.62	26.93	6
UTR - BELOW	17.69	3.96	7

- - - HIGH RAIN - - TURBIDITY - - DURING CONSTRUCTION - - -

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	4.34	0.66	14
TINKER CREEK	6.02	1.53	13
MCQUEEN BRANCH	236.13	62.53	12
UTR - MIDDLE	11.50	3.53	7
CROUCH BRANCH	187.83	47.98	6
UTR - BELOW	16.16	4.90	7

- - - HIGH RAIN - - PERCENT ASH - - DURING CONSTRUCTION - - -

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	52.62	0.80	14
TINKER CREEK	51.23	1.62	13
MCQUEEN BRANCH	87.04	1.51	12
UTR- MIDDLE	56.04	5.23	7
CROUCH BRANCH	88.77	0.56	6
UTR - BELOW	63.24	3.20	7

- - - HIGH RAIN - - SPECIFIC CONDUCTANCE - - DURING CONSTRUCTION - - -

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	17.38	0.83	14
TINKER CREEK	32.91	3.65	13
MCQUEEN BRANCH	66.80	8.97	12
UTR - MIDDLE	65.30	39.84	7
CROUCH BRANCH	108.27	6.54	6
UTR- BELOW	25.32	1.98	3

MEANS BY CONSTRUCTION PERIOD

- - - - HIGH RAIN - - TSS - - AFTER CONSTRUCTION - - -

LOCATION	MEAN TSS	STD. ERR.	N
UTR - ABOVE	11.35	1.78	42
TINKER CREEK	15.74	1.99	42
MCQUEEN BRANCH	147.74	27.80	42
UTR - MIDDLE	21.66	4.38	21
CROUCH BRANCH	170.64	31.17	21
UTR - BELOW	43.74	12.88	21

- - - - HIGH RAIN - - TURBIDITY - - AFTER CONSTRUCTION - - -

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	8.36	2.92	42
TINKER CREEK	6.99	1.23	42
MCQUEEN BRANCH	172.64	26.24	42
UTR - MIDDLE	24.23	5.95	21
CROUCH BRANCH	259.05	44.20	21
UTR - BELOW	50.82	16.80	21

- - - - HIGH RAIN - - PERCENT ASH - - AFTER CONSTRUCTION - - -

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	57.01	1.18	42
TINKER CREEK	53.31	1.11	42
MCQUEEN BRANCH	85.87	0.79	42
UTR - MIDDLE	66.99	2.41	21
CROUCH BRANCH	87.80	1.62	21
UTR - BELOW	71.54	2.53	21

- - - - HIGH RAIN - - SPECIFIC CONDUCTANCE - - AFTER CONSTRUCTION - - -

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	17.86	0.43	42
TINKER CREEK	30.21	1.19	42
MCQUEEN BRANCH	57.68	7.81	42
UTR - MIDDLE	27.63	2.66	21
CROUCH BRANCH	82.92	6.44	21
UTR - BELOW	26.35	1.41	21

III. AMPHIBIAN USE OF BREEDING SITES CREATED AS EXPERIMENTAL MITIGATION FOR WETLAND LOSS

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

INTRODUCTION

Creation or restoration of wetlands is frequently required in the United States as mitigation for filling wetlands that are legally protected (Salvesen 1990). This mitigation is usually expected to be "in-kind" with respect to wetland type, as well as "on-site". However, there are few data on the extent to which wetlands constructed from uplands are ecological equivalents of those that they replaced (Kusler and Kentula 1990, Kentula et al. 1993). Post-construction monitoring of these wetlands is rare. Even when monitoring occurs, it is often qualitative and short-term, and fails to consider faunal useage (Kusler and Kentula 1990, Kentula et al. 1993).

Constructed wetlands are typically planted with vegetation but not intentionally stocked with animals. The prevailing wisdom is that if vegetation and an appropriate hydroperiod are provided, fauna will colonize and use the site unless it is located many kilometers from other similar wetlands and has no surface water connections (Brooks 1990, Broome 1990, Erwin 1990, Hammer 1992).

Amphibians are an archtypical component of the fauna of freshwater wetlands, and large and diverse amphibian communities are often found in wetland habitats (Sharitz and Gibbons 1982, Moler and Franz 1988, Pechmann et al. 1989, Dodd 1992, Hammer 1992). There has been increased concern about declines and disappearances of amphibian populations worldwide, caused primarily by habitat destruction and modification (Wake and Morowitz 1990). It is important to ascertain the extent to which wetlands constructed to replace those lost to human activities maintain comparable populations of amphibians.

A Carolina bay wetland (Sharitz and Gibbons 1982, Ross 1987) called Sun Bay, located on the U.S. Department of Energy's Savannah River Site in South Carolina, USA, was filled in 1983 for a construction project. Amphibian populations were monitored at Sun Bay prior to and during construction. Four

artificial ponds were built on the periphery of the construction site three months before construction began, in an experimental attempt to mitigate the loss of amphibian habitat. Amphibian colonization and population dynamics were studied at these "refuge ponds" for eight and one half years to assess the success of the mitigation experiment. We here report the results. Comparisons are also made to studies conducted at a similar "reference wetland", Rainbow Bay, located 4 km from Sun Bay.

The wetland amphibian community

Most of the amphibian species that were found at Sun Bay are primarily terrestrial (often fossorial), but migrate to ponds to breed and have an aquatic larval stage that lasts from two weeks to several months. Breeding seasons vary among species. Among the salamanders, *Ambystoma opacum* breeds in the autumn and *Eurycea quadridigitata* in the autumn and winter. Other *Ambystoma* and the chorus frogs *Pseudacris* breed in the winter in South Carolina. The spadefoot toad, *Scaphiopus holbrookii*, and the southern leopard frog, *Rana utricularia*, may breed after warm rains at any time of the year in this region. All other species that were found at Sun Bay breed in the spring and summer. Although the salamander *Notophthalmus viridescens* breeds in the spring, mature efts and adults migrate to ponds during autumn and winter. Adult *N. viridescens* do not emigrate from ponds on the Savannah River Site unless they dry, and then some may remain in the pond basin.

If a pond does not dry, larval *Ambystoma talpoideum* and *Notophthalmus viridescens* can delay the onset or completion of metamorphosis and become paedomorphic. That is, they can attain sexual maturity while remaining in the pond and retaining gills and sometimes other larval traits (Semlitsch and Gibbons 1985, Harris 1987, Reilly 1987). Paedomorphs of both species may later metamorphose.

The terrestrial home ranges of pond-breeding amphibians are usually within a few hundred meters of their breeding pond (e.g., Jameson 1956, Kramer 1973, Williams 1973, Douglas and Monroe 1981, Semlitsch 1981, 1983b), although those of some species of *Bufo* (true toads) can extend up to 3 km away (Sinsch

1990, 1992). The location of terrestrial home ranges has been studied for three salamander species that bred at Sun Bay. *Ambystoma opacum* migrated to home ranges an average of 193.7 m from a breeding pond in Indiana, range 0-450 m (Williams 1973). *Ambystoma talpoideum* adults were found to live 81-261 m from the pond, and juveniles 12-67 m, in a study conducted at Sun Bay and Rainbow Bay by Semlitsch (1981). A single *A. tigrinum* was followed 162 m from Rainbow Bay by Semlitsch (1983b). Construction impacts extended at least 300 m from Sun Bay in all directions, and more than 500 m in most. Therefore, Sun Bay amphibians lost most of their terrestrial habitat as well as their breeding site to construction.

Many amphibian species are philopatric, i.e., individuals usually use the same breeding site every year (e.g., Twitty 1959, Oldham 1966, Whitford and Vinegar 1966, Oldham 1967, Gill, 1978, Semlitsch 1981, Breden 1987, Semlitsch et al. 1988, Berven and Grudzien 1990, Reading et al. 1991, Scott 1994), and the same terrestrial home range (e.g., Haapanen 1970, Williams 1973, Breden 1987). Breeding adults are often philopatric to their natal pond (Breden 1987, Semlitsch et al. 1988, Berven and Grudzien 1990, Reading et al. 1991). Philopatry is seldom absolute, however. For example, Breden (1987) found that 73% of *Bufo woodhousei fowleri* used their natal pond for first reproduction, 24% used nearby ponds, and one used a pond 2 km away. Eighty-three percent of adult *B. w. fowleri* bred in the same pond in consecutive years, while the other 17% relocated. Similar proportions of philopatry and dispersal have been reported for *Bufo bufo*, as well as a negative correlation between number relocating and distance between ponds (Reading et al. 1991). *Rana sylvatica* (Berven and Grudzien 1990) and *Notophthalmus viridescens* (Gill, 1978) were both found to be 100% faithful to breeding ponds as adults. Eighty-two percent of the *R. sylvatica* bred at their natal pond, while the other 18% dispersed to ponds an average of 1,169 m away (maximum 2,530 m). Gill (1978) inferred that juvenile dispersal occurred in *N. viridescens*, occasionally to ponds many kilometers away. Marked adult *Rana pipiens* have been recaptured at wetlands as far as 5.2 km from their natal pond (Dole

1971).

Philopatry can also vary with sex. Sinsch (1992) found that most male *Bufo calamita* were philopatric to their breeding pond, but that female *B. calamita* were not. Although adult philopatry to the natal pond is the rule for *Ambystoma talpoideum* (Semlitsch 1981, Semlitsch et al. 1988) and *A. opacum*, (Scott 1994), individuals of both species that were marked at Rainbow Bay at metamorphosis have been found breeding at a pond 1 km distant (personal observations). Acoustic, magnetic, olfactory, and visual cues all appear to play a role in orientation and homing in amphibians (Twitty 1961, Oldham 1967, Landreth and Ferguson 1967, Taylor and Adler 1973, Grubb 1975, Hershey and Forester 1979, Phillips 1986, McGregor and Teska 1989, Sinsch 1990, Rodda and Phillips 1992).

Pond creation, pond loss, and amphibians

Amphibians are commonly observed to colonize ponds created intentionally or unintentionally by humans (Fog 1988, Schlupp et al. 1989, Brooks 1990, Laan and Verboom 1990, Adam and Lacki 1993, personal observations). Rates of colonization can be affected by distance from other ponds, characteristics of the intervening terrestrial habitat, dispersal capacity and site fidelity of the species, and size of source populations (Laan and Verboom 1990). In our study, new ponds were built a few months before the nearest natural wetland and much of the surrounding terrestrial amphibian habitat were eliminated. It was clear that significant direct amphibian mortality would result from bulldozing and other construction activities, reducing the number of potential colonizers. A central question was whether surviving individuals would breed at the new refuge ponds or return to Sun Bay, even though it had been drained and filled and the surrounding vegetation and topography had been drastically altered.

There have been several reports of amphibians returning to former breeding sites even after they had been filled: Anderson (1954) for *Gastrophryne carolinensis*, Heusser (1960) for *Bufo bufo*, Shoop (personal observation, cited in Shoop and Doty 1972) for *Ambystoma talpoideum*, Uzzell

(personal communication, cited in Shoop and Doty 1972) for *A. laterale*, and Frazer (1973) for unspecified frogs and toads. The subsequent fate of these populations was not reported except by Frazer. He noted that a few made their way to an undrained part of the breeding canal, where they became established after being assisted over an embankment.

Schlupp et al. (1989) successfully relocated *Bufo bufo* to a newly-constructed breeding site by capturing them on their way to another pond, placing them the new pond, and keeping them there with a fence throughout the breeding season. Within three years, most of the *Bufo* bred in the new pond of their own accord. Cook and Pinnock (1987), Cook (1989), and Matthews et al. (1991), reported success at establishing amphibian populations in newly-built ponds by stocking eggs, larvae, or adults, mostly from nearby sites threatened by development.

We chose not to stock our ponds, because amphibians and other fauna are not usually stocked in constructed wetlands, and we wanted to study the effectiveness of typical procedures. The philosophy of our 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 for any other functions of the lost wetland other than its role as an amphibian breeding site.

METHODS

Study site

The study was conducted in Aiken County, South Carolina, USA on the U.S. Department of Energy's 780-km² Savannah River Site. Sun Bay was a Carolina bay, one of thousands of elliptical depressions of unresolved geological origin common to the southeastern U.S. Atlantic Coastal Plain (Sharitz and Gibbons 1982, Ross 1987). Sun Bay was approximately 1 ha in area, had a maximum depth of about 1 m, and had no surface connection to other bodies of water. It was a temporary pond that usually filled in the winter and dried in the spring or summer. Filling and drying dates varied widely from year to year, depending on temperature and rainfall (Semlitsch 1983a, Semlitsch 1987,

Caldwell 1987, Pechmann et al. 1989). In 1978, before our study began, a ditch was dug that partially drained the bay for pre-construction surveys. The ditch reduced water volume by about 75%, decreased depth (maximum was 0.35 m during our study), and caused the pond to dry earlier each year (Semlitsch 1983a, 1987, Caldwell 1987, Pechmann et al. 1989). Thus, our pre-construction studies were not pre-disturbance.

In 1979, the center part of Sun Bay contained herbaceous vegetation, primarily *Panicum* sp. (panic grass), *Juncus* spp. (rushes), *Eleocharis* spp. (spike rushes), *Polygonum* sp. (knotweed), and *Viola lanceolata* (lance-leaved violet). *Cephalanthus occidentalis* (buttonbush) grew primarily around the outer edge of the herbaceous area, but also in the middle. A forested zone of *Liquidamber styraciflua* (sweetgum) occupied the periphery of the bay. The composition and extent of these vegetation zones probably varied over time in response to variation in hydroperiod and other factors, as has been observed in other Carolina bays such as Rainbow Bay (personal observations). Approximately 40% of the bay's vegetation was cleared with a bulldozer in 1978 for pre-construction seismic surveys and for the ditch. Weedy pioneer species invaded these bare areas.

Terrestrial habitats within a 1 km radius of Sun Bay consisted primarily of deep, well-drained sandy soils planted with *Pinus taeda* (loblolly pine) and *P. elliottii* (slash pine). These pine stands were of various ages, the oldest having been planted in the early 1950s on abandoned agricultural fields, and the youngest in 1975 following a clear-cut. Two of the refuge ponds, B and D (Fig. III-1), were located in *P. elliottii* plantations that also contained scattered *P. taeda*. The area around Pond D had a well-developed mixed species understory and shrub layer, and only a thin litter layer, perhaps because of prescribed burning. Pond B was surrounded by disturbed soil in which the trees grew poorly. The understory around Pond B contained only pine.

Other plant communities found within 1 km of Sun bay included *Pinus palustris* (longleaf pine) stands, a stand of *Quercus laevis* (turkey oak), mixed upland hardwoods, and bottomland hardwoods. Refuge Pond C (Fig. III-1)

was located in a longleaf pine stand having a hardwood midstory and a thick litter layer. Pond A (Fig. III-1) was on a slope, and surrounded by a forest dominated by mixed hardwoods on the south and southwest and *P. taeda* elsewhere. The forest on all sides of Pond A was well-stratified, having well-developed hardwood shrub and ground vegetation layers compared to the other refuge pond sites.

Human structures within 1 km of Sun Bay before the new construction included part of an industrial site, a borrow pit, two paved roads, two dirt roads, and a power line (Fig. III-1). These structures were surrounded by mowed grass or herbaceous weeds. Numerous paths were cleared with a bulldozer through the vegetation around Sun Bay during pre-construction surveys that began in 1978.

Two small streams, McQueen Branch and Crouch Branch, are each located within 1 km of the site of Sun Bay (Fig. III-1). These streams support a different suite of amphibian populations than did the bay, including *Amphiuma means* (two-toed amphiuma), *Desmognathus auriculatus* (southern dusky salamander), *Pseudotriton ruber* (red salamander), *P. montanus* (mud salamander), and *Eurycea cirrigera* (two-lined salamander). The only other aquatic habitats within 1 km of Sun Bay were roadside ditches and small, temporary puddles, but these habitats are used extensively as breeding sites by species such as *Scaphiopus holbrookii* (eastern spadefoot toad), *Gastrophryne carolinensis* (eastern narrow-mouthed toad), and *Hyla squirella* (squirrel treefrog). There is a farm pond 1.2 km east-southeast of the former bay, and four Carolina bays each approximately 2 km away, two in a northeast and two in a south-southeast direction. Thus, individuals from Sun Bay were not the only potential source of colonists for the refuge ponds.

The construction project

The U.S. Department of Energy Defense Waste Processing Facility and associated structures were built on the site of Sun Bay and the surrounding area. Clearing and grading began in September 1983, and encompassed the tract between Savannah River Site Road F on the north, Site Road 4 on the northwest,

the powerline on the west, and the H area industrial site on the south, to beyond McQueen Branch on the southeast (Fig. III-1). Sun Bay was filled with soil in October 1983 while the bay was dry. Standing water collected in a low area on the NW side of the former wetland after rains in mid-November. The water remained until 21 December 1983, when a ditch was dug that permanently drained the site. The site of the former wetland became a parking lot for the facility.

Three sedimentation ponds were built near the perimeter of the cleared and graded area, one on Crouch Branch and two on McQueen Branch. These ponds, completed in June 1984, were designed to mitigate the impacts of erosion from the construction site on these streams. We did not monitor amphibian populations at these sedimentation ponds, but they have probably provided suitable breeding sites for some species.

Clearing and grading for an associated facility, Z-area, built north of Site Road F, began in the summer of 1985 (Fig. III-1). The power line located on the west side of the construction site was moved closer to Site Road 4 in the autumn of 1985, disturbing additional terrestrial habitat around one of the refuge ponds (Fig. III-1). Exterior construction work on all facilities was completed by FY-1988, but interior work and testing were still ongoing in FY-1993.

Refuge pond design

The four refuge ponds (A, B, C, and D) were completed on 20 June 1983 (Fig. III-1). They were built between 300 m and 600 m from Sun Bay, which was as close as permitted by construction plans (including Z-Area). When possible, sites for ponds were chosen where puddles of water tended to collect naturally. The disturbed soil at the site of Pond B suggested that it may have been an old soil borrow area. 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 in the middle of approximately 1 m. Each is 200 m² in area, which is a total of 800 m² for 4 ponds. The wetland they replaced was approximately 10,000 m², so our study should be viewed as an experimental "pilot project", not as mitigation *per se*. Plywood boards were placed around each pond to provide shelter for amphibians until natural vegetation could become established.

Ponds were originally lined with 20-25 cm of hard-packed clay so that they would collect and hold rainwater. Most Carolina bays are underlaid by an impervious clay lens, and usually receive no water input other than rain (Bryant and McCracken 1964, Sharitz and Gibbons 1982, Schalles and Shure 1989, Lide 1991). Rainfall was monitored daily with a rain gauge. The water level of each pond and of Rainbow Bay was monitored weekly with a staff gauge located in the middle.

Refuge pond water retention was poor during the first year after they were built, in spite of high rainfall. To rectify this problem fish-grade plastic (CPE) pond liners were installed on 19 November 1984. Because the plastic liners initially provided an inert substrate, terrestrial leaf litter was added to the ponds during February and March 1985. These leaves supplied cover, nutrients, and organic matter for biota.

After installation of the plastic liners the refuge ponds became permanent ponds. Refuge Ponds A and B were each pumped to one-third of their 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 designed to simulate the annual drying characteristic of Rainbow Bay and the former Sun Bay.

At the request of the Department of Energy, Refuge Pond C was dismantled on 7 June 1985 to accommodate expansion of the planned Z-Area.

Sampling techniques

We monitored amphibian populations at the refuge ponds using terrestrial drift fences with pitfall traps (Gibbons and Semlitsch 1982). These were installed 20-21 June 1983 and deactivated 9 December 1991. Fences were of 50-cm-high aluminum flashing buried 10 cm in the ground, and completely encircled each pond. Pitfall traps were 40 liter buckets buried flush against the fence on each side every 10 m. Traps were checked daily, and animals released on the opposite side of the fence, the presumed direction of movement.

Most amphibians captured were marked by toe-clipping. A combination of individual marks, year-pond cohort marks, and general group marks was used. Our sampling techniques provided a census of the numbers of adults that entered each pond to breed each year, as well as the numbers of newly-metamorphosed juveniles that emigrated to surrounding terrestrial habitats.

The capture efficiency of drift fences with pitfall traps differs among species (Gibbons and Semlitsch 1982, Dodd 1991, personal observations). Practically all individuals of some species are captured, for example, ambystomatid salamanders and bufonid toads. Other amphibians such as treefrogs and ranid frogs frequently jump or climb over the fence and out of the traps. Juveniles in these groups are captured more effectively than adults, as the juveniles are less adept at trespass. Analyses of population trends over time make the assumption that there is no trend in the sampling efficiency of the drift fences, which is reasonable if the fences and traps are maintained well. Comparisons among sites assume that the capture efficiency of drift fences and pitfall traps of the same design does not differ among sites, which is most defensible for fences that completely encircle ponds.

A drift fence with pitfall traps was used to monitor amphibian migrations at Sun Bay prior to construction from 8 February 1979-24 June 1982, after which sampling was discontinued at the request of the Department of Energy. The fence and traps were of the same design used at the refuge ponds, and most amphibians captured at Sun Bay were also marked by toe-clipping.

These data are summarized only briefly here for comparative purposes. Further details are provided by SREL (1980), Vitt (1981), Vitt et al. (1982), Semlitsch (1983a, 1987), Caldwell (1987), and Pechmann et al. (1989).

Drift fences with pitfall traps also were used to monitor amphibian breeding migrations to the site of the former Sun Bay during construction. Because of the extensive construction activities, these fences were employed intermittently and covered only a small part of the perimeter of the former wetland. Four-and-one-half-liter pitfall traps were used at these fences instead of the 40-liter traps used elsewhere to facilitate frequent installation and removal. These small traps were not as effective as the larger traps.

One 50-m drift fence located on the northwest side of the former bay was used for sampling from 13 December 1983 to 11 May 1984. Two temporary 50-m fences were employed 17 December 1984-3 July 1985 and 21 November 1985-29 August 1986: one on the northwest side and the other on the northeast. A single fence on the northeast side was used for sampling from 29 August 1986 to 16 September 1987. Monitoring of the Sun Bay site was discontinued after this date because captures of amphibians had dwindled to near zero. Sampling differences cloud among-year comparisons of amphibian populations at Sun Bay during construction, as well as comparisons to the refuge ponds, but were unavoidable due to the construction activities.

In addition to the drift fences, the standing water at the edge of the former Sun Bay was sampled with minnow traps from 12 December 1983 until 21 December 1983, after which the site was completely drained by a ditch. We then sampled the drainage ditch with the minnow traps until 31 March 1984. Each refuge pond was sampled with minnow traps from 10 January 1987 to 15 April 1987 in order to determine if paedomorphic salamanders were present. All minnow traps were checked daily and all captured animals released immediately. Adult amphibians and salamander larvae captured in minnow traps were marked by toe-clipping. Each refuge pond was surveyed qualitatively with dip nets and a seine on 17 April 1991 for the presence of adult *Notophthalmus*

viridescens.

RESULTS

Sun Bay

Four to six species of salamanders and seven to 15 species of frogs and toads probably bred at Sun Bay prior to construction (Table III-1). Breeding population sizes varied considerably during the pre-construction survey (1979-1982). No juvenile recruitment was observed during this period for some species, and for the others recruitment was low and sporadic (Table III-1). Observations indicated that this resulted in part from the fact that the Sun Bay usually dried before many larvae could reach the minimum size for metamorphosis. *Ambystoma talpoideum* and *Notophthalmus viridescens* were the most commonly captured salamanders before construction, and *Bufo terrestris*, *Gastrophryne carolinensis*, *Pseudacris crucifer*, *P. ornata*, and *Scaphiopus holbrookii* the most commonly captured frogs and toads.

Some species continued breeding migrations to the site of Sun Bay for a period of time after it was filled with soil in 1983 (Table III-2). By the 1987 breeding seasons, however, only one breeding adult was captured at Sun Bay, a female *Rana utricularia*.

The refuge pond environment

The hydrologic cycles of the refuge ponds did not match that of the undisturbed reference wetland, Rainbow Bay (Fig. III-2). Rainbow Bay usually filled in the winter and dried in the spring or summer, depending upon rainfall, as had Sun Bay. The refuge ponds filled and dried more frequently during the first 17 months after they were built than did Rainbow Bay (Fig. III-2). Only ponds A and B held water for more than a few weeks at a time during this period, as they were built on sites where water tended to collect naturally. The refuge ponds became permanent ponds after the pond liners were installed (Fig. III-2). Ponds A and B remained dry for less than a week after the water was pumped out of them in 1987 (Fig. III-2). This was a shorter dry period than exhibited by Rainbow Bay during any year of the study.

Grasses and forbs initially colonized the bare soil that surrounded each

pond after their construction. These were gradually replaced by volunteer *Pinus taeda* at Pond A and *P. elliottii* at ponds B and D. There were annual blooms of filamentous green algae in the ponds. An emergent sedge (*Scirpus cyperinus*) became established in the shallow water along the shores. Aquatic insects, including large predaceous Odonata nymphs, became common in the ponds. Crows, sandpipers, and other birds often fed in the water around the edges of the ponds.

Frogs and Toads

The frogs and toads *Bufo terrestris*, *Gastrophryne carolinensis*, *Pseudacris crucifer*, and *Rana utricularia* colonized the refuge ponds within a year, and breeding populations of these species were present at the ponds during every year of the study (Fig. III-3, Table III-3). Smaller numbers of adults of 9 other species of anurans were captured during their breeding seasons in one or more years at the refuge ponds (Fig. III-3, Table III-3). Numbers must be judged keeping in mind that sampling efficiencies were low for adult *Acris*, *Rana* and *Hyla*. As an extreme example, no adult *H. gratiosa* were ever captured in the refuge pond pitfall traps even though juveniles were produced at all three remaining ponds every year beginning in 1985 (Table III-3). More adult *Scaphiopus holbrookii*, *B. quercicus*, *H. femoralis*, *H. chrysoscelis*, and *R. clamitans* were captured in the first part of the study than the latter part, and the reverse was true for *A. gryllus*, but sample sizes were too small to draw any conclusions about trends. More individuals of all frog and toad species were caught at the refuge ponds than at Sun Bay each year that both locations were monitored, except 1984 for *P. ornata*, but sampling efficiency was greater at the refuge ponds (Fig. III-3, Tables III-2 and III-3). Only four *B. terrestris*, one *G. carolinensis*, and two of the *R. utricularia* captured at the refuge ponds had probably been marked at Sun Bay during pre-construction surveys.

No juveniles metamorphosed and emigrated from the refuge ponds in 1983, and only 7 juvenile *Hyla chrysoscelis* and 1 juvenile *Hyla femoralis* were observed in 1984 (Fig. III-3, Table III-3). Observations indicated that the

low juvenile recruitment during these first two years was due in part to the fact that the ponds dried frequently, killing the tadpoles that were present. Substantial production of frog and toad juveniles began in 1985 following installation of the pond liners. Juveniles of ten species of frogs and toads metamorphosed and emigrated from the refuge ponds during the study (Fig. III-3, Table III-3). The numbers of juveniles produced varied considerably among species, ponds, and years. *Pseudacris crucifer* and *Rana utricularia* produced the most frog and toad juveniles at the refuge ponds. The largest cohort of both species was produced in 1985, the first year that the ponds filled with water for an extended period (Figs. III-2 and III-3, Table III-3). The next largest cohort of both species came in 1988, primarily from ponds A and B which had been pumped dry in the autumn of 1987. Nearly all *R. utricularia* juveniles also came from Ponds A and B in other years, whereas Pond D produced the most *P. crucifer* juveniles overall. *P. crucifer* had been one of the three dominant species at Sun Bay in terms of juvenile recruitment during pre-construction studies, but no juvenile recruitment of *R. utricularia* was observed there from 1979-1982 (Table III-1).

Relatively large numbers of juvenile *Acris gryllus*, *Bufo terrestris*, and *Hyla gratiosa* also metamorphosed and emigrated from the refuge ponds (Fig. III-3, Table III-3). The largest number of all three species came from Pond D, but nearly as many *H. gratiosa* came from Pond B. No juvenile recruitment of *A. gryllus* was observed at the ponds until 1987, the same year that adults of this species were first captured. After that a cohort of *Acris* was produced every year, the largest during the last year of the study. The only cohort of *Rana clamitans* was produced at Pond A during the last year of the study. In contrast to *A. gryllus* and *R. clamitans*, juvenile recruitment of *Hyla chrysoscelis* at the refuge ponds occurred primarily in the first part of the study. Eighty-six percent of the juvenile *H. chrysoscelis* were collected in 1985, primarily from ponds A and B. No juvenile recruitment of *Acris gryllus*, *Hyla chrysoscelis*, or *H. gratiosa* was observed at Sun Bay from 1979-1982.

Only a few *Rana catesbeiana* and *Pseudacris ornata* juveniles and a single *Hyla femoralis* juvenile were produced at the refuge ponds (Fig. III-3, Table III-3). Most of the *P. ornata* came from Pond B in the year after it was pumped dry. *Pseudacris ornata* had been one of the dominant frogs and toads at Sun Bay in terms of juvenile recruitment, but no *R. catesbeiana* or *H. femoralis* recruitment was observed there during pre-construction studies (Table III-1). No juvenile *Gastrophryne carolinensis* or *Scaphiopus holbrookii* were produced at the refuge ponds, despite the fact that adults of these species were frequently captured there. *Scaphiopus holbrookii* was the only frog or toad that produced juveniles at Sun Bay during pre-construction studies but did not produce any at the refuge ponds.

Salamanders

More adult *Ambystoma talpoideum* and *Notophthalmus viridescens* were caught at Sun Bay than at the refuge ponds during FY-1984, despite the construction and the less efficient sampling at Sun Bay (Table III-2, Fig. III-4). Few salamanders were captured at either location in FY-1985, a drought year. More adult *A. talpoideum* and *N. viridescens* were caught at the refuge ponds than at Sun Bay during the next two years, which were the last that Sun Bay was sampled, although numbers are not directly comparable because sampling effort was greater at the refuge ponds (Table III-2, Fig. III-4). The number of these two species that entered the refuge ponds during their FY-1986 breeding seasons was higher than in previous years, especially for *Ambystoma talpoideum* at Pond D (Fig. III-4). These higher numbers of immigrating adult salamanders generally persisted from FY-1987 to FY-1989, and numbers increased sharply again in FY-1990.

Three of the 19 *N. viridescens* and 46 of the 99 *A. talpoideum* adults that entered the refuge ponds during the first 4 years of the study had been marked previously at Sun Bay. *Ambystoma talpoideum* and *N. viridescens* were the most common salamanders at Sun Bay prior to construction (Table III-1). Three other species of salamanders were collected at the Sun Bay drift fence prior to construction: *A. opacum*, *A. tigrinum*, and *Eurycea quadridigitata*

(Table III-1). Only a few individuals of these species were captured at Sun Bay or the refuge ponds after construction began (Tables III-1 and III-2; Fig. III-4). None of those captured at the refuge ponds had been marked previously at Sun Bay.

Juvenile salamanders were not produced at the refuge ponds until FY-1986, the first year of notable colonization by adults (Fig. III-4). Hundreds of *Ambystoma talpoideum* and *Notophthalmus viridescens* metamorphosed and emigrated from the refuge ponds from FY-1986 to FY-1991 (Fig. III-4). These are the only two salamander species for which juvenile recruitment has been observed at the refuge ponds, however. Each of the two species became established primarily at two of the three remaining refuge ponds. Only 10 *A. talpoideum* have metamorphosed and emigrated from Pond A, and only two *N. viridescens* from Pond B. Pond D is the only one at which both species have produced cohorts during the last four years of the study.

By the end of the study, most of the adult *Ambystoma talpoideum* migrating to the refuge ponds to breed had been born at them. Out of a sample of 228 *A. talpoideum* marked at metamorphosis that subsequently returned, 95% returned to their home refuge pond and 5% returned to a different refuge pond. All but one of the movements among ponds were between ponds B and D, the two ponds that most of the metamorphosed *A. talpoideum* have come from.

The presence of paedomorphic *Ambystoma talpoideum* and *Notophthalmus viridescens* at the refuge ponds was established by their capture in minnow traps during FY-1987 (Table III-3, part II-A). Mature male paedomorphs of each species can be recognized externally during the breeding season by the appearance of their cloaca and the presence of gills. Mature female paedomorphs cannot always be differentiated from overwintering larvae of either sex without dissection. Yolked ova were visible through the venter of some of the gilled *N. viridescens* caught in the minnow traps, indicating that they were mature paedomorphic females. Yolked ova were not observed through the venter of any of the gilled *A. talpoideum*, but most may have bred before the minnow traps were deployed. One or two gilled males and females of each

species were dissected to confirm that they were sexually mature. *Ambystoma talpoideum* paedomorphs were found primarily in ponds B and D, and *N. viridescens* paedomorphs were caught only in ponds A and D.

Some of the known paedomorphic male and suspected paedomorphic female *Ambystoma talpoideum* captured in the minnow traps in FY-1987 metamorphosed and emigrated from the refuge ponds during March and April of that year (Table III-3, part II-A). One of these females was dissected and confirmed to be a former paedomorph. A subset of these males and females returned to the refuge ponds to breed as metamorphs in subsequent years.

None of the paedomorphic *Notophthalmus viridescens* captured in the minnow traps were ever captured as metamorphs at the drift fence (Table III-3, part II-A). Some of the *N. viridescens* captured with nets in April 1991 were adults whose gills were reduced to small nubs, indicating that some paedomorphic individuals metamorphosed but remained in the ponds. *Notophthalmus viridescens* were captured only at refuge ponds A and D in the April 1991 survey.

Ambystoma talpoideum metamorphosed and emigrated from the refuge ponds throughout the year, although primarily in the spring and autumn. Sex and maturity could not be judged externally in most individuals that metamorphosed. A sample of 23 newly-metamorphosed individuals collected in March and April of 1987 and 1991 was dissected and found to consist of a mixture of juveniles and former paedomorphs of both sexes. There was often a natural break in the migration of newly-metamorphosed *A. talpoideum* from the refuge ponds around the middle of May, just before *A. talpoideum* juveniles begin to metamorphose and emigrate from temporary ponds without paedomorphs such as Rainbow Bay. Individuals that emigrated from the refuge ponds from 20 May-31 December were therefore judged to consist primarily of juvenile young-of-the-year. *Ambystoma talpoideum* that metamorphosed and emigrated from 1 January to 19 May were considered to be a mix of overwintering juveniles and former paedomorphs. These individuals were added to the juveniles from the previous calendar year, but as a separate category (Fig. III-4).

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 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 hatched (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 (but see Whiteman 1994).

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 holbrookii* and *Gastrophryne 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.

Numbers and diversity of amphibians at the Rainbow Bay control site have generally exceeded those at the refuge ponds. Juvenile production at Rainbow Bay in many years has been reduced by early pond drying due to drought (Pechmann et al. 1989, 1991), whereas the refuge ponds have not dried since pond liners were installed in FY-1985.

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*. 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 '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. 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. Thus, our results suggest that 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.

LITERATURE CITED

Adam, M. D. , and M. J. Lacki. 1993. Factors affecting amphibian use of road-rut ponds in Daniel Boone National Forest. *Transactions of the Kentucky Academy of Science* 54:13-16.

Anderson, P. K. 1954. Studies in the ecology of the narrow-mouthed toad, *Microhyla carolinensis carolinensis*. *Tulane Studies in Zoology* 2:15-46.

Berven, K.A., and T.A. Grudzien. 1990. Dispersal in the wood frog (*Rana sylvatica*): implications for genetic population structure. *Evolution* 44:2047-2056.

Breden, F. 1987. The effect of post-metamorphic dispersal on the population genetic structure of Fowler's toad, *Bufo woodhousei fowleri*. *Copeia* 1987:386-395.

Brooks, R.P. 1990. Wetland and waterbody restoration and creation associated with mining. Pages 529-548 in J.A. Kusler and M. E. Kentula, editors. *Wetlands creation and restoration: the status of the science*. Island Press, Washington, D.C., USA.

Broome, S.W. 1990. Creation and restoration of tidal wetlands of the southeastern United States. Pages 37-72 in J.A. Kusler and M. E. Kentula, editors. *Wetlands creation and restoration: the status of the science*. Island Press, Washington, D.C., USA.

Bryant, J.P., and R.J. McCracken. 1964. Properties of soils and sediments of the Carolina bays. *Journal of the Elisha Mitchell Scientific Society*. 80:166.

Caldwell, J. P. 1987. Demography and life history of two species of chorus frogs (Anura: Hylidae) in South Carolina. *Copeia* 1987:114-127.

Cook, R. P. 1989. And the voice of the grey tree frog was heard again in the land. *Park Science* 9(3):6-7.

Cook, R. P. , and C. A. Pinnock. 1987. Recreating a herpetofaunal community at Gateway National Recreation Area, New York. 151-154 in L. W. Adams and D. L. Leedy. Integrating man and nature in the metropolitan environment. *Proceedings of the National Symposium on Urban Wildlife*, Chevy Chase, Maryland, 4-7 November 1986. National Institute for Urban Wildlife, Columbia, Maryland, USA.

Dodd, C. K., Jr. 1991. Drift fence-associated sampling bias of amphibians at a Florida Sandhills temporary pond. *Journal of Herpetology* 25:296-301.

Dodd, C.K.,Jr. 1992. Biological diversity of a temporary pond herpetofauna in north Florida sandhills. *Biodiversity and Conservation* 1:125-142.

Dole, J. W. 1971. Dispersal of recently metamorphosed leopard frogs, *Rana pipiens*. *Copeia* 1971:221-228.

Douglas, M.E., and B.L. Monroe, Jr. 1981. A comparative study of topographical orientation in *Ambystoma* (Amphibia: Caudata). *Copeia* 1981:460-463.

Erwin, K.L. 1990. Freshwater marsh creation and restoration in the southeast.

Erwin, K.L. 1990. Freshwater wetland creation and restoration in the southeast. Pages 233-248 in J.A. Kusler and M. E. Kentula, editors. *Wetlands creation and restoration: the status of the science.* Island Press, Washington, D.C., USA.

Fog, K. 1988. Pond restorations on Bornholm. *Memoranda Societas Fauna Flora Fennica* 64:143-145.

Frazer, J. D. 1973. *Amphibians*. Wykeham Publications, London, England. Gill, D. E. 1978. The metapopulation ecology of the red-spotted newt, *Notophthalmus viridescens* (Rafinesque). *Ecological Monographs* 48:145-166.

Gibbons, J.W., and R.D. Semlitsch. 1982. Terrestrial drift fences with pitfall traps: an effective technique for quantitative sampling of animal populations. *Brimleyana* 7:1-16.

Gill, D. E. 1978. The metapopulation ecology of the red-spotted newt, *Notophthalmus viridescens* (Rafinesque). *Ecological Monographs* 48:145-166.

Grubb, J. C. 1975. Olfactory orientation in southern leopard frogs, *Rana utricularia*. *Herpetologica* 31:219-221.

Haapanen, A. 1970. Site tenacity of the common frog (*Rana temporaria* L.) and the moor frog (*R. arvalis* Nilss.). *Annales Zoologici Fennici* 7:61-66.

Hammer, D.A. 1992. *Creating freshwater wetlands*. Lewis Publishers, Boca Raton, Florida, USA.

Harris, R. N. 1987. Density-dependent paedomorphosis in the salamander *Notophthalmus viridescens dorsalis*. *Ecology* 68:705-712.

Hershey, J.L., and D.C. Forester. 1979. Sensory orientation in *Notophthalmus v. viridescens* (Amphibia: Salamandridae). *Canadian Journal of Zoology* 58:266-276.

Heusser, H. 1960. Über die beziehungen der erdkröte (*Bufo bufo* L.) zu ihrem laichplatz II. *Behaviour* 16:93-109.

Jameson, D.L. 1956. Growth, dispersal and survival of the Pacific tree frog. *Copeia* 1956:25-29.

Kentula, M. E., R. P. Brooks, S. E. Gwin, C. C. Holland, A. D. Sherman, and J. C. Sifneos. 1993. An approach to improved decision-making in wetland restoration and creation. Lewis Publishers, Boca Raton, Florida.

Kramer, D.C. 1973. Movements of western chorus frogs *Pseudacris triseriata triseriata* tagged with Co⁶⁰. *Journal of Herpetology* 7:231-235.

Kusler, J. A., and M. E. Kentula, eds. 1990. Wetlands creation and restoration: the status of the science. Island Press, Washington, D.C., USA.

Laan, R. , and B. Verboom. 1990. Effects of pool size and isolation on amphibian communities. *Biological Conservation* 54:251-262.

Landreth, H.F., and D.E. Ferguson. 1967. Newt orientation by sun-compass. *Nature* 215:516-518.

Lide, R. F. 1991. Hydrology of a Carolina bay located on the Upper Coastal Plain, western South Carolina. Thesis. The University of Georgia, Athens, Georgia, USA.

Madison, D.M. and C.R. Shoop. 1970. Homing behavior, orientation, and home range of salamanders tagged with tantalum-182. *Science* 168:1484-1487.

Matthews, M. J., R. P. Cook, J. T. Tanacredi, and J. J. Pane. 1991. Interagency cooperation in restoring freshwater wetlands in an urban national recreation area. 151-155 in L. W. Adams and D. L. Leedy. *Wildlife conservation in metropolitan environments*. National Institute for Urban Wildlife, Columbia, Maryland, USA.

McGregor, J.H., and W.R. Teska. 1989. Olfaction as an orientation mechanism in migrating *Ambystoma maculatum*. *Copeia* 1989: 779-781.

Moler, P.E., and R. Franz. 1988. Wildlife values of small, isolated wetlands in the Southeastern coastal plain. Pages 234-241 in R.R. Odom, K.A. Riddleberger, and J.C. Ozier, editors. *Proceedings of the third nongame and endangered wildlife symposium*. Georgia Department of Natural Resources, Social Circle, Georgia, USA.

Oldham, R. S. 1966. Spring movements in the American toad, *Bufo americanus*. *Canadian Journal of Zoology* 44:63-100.

Oldham, R.S. 1967. Orienting mechanisms of the green frog, *Rana clamitans*. *Ecology* 48:477-491.

Pechmann, J.H.K., D.E. Scott, J.W. Gibbons, and R.D. Semlitsch. 1989.

Influence of wetland hydroperiod on diversity and abundance of metamorphosing juvenile amphibians. *Wetlands Ecology and Management* 1:3-11.

Pechmann, J.H.K., R.D. Semlitsch, R.M. Lew, and D.T. Mayack. 1984. Annual Report, FY-1983-84. Ecological studies related to the construction of the Defense Waste Processing Facility on the Savannah River Plant. NTIS Publ. SREL 17 UC-66e.

Pechmann, J.H.K., D.E. Scott, and J.N. Knox. 1985. Annual Report, FY-1985. Ecological studies related to construction of the Defense Waste Processing Facility on the Savannah River Plant. NTIS Publ. SREL 19 UC-66e.

Pechmann, J.H.K. and R.D. Semlitsch. 1986. Diel activity patterns in the breeding migrations of winter-breeding anurans. *Can. J. Zool.* 64: 1116-1120.

Pechmann, J.H.K., D.E. Scott, R.D. Semlitsch, J.P. Caldwell, L. J. Vitt, and J. W. Gibbons. 1991. Declining amphibian populations: the problem of separating human impacts from natural fluctuations. *Science* 253:892-895.

Phillips, J. B. 1986. Two magnetoreception pathways in a migratory salamander. *Science* 233:765-767.

Reading, C. J., J. Loman , and T. Madsen. 1991. Breeding pond fidelity in the common toad, *Bufo bufo*. *Jounal of Zoology*, London 225:201-211.

Reilly, S. M. 1987. Ontogeny of the hyobranchial apparatus in the salamanders *Ambystoma talpoideum* (Ambystomatidae) and *Notophthalmus viridescens* (Salamandridae): The ecological morphology of two neotenic strategies. *Journal of Morphology* 191:205-214.

Rodda, G. H. , and J. B. Phillips. 1992. Navigational systems develop along similar lines in amphibians, reptiles, and birds. *Ethology Ecology and Evolution* 4:43-51.

Ross, T.E. 1987. A comprehensive bibliography of the Carolina bays literature. *The Journal of the Elisha Mitchell Scientific Society* 103:28-42.

Salvesen, D. 1990. Wetlands: mitigating and regulating development impacts. *The Urban Land Institute, Washington, D.C., USA.*

Savannah River Ecology Laboratory. 1980. Annual Report, FY-1980. A biological inventory of the proposed site of the Defense Waste Processing Facility on the Savannah River Plant in Aiken, South Carolina. NTIS publ. SREL-7 UC-66e. 179 pp.

Schalles, J.F. 1979. Comparative limnology and ecosystem analysis of Carolina bay ponds on the upper coastal plain of South Carolina. Ph.D. Thesis. Emory University, Atlanta, Ga.

Schalles, J. F. , and D. J. Shure. 1989. Hydrology, community structure, and productivity patterns of a dystrophic Carolina bay wetland. *Ecological Monographs* 59:365-385.

Schlupp, I., M. Kietz, R. Podloucky , and F. M. Stolz. 1989. Pilot project Braken: preliminary results from the resettlement of adult

toads to a substitute breeding site. 127-133 in T. E. S. Langton. Amphibians and roads. Proceedings of the Toad Tunnel Conference, Rendsburg, Federal Republic of Germany, 7-8 January 1989. ACO Polymer Products Ltd, Shefford, Bedfordshire, England.

Scott, D.E., J.H.K. Pechmann, J.N. Knox, R.A. Estes, and A.M. Dancewicz. 1986. Annual Report, FY-1986. Ecological studies related to construction of the Defense Waste Processing Facility on the Savannah River Plant. NTIS Publ. SREL-32 UC-66e.

Scott, D. E. 1994. The effect of larval density on adult demographic traits in *Ambystoma opacum*. *Ecology* 75:1383-1396.

Semlitsch, R.D. 1981. Terrestrial activity and summer home range of the mole salamander (*Ambystoma talpoideum*). *Canadian Journal of Zoology* 59:315-322.

Semlitsch, R.D. 1983a. Structure and dynamics of two breeding populations of the eastern tiger salamander, *Ambystoma tigrinum*. *Copeia* 1983:608-616.

Semlitsch, R.D. 1983b. Terrestrial movements of an eastern tiger salamander, *Ambystoma tigrinum*. *Herp Review* 14: 112-113.

Semlitsch, R. D. , and J. W. Gibbons. 1985. Phenotypic variation in metamorphosis and padomorphosis in the salamander *Ambystoma talpoideum*. *Ecology* 66:1123-1130.

Semlitsch, R. D. 1987. Relationship of pond drying to the reproductive success of the salamander *Ambystoma talpoideum*. *Copeia* 1987:61-69.

Semlitsch, R. D., D. E. Scott , and J. H. K. Pechmann. 1988. Time and size at metamorphosis related to adult fitness in *Ambystoma talpoideum*. *Ecology* 69:184-192.

Shoop, C. R. , and T. L. Doty. 1972. Migratory orientation by marbled salamanders (*Ambystoma opacum*) near a breeding area. *Behavioral Biology* 7:131-136.

Sharitz, R.R., and J.W. Gibbons. 1982. The ecology of southeastern shrub bogs (pocosins) and Carolina bays: a community profile. FWS/OBS-82/04. U.S. Fish and Wildlife Service, Washington, D.C., USA.

Sinsch, U. 1990. Migration and orientation in anuran amphibians. *Ethology Ecology and Evolution* 2:65-79.

Sinsch, U. 1992. Structure and dynamic of a natterjack toad metapopulation (*Bufo calamita*). *Oecologia* 90:489-499.

Taylor, D.H., and K. Adler. 1973. Spatial orientation by salamanders using plane-polarized light. *Science* 181:285-287.

Twitty, V.C. 1959. Migration and speciation in newts. *Science* 130:1735-1743.

Twitty, V.C. 1961. Experiments on homing behavior and speciation in *Taricha*. Pages 415-459 in: W.F. Blair, editor. *Vertebrate speciation*. University of Texas Press, Austin, Texas, USA.

Vitt, L.J. 1981. Annual Report, FY-1981. A biological inventory of the proposed site of the Defense Waste Processing Facility on

Vitt, L.J. 1981. Annual Report, FY-1981. A biological inventory of the proposed site of the Defense Waste Processing Facility on the Savannah River Plant in Aiken, South Carolina NTIS publ. SREL-8 UC-66e. 86 pp.

Vitt, L.J., R.D. Semlitsch and M.L. Cothran. 1982. Annual Report, FY-1982. A biological inventory of the proposed site of the Defense Waste Processing Facility on the Savannah River Plant in Aiken, South Carolina. NTIS publ. SREL-13 UC-66e. 146 pp.

Wake, D.B., and H.J. Morowitz. 1990. Declining amphibian populations - a global phenomenon? Report to Board on Biology, National Research Council, on workshop in Irvine, California, USA, 19-20 February 1990; reprinted *Alytes* 9:33-42.

Whiteman, H. H. 1994. Evolution of facultative paedomorphosis in salamanders. *The Quarterly Review of Biology* 69:205-221.

Williams, P.K. 1973. Seasonal movements and population dynamics of four sympatric mole salamanders, genus *Ambystoma*. Dissertation. Indiana University, Bloomington, Indiana, USA.

Whitford, W. G. , and A. Vinegar. 1966. Homing, survivorship, and overwintering of larvae in spotted salamanders, *Ambystoma maculatum*. *Copeia* 1966:515-519.

TABLE III-1. Breeding population sizes and juvenile recruitment of amphibians at Sun Bay prior to construction.

	1979			1980			1981			1982		
	M	F	J	M	F	J	M	F	J	M	F	J
Salamanders												
<i>Ambystoma opacum</i>	-- ^a	-- ^a	0	11	10	19	27	7	31	8	5	93
<i>A. talpoideum</i>	469 ^b	531	0	3013	3300	0	113	53	0	100	974	0
<i>A. tigrinum</i>	20 ^b	25 ^b	1	13	8	0	3	0	0	17	9	0
<i>Eurycea quadridigitata</i>	-- ^a	-- ^a	0	1	4	0	1	0	0	1	1	0
<i>Notophthalmus</i>	-- ^a	-- ^a	23	1271	1005	0	431	207	0	179	144	0
<i>Siren intermedia</i>	-- ^c	-- ^c	-- ^c	-- ^c	-- ^c	-- ^c	-- ^c	-- ^c	-- ^c	-- ^c	-- ^c	-- ^c
Frogs and Toads												
<i>Acris gryllus</i>	3	0	0	2	7	0	1	1	0	0 ^b	0 ^b	0
<i>Bufo quercicus</i>	0	1	0	0	0	0	5	3	0	3	0	0
<i>B. terrestris</i>	244	61	617	718	99	0	96	18	0	115	70 ^b	0
<i>Gastrophryne</i>	685	516	0	100	23	0	288	192	0	60 ^b	18 ^b	0
<i>Hyla chrysoscelis</i>	4	3	0	1	1	0	0	0	0	0 ^b	0 ^b	0
<i>H. femoralis</i>	1	0	0	0	0	0	0	0	0	0 ^b	0 ^b	0
<i>H. gratiola</i>	1	2	0	0	0	0	0	0	0	0 ^b	0 ^b	0
<i>H. squirella</i>	0	0	0	0	0	0	0	0	0	0 ^b	0 ^b	0
<i>Pseudacris crucifer</i>	145 ^b	179	50	162	333	166	105	183	75	21	36	377
<i>P. nigrita</i>	0 ^b	0 ^b	0	8	6	0	2	2	0	0	0	0
<i>P. ornata</i>	61 ^b	61 ^b	31	165	138	19	73	45	55	62	55	423
<i>Rana catesbeiana</i>	0	0	0	0	2	0	0	0	0	0 ^b	0 ^b	0
<i>R. clamitans</i>	2	15	0	1	4	25	0	0	0	2 ^b	3 ^b	0
<i>R. utricularia</i>	26 ^b	68 ^b	0	51	32	0	15	17	0	2 ^b	2 ^b	0
<i>Scaphiopus holbrookii</i>	158 ^b	100	58	451	361	0	5	4	0	16 ^b	4 ^b	0

^a Drift fence and pitfall traps not in place during breeding migration period.

^b Drift fence and pitfall traps not in place only during part of breeding migration period.

^c Fully aquatic species, no estimates available.

TABLE III-2. Amphibians captured during breeding migrations at Sun Bay after it was filled with soil.

	1984		1985		1986		1987	
	M	F	M	F	M	F	M	F
Salamanders								
<i>Ambystoma opacum</i>	1 ^a	0 ^b	0	0				
<i>A. talpoideum</i>	20 ^b	14 ^b	0 ^b	1 ^b	4	5	0	0
<i>A. tigrinum</i>	0 ^b	0 ^b	0 ^b	0 ^b	0	0	0	0
<i>Eurycea quadridigitata</i>	-- ^a	0	0					
<i>Notophthalmus viridescens</i>	13 ^b	5 ^b	0	0				
<i>Siren intermedia</i>	-- ^c							
Frogs and Toads								
<i>Acris gryllus</i>	0 ^b	0 ^b	0 ^b	0 ^b	0	0	0	0
<i>Bufo quercicus</i>	0 ^b	0 ^b	0 ^b	0 ^b	0	0	0	0
<i>B. terrestris</i>	9 ^b	3 ^b	3	3	0	0	0	0
<i>Gastrophryne carolinensis</i>	2 ^b	1 ^b	2 ^b	2 ^b	0 ^b	0 ^b	0	0
<i>Hyla chrysoscelis</i>	0 ^b	0 ^b	0 ^b	0 ^b	0	0	0	0
<i>H. femoralis</i>	0 ^b	0 ^b	0 ^b	0 ^b	0	0	0	0
<i>H. gratiosa</i>	0 ^b	0 ^b	0 ^b	0 ^b	0	0	0	0
<i>H. squirella</i>	0 ^b	0 ^b	0 ^b	0 ^b	0	0	0	0
<i>Pseudacris crucifer</i>	3 ^b	3 ^b	1 ^b	0 ^b	0	0	0	0
<i>P. nigrita</i>	0 ^b	0 ^b	0 ^b	0 ^b	0	0	0	0
<i>P. ornata</i>	8 ^b	2 ^b	0 ^b	0 ^b	0	0	0	0
<i>Rana catesbeiana</i>	0 ^b	0 ^b	0 ^b	0 ^b	0	0	0	0
<i>R. clamitans</i>	1 ^b	0 ^b	0 ^b	0 ^b	0	0	0	0
<i>R. utricularia</i>	10 ^b	3 ^b	0 ^b	0 ^b	0 ^b	1 ^b	0	1
<i>Scaphiopus holbrookii</i>	5 ^b	3 ^b	1 ^b	0 ^b	1 ^b	2 ^b	0	0

^a Drift fence and pitfall traps not in place during breeding migration period.

^b Drift fence and pitfall traps not in place only during part of breeding migration period.

^c Fully aquatic species, no estimates available.

TABLE III-3. PART IA. Adult Breeding Populations at the Refuge Ponds and Sun Bay.

	<i>Bufo terrestris</i>		<i>Pseudacris ornata</i>		<i>Rana utricularia</i>	
1982-1983	male	female	male	female	male	female
Pond A	1	3	0	0	0	0
Pond B	0	2	0	0	0	0
Pond C	0	2	0	0	0	0
Pond D	0	1	0	0	0	0
Sun Bay	0	0	0	0	0	0
1983-1984	male	female	male	female	male	female
Pond A	4	3	0	0	3	2
Pond B	6	1	1	0	7	8
Pond C	5	1	0	2	2	0
Pond D	1	2	1	1	1	0
Sun Bay	9	3	8	2	10	3
1984-1985	male	female	male	female	male	female
Pond A	27	3	0	0	6	1
Pond B	37	19	0	2	5	1
Pond C	11	6	1	1	2	0
Pond D	28	9	0	1	2	0
Sun Bay	3	3	0	0	0	0
1985-1986	male	female	male	female	male	female
Pond A	30	10	0	0	36	7
Pond B	49	22	3	0	36	6
Pond C	--	--	--	--	--	--
Pond D	23	11	1	0	13	3
Sun Bay	0	0	0	0	0	1
1986-1987	male	female	male	female	male	female
Pond A	19	4	0	0	14	8
Pond B	12	2	0	0	1	2
Pond C	--	--	--	--	--	--
Pond D	4	7	0	0	0	0
Sun Bay	0	0	0	0	0	1
1987-1988	male	female	male	female	male	female
Pond A	5	8	1	0	13	0
Pond B	11	3	4	1	3	1
Pond C	--	--	--	--	--	--
Pond D	16	10	2	2	1	0
Sun Bay	--	--	--	--	--	--
1988-1989	male	female	male	female	male	female
Pond A	9	4	0	0	21	1
Pond B	8	5	4	1	6	0
Pond C	--	--	--	--	--	--
Pond D	18	8	0	0	0	0
Sun Bay	--	--	--	--	--	--
1989-1990	male	female	male	female	male	female
Pond A	9	4	0	0	4	3
Pond B	5	2	0	0	2	2
Pond C	--	--	--	--	--	--
Pond D	26	10	0	0	0	0
Sun Bay	--	--	--	--	--	--
1990-1991	male	female	male	female	male	female
Pond A	19	5	0	0	4	3
Pond B	23	11	0	0	2	1
Pond C	--	--	--	--	--	--
Pond D	23	11	0	0	1	0
Sun Bay	--	--	--	--	--	--

TABLE III-3. PART IB.

	<i>Hyla crucifer</i>		<i>Pseudacris nigrita</i>		<i>Rana catesbeiana</i>	
1982-1983	male	female	male	female	male	female
Pond A	0	0	0	0	0	0
Pond B	0	0	0	0	0	0
Pond C	0	0	0	0	0	0
Pond D	0	0	0	0	0	0
Sun Bay	0	0	0	0	0	0
1983-1984	male	female	male	female	male	female
Pond A	1	1	0	0	0	0
Pond B	5	8	0	0	0	1
Pond C	1	3	0	0	0	0
Pond D	0	1	0	0	0	0
Sun Bay	3	3	0	0	0	0
1984-1985	male	female	male	female	male	female
Pond A	1	2	0	0	0	0
Pond B	2	5	1	0	0	0
Pond C	6	9	0	0	0	0
Pond D	5	5	0	1	0	0
Sun Bay	1	0	0	0	0	0
1985-1986	male	female	male	female	male	female
Pond A	12	13	0	0	2	1
Pond B	54	61	1	0	0	0
Pond C	--	--	--	--	--	--
Pond D	19	15	0	2	0	0
Sun Bay	0	0	0	0	0	0
1986-1987	male	female	male	female	male	female
Pond A	2	1	0	0	0	1
Pond B	2	0	0	0	0	0
Pond C	--	--	--	--	--	--
Pond D	3	2	0	0	0	0
Sun Bay	--	--	--	--	--	--
1987-1988	male	female	male	female	male	female
Pond A	10	12	0	0	0	0
Pond B	3	5	0	0	0	0
Pond C	--	--	--	--	--	--
Pond D	0	0	0	0	1	0
Sun Bay	--	--	--	--	--	--
1988-1989	male	female	male	female	male	female
Pond A	14	15	0	0	0	0
Pond B	2	5	0	0	0	0
Pond C	--	--	--	--	--	--
Pond D	3	3	0	0	0	0
Sun Bay	--	--	--	--	--	--
1989-1990	male	female	male	female	male	female
Pond A	10	9	0	0	0	1
Pond B	0	5	0	0	0	0
Pond C	--	--	--	--	--	--
Pond D	5	5	0	0	0	0
Sun Bay	--	--	--	--	--	--
1990-1991	male	female	male	female	male	female
Pond A	0	0	0	0	0	0
Pond B	0	1	0	0	0	0
Pond C	--	--	--	--	--	--
Pond D	3	3	0	0	0	0
Sun Bay	--	--	--	--	--	--

TABLE III-3. PART IC.

	<i>Gastrophryne carolinensis</i>		<i>Rana clamitans</i>		<i>Scaphiopus holbrookii</i>	
1982-1983	male	female	male	female	male	female
Pond A	6	5	0	0	0	0
Pond B	11	8	0	0	0	1
Pond C	7	1	0	0	2	0
Pond D	5	4	0	0	0	3
Sun Bay	0	0	0	0	0	0
1983-1984	male	female	male	female	male	female
Pond A	17	7	0	0	0	1
Pond B	8	9	1	3	5	1
Pond C	2	2	2	1	8	5
Pond D	12	9	1	1	1	1
Sun Bay	2	1	1	0	5	3
1984-1985	male	female	male	female	male	female
Pond A	14	19	5	0	0	0
Pond B	5	3	2	2	4	2
Pond C	5	3	1	0	1	0
Pond D	11	5	0	0	2	2
Sun Bay	2	2	0	0	1	0
1985-1986	male	female	male	female	male	female
Pond A	12	17	1	2	0	0
Pond B	6	4	2	2	2	3
Pond C	--	--	--	--	--	--
Pond D	2	0	0	1	1	1
Sun Bay	0	0	0	0	1	2
1986-1987	male	female	male	female	male	female
Pond A	7	11	0	0	4	1
Pond B	2	4	0	0	4	3
Pond C	--	--	--	--	--	--
Pond D	7	2	0	0	0	0
Sun Bay	--	--	--	--	--	--
1987-1988	male	female	male	female	male	female
Pond A	8	5	0	0	0	2
Pond B	9	2	0	1	2	2
Pond C	--	--	--	--	--	--
Pond D	2	5	0	0	0	0
Sun Bay	--	--	--	--	--	--
1988-1989	male	female	male	female	male	female
Pond A	8	4	0	0	1	0
Pond B	1	3	0	0	0	1
Pond C	--	--	--	--	--	--
Pond D	17	18	0	2	0	0
Sun Bay	--	--	--	--	--	--
1989-1990	male	female	male	female	male	female
Pond A	10	1	0	1	0	0
Pond B	4	3	0	0	0	1
Pond C	--	--	--	--	--	--
Pond D	2	8	0	0	0	0
Sun Bay	--	--	--	--	--	--
1990-1991	male	female	male	female	male	female
Pond A	11	6	0	0	0	0
Pond B	7	14	0	0	0	2
Pond C	--	--	--	--	--	--
Pond D	33	49	1	0	0	0
Sun Bay	--	--	--	--	--	--

TABLE III-3. PART ID.

	<i>Hyla cinerea</i>		<i>Hyla gratiosa</i>		<i>Hyla femoralis</i>	
1982-1983	male	female	male	female	male	female
Pond A	0	0	0	0	0	0
Pond B	0	0	0	0	3	7
Pond C	0	0	0	0	0	0
Pond D	0	0	0	0	0	0
Sun Bay	0	0	0	0	0	0
1983-1984	male	female	male	female	male	female
Pond A	0	0	0	0	0	0
Pond B	0	0	0	0	1	1
Pond C	0	0	0	0	0	0
Pond D	0	0	0	0	0	1
Sun Bay	0	0	0	0	0	0
1984-1985	male	female	male	female	male	female
Pond A	0	0	0	0	0	1
Pond B	0	0	0	0	1	1
Pond C	0	0	0	0	0	0
Pond D	0	0	0	0	0	0
Sun Bay	0	0	0	0	0	0
1985-1986	male	female	male	female	male	female
Pond A	0	0	0	0	0	0
Pond B	0	0	0	0	0	0
Pond C	0	0	0	0	0	0
Pond D	0	0	0	0	1	0
Sun Bay	0	0	0	0	0	0
1986-1987	male	female	male	female	male	female
Pond A	0	0	0	0	0	0
Pond B	0	0	0	0	0	0
Pond C	--	--	--	--	--	--
Pond D	0	0	0	0	0	0
Sun Bay	--	--	--	--	--	--
1987-1988	male	female	male	female	male	female
Pond A	0	0	0	0	0	0
Pond B	0	0	0	0	0	0
Pond C	--	--	--	--	--	--
Pond D	0	0	0	0	0	0
Sun Bay	--	--	--	--	--	--
1988-1989	male	female	male	female	male	female
Pond A	0	0	0	0	0	0
Pond B	0	0	0	0	0	0
Pond C	--	--	--	--	--	--
Pond D	0	0	0	0	0	0
Sun Bay	--	--	--	--	--	--
1989-1990	male	female	male	female	male	female
Pond A	0	0	0	0	0	0
Pond B	0	0	0	0	0	0
Pond C	--	--	--	--	--	--
Pond D	0	0	0	0	0	0
Sun Bay	--	--	--	--	--	--
1990-1991	male	female	male	female	male	female
Pond A	0	0	0	0	0	0
Pond B	0	0	0	0	0	0
Pond C	--	--	--	--	--	--
Pond D	0	0	0	0	0	0
Sun Bay	--	--	--	--	--	--

TABLE III-3. PART IE.

	<i>Hyla squirella</i>		<i>Hyla versicolor</i>		<i>Bufo quercicus</i>	
1982-1983	male	female	male	female	male	female
Pond A	0	0	0	0	0	0
Pond B	0	0	0	0	0	0
Pond C	0	0	0	0	0	0
Pond D	0	0	0	0	0	0
Sun Bay	0	0	0	0	0	0
1983-1984	male	female	male	female	male	female
Pond A	0	0	0	2	0	0
Pond B	0	0	1	1	3	1
Pond C	0	0	0	0	0	0
Pond D	0	0	0	0	0	0
Sun Bay	0	0	0	0	0	0
1984-1985	male	female	male	female	male	female
Pond A	0	0	1	0	0	0
Pond B	0	0	0	1	0	0
Pond C	0	0	0	0	0	0
Pond D	0	0	0	1	0	0
Sun Bay	0	0	0	0	0	0
1985-1986	male	female	male	female	male	female
Pond A	0	0	0	0	0	0
Pond B	0	0	0	1	0	0
Pond C	0	0	0	0	0	0
Pond D	0	0	0	0	0	0
Sun Bay	0	0	0	0	0	0
1986-1987	male	female	male	female	male	female
Pond A	0	0	0	0	0	0
Pond B	0	0	0	1	0	0
Pond C	--	--	--	--	--	--
Pond D	0	0	1	1	0	0
Sun Bay	--	--	--	--	--	--
1987-1988	male	female	male	female	male	female
Pond A	0	0	1	0	0	0
Pond B	0	0	0	0	0	0
Pond C	--	--	--	--	--	--
Pond D	0	0	0	0	0	0
Sun Bay	--	--	--	--	--	--
1988-1989	male	female	male	female	male	female
Pond A	0	0	0	0	0	0
Pond B	0	0	0	0	0	0
Pond C	--	--	--	--	--	--
Pond D	0	0	0	0	0	0
Sun Bay	--	--	--	--	--	--
1989-1990	male	female	male	female	male	female
Pond A	0	0	0	0	0	0
Pond B	0	0	0	0	0	0
Pond C	--	--	--	--	--	--
Pond D	0	0	0	0	0	0
Sun Bay	--	--	--	--	--	--
1990-1991	male	female	male	female	male	female
Pond A	0	0	0	0	0	0
Pond B	0	0	1	0	0	0
Pond C	--	--	--	--	--	--
Pond D	0	0	0	0	0	0
Sun Bay	--	--	--	--	--	--

TABLE III-3. PART IF.

	<i>Ambystoma talpoideum</i>		<i>Ambystoma opacum</i>		<i>Ambystoma tigrinum</i>	
	male	female	male	female	male	female
1982-1983						
Pond A	0	0	0	0	0	0
Pond B	0	0	0	0	0	0
Pond C	0	0	0	0	0	0
Pond D	0	0	0	0	0	0
Sun Bay	0	0	0	0	0	0
1983-1984	male	female	male	female	male	female
Pond A	0	0	0	0	0	0
Pond B	0	0	0	0	0	0
Pond C	4	2	0	0	0	0
Pond D	2	1	0	0	0	0
Sun Bay	20	14	1	0	0	0
1984-1985	male	female	male	female	male	female
Pond A	0	0	0	0	0	0
Pond B	1	0	0	0	0	0
Pond C	0	2	0	0	0	0
Pond D	0	0	0	0	0	0
Sun Bay	0	1	0	0	0	0
1985-1986	male	female	male	female	male	female
Pond A	5	3	0	0	0	0
Pond B	6	3	0	0	0	1
Pond C	0	0	0	0	0	0
Pond D	23	22	0	0	0	0
Sun Bay	4	5	0	0	0	0
1986-1987	male	female	male	female	male	female
Pond A	5	0	0	0	0	0
Pond B	7	4	0	0	1	0
Pond C	--	--	--	--	--	--
Pond D	21	14	0	0	0	0
Sun Bay	--	--	--	--	--	--
1987-1988	male	female	male	female	male	female
Pond A	0	1	0	0	0	0
Pond B	6	3	0	0	0	0
Pond C	--	--	--	--	--	--
Pond D	14	9	0	0	0	0
Sun Bay	--	--	--	--	--	--
1988-1989	male	female	male	female	male	female
Pond A	1	0	0	0	0	0
Pond B	18	11	0	0	1	0
Pond C	--	--	--	--	--	--
Pond D	31	20	0	0	0	0
Sun Bay	--	--	--	--	--	--
1989-1990	male	female	male	female	male	female
Pond A	1	1	0	0	0	0
Pond B	32	31	0	0	1	0
Pond C	--	--	--	--	--	--
Pond D	71	67	0	0	0	0
Sun Bay	--	--	--	--	--	--
1990-1991	male	female	male	female	male	female
Pond A	1	0	0	0	0	0
Pond B	19	21	0	0	0	0
Pond C	--	--	--	--	--	--
Pond D	59	65	0	0	0	0
Sun Bay	--	--	--	--	--	--

TABLE III-3. PART 1G.

	<i>Acris gryllus</i>		<i>Eurycea quadridigitata</i>	
1982-1983	male	female	male	female
Pond A	0	0	0	0
Pond B	0	0	0	0
Pond C	0	0	0	0
Pond D	0	0	0	0
Sun Bay	0	0	0	0
1983-1984	male	female	male	female
Pond A	0	0	1	0
Pond B	0	0	0	0
Pond C	0	0	0	0
Pond D	0	0	0	0
Sun Bay	0	0	0	0
1984-1985	male	female	male	female
Pond A	0	0	0	0
Pond B	0	0	0	0
Pond C	0	0	0	0
Pond D	0	0	1	0
Sun Bay	0	0	0	0
1985-1986	male	female	male	female
Pond A	0	0	0	0
Pond B	0	0	0	0
Pond C	0	0	0	0
Pond D	0	0	0	0
Sun Bay	0	0	0	0
1986-1987	male	female	male	female
Pond A	1	1	0	0
Pond B	0	0	0	0
Pond C	--	--	--	--
Pond D	1	3	0	0
Sun Bay	--	--	--	--
1987-1988	male	female	male	female
Pond A	1	0	0	0
Pond B	0	0	0	0
Pond C	--	--	--	--
Pond D	0	0	0	0
Sun Bay	--	--	--	--
1988-1989	male	female	male	female
Pond A	0	0	0	0
Pond B	0	1	0	0
Pond C	--	--	--	--
Pond D	0	6	0	0
Sun Bay	--	--	--	--
1989-1990	male	female	male	female
Pond A	0	0	0	0
Pond B	1	1	0	0
Pond C	--	--	--	--
Pond D	9	6	0	0
Sun Bay	--	--	--	--
1990-1991	male	female	male	female
Pond A	0	0	0	0
Pond B	1	1	0	0
Pond C	--	--	--	--
Pond D	8	14	0	0
Sun Bay	--	--	--	--

TABLE III-3. PART IH. Efts and Adults of *Notophthalmus viridescens* (breeding populations). "U" indicates unsexable.

		<i>Notophthalmus viridescens</i>			
		male/female/male eft/female eft/ "u" eft			
1982-1983					
Pond A		0	0	0	0
Pond B		0	0	0	0
Pond C		0	0	0	0
Pond D		1	0	0	0
Sun Bay		0	0	0	0
1983-1984					
Pond A		0	0	1	0
Pond B		0	0	0	0
Pond C		0	0	0	1
Pond D		0	1	0	0
Sun Bay		13	5	0	0
1984-1985					
Pond A		0	0	0	0
Pond B		0	0	0	0
Pond C		0	0	0	0
Pond D		0	0	0	0
Sun Bay		0	0	0	0
1985-1986					
Pond A		0	2	0	2
Pond B		0	1	0	1
Pond C		0	0	0	0
Pond D		0	0	2	3
Sun Bay		0	0	0	0
1986-1987					
Pond A		1	2	0	0
Pond B		0	1	0	0
Pond C		--	--	--	--
Pond D		1	3	0	1
Sun Bay		0	0	0	0
1987-1988					
Pond A		3	8	0	0
Pond B		0	1	0	1
Pond C		--	--	--	--
Pond D		0	0	0	1
Sun Bay		--	--	--	--
1988-1989					
Pond A		1	1	1	0
Pond B		0	0	0	0
Pond C		--	--	--	--
Pond D		1	2	0	0
Sun Bay		--	--	--	--

1989-1990					
Pond A	0	0	1	1	0
Pond B	2	0	0	1	0
Pond C	--	--	--	--	--
Pond D	14	14	6	8	1
Sun Bay	--	--	--	--	--
1990-1991					
Pond A	1	0	1	2	1
Pond B	0	0	0	0	0
Pond C	--	--	--	--	--
Pond D	5	5	10	17	1
Sun Bay	--	--	--	--	--

TABLE III-3. PART IIA. Gilled, probably paedomorphic *Notophthalmus viridescens* caught in minnow traps and subset later recaptured at the drift fence.

		Minnow Trap Captures		
1986-1987		male	female	recaptures
Pond A		7	11	0
Pond B		0	0	0
Pond D		8	14	0

Gilled, probably paedomorphic *Ambystoma talpoideum* caught in minnow traps and subset later recaptured at the drift fence.

		Minnow Trap Captures			
1986-1987		male	female	Mrecap	Frecap
Pond A		0	1	0	0
Pond B		12	15	4	3
Pond D		5	7	4	3

Ambystoma talpoideum juveniles mid-May through 31 December. Sexes have been pooled.

1986	
Pond A	6
Pond B	32
Pond D	5
1987	
Pond A	1
Pond B	21
Pond D	196
1988	
Pond A	0
Pond B	69
Pond D	95
1989	
Pond A	0
Pond B	34
Pond D	82
1990	
Pond A	0
Pond B	39
Pond D	5
1991	
Pond A	0
Pond B	78
Pond D	176

Ex-paedomorphic *Ambystoma talpoideum* and juveniles that overwintered. The sexes have been pooled.

1986-1987	
Pond A	3
Pond B	68
Pond D	30
1987-1988	
Pond A	0
Pond B	0
Pond D	116
1988-1989	
Pond A	0
Pond B	76
Pond D	43
1989-1990	
Pond A	0
Pond B	55
Pond D	121
1990-1991	
Pond A	0
Pond B	64
Pond D	20

Juvenile *Ambystoma talpoideum* Produced at the Refuge Ponds. This table includes juveniles that overwintered and ex-paedomorphs, except for 1991 when these were not sampled.

	Pond A	Pond B	Pond C	Pond D	Totals
1984	0	0	0	0	0
1985	0	0	0	0	0
1986	9	100	--	35	144
1987	1	21	--	312	334
1988	0	145	--	138	283
1989	0	89	--	203	292
1990	0	103	--	25	128
1991	0	78	--	176	254
Totals	10	536	0	889	1435

TABLE III-3. PART IIB. Juvenile *Notophthalmus viridescens* produced at the Refuge Ponds.

	Pond A	Pond B	Pond C	Pond D	Totals
1984	0	0	0	0	0
1985	0	0	0	0	0
1986	11	0	--	8	19
1987	41	2	--	1	44
1988	88	0	--	58	146
1989	329	0	--	45	374
1990	56	0	--	67	123
1991	183	0	--	7	190
Totals	708	2	0	186	896

TABLE III-3. PART IIC. Juvenile *Bufo terrestris* produced at the Refuge Ponds.

	Pond A	Pond B	Pond C	Pond D	Totals
1984	0	0	0	0	0
1985	50	16	0	0	66
1986	1	1	--	14	16
1987	0	0	--	0	0
1988	3	0	--	298	301
1989	0	0	--	210	210
1990	2	0	--	19	21
1991	2	0	--	144	146
Totals	58	17	0	685	760

TABLE III-3. PART IID. Juvenile *Acris gryllus* produced at the Refuge Ponds.

	Pond A	Pond B	Pond C	Pond D	Totals
1984	0	0	0	0	0
1985	0	0	0	0	0
1986	0	0	--	0	0
1987	5	0	--	13	18
1988	0	0	--	31	31
1989	1	15	--	54	70
1990	0	6	--	49	55
1991	3	10	--	207	220
Totals	9	31	0	354	394

TABLE III-3. PART IIE. Juvenile *Pseudacris crucifer* produced at the Refuge Ponds.

	Pond A	Pond B	Pond C	Pond D	Totals
1984	0	0	0	0	0
1985	306	85	313	640	1344
1986	0	3	--	1	4
1987	0	0	--	1	1
1988	97	147	--	8	252
1989	0	6	--	3	9
1990	1	0	--	54	55
1991	0	2	--	53	55
Totals	404	243	313	760	1720

TABLE III-3. PART IIF. Juvenile *Hyla gratiosa* produced at the Refuge Ponds.

	Pond A	Pond B	Pond C	Pond D	Totals
1984	0	0	0	0	0
1985	24	100	0	41	165
1986	10	15	--	98	123
1987	32	17	--	5	54
1988	2	16	--	65	83
1989	3	138	--	23	164
1990	6	35	--	126	167
1991	1	69	--	45	115
Totals	78	390	0	403	871

TABLE III-3. PART IIIG. Juvenile *Hyla femoralis* produced at the Refuge Ponds.

	Pond A	Pond B	Pond C	Pond D	Totals
1984	1	0	0	0	1
1985	0	0	0	0	0
1986	0	0	--	0	0
1987	0	0	--	0	0
1988	0	0	--	0	0
1989	0	0	--	0	0
1990	0	0	--	0	0
1991	0	0	--	0	0
Totals	1	0	0	0	1

TABLE III-3. PART IIH. Juvenile *Hyla chrysoscelis* produced at the Refuge Ponds.

	Pond A	Pond B	Pond C	Pond D	Totals
1984	7	0	0	0	7
1985	59	77	0	6	142
1986	0	0	--	1	1
1987	2	2	--	0	4
1988	0	0	--	1	1
1989	0	0	--	1	1
1990	1	0	--	6	7
1991	0	3	--	0	3
Totals	69	82	0	15	166

TABLE III-3. PART III. Juvenile *Pseudacris ornata* produced at the Refuge Ponds.

	Pond A	Pond B	Pond C	Pond D	Totals
1984	0	0	0	0	0
1985	0	0	0	0	0
1986	0	0	--	0	0
1987	0	0	--	0	0
1988	1	6	--	0	7
1989	0	1	--	1	2
1990	0	0	--	0	0
1991	0	0	--	0	0
Totals	1	7	0	1	9

TABLE III-3. PART IIJ. Juvenile *Rana catesbeiana* produced at the Refuge Ponds.

	Pond A	Pond B	Pond C	Pond D	Totals
1984	0	0	0	0	0
1985	0	0	0	0	0
1986	0	0	--	0	0
1987	0	9	--	0	9
1988	0	0	--	0	0
1989	0	0	--	0	0
1990	0	0	--	0	0
1991	6	0	--	0	6
Totals	6	9	0	0	15

TABLE III-3. PART IIK. Juvenile *Rana clamitans* produced at the Refuge Ponds.

	Pond A	Pond B	Pond C	Pond D	Totals
1984	0	0	0	0	0
1985	0	0	0	0	0
1986	0	0	--	0	0
1987	0	0	--	0	0
1988	0	0	--	0	0
1989	0	0	--	0	0
1990	0	0	--	0	0
1991	88	0	--	0	88
Totals	88	0	0	0	88

TABLE III-3. PART III. Juvenile *Rana utricularia* produced at the Refuge Ponds.

	Pond A	Pond B	Pond C	Pond D	Totals
1984	0	0	0	0	0
1985	19	646	0	0	665
1986	1	6	--	7	14
1987	21	0	--	0	21
1988	287	72	--	0	359
1989	18	5	--	0	23
1990	76	177	--	0	253
1991	176	3	--	3	182
Totals	598	909	0	10	1517

LOCATION OF REFUGE PONDS

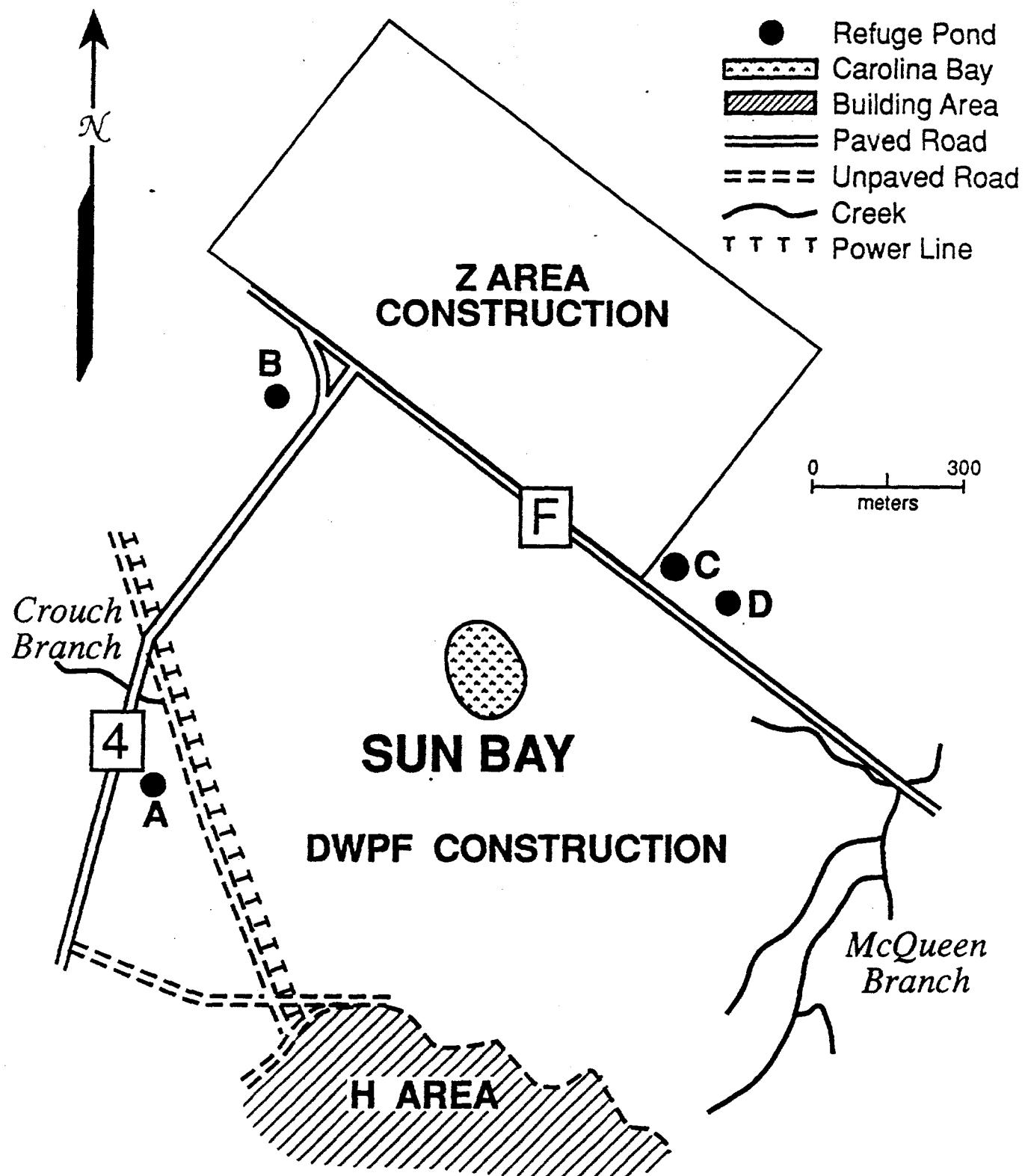


Fig. III-1. Location of refuge ponds in relation to DWPF construction.

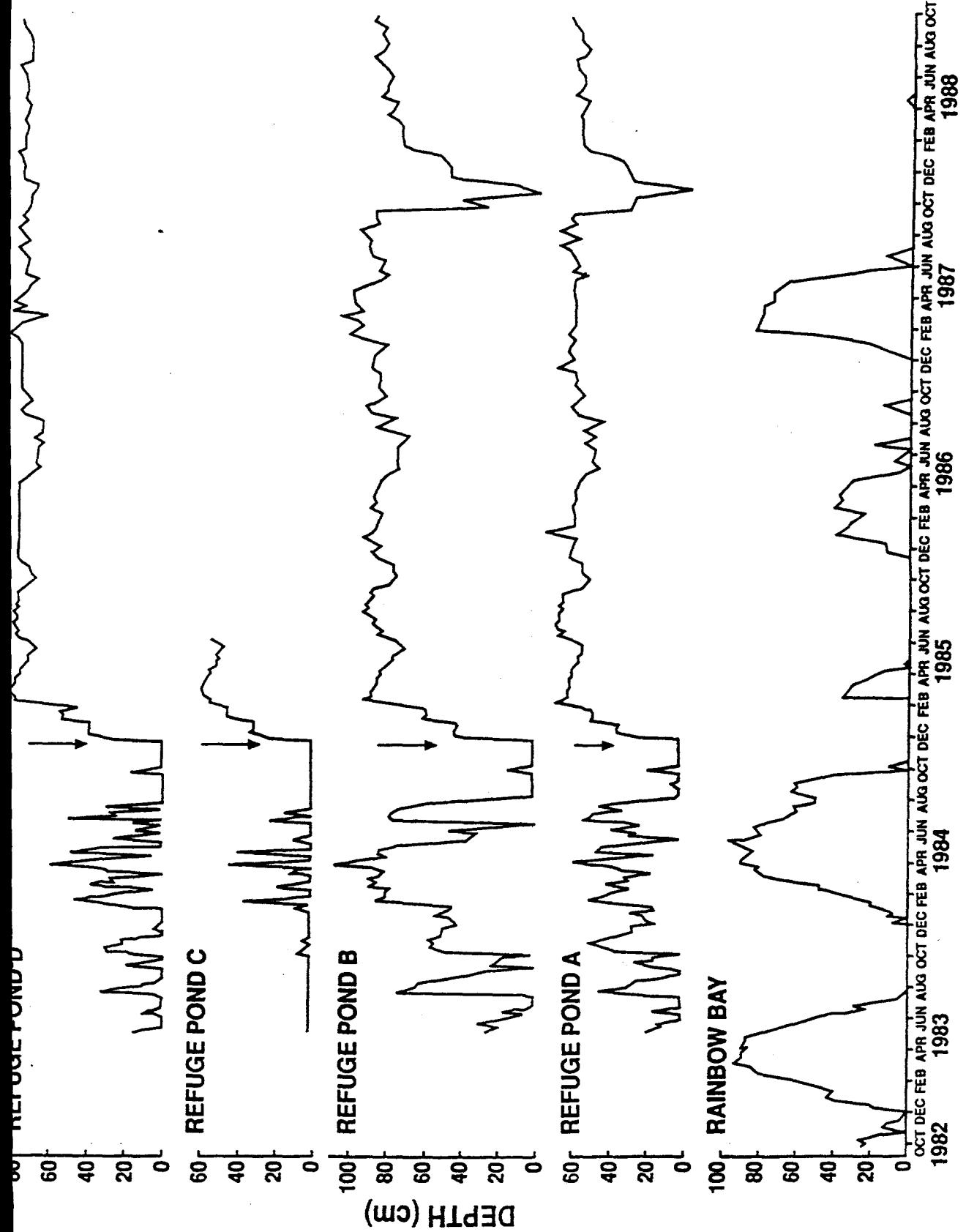


Fig. III-2. Water depth in the refuge ponds and Rainbow Bay from 1982 - 1988.

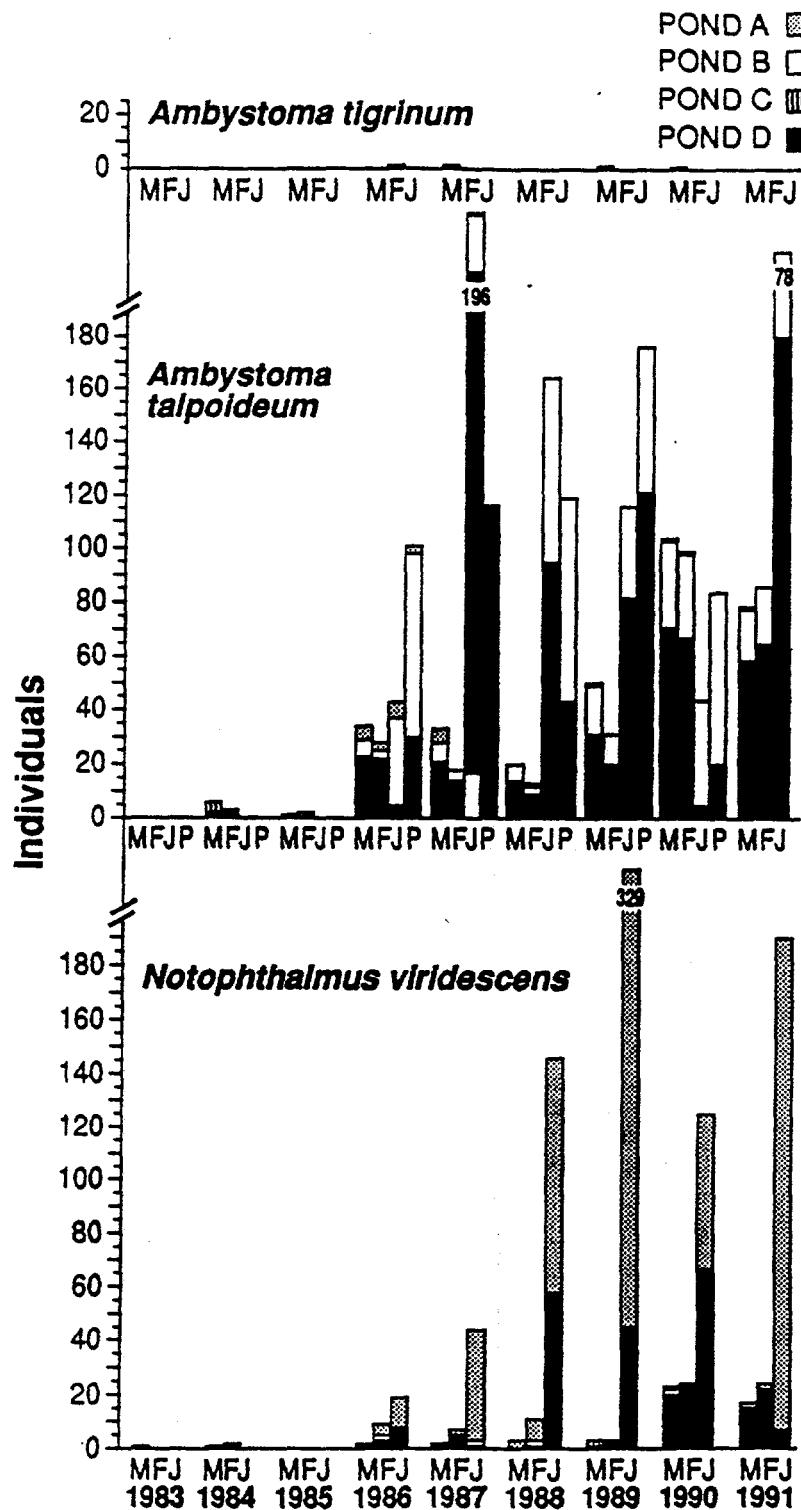


Fig. III-4. Number of breeding adult and metamorphic salamanders in refuge ponds from 1983 - 1991. M=males, F=females, J=metamorphs, P=paedomorphs

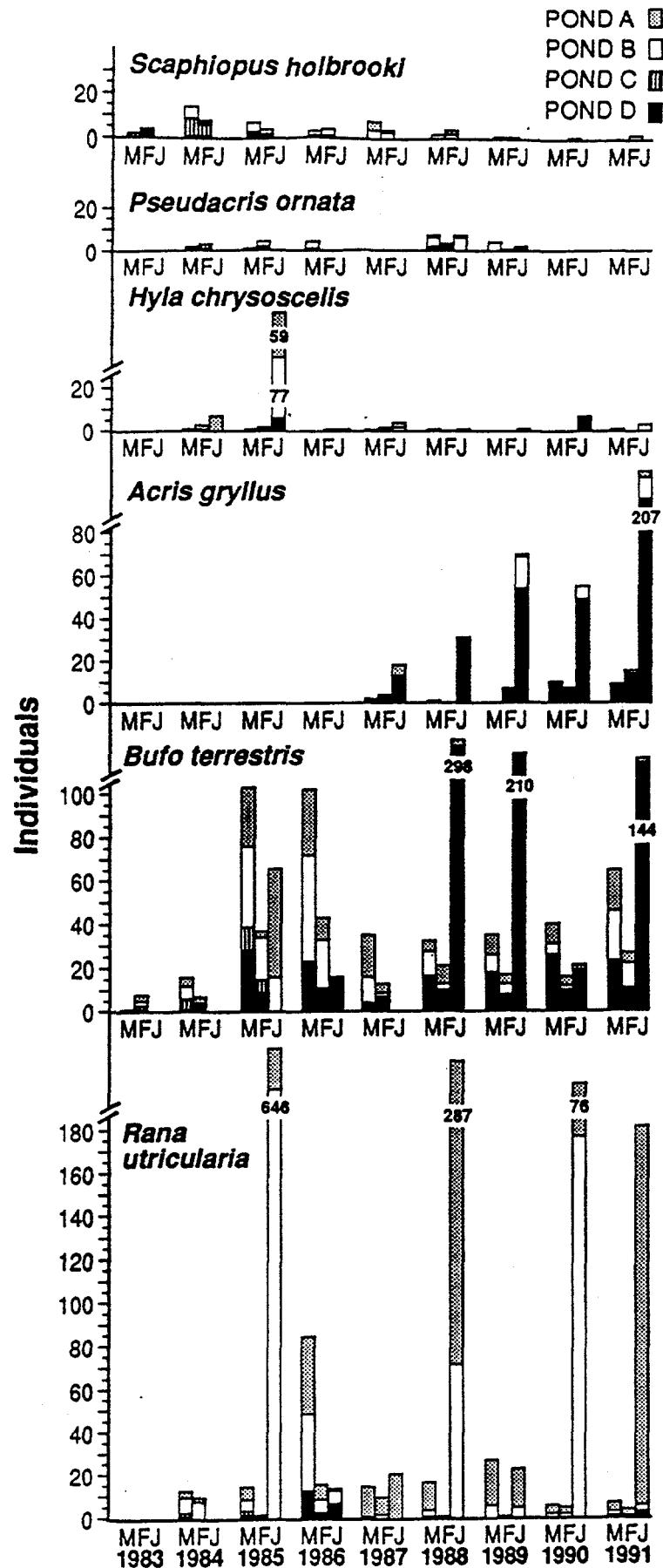


Fig. III-3. Number of breeding adult and metamorphic anurans in refuge ponds from 1983 - 1991. M=males, F=females, J=metamorphs