THE APPLICATION OF REMOTE SENSING TECHNIQUES FOR DATA COLLECTION ON THE MISSISSIPPI RIVER

by

Patrick C. Harris
Potamology Section, River Stabilization Branch
U. S. Army Corps of Engineers, Vicksburg District
Vicksburg, Mississippi

INTRODUCTION

The potamology program of the Vicksburg District is involved in the development of the science of river engineering. The ultimate goal is to develop a workable knowledge of the basic principles controlling the transport of water and sediment in the lower Mississippi River and to apply this knowledge toward effectively and economically stabilizing the river for flood control and navigation. In 1966 a detailed data collection program was started in the Vicksburg District's portion of the Mississippi River. The present program covers the entire 300 miles of river within the District with each survey providing the following data:

a. Hydrographic survey

b. Bed form profiles

c. Surface current directions

d. Discharge and horizontal velocity distribution

e. Subsurface current direction

f. Bed material samples

g. Suspended sediment measurement

h. Water surface profile

Effective river management and control requires the constant surveillance and analysis of the natural and man made effects both in and near the main channel. Present day surveying techniques are too costly and time consuming to gather necessary data in a river during a particular flow condition. In order to determine if a remote sensing system may offer a means of replacing or enhancing our data collection, the Vicksburg District has a contract with Colorado State University on the investigation of remote sensing equipment and techniques to obtain data from the Mississippi River. The interpretation of the data is being done independantly by Colorado State University and the Potamology Section of the Vicksburg District.

Remote sensing is defined as a procedure for obtaining information about an object without actually being in physical contact with the object.

The remote sensing systems used for this study are readily available, relatively inexpensive and are intended to function specifically as an operational package for enhancing data collection. The remote sensing instrumentation used was mounted in a medium twin engine aircraft and flown at conventional altitudes and air speeds. The multi-remote-sensor package affords the opportunity for simultaneously recording the reflected and emitted electro-magnetic energy in several portions of the spectrum.

INSTRUMENTATION

The study was of a feasibility nature rather than a study to determine exact quantification of the various objectives. The sensors evaluated were a mapping camera using color and color infrared film, a multi-band camera system, and a thermal infrared imaging system. This system operates over the visible portion of the spectrum, the photographic near infrared, and in the 2.5-5.5 micron and the 8-14 micron band width of the thermal infrared portion of the electromagnetic spectrum.

Color photography records images in their natural color in the visible portion of the electro-magnetic spectrum from 0.40 to 0.70 micron wave length. Each object appears to have its own particular color because of its characteristic reflection curve.

Color infrared photography produces a false color reproduction of absorption and reflection patterns on film. This film is normally used with a Wratten Number 12 filter to block out the ultraviolet and blue light which is sensitive to all three layers of the film. With this filter the film records images in the visible and near infrared region of 0.5 to 1.0 micron range of the electro-magnetic spectrum. This film is particularly useful for penetrating haze.

A thermal infrared scanner operates beyond the photographic infrared range in the 1 to 14 micron range. The scanner records temperature differences, that is the emitted energy of an object. The region of maximum emission and minimum reflection is normally in the 7-14 micron range. The significance of the imagery depends on the time of day the imagery is taken and the preceding weather conditions. The scanner can be operated during the day or night with a certain time giving the greatest contrast for the phenomena of interest.

A multi-band camera system is designed to take simultaneous multiple photographs of an object with each photograph recording a different band of the spectrum. A viewer is needed to project any one or combination of the photographs through color filters to enhance the object in question. In our study a four lens multi-band camera was used to expose black and white infrared film in the blue, green, red, and infrared wave length. The benefits of natural and false color films can be achieved with this system thru the use of black and white film and processing. A much greater flexibility is available to the user in selecting hue and brightness levels to best emphasize the phenomena of interest.

PROCEDURE

Two reaches (Figure 1) were selected which portray the items of interest. The first area called the Baleshed reach is 20 miles long in the vicinity of Lake Providence, Louisiana which includes the Baleshed, Ben Lomond, and Ajax Bar dike systems. The second area called the Point Pleasant reach is 10 miles long approximately 15 miles south of Vicksburg which includes the divided flow at Point Pleasant and the dike system at Yucatan.

The actual flights took place during the week of 26-31 July 1971. Weather conditions during the week were extremely unfavorable for taking aerial photography. Local thunderstorms occurred throughout the week with early morning fog and heavy to light cloud coverage. Some of the flight lines and altitudes had to be altered to avoid some of the cloud coverage. The clarity of the photographs particularly the color infrared photographs demonstrated what can be done under adverse weather conditions for aerial photography.

Full coverage of both sites was achieved with color infrared, thermal infrared and multi-band photography. Most of the color infrared photography was taken at scales of 1:12,000 and 1:6,000 with some coverage at 1:3,000 and 1:18,000. The only color photographs taken were of a special target site in Baleshed reach. Weather conditions did not permit full coverage with color photography due to poor lighting conditions for proper exposure.

GROUND TRUTH INFORMATION

The ground truth information obtained during the flights consisted primarily of a regular potomology survey. In addition to the regular measurements, surface suspended sediment and temperature measurements were made on five velocity ranges and one range 500 feet downstream from each velocity range in the Baleshed reach. In the Point Pleasant reach three velocity ranges were used. Measurements were made at five points across the cross section for each day during the flights.

On approximately a 2-mile reach near the Ben Lomond dike field, targets were set out with known horizontal and vertical coordinates for photographic control. The targets were surveyed into second order accuracy in order to test the use of modern analytical photogrammentry techniques to measure certain features of interest. The high order of accuracy was to ensure good ground control for measuring differences in water surface elevation. Extra gages were used in this reach to closely check the results of vertical measurements on the water surface.

OBJECTIVES

There were two primary objectives in this initial study. Objective number one deals with the preliminary feasibility evaluation of multi-remote sensor data for identifying certain features in and along the river. Particular emphasis was placed on recording and interpreting imagery of the following phenomena: flow patterns, suspended sediment distribution, surficial sediment deposits and erosion patterns, potential earthslide areas along the banks, vegetation (type and extent), soil type and moisture content on the flood plain and banks and in the levees, water depth effects, bedform effects, effect of man-made structures on the flow and sedimentation patterns, temperature patterns at the surface of the water, direct water depth determinations, suspended sediment concentration measurements, and the general ecology of the study reaches. Objective number two was to obtain a preliminary evaluation of the use of analytical photogrammetry for precisely describing the geometry pertaining to the characteristic shapes found in a river channel. The particular measurements to be made were: radius of bends, shape of middle, point and alternate bars, shape of bank erosion and volume estimates of erosion and sedimentation processes, water surface flow patterns, water surface slopes, flow velocities from floating debris, areal size and distribution of eddies, and channel widths.

RESULTS

The primary objective of the study was to determine the potential for measuring the characteristics of the river and the remote sensing system for measuring the characteristics. Certainly, the identification of some of the parameters considered were not practical with this system and may not be practical with any presently operating remote sensing system. The principal phenomenon detected are related to the surface of the water. Depth penetration can not be achieved due to the reflectance of the suspended sediment of the Mississippi River.

The system that offers the most detail for describing the phenomenon of interest was the color infrared film. The principal phenomenon detected were: The basic flow patterns, the transverse and longitudinal surface sediment distribution, the velocity field, the bed form effects, and changes in bank material. These will be discussed in further detail in the following sections.

The thermal infrared scanning system did not offer any more informataion than the color infrared photography. The temperature gradient of the Mississippi River at the time of the flights was too low for any practical results.

The multi-band imagery is still being analyzed but is generally thought not to offer any more enhancement that the color infrared photography.

FLOW PATTERNS

Flow patterns related to mixing processes, confluence of divided flows, mixing processes in conjunction with vortices and shear flows, and flow patterns related to local disturbances such as structures, scallops, and bank failure areas are identified on the color infrared photographs. Generally any disturbance, foam or difference in sediment concentration in the water greatly enhances the ability to detect flow patterns.

A very dramatic flow pattern occurs where the chute flow recombines with flow that comes around the bend at Point Pleasant. There is a line of large vortices rotating in a clockwise direction showing the mixing patterns of the two flows. A sketch of the flow pattern is shown in Figure 2.

Color infrared photography enhances the ability to observe the mixing processes of tributary inflow particularly if the sediment characteristics are different. Where the Big Black River empties into the Mississippi, one can follow the heavy sediment laden Big Black flow down the left bank of the Mississippi for several miles. It appears that very little lateral mixing occurs; the flow remains in a band approximately 200 feet wide for several miles downstream. Figure 3 shows a sketch of the inflow pattern.

Another example of a different type of mixing process is the plume of clearer water from Palmyra Lake entering into the Mississippi in the bendway at Point Pleasant. By studing the blue wedge of water, one obtains the impression that it acts somewhat as a dike helping to divert the main current away from the outside of the bend. Immediately downstream of the wedge the heavier sediment laden water is being swept back towards the bank.

Eddy action can be identified and studied on color infrared photography. Eddy action forms large scour holes which endanger dikes and revetments. One good practical application would be the identification of the size and location of an eddy at different stages.

Basic flow patterns are evident in many photographs from foam, debris or distrubances on the water surface in which the general direction of flow can be followed. The line of attack, current direction and convergence or divergence of flow can be detected from the color infrared photographs. This is presently being done by the use of surface floats on hydrographic surveys.

SURFACE INDICATIONS OF SUSPENDED SEDIMENT DISTRIBUTION

Using color infrared film, the color of the water surface is an excellent index to the level and type of suspended sediment transport taking place in any given cross-section at any particular time. Clear water with little suspended sediment appears dark-blue in color; the color changes to a lighter blue with larger quantities of suspended sediment at the surface. By considering the color of the water surface one obtains an indication as to where the major transport activity is occurring in the cross-section.

More sediment patterns appear in the Point Pleasant reach than in the Baleshed reach. From the color infrared photographs the sediment concentrations in the Baleshed reach appear relatively uniform which is confirmed by the ground truth surface suspended sediment measurements. During the day of the flight the suspended sediment concentrations were approximately 180 p.p.m. with variations of plus or minus 10 p.p.m. During the 6 days of measurements the average concentrations decreased approximately 10 percent. The stage at Baleshed was generally uniform with the greatest change occurring during the last 2 days with a decrease of 0.6 foot.

From the ground truth samples, the sediment concentration were higher in the Point Pleasant reach than in the Baleshed reach. The average concentrations increased approximately 50 percent during the 4 days of measurements with an increase in stage of 1.5 feet. During the day of the flight the average suspended sediment concentrations were 230 p.p.m., with individual measurements ranging from 90 p.p.m. to 320 p.p.m. On individual ranges the color patterns indicated the differences in sediment concentrations with the lighter blue areas corresponding to the higher concentrations.

Relative differences in sediment movement may be more important than the actual sediment measurements. Since the sediment concentrations changed drastically during the week, a measurement during one day may give a false impression of sediment movement. Color infrared photographs would give the source and sink areas of sediment movement which would be more important than the actual measurement. The actual ground measurement would indicate how much suspended sediment is moving past that section at that particular time. Whereas the color infrared photograph would give an indication of areas of aggradation and degradation.

Densitometers suitably filtered to measure the spectral characteristics of water photographs may be used to qualify the intensity of the blue tone which in turn may be related to the actual suspended sediment concentration for that particular body of water. This would seem to be feasible and represents a procedure for approximating suspended sediment concentrations in certain situations. For practical application, one must recognize that the color may be affected by the presence of other pollutants, as well as variations in film type, film exposure, film processing, and atmospheric conditions. Relative differences seem to be possible particularly if stereo pairs are used.

VELOCITY FIELDS IN THE STREAM CROSS-SECTION

Several aspects of the velocity field are important: (1) the velocity distribution at any cross-section; (2) the identification of secondary cells of water flowing side by side; (3) the difference in the velocity distribution where the divided flows recombine; (4) the identification of large vortices formed by channel geometry and bank alignment structures. It is possible to obtain excellent information regarding velocities in all of those catagories by utilizing the color infrared film.

On several of the photos one can see several cells or bands of flows with different velocities with small vortices separating each band. The small vortices and their direction of rotation indicate which band has the higher velocity. Below the conjunction of a divided flow area large vortices occur between the two flows indicating the mixing between the two channels and the relative difference between the velocities of the two channels. One might be able to relate the size and spacing of these vortices through the fundamentals of fluid mechanics to the difference in average velocities between the two segments of flow.

Some indication of the velocity distribution in the cross-section can be obtained by the difference in color due to the surface suspended sediment in the cross-section. Knowing the width of the channel, the discharge at that particular stage, and using the differences in color one can possibly relate the transport and velocities to approximate a velocity distribution through the cross-section as well as the position of the main current of the stream.

BED FORM EFFECTS

In alluvial channels a variety of bed forms results from the interaction between the flow and the alluvium. These bed forms have a very significant effect on channel geometry, resistance to flow, sediment transport, and channel alignment. The bed forms fall in two categories: (1) the bars which include point bars, alternate bars, and middle bars; and (2) the bed forms themselves which include, ripples, ripples on dunes, dunes, and transitional regions where the dunes are tending to vanish in favor of a plain bed.

Photography can be used to identify the exposed bars and the forms of bed roughnesses that occur on them. Color infrared photography gives the best contrast and detail for identifying the roughness elements on the exposed bars and the direction of flow when they were formed. The direction of flow over the bars at different stages can be determined from the flow patterns on the bars and how the main flow shifts from one stage to another. Spacings, lengths, and amplitudes of the bed roughness on the bars can be determined by analytical photogrammetric techniques. One pattern found on the color infrared photographs of the middle bar at Point Pleasant shows the relative direction of bed movement at two different stages. One bed form was perpendicular to another indicating the different directions of flow when they were formed. Other bed forms can be found on the exposed bars in the Baleshed reach. In the Ben Lomond dike field, the bed forms show how the bed load has moved into the dike field at higher stages.

A study of the shape and development of bars is important to determine the best shape and dimensions of dike fields. Photography taken at low stages offers the best method for studying bar configuration. Dike fields should form a fill that best approach a natural bar formation.

RIVER BANKS

Color infrared photography can be used to distinguish zones along the bank that are moist areas versus those areas that are relatively dry. Moist, clayey soils are relatively highly resistant to erosion by water; clay materials, since they retain considerable moisture in the vicinity of a river bank, generally have a characteristic darker tone. Clay materials have a very steep angle of repose and often exhibit a honeycombed effect; whereas, more easily erodible sands have a smaller angle of repose, smoother texture, and generally exhibit a lighter tone corresponding to a lower moisture content. If the bank is exposed, an approximate soil profile can be determined from the top bank to the water's edge.

On the top bank, one can tell soil changes by changes in vegetation growth and appearance. Color infrared photography is excellent for observing vegetation, one is able to tell the vigor of growth and detect moisture stress in plants.

Photography probably will not replace the borings for soil surveys used in revetment and dike location, but would be a tool to better locate the borings and interpret conditions between boring holes. In the standard procedure of locating the boring holes a fixed distance apart, a troublesome soil pocket or lens could be missed; whereas with color infrared photography this area could be detected.

Flow slides and shear failures can be identified from photography due to their characteristic shape. Photography may enhance the ability to classify these areas over the conventional hydrographic surveys and cross-sections.

PHOTOGRAMMETRIC MEASUREMENTS

Work is still proceeding in the analytical photogrammetric techniques. It is fairly well known that horizontal distances can be accurately measured to describe river geometry. The main area of concentration is being directed toward measuring differences in water surface elevations both longitudinal and transverse.

An attempt is being made to determine velocity vectors from displacements of floating debris. However this has limited application unless there is a considerable amount of debris to represent a sufficient number of points within the cross-section. Practical application of this procedure may be limited to rising stages which produce more debris.

Volume estimates can be made from exposed bars. Time lapsed stereo pairs of particular bars could provide a method of determining the amount of scour and deposit on bars. This could be most effectively done from one low-water season to next by using either an analog approach or analytical approach. The analog approach would be the preferable method for mapping contours; whereas the analytical approach would be more accurate for cross-sections. The method would depend on the desired accuracy. Work is still being done to determine the best procedure and the amount of control needed.

CONCLUSIONS

This paper has briefly shown some of the preliminary results of a feasibility study of using remote sensing techniques to gather data from the Mississippi River. In almost all cases the color infrared photography is as good or better an interpretive base for river studies than any other format used. Color infrared photography is particularly useful for penetrating light haze found in humid regions, consequently good high altitude photographs can be taken. Some of the same characteristics of interest can be seen on all types of photography, but color infrared photography offers more enhancement and contrast.

Rivers are in a constant state of dynamic readjustment to meet varying constraints by either man or nature. The Point Pleasant reach appeared to be undergoing more of a dynamic change than the Baleshed reach. Remote sensing techniques can define the degree of dynamic changes and could give indications of potential troublesome reaches.

The long range potential of remote sensing techniques for rivers needs further development. More flights at convential altitudes are anticipated, along with some satellite imagery, in particular from NASA's ERTS and Skylab programs.

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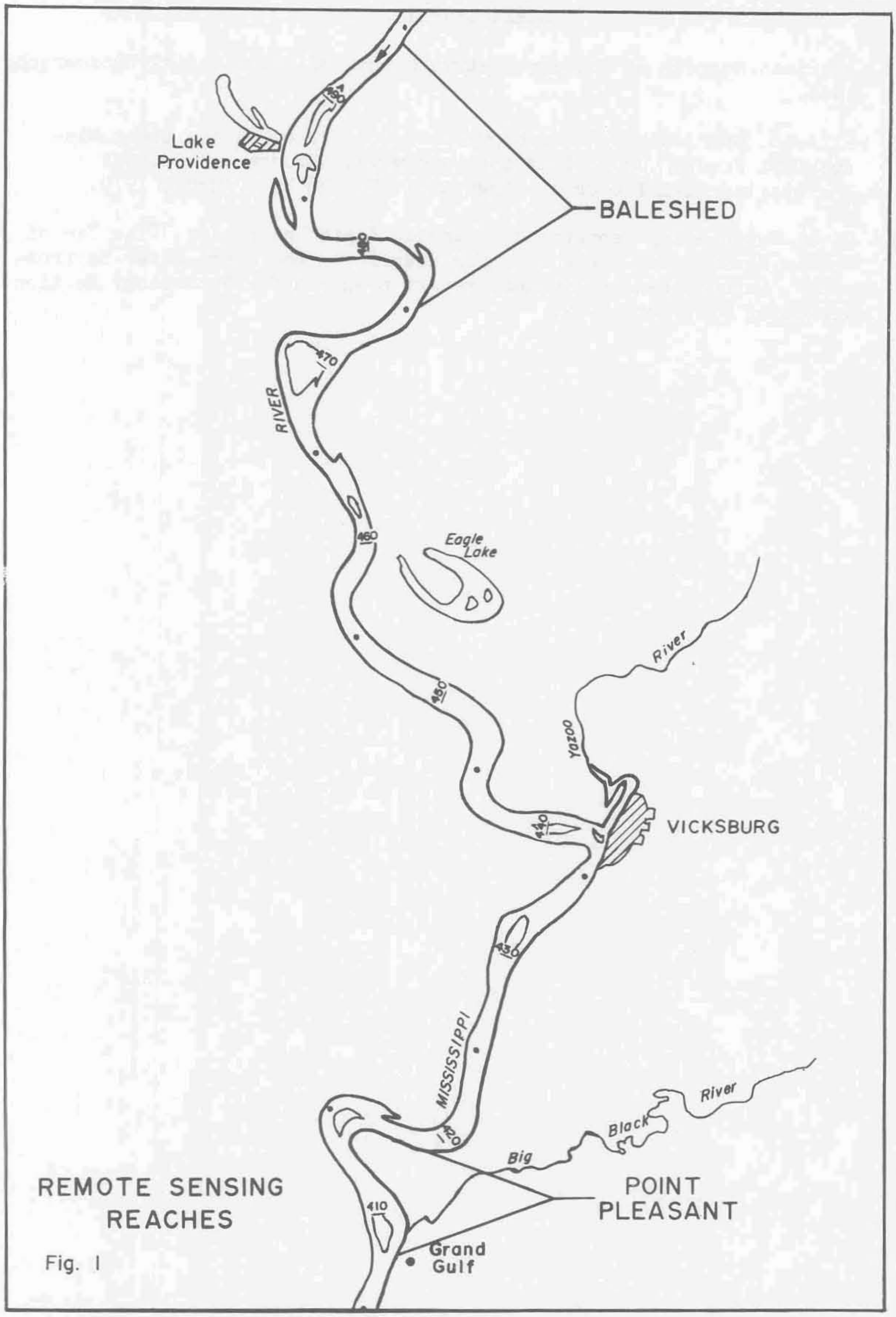
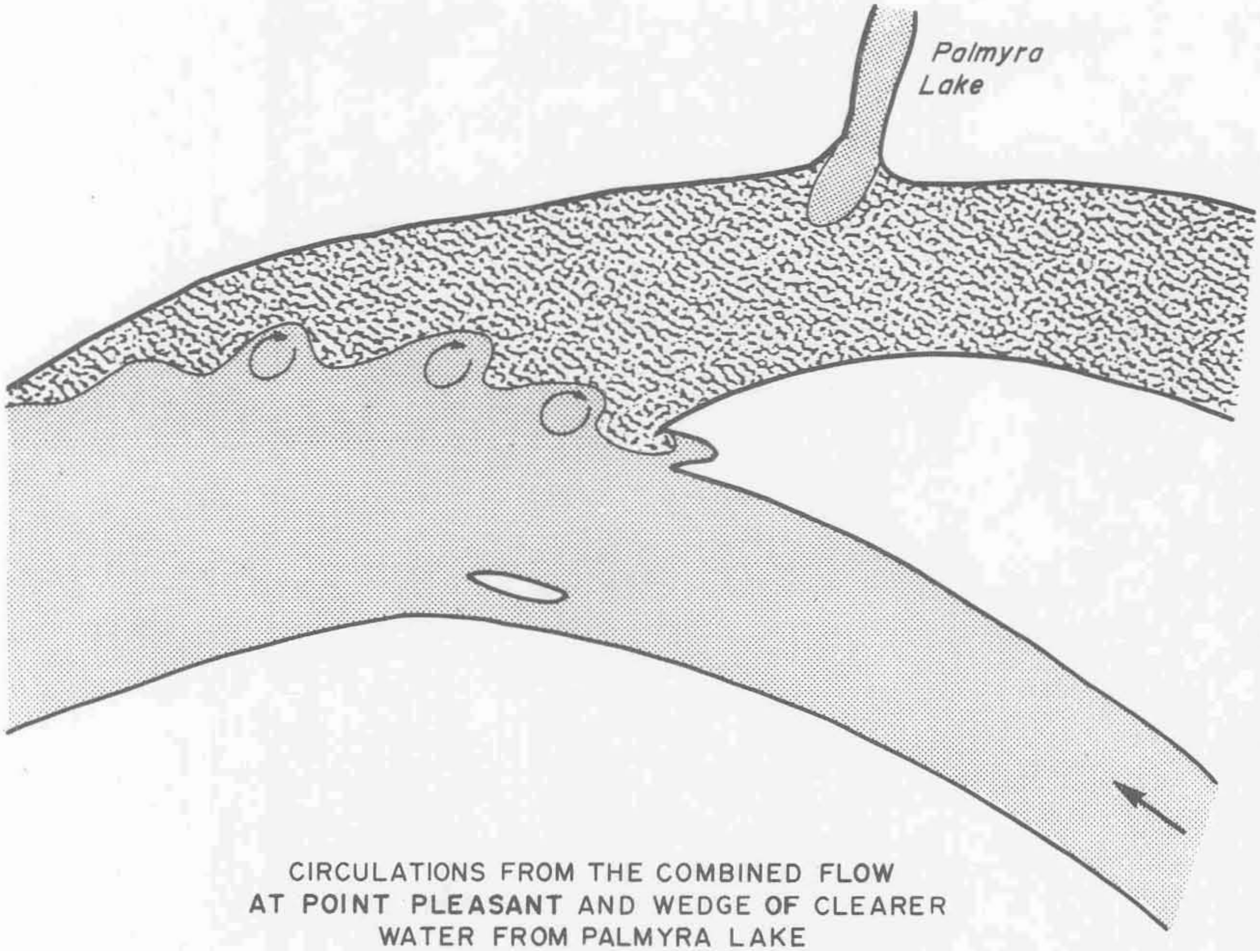
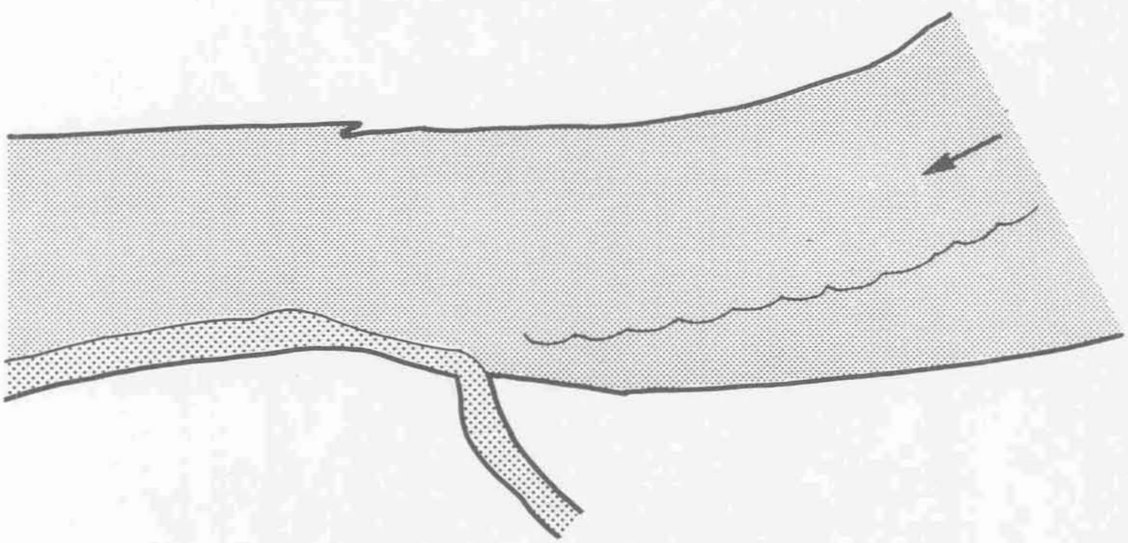

Lake
Providence
BALESHED
RIVER
Eagle
Lake
River
Yazoo
VICKSBURG
MISSISSIPPI
River
Black
Big
POINT
PLEASANT
Grand
Gulf
REMOTE SENSING
REACHES

Fig. 1



CIRCULATIONS FROM THE COMBINED FLOW AT POINT PLEASANT AND WEDGE OF CLEARER WATER FROM PALMYRA LAKE

Fig. 2



INFLOW FROM BIG BLACK RIVER

Fig. 3