AUGMENTATION OF LOW FLOWS OF THE UPPER SUNFLOWER RIVER

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INTRODUCTION

The Delta region has become a large water user in the last two decades. Most of the increase in water use is associated with agriculture for crop irrigation and catfish production. The heavy use of the area's water supplies has begun to cause concern. In some areas, the Mississippi River Alluvial Aquifer is declining at more than one-half foot per year and many stream base flows are also decreasing. The Delta is using more water each year than existing sources can supply. Two general areas of water resource problems that must be addressed are: 1) meeting the high water demand period for agricultural water use during the summer, and 2) maintaining stream flows during extended dry periods for water quality reasons, including the need for wildlife and fisheries habitat.

In response to these water supply and related water quality problems, the Yazoo Mississippi Delta Joint Water Management District (YMD) has begun to evaluate measures needed to balance the region's long term water supplies with demands. YMD is the local sponsor for a Soil Conservation Service project to evaluate the feasibility of the development of alternative water supplies for the Delta. This project will evaluate such water sources as diversions from the Mississippi or Yazoo Rivers into the Sunflower Basin, on farm storage, weirs, artificial recharge, and others. Almost all of these alternative waters supplies will require transporting and managing surface water in existing stream channels. An understanding of how water moves through these channels is essential to planning and management of regional surface waters. Surface water models for water quantity and quality must be developed for these purposes.

YMD conducted a test in October of 1992 to monitor how the upper Sunflower River flows would react to additions of alternative water supplies during low flow periods. For this test, discharges from alluvial aquifer wells were directed into the Sunflower River or its main tributaries. The objectives of the experiment were to:

1. Obtain operational experience in managing a river and its interaction with an alternative water supply.
2. Estimate the order of magnitude of transmission losses of added flows in the upper Sunflower River.
3. Estimate the transmission velocities of added water through the upper Sunflower River.

METHODS

The general study area was the Sunflower River from Clarksdale to the town of Sunflower (see Figure 1). The town of Sunflower was chosen as the lowest reach of the test because there is a US Army Corps of Engineers transmitting stage recorder on the Sunflower River at Sunflower and because the Quiver River flows into the Sunflower River a few miles downstream. The flow augmentations were carried out during October of 1992. The lowest flows of the year historically occur during October for Delta streams. Any rainfall event causing significant amounts of runoff would prematurely end the test. Consistent with the low flows in October, October is the lowest rainfall month and was the best time of year to complete the test without rainfall interference. Also, during October most irrigation wells are not being used. The irrigation season typically ends in August or September. Therefore, irrigation wells were available as a water supply. Cooling tower wells were also available from a Clarksdale power generating plant. The cooling wells discharge directly into the Sunflower River and withdraw from the alluvial aquifer. All irrigation wells in the region are located in the alluvial aquifer. The alluvial aquifer underlying the northwest reaches of the Sunflower River has experienced only small water level declines. This is probably due to that area's proximity to the Mississippi River, which is considered to be the main recharge source to the alluvial aquifer in that area. Using water from this area of the aquifer appears to present little risk to the ground water supply with a potential for substantial benefits to surface water problems. Managing the different water resources for the greatest benefits represents true conjunctive use of the resources.

The details of the technical aspects of the experiment are:

1. The YMD geographic information system (GIS) with the database containing the information on permitted wells was used to locate wells along the northwest reaches of the major tributaries of the Sunflower River. A buffer search along the major streams was performed to locate wells within one half mile of the channel. The owner names in the permit database were used to assist in contacting well owners and operators. Owners of selected wells were contacted and requested to cooperate with the test. YMD offered to reimburse the owner for the use of the well at $3.50 per hour of well operation. YMD also offered to pay wages of farm labor to lay the necessary pipe to configure a well to discharge into a receiving channel. Most well owners agreed to cooperate in the test and had their wells configured to discharge by early October. Nineteen wells were secured for use in the test. This included 5 cooling wells in Clarksdale and 14 irrigation wells along Harris Bayou and the Hushpuckena River.
2. In preparation for and monitoring of test progress, hourly river stage data on the Sunflower River at the town of Sunflower was received from the US Army Corps of Engineers computer system by modem. The stage data was available every 4 hours in one hour intervals.
3. As flows in the River began to stabilize at low flow levels, open channel stream flow measurements were made in the Sunflower River with a vertical axis current meter. The flow measurements were made on October 5 and 6. These measured flows were treated as base flows and were assumed not to change significantly during the remainder of the test. Harris Bayou and the Hushpuckena River were dry at this date and remained dry until a few days after pumping began into each channel.
4. Four wells along Harris Bayou were started on October 6 and 9 to provide initial data on losses and travel times to be used for the larger test that started on October 13.
5. Well discharges were measured with a non-intrusive ultrasonic flow meter. A time totalizer was placed on each well that accumulated the hours of well operation. The hours of well operation were used as the time for which well owners were reimbursed and as an additional check of assurance that wells were operating when expected.
6. On October 18, river flows at the town of Sunflower began to increase from the main augmentation that had started on October 13. Another set of open channel stream flow measurements were made on October 19 and 20 when the river flow stabilized from the major flow augmentation addition that had begun on October 13. The October 19 and 20 river flows were assumed to be due to base flow plus augmentation flow.

RESULTS

Operational Experience

Some of the field operation experiences gained from this test were:

1. Agricultural wells were more difficult to manage than the cooling wells in Clarksdale. The fact that the irrigation wells were widely spaced and of many different configurations made it difficult to keep track of well activity.
2. Diesel wells were more difficult to manage than electric wells. Mechanical and fuel problems were more common in the diesel powered irrigation wells than their electric counterparts.
3. It was necessary to closely watch for channel bank erosion at the sites of irrigation well discharge into the streams. At most irrigation well sites, the discharge of the well was at a new location on the channel. Bank erosion was common and at times severe.
4. Beaver dams in the tributaries complicated estimates of movement of added water in Harris Bayou and the Hushpuckena River. Discharging into smaller channels will probably always be complicated by beaver dams.

Velocity of Flow Augmentation Front

The hydrograph for the Sunflower River at the town of Sunflower is given in Figure 2. The lowest flows occurred from October 6 through 9, just before flows from the Harris Bayou wells reached the gauge at Sunflower.

The largest single increase in flow additions to the River occurred on October 13 and 15. The five wells in Clarksdale were started on the 13th while the Hushpuckena River wells were started mostly on the 15th. The difference in the beginning time at Clarksdale and on the Hushpuckena River was estimated to allow water from both sources to reach the town of Sunflower at about the same time. The estimate appears to have been about correct since a single large flow increase event began on October 18 with a peak stable flow occurring on the 20th.

These data suggest that 5 days were required for the water added in Clarksdale to reach the town of Sunflower. The distance from Clarksdale to Sunflower is 100 river miles with a change of 40 feet in elevation. Over the upper reaches of the Sunflower River, at stages recorded at the town of Sunflower of about 0 feet, the water front advanced at about 1.2 feet per second (equal to 0.8 miles per hour and 20 miles per day).

The Clarksdale wells were shut off on October 20, after about 12 hours of stable river flows at Sunflower. The wells on the Hushpuckena River and Harris Bayou were shut off on October 21 and 22. Again, the delay in shutting off the lower reach wells was to produce a declining front that would reach the stage recorder as one event.

The flow recession occurred much faster than the flow increase front. Less than 2 days were required for flows at Sunflower to begin to decline after wells in Clarksdale were shut off.

The difference in the advancing and recessional rates was probably due to the flow patterns in the Sunflower River under the test conditions. At low flows, the Sunflower River is mostly a series of pooled areas separated by short reaches of higher velocity water.

Transmission Losses

The stream flow measurements taken on October 5 and 6 are given in Table 1.

Table 1. Sunflower River base flow measurements taken on October 5 and 6, 1992. Results are assumed to represent base flows during test. All tributaries to the Sunflower river above the town of Sunflower were dry at this time.

Location on Sunflower River	ft^3/second
Above Clarksdale	5
Below Clarksdale	7
At town of Sunflower	19

No surface runoff was observed during the time these measurements were made. The data indicate that permitted discharges into the Sunflower River in Clarksdale are about 2 cubic feet per second (cfs) and that the base flow at the town of Sunflower is 19 cfs. The base flows were assumed to not change during the augmentation test.

Flows added to the Sunflower River system were measured by 2 methods. The first method was to measure and accumulate the discharges from the individual wells which were operating at different times. The second method was to measure open channel flows just down stream of the added flows. Changes in open channel flows before and after pumping began were calculated as the increase in flow associated with the augmentation. Channel flow measurements were made just below Clarksdale and at the confluence of Harris Bayou and the Hushpuckena River with the Sunflower River. No flow measurements were needed on Harris Bayou or the Hushpuckena River because they were dry before the beginning of pumping into those channels. The results of the two methods are give in Table 2.

Table 2. Well discharge and stream flows taken during time of major flow augmentation on October 19. The stream flow measurement below Clarksdale has the 7 cfs base flow measured on October 6 subtracted from the actual flow measurement.

	Well Discharges cfs	Stream Flows cfs
Below Clarksdale	23	28
Harris Bayou	15	8
Hushpuckena River	10	7
Total	48	43

Accumulated well discharges were expected to be slightly higher than stream flow values. Some channel loss was expected between the points of well discharge into Harris Bayou and the Hushpuckena River and their confluence with the Sunflower River where the stream flow measurements were made. Generally, the two methods compare favorably with only about a 10% difference between methods. To calculate transmission losses, an average between the two methods (45 cfs) was used in further calculations. Flow data from October 19 were used to calculate transmission losses.

On October 19, the stream flow in the Sunflower River at Sunflower was 68 cfs. Of this flow, 19 cfs was

assumed to be base flow taken from the October 6 measurements (see Table 1). These calculations (68 cfs - 19 cfs = 49 cfs) indicate that the flow at Sunflower was 49 cfs above base flow on October 19. The calculated additional flow measured at Sunflower of 49 cfs was about 6% higher than the flows added to the river based on upstream channel flow measurements and well discharges.

With a perfect accounting of water flows in the River system, the added flows should be equal to or less than the flow above base flow measured at the town of Sunflower. The fact that the added flows are less than the additional flow above base flow can be accounted for by two possibilities.

1. Undocumented new flows were entering the system during the later stages of the test. Field inspections of channels leading into the Sunflower River failed to reveal any unaccounted inflows to the river system. The only additional inflows observed during the test were relatively small, short lived discharges from Clarksdale during a storm event on October 15. Runoff from the city lasted about 4 hours and did cause a small increase (0.4 foot) in the stage below Clarksdale.

2. Transmission losses were very small and the low inflow values compared to flows at the town of Sunflower were due to measurement error. Under the field conditions encountered, an accuracy of 10% in the flow measurements would be considered acceptable. The 6% difference between accumulated inflows and additional flow at the town of Sunflower could be expected if transmission losses were small and flows are measured to within about 10%.

Costs of the Test Related to Pumping Water

The costs of pumping the water from the Clarksdale cooling tower wells were covered by the North Delta Joint Municipal Water Management District and are not available at the time of writing. The water pumped from these wells represents more then one-third of the total volume of water used. Costs associated with the irrigation wells were $7,666 for reimbursements to well owners for 2190 hours of well operation at $3.50 per hour and $777 for well owners' labor to configure wells to discharge into stream channels. Total out of pocket cost to the YMD Joint Water Management District was $8,444. Costs associated with pumping by the North Delta Joint Municipal Water Management District were probably about $2,000.

CONCLUSIONS

1. The use of alluvial aquifer wells to augment Sunflower River low flows in October was operationally accomplishable with fewer difficulties than expected.
2. Water additions were transmitted along the Sunflower River at low stages at about 1.2 feet per second (0.8 river miles per hour or 20 miles per day) based on a 5 day time of travel from Clarksdale to the town of Sunflower, covering 100 miles.
3. Transmission losses were very small. Under the channel and stage conditions of the test, the losses appeared to be less than 10%.

ACKNOWLEDGEMENTS

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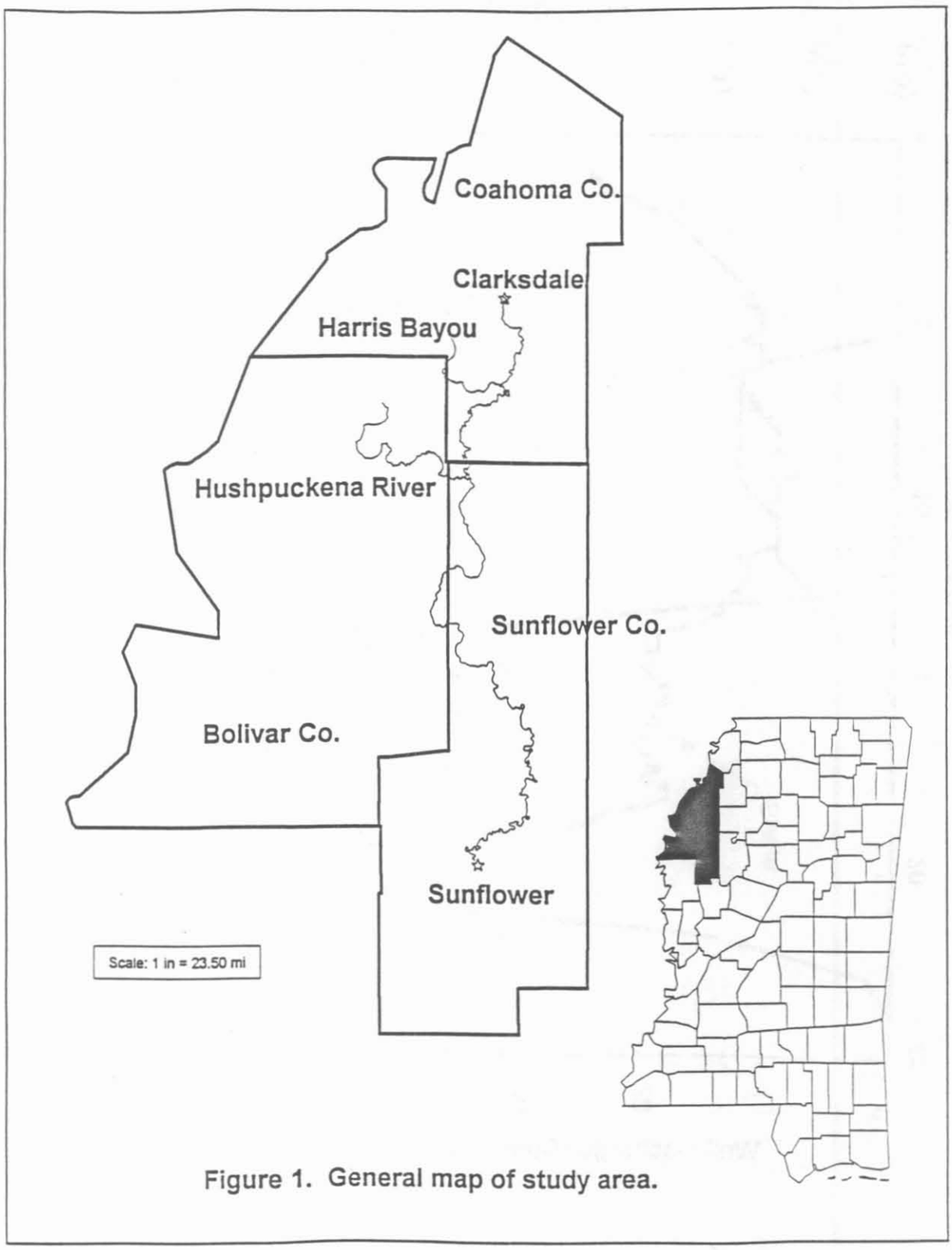

Figure 1. General map of study area.

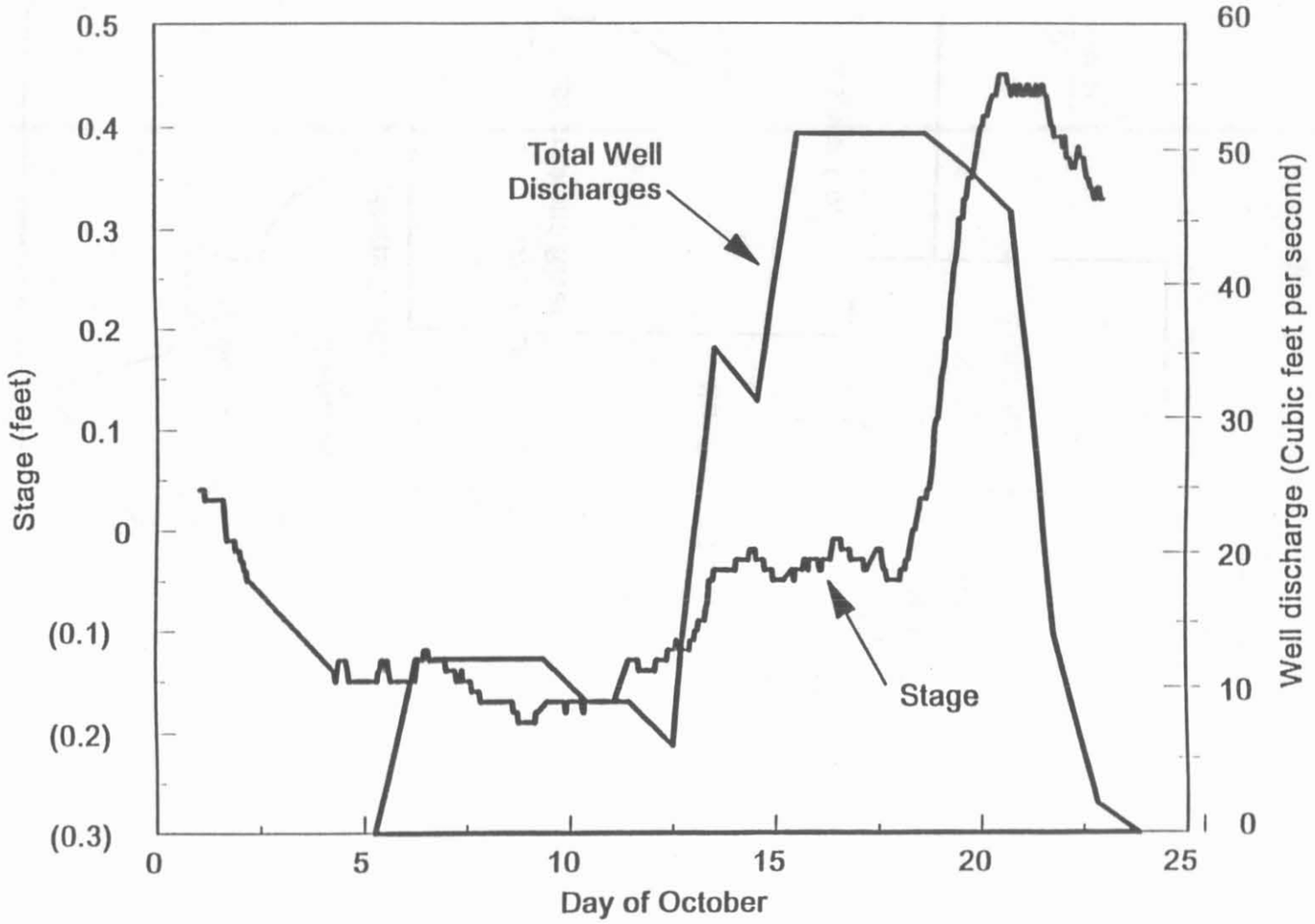

Figure 2. Hourly stage of the Sunflower River at the town of Sunflower and daily well discharge.