WATER QUALITY ASSESSMENT OF FLOODWATER RETARDING STRUCTURES

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INTRODUCTION

Otoucalofa Creek is a fourth order stream originating and flowing (23 miles) through three counties (Yalobusha, Lafayette, and Calhoun) in North Central Mississippi (USA) before joining the Yocona River and emptying into Enid Reservoir. The creek drains approximately 71,000 acres through channels that were 64% stabilized by snag and debris removal in the mid-1980s and early-1990s. Enid Reservoir receives this drainage into its permanent man-made pool of approximately 6,100 acres and flood control pool of 28,000 acres. In 1989, the Natural Resources Conservation Service (NRCS), formerly SCS or Soil Conservation Service, and the Agricultural Research Service (ARS) collaborated on a project to install and evaluate a series of floodwater retarding structures (FWS) on tributaries of Otoucalofa Creek. Plans for this project were first discussed in 1988 with postponements for various reasons pushing scheduled startup and completion dates of the first lakes into 1994. Only eight of the originally planned twenty-six FWS were completed due to fiscal cutbacks. Project goals were to reduce flooding in and around Water Valley, Mississippi, and to reduce sediment loading and transport into Enid Reservoir by catchment and controlled release of runoff from the small watershed lakes created behind the FWS. Water Valley is a small town in the central Otoucalofa Creek floodplain with population approximately 4,000. This project was one of many in the larger Demonstration Erosion Control (DEC) Project evaluating new erosion control technology in the Yazoo Basin of North Central Mississippi.

The objective of this paper was to evaluate the effect of floodwater retarding structures and low flow augmentation on water quality. Four gauging sites for stage-discharge relationships and water sampling for sediment and chemical analyses were positioned on undisturbed reaches of the Otoucalofa Creek in close proximity to the NRCS standard earthen design dams. Gauging sites were established three years prior to the 1994 construction of dams to establish background flows and sediment loadings.

Descriptions of Watersheds and Floodwater Retarding Structures

Study sites were located on land owned by Weyerhaeuser Timber Company (managed by Mr. Darryl Maddox), Mr. Charles L. Costner, Mr. Tommy Fay Inman, and Mr. James A. Mosley, and are hereafter referred to as FWS-1, FWS-2, FWS-3, and FWS-4, respectively. Watershed area and floodwater retarding structure design specifications for the individual lakes can be seen in Table 1.

Falaya and Collins series soils predominated the creek floodplains with Dulac, Providence, and Freeland soils on the gentler slopes (2-12%), and Cuthbert, Dulac, and Ruston mixes on the steeper slopes (12-35%). Erosion on slopes surrounding the creek floodplains was moderate to severe according to the SCS Soil Survey of Calhoun County, Mississippi.

Undisturbed watershed timber consisted mostly of a mix of oaks, poplar, sweetgum, and hickory, as well as scattered pines and eastern red cedar. Understory vegetation increased in density nearer the creek channels and was a mix of shrubs, vines, and grasses. Land use alterations along parts of the channels included a small stand of 20 year-old planted pines at FWS-1, cattled pasture at FWS-3, and cattled pasture alternated with cropping (corn and millet) at FWS-4. FWS-2 was essentially undisturbed until midway through the project when it was logged (clear-cut on slopes and selectively cut in floodplain). Selected timber was cut from the top of the creek bank at FWS-4 in 1995 with some debris falling into the channel.

Description and Criteria of Study Sites

The first four floodwater retarding structures scheduled for completion in Otoucalofa Creek watershed were chosen as study sites. All four FWS were of the NRCS standard earthen design dam with two incorporating low flow augmentation features. The low flow augmentation feature consisted of a smaller secondary release pipe built into the dam to "augment" normally low summer flows. Criteria for site selection and placement of monitoring and sampling equipment were: 1) that they be located in an undisturbed reach of creek in close proximity to the dam; 2) that they be in a relatively straight stretch of creek; and 3) that, where possible, they be installed in a clay bed at the bottom of the channel. Site locations meeting these criteria were found ranging from 1200-1500 feet downstream of the dams.

MATERIALS AND SETUP

Reaches were marked and surveyed in the driest part of the summer of 1990. Four transects were surveyed across the selected 50-ft reach of each tributary with the third downstream cross section of the reach being the approximate location of the site. A float was timed repeatedly (4 repetitions) through the marked reaches on each tributary and the average time taken to determine the flow velocity. This velocity, in combination with the survey data, was used to calculate flow rates for each channel at any given stage.

At each site, a section of 18-inch diameter culvert was cut to the appropriated length and installed vertically in clay in the deepest part of the channel to create a stilling well (Figure 1). Water was blocked off or diverted from the culvert base and concrete poured in and around the culvert base to below channel bottom level. This served to both stabilize the culvert base and to give a constant bottom for reference over the course of the project. Slits and clean-out doors were cut in the base of each culvert to allow water entry and sand and/or sediment removal following storms. A catwalk was built from the banktop and attached to the culvert. Potentiometer equipped Belfort chart-type stage recorders (float and tape) were placed in instrument shelters atop the culverts (Cullum et al. 1992). The potentiometer transmitted stage (float rise) to an Omnidata Model EL824-MS Easylogger (version 3.02) in a separate instrument enclosure where data was recorded on storage packs until retrieval. Easyloggers were programmed to activate adjacent Isco Model 3700 composite water samplers (Grissinger and Murphree 1991) when a preset stage and amount of runoff was detected. The water samplers were mounted on large polyethylene containers and programmed to take time-weighted (5-minute interval) composite water samples. Power for all instrumentation was provided by a 12-volt marine rechargeable battery connected to a diode-equipped solar panel. A rain gauge was installed at FWS-3 to monitor watershed precipitation.

Sites were checked following heavy individual storm events or weekly depending on rainfall. Strip charts were changed each trip as was the rain gauge chart at FWS-3. Data storage packs (dsp(s), Easylogger programs, and power supply voltage were checked at each site. Dsp(s) were exchanged when remaining storage capacity was 30% or less and returned to the National Sedimentation Laboratory for transferring into a personal computer using Crosstalk (a registered trademark) communication software. Files were converted into spreadsheet files for data analysis.

After the automatic water sampler collected composite runoff samples through the runoff event, the water container was removed from the instrument house, water samples thoroughly mixed, and two 1-liter composite water samples were taken in collapsible plastic containers. On return to the laboratory, one of these samples was immediately refrigerated for chemical analysis and the other sample was used for chlorophyll and sediment analysis. Water samples were collected from the channel weekly, using a bucket and rope, and treated and analyzed similar to the previous runoff samples. Samples later were taken biweekly after sufficient background data was collected.

Hydrographs for each of the four sites were either recreated from the stage and information recorded in the Easylogger or generated from the stripchart of the stage recorder.

RESULTS AND DISCUSSION

The floodwater retarding structures controlled the discharge and rate from the contributing drainage area above the tributaries by reducing peak stage or flowrate and increasing average stage or flowrate. An example of stage-time hydrographs before and after FWS construction for rainfall events greater than one inch is displayed in Figure 2.

The runoff hydrographs were subdivided into three time periods based on the construction phase of the earthen dams: before, during, and after floodwater retarding structure construction. The period during construction was eliminated from these assessments. Rainfall during this period was taken out of the analyses. A maximum of 34 rainfall events measuring one inch or greater produced significant runoff events from gauging sites from 1991 through 1996 which were subdivided into before construction and after construction periods. Water parameters and chemistry of the runoff resulting from these rainfall events were documented in Table 2.

Controlled release of flow after dam closure reduced both maximum stage and maximum discharge. As a result of reducing peak stage and peak discharge, the average stage and discharge are higher for longer time periods (Table 2). Average stage was increased by an average of 105% and maximum stage was reduced by 33%. Average discharge was increased by 48% and peak discharge was decreased by 74%. The before construction average stage resulted in higher variability among the tributaries than what could be determined as a result of the low flow augmentation. Flow from the low-flow pipes would not be measurable during runoff events due to the large quantities flowing through the riser. Normal flow regimes were great enough during low flow so that flow augmentation was not significant. Low flow augmentation would be a positive factor during drought periods when base flow would remain stable for a longer duration.

Total solids were reduced an average of 61% due to the settling of the suspended solids in the catchment of the dam when compared to before dam construction. Suspended solids were reduced by 65% and dissolved solids were reduced by 34.6% when comparing before and after construction periods (Figure 3).

Other water quality changes were also related to "ponding" effects (Table 2). Temperature increased 2 to 4° C because the greatly enlarged surface area and water residence time allowed warming from solar radiation. The slight increases in conductivity were likely linked to increased evaporation and phytoplankton production. Phytoplankton varied in individual streams before reservoir construction and was dependent upon solar radiation/riparian vegetation and water residence time as impacted mainly by beaver dams. After dam closure, the ponded water began to develop a standing water phytoplankton. The increase in primary productivity removed hydrogen ions and increased the pH of water in all four reservoirs as was measured by chlorophyll. Both filterable ortho-phosphate and total phosphorus were reduced, as expected, by an average of 44 and 72 percent, respectively. Reduction resulted from settling of suspended solids and increased phytoplanton growth as the result of ponding and increased residence time (Figure 4). Ammonium and nitrate concentrations were not significant before or after construction. All water quality parameters were below limits set by the Environmental Protection Agency.

CONCLUSIONS

Benefits of this project were numerous. Low flow augmentation apparently maintained base flow for a longer time in dry summers and the floodwater retarding structures raised average stages, giving the landowners more usable water according to personal communication with landowners. Sediment concentrations were reduced by an average of 61% resulting in proportionally cleaner water flowing into Enid Reservoir. While at this time there is no quantitative way to measure flooding impacts in and around Water Valley, or that flooding will not reoccur, it is reasonable to assume that the eight completed FWS will reduce that potential. Although not part of this study, significant use of these FWS-created lakes by wildlife and waterfowl was noticed. Also, the landowners wasted little time in stocking these lakes with their favorite fish. Projects of this type can benefit many people and require careful economic cost/benefits analysis. Maximum benefits from this project would have been achieved had all FWS planned been completed. The reality was that this was a costly project and that fiscal reductions cut both the project scope and staff designing these structures. For anyone considering a similar project, the project is highly recommended to be relatively close for site servicing or if that is not possible that some sort of telemetry is used to monitor site/sampler activity.

An interesting note was the beaver activities in creating their own dams within this project area. For all the problems they caused during this project, beaver dams and pools were producing similar effects as the FWS lakes were designed to do, except on a smaller scale. Of course, timber damage due to feeding and flooding by beavers would be unacceptable in many areas, but there is a potential benefit for their use in acceptable areas or in large isolated public or private lands with problems similar to this study area.

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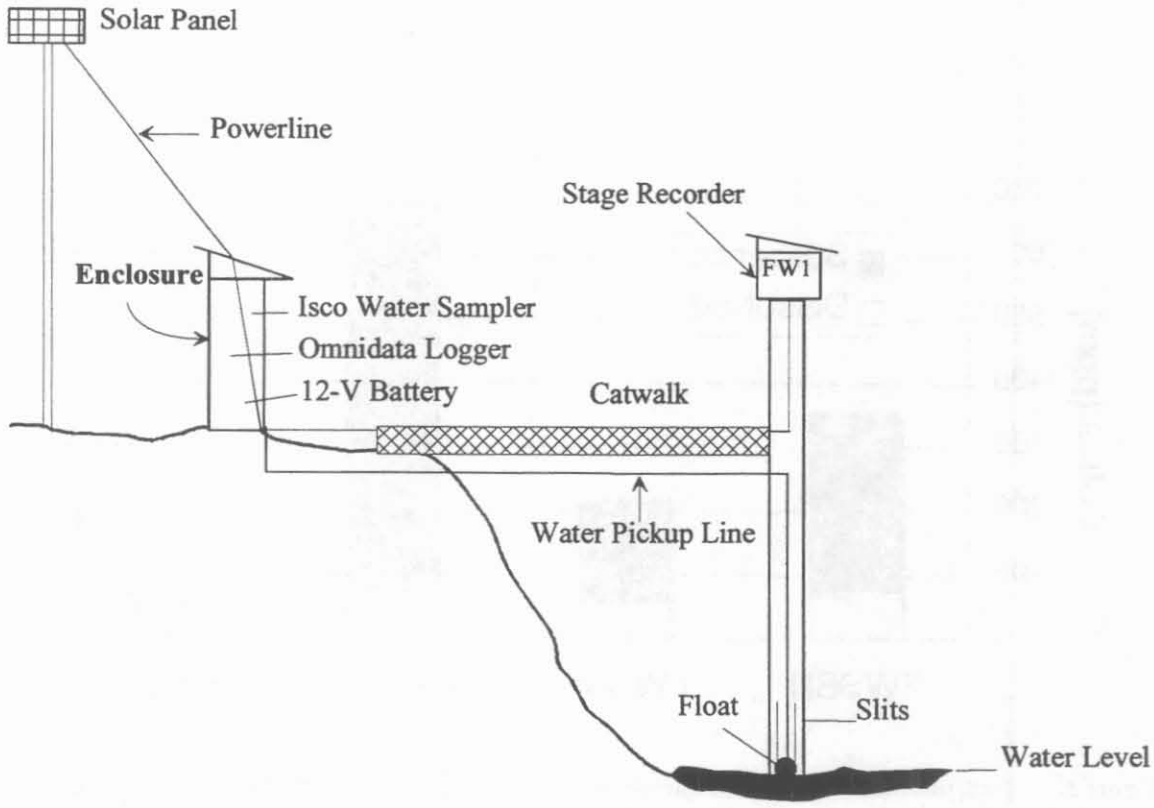

Figure 1. Diagram and picture of instrumentation for stream discharge and water quality sampling.

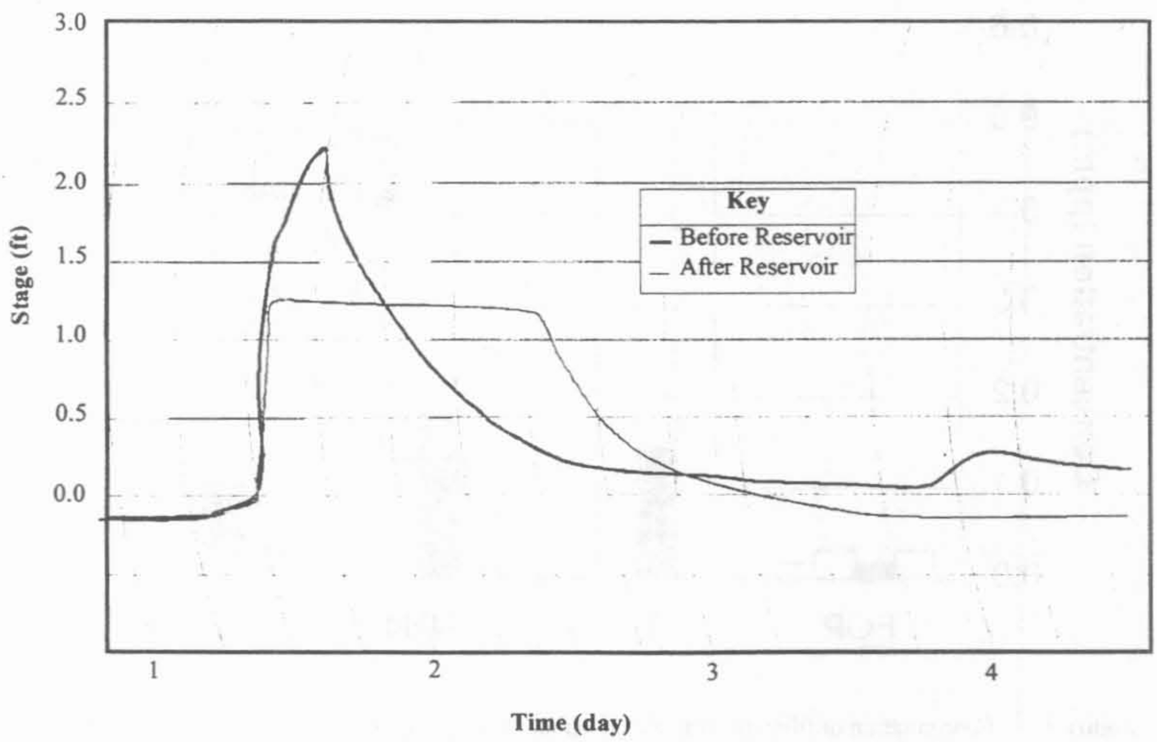

Figure 2. Stage-time relationship from FWS-2 tributary for rainfall events of 2.3 inch.

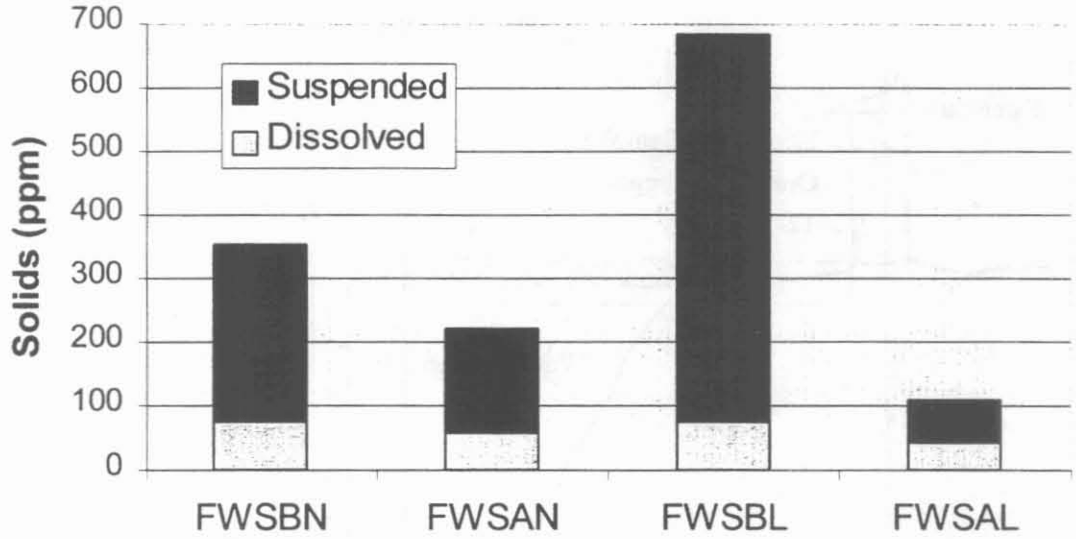

Figure 3. Total, suspended, and dissolved solids for the floodwater retarding structures (FWS. Notation of the columns are B, A, N, and L denotes before construction, after construction, without low flow, and low flow, respectively).

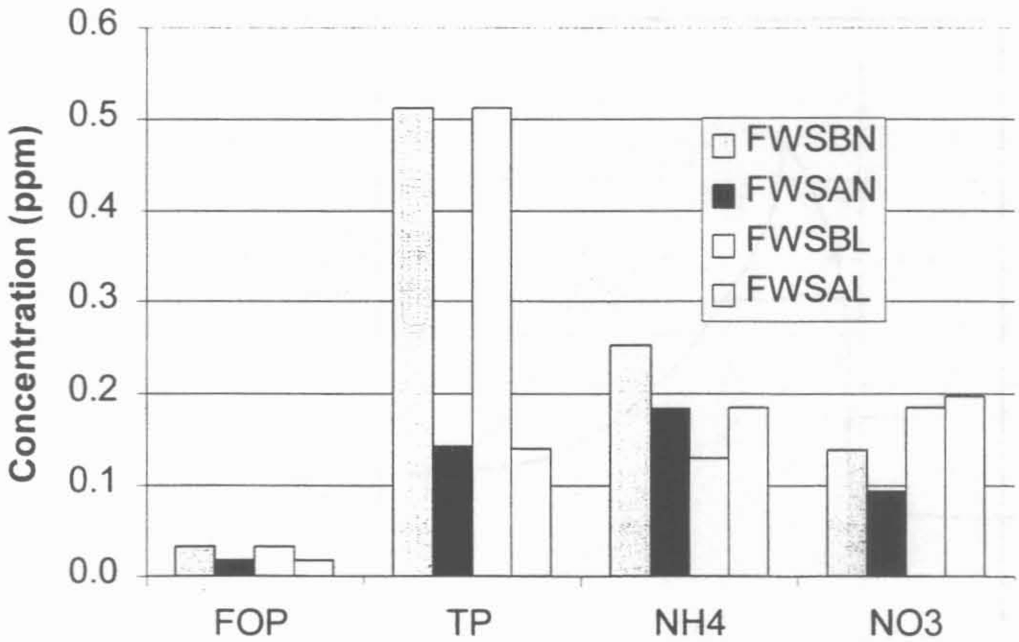

Figure 4. Concentration of filterable organic phosphate, total phosphorus, ammonium, and nitrate for the floodwater retarding structures (FWS. In key the B, A, N, and L denotes before construction, after construction, without low flow, and low flow, respectively).

Table 1. Floodwater retarding structure design specifications and watershed areas.

Structure Number	Watershed Size (acres)	Permanent Pool Size (acres)	Flood Pool Size (acres)	Maximum Flow Rate (cfs)	Low Flow Rate (csm)
FWS-1	1114	26.3	65.5	58	N/A
FWS-2	755	15.2	42.8	31	0.2
FWS-3	442	12.9	27.1	28	N/A
FWS-4	762	20.4	45.8	30	0.2

Table 2. Gauging station stage, discharge, total flow, and water chemistry.

Structure	Average Stage(ft)	Maximum Stage (ft)	Average Discharge (cfs)	Maximum Discharge (cfs)	Total Flow (MG)	Total Solids (ppm)	Dissolved Solids (ppm)	Suspended Solids (ppm)	Temperature (°C)	Conductivit (ms/cm)	pH	FOP (ppm)	TP (ppm)	NH_4 (ppm)	NO_3 (ppm)	Chlorphyl (ppm)	Dissolved Oxygen (ppm)
FWS-without LF†																	
Pre Construction	0.59	2.60	4.97	87.77	12.52	351.50	75.50	276.00	14.6	37.5	6.0	0.032	0.512	0.252	0.138	13.16	8.7
Post Construction	1.06	1.82	7.44	24.52	36.40	219.00	57.50	161.50	16.4	54.0	6.5	0.018	0.141	0.182	0.093	15.24	10.0
% Change	79.7	-30.0	49.7	-72.1	190.7	-37.7	-23.8	-41.5	12.3	44.0	8.5	-43.8	-72.5	-27.8	-33.0	15.8	15.0
FWS-with LF‡																	
Pre Construction	0.43	2.32	2.66	73.88	5.71	682.00	76.00	606.00	14.2	22.0	6.0	0.032	0.512	0.130	0.185	7.05	8.9
Post Construction	1.00	1.48	3.88	18.04	15.07	106.50	41.50	65.00	18.4	43.5	6.7	0.018	0.141	0.184	0.197	22.85	9.7
% Change	132.6	-36.2	45.9	-75.6	163.9	-84.4	-45.4	-89.3	29.4	97.7	11.3	-45.3	-72.6	41.5	6.8	224.3	9.4

† FWS-without LF = Floodwater Retarding Structure without low flow augmentation device

‡ FWS-with LF = Floodwater Retarding Structure with low flow augmentation device