LOUISIANA WATER RESOURCES RESEARCH INSTITUTE

BULLETIN 12A SEPTEMBER 1980

ALTERNATE WATER SOURCES FOR THE BATON ROUGE -NEW ORLEANS INDUSTRIAL CORRIDOR

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JOHN R. HARRIS

ASSOCIATE PROFESSOR OF CIVIL ENGINEERING

LOUISIANA STATE UNIVERSITY

BATON ROUGE

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ALTERNATE WATER SOURCES FOR THE BATON ROUGE-NEW ORLEANS INDUSTRIAL CORRIDOR

DESCRIPTORS: New Orleans, Atchafalaya River, Old River Control Structure, Disasters-floods, Salt-water Wedge, Conjunctive Use, Alternate Water Sources

IDENTIFIERS: Pearl River Supply, Low Flow Augmentation, Well Fields, Water Shortage, Water Replacement, Water Supply, Water Utilization

A B S T R A C T : The Lower Mississippi River is the source of fresh water for most of the municipalities and industries located along its banks below East and West Baton Rouge Parishes. The Flood Control Act of 1954 authorized the construction of a complex at Old River, above Baton Rouge, to divert part of the flood waters from the Mississippi River to the Atchafalaya River-the Old River Control Structure (O.R.C.S.)

During a major flood in 1973 the left wing wall of the low-sill structure collapsed. A cavity 55 ft deep had been scoured in the inflow channel under the structure. It is likely that the same or similar conditions will recur and that a failure of the O.R.C.S. is a possibility. Should the structure fail the Mississippi River would be lost as a source of fresh water below this point due to the intrusion of salt water from the Gulf of Mexico during the first period of low water. The many users below East and West Baton Rouge Parishes would have to find alternate sources of supply.

The consequences of the failure are described in detail and alternate sources are proposed. The New Orleans area and the municipalities and industries downstream would be supplied with water from the Pearl River. During periods of low discharge in the Pearl, a well field would supply the demand. This well field would be replenished with the use of filtered Pearl River water during periods of high water. The West Bank and Bayou Lafourche would be supplied with water from the Atchafalaya River. The remainder of the area would use water from the Amite River supplemented with water from a well field near French Settlement. Estimated cost of raw water delivered to the intake of the user, 1976 prices, about 25¢/kilogal.

REFERENCE: Harris, John R., ALTERNATE WATER SOURCES FOR THE BATON ROUGE-NEW ORLEANS INDUSTRIAL CORRIDOR *Louisiana Water Resources Research Institute*, Bulletin 12 A, Louisiana State Univ., B.R., Sept. 1980.

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I

INTRODUCTION

Mississippi River water is the source of fresh water for most industries and towns in the Louisiana Parishes located along the Mississippi River below Baton Rouge. The Lower Mississippi, with an average flow of some 300 billion gallons per day, provides about 95% of the fresh water requirements in this area.

The economic advantages provided by the Mississippi River, as the terminus of a 12,350 mile waterway transport system, coupled with nearby mineral resources have attracted billions of dollars of industrial development into the area downstream from Baton Rouge. New Orleans, the second largest port in the nation and Baton Rouge, the seventh largest, are both located on this stretch of the river. Accompanying the industrial growth has been an increase in the use of fresh water. Total water pumpage in the parishes along the Mississippi River below Old River increased from 3.2 billion gallons per day in 1965 to alomost 7.0 billion gallons per day in 1975.

A structure was constructed at the Old River to control the volume of water which flows from the main stem of the Mississippi River into the Atchafalaya Basin. Scour around the main flow control structure and the shifting of the Mississippi River channel toward the structure have increased its vulnerability to destruction and have raised questions concerning the consequences that might result from the failure of the structure.

A failure of the structure and the consequent loss of control over the flow at Old River would probably result in the diversion of the main flow of the Mississippi River to the Gulf of Mexico via the Atchafalaya River. Such a diversion could cause a shortage of fresh water in the Mississippi below Old River. The fresh water would be replaced by salt water entering the Mississippi River at its mouth at the Gulf of Mexico and moving northward up the channel. As the amount of fresh water flowing downstream decreased, the channel would fill with salt water from the Gulf up to the diversion point at Old River. Those who depend upon the Mississippi River for fresh water would have to develop alternative sources of supplies.

The primary purpose of this study is to evaluate the potential consequences caused by the failure of the control structure to the users of fresh water, who are located on the stretch of river between the Old River Control Structure and the Gulf of Mexico. Another purpose was to study several possible alternative sources of water supply and produce order-of-magnitude cost estimates of each. Such costs for alternative fresh water supplies would be directly attributable to the failure of the Old River Control Structure. Thus the benefits of preserving the control structure at Old River, if this is in fact feasible, would be partly expressed by these cost estimates.

This paper, and the studies leading to its development, were funded by the Louisiana Water Resources Research Institute, at Louisiana State University in Baton Rouge as project A-040-LA.

The work was started by Dr. E. Barcus Jernigan while he was Assistant Professor of Civil Engineering at L.S.U. Dr. Jernigan completed an extensive literature search. In addition the basic concept of Alternate A and the complicated Wang computer program for obtaining cost data were developed by Dr. Jernigan before leaving Louisiana State University. These have been used with his permission.

Professor Raphael G. Kazmann, Professor of Civil Engineering, Louisiana State University, was very helpful in the hydrologic evaluations, that include the mass curve analyses, well field calculations and aquifer yields. The author is grateful to Professor Kazmann for this invaluable assistance, and for his general review of the paper.

Figures 6 through 10 were prepared by Mrs. Norma Duffy, Head of the Drafting Department, Division of Engineering Research, Louisiana State University from rough sketches prepared by the author and her contribution is gratefully acknowledge.

II

THE MISSISSIPPI RIVER BELOW OLD RIVER

The Mississippi River System drains 1.24 million square miles of central United States. This includes most of the area from the Rocky Mountains in the West to the Appalachians in the East. The Mississippi River discharges into the Gulf of Mexico through two major distributaries, the Lower Mississippi River and the Atchafalaya River. The distribution of flow between these two rivers is controlled by the structure at Old River just below mile 315 above Head of Passes (AHP) on the Mississippi River. The structure was designed to divert about 25% of the Mississippi River discharge to the Atchafalaya River. The mean annual discharge through the Lower Mississippi and Atchafalaya are about 465,000 cubic feet per second (cfs) and 187,000 cfs respectively.

Little of the flow discharged through the Lower Mississippi River originates below the latitude of Old River. Drainage in Southeastern Louisiana, east of the Atchafalaya Basin, is generally away from or parallel to the river. No tributaries enter the Mississippi River below Baton Rouge.

The most devastating flood recorded on the Lower Mississippi River occurred in 1927. Maximum flow on the Mississippi at Vicksburg was computed to have been 2,280,000 cfs on May 4, 1927. Seventeen million acres were flooded and property damage equivalent to over one billion dollars (in 1977 dollars) was incurred along the Mississippi. The Mississippi River levee below New Orleans had to be breached by dynamite in order to prevent flooding of New Orleans. After the flood the U.S. Congress authorized the Mississippi River Commission and the U.S. Army Corps of Engineers to develop a unified flood control plan for the Mississippi River Valley. This project, entitled the "Mississippi River and Tributaries Flood Control Plan", was to "protect the alluvial valley of the Mississippi from the maximum flood predicted as possible" (U.S. Army Corps of Engineers, 1973, unpaginated). This "maximum flood" has become known as the Project Flood. The Project Flood flows would be about one-third greater than the 1927 flood, with a total flow of 3,030,000 cfs in the Mississippi and Atchafalaya Rivers below the latitude of the Red River Landing.

Elements of the project included levees to contain flows, floodways to bypass excess flows, stabilization of the river channel, and control of drainage from tributaries by dams and reservoirs. According to the plan for the Project Flood, half the total flow, about 1,500,000 cfs would pass through the Lower Mississippi River to the Gulf of Mexico and the remainder would pass through the Atchafalaya Basin.

The Old River Control Structure (ORCS) is a vital element in flood protection plans for both the Lower Mississippi River and the Atchafalaya Basin. In order to prevent the channel capacity in the Lower Mississippi from being exceeded, water must be diverted through the ORCS, the Morganza Spillway and the Bonnet Carre Spillway, the last being located several miles north of New Orleans.

III

THE OLD RIVER CONTROL STRUCTURE

The Atchafalaya River offers a shorter course to the Gulf of Mexico from Old River than does the Lower Mississippi. The average water surface slope to the Gulf in the Atchafalaya is almost twice that of the Lower Mississippi River. Until the late 1890's, the Atchafalaya had not developed sufficiently to accomodate large flows and the Atchafalaya was nothing but a minor outlet for Mississippi River water. In response to civil works intended to improve navigation and reduce flooding, the proportion of the flow of the Mississippi River diverted by Old River into the Atchafalaya began to increase steadily.

As the flow through Old River to the Atchafalaya increased, it soon became apparent that some action would be necessary to prevent the eventual capture of the Mississippi by the Atchafalaya. The construction of low sill concrete dams in the upper Atchafalya in 1928 in order to reduce, if not eliminate, the increase in the rate of water diversion, proved ineffective.

On September 3, 1954, the 83rd Congress enacted the Flood Control Act of 1954, Public Law No. 780, which authorized construction of a complex at Old River to maintain the Mississippi River in its present course by controlling the rate at which flow is diverted into the Atchafalya River. The structures were to maintain diversion at the rate which existed in 1950, when approximately 25% of the total flow of the Mississippi discharged through Old River.

Two structures to control discharge were constructed just above Old River at mile 315 AHP on the West Bank of the Mississippi. In addition to the diversion control structures, a navigation lock at Old River was authorized to provide for navigation between the Mississippi and Atchafalaya. These structures were to be operated, 1) to provide for controlled diversion of water from the Mississippi during low and normal flows at the rates which existed in 1950, 2) to maintain navigation between the two rivers, and 3) to divert flood flows from the Mississippi to the Atchafalaya as prescribed by the Mississippi River Commission flood control plan for the Lower Mississippi River.

Construction of the low sill structure, and its inflow and outflow channels were completed in 1959. The structure has a total span of 566 feet with 11 bays each having a width of 44 feet. The three center bays have a weir crest elevation of minus five (-5) feet Mean Sea Level (MSL). The other eight bays have a weir crest elevation of 10 feet MSL. Each bay is equipped with a vertical steel lift gate. A mobile gantry crane provides a means of opening and closing the bays independently. A short inflow channel from the Mississippi River to the low sill structure and an outflow channel about seven miles long from the structure to the Red River at mile 12 above its mouth, were excavated. The bearing piles supporting the structure were set at elevation -90 feet MSL. Steel sheet pilings for seepage control were set to elevation -36 feet MSL.

A second control structure, the overbank structure, was also completed in 1959. It consists of 73 gated bays, each with a width of 44 feet between piers, giving a total width of 3,356 feet. The weir crest of these bays is 52 feet MSL. Flow through the bays can be controlled by hinged timber needles operated by two traveling cranes. The natural Old River channel was closed with an earthen dam in October, 1963.

Total cost originally estimated for the project in 1953 dollars was about $46,750,000 initial cost or $1,880,000 in annual charges, excluding the cost of the navigational lock and channels. Minimum annual tangible benefits were estimated at $14,600,000, for a benefit-cost ratio of 7.7 to 1 (House of Representatives Document No. 478, 1954, PP. 22-23). This does not include intangible benefits such as preventing the loss of the Mississippi as a water supply for the Baton Rouge - New Orleans industrial complex and the probable expense of channel maintenence and bank stabilization due to increased meandering of the Mississippi River. As of 1975, the current estimated Federal cost of the ORCS was $81,200,000 and the project was 83% complete (Mississippi River Commission document, 1976, pp 42-48).

Scouring Around the Structure

The record of Scour in the diversion channel at Old River is well known (Hebert, 1967, p. 51 and Horne, 1975, pp. 1-15). Scour was anticipated by the Corps of Engineers in the original project design and provision was made to place revetment along the banks of the inflow and outflow channels. The designers also recognized that downstream raveling could also be a problem. The finally selected site was chosen because at this point the channel would have to pass through clay deposits and the clay has properties that would make the channel easier to protect against raveling (Graves, 1958, p. 1147). Although problems with scour had been anticipated, the severity of the problems was underestimated. The initial operational test of the structure was accomplished in 1961. Shortly thereafter, in 1962, scour protection and repair activities in the immediate vicinity of the low sill structure were required. Additional work was undertaken in 1963, 1964, 1966, 1968, 1973 and 1974 (Corps of Engineers Annual Reports, 1962-74).

After three months of operation in 1961, a scour hole 30 feet deep (to -40 feet MSL) was formed in the outflow channel just downstream from the structure. The hole was filled with stone and riprap, but when operations were resumed in 1962 the scour hole reformed in the channel to a depth of -90 feet MSL. The hole was again repaired and the riprap paving was extended in an attempt to reduce the erosion in the outflow channel. The problem seemed solved until a rise in 1964 deepened the cavity to -140 feet MSL, and caving occurred along the banks of the outflow channel. The maximum flow through the low sill structure in 1964 was about 300,000 cfs on March 24th when the Mississippi River stage was 42.5 feet MSL. Repairs were made with articulated concrete matting and about 150,000 tons of stone and riprap (Corps of Engineers Annual Reports, 1962-74).

Discharges Through the Structure

The hydraulic analysis of the final design of the Old River complex (Graves, 1958, pp 1148, 1149) indicated that a maximum of 700,000 cfs would flow through the low sill and overbank structures during the Mississippi River and Tributaries Project Flood, with the Mississippi River stage at 64.0 and the stage downstream from the structures at about 62.5 MSL. About 325,000 cfs of the 700,000 cfs were to pass through the low sill structure during this projected flood. Since the actual discharge through the ORCS depends on the actual upstream and downstream stages during a flood, this 325,000 cfs figure cannot be considered the "design capactiy". However, this figure should be noted as being one of the highest expected discharges since it was assumed to occur during the Project Flood.

The flood of 1973 was a major flood for the Lower Mississippi River. The maximum flow in the Mississippi above Old River was 2,041,000 cfs. The peak flow in the Mississippi below Old River was 1,498,000 cfs. This was equal to the maximum flow for which flood protection works had been designed and which could be safely passed without endangering New Orleans and other areas along the Lower Mississippi.

During this major flood, the left wing wall of the inflow channel to the low-sill structure collapsed. Investigations revealed a cavity 55 feet deep had been scoured in the inflow channel under the structure. This cavity exposed the supporting pilings down to elevation -50 feet MSL. The tips of the pilings are set at -90 feet MSL. Figures 1 and 2 show cross sectional views of the scour hole at the structure as measured in May, 1973 (cross-sections developed based on contour map presented by Horne, 1976, pp. 13 and 15, after U.S. Army Corps of Engineers drawings). In the outflow channel, the scour hole had been re-opened to a depth of -50 feet MSL. Following the collapse of the wing wall the Corps of Engineers acted quickly to reduce the flows through the low sill structure by lowering the stage of the Mississippi River at that location as much as possible. This was accomplished by opening the Morganza control structure about 35 miles downstream.

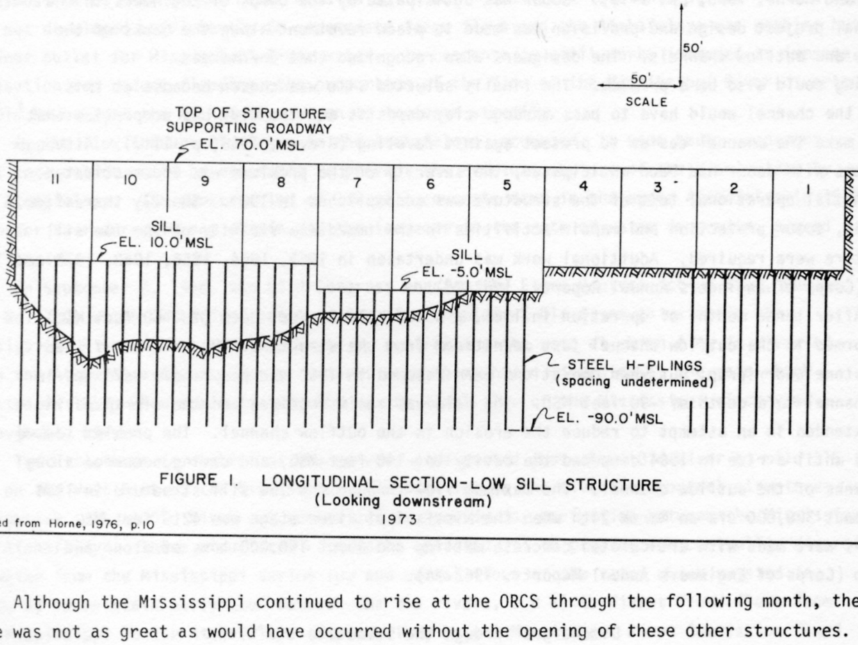


FIGURE I. LONGITUDINAL SECTION-LOW SILL STRUCTURE
(Looking downstream)
1973

Adapted from Horne, 1976, p.10

Although the Mississippi continued to rise at the ORCS through the following month, the rise was not as great as would have occurred without the opening of these other structures. The stage at the upstream face of the low sill structure was about 60.1 on May 15, with a downstream stage near 59.3. The resulting discharge through both of the Old River control structures under these conditions was the highest to date; about 610,000 cfs (Corps of Engineers, 1973). About 390,000 cfs of this discharge was through the low sill structure (Mississippi River Commission, design Memo No. 4). The Corps of Engineers reported a maximum discharge of 500,000 cfs through the low sill structure on this date. This estimated discharge is approximately 50 percent higher than the 325,000 cfs which was expected to pass through the low sill structure according to the anticipated Mississippi River and Tributaries Project Flood.

Future Scour

There are some indications that the conditions which produced high discharge and turbulent flows, similar to those that caused the scouring in the Old River diversion channel, will become more severe in the future. With the existing physical arrangement at the low

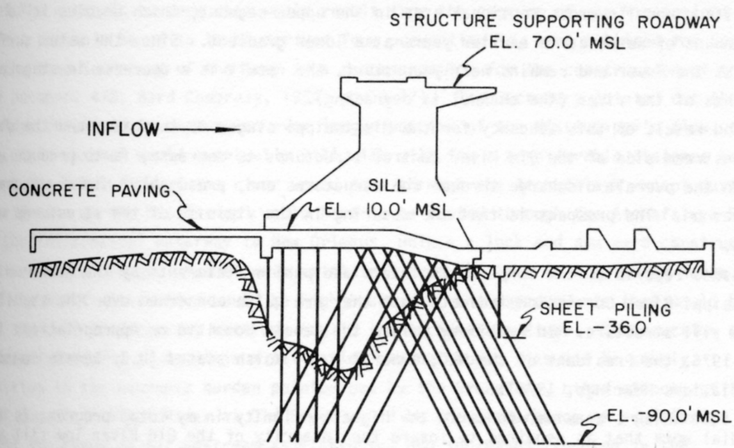


FIGURE 2. CROSS SECTION-LOW SILL STRUCTURE
(At bays 10/11)
1973

Adapted from Horne, 1976, p.10

sill structure, the velocity and discharge through the structure are determined by the water surface elevations in the Mississippi River and in the diverson channel downstream from the structure. As would be expected, large differences in elevation of the water surfaces produce high discharges and velocities through the structure. High discharges may result from several combinations of stage changes such as an increase in the Mississippi stage, a decrease in the downstream stage of the channel, or both. Observed trends in deposition and degradation seem to simultaneously result in a gradual increase in Mississippi River stages and gradual decreases in downstream stages at Old River.

The flood of 1973 revealed the fact that the hydraulic efficiency of the Mississippi River channel seemed to have deteriorated throughout its lower length. Stages were higher for a given discharge than they had been in the past. For example, a 1,800,000 cfs flow at Vicksburg in 1950 resulted in a stage of 43.7 feet. In 1973, this same discharge resulted in a stage of 50.6 (or 6.9 feet higher). A brief post flood report by the Army Corps of Engineers on the 1973 flood explained this deterioration in the lower Mississippi channel as follows (Corps of Engineers, Mississippi River and Tributaries, Post Flood Report, 1973, pp. 63 & 65):

> "Channel efficiency has diminished thoughout the lower Mississippi River due to changes arising from the dynamic nature of the alluvial river, the persistent tnedency of the river to meander, the instability introduced by the cutoff program, and a generally incomplete river stabilization program."

Further,

> "Some deterioration or loss in flow capacity has occurred continuously since 1950...As channel stabilization works are currently estimated to be 58 percent complete within the middle reach, some additional deterioration can be expected...."

While the stages of the Mississippi River side of the Old River control structures appear to be rising, on the downstream side, both in the Red River backwater area and in the upper reaches of the Atchafalaya River, the stages appear to be declining (Horne, 1976, p 25). As predicted by Fisk (1952, pp 26-28) the Atchafalaya River has been deepening and enlarging its channel's cross sectional area in the upper segment, which enables it to carry the same amount of water as in earlier years at a lower gradient. Since the water surface elevation at the lower end remains nearly constant, the result is a decrease in stage at the upper reaches of the river (the channel is degrading).

The end result of this tendency for the Mississippi stages to increase, and the stages of the downstream side of the Old River control structures to decrease, is to produce an increase in the overall discharge through the structures and, presumably, higher discharges as time goes on. The prospect is that the scouring in the vicinity of the structures will grow worse.

Published reports of the Corps of Engineers and public statements by the Chairman of the Mississippi River Commission indicate that they are quite concerned over the stability of the low sill structure. In testimony before the Senate Committe on Appropriations in February, 1976, the President of the MRC, General F. P. Koish stated (U.S. Senate Committe on Appropriations Hearings, 1976)...

> "The item which I consider to carry the highest priority in my total program, is the remedial work that is required to insure the integrity of the Old River low sill and overbank structures and ultimately the Mississippi River and Tributaries flood control system. If I had to select a single feature as being the most important to the viability of the Mississippi River and Tributaries project it would be these structures."

Possible Failure of the Low Sill Structure

In the preceding section of this report the problems with scour at the low sill structure were outlined and evidence has been presented to show that the discharges through the structure are increasing over the years. Under these circumstances, failure of the low sill structure is possible, and it is appropriate to discuss the potential consequences that would result from this failure.

The phrase "failure of the low sill structure" as used herein refers to any circumstance which would result in uncontrolled diversion of water from the Mississippi River into the Red and/or Atchafalaya Rivers at the Old River site. Failure could result from events such as collision by river traffic as occurred in April, 1964 and again in December, 1965; from acts of sabotage or war; from the undermining of the foundation by scour with subsequent settlement or total collapse; from the scouring out of an unobstructed channel under or around the edge of the structure; or by any set of combinations of these possibilities.

The intent of this study was to concentrate on the consequence of catastrophic failure of the structure. No attempt has been made to discuss such topics as the probabilities associated with the various modes of failure, various possible river conditions on the Mississippi, Red, and Atchafalaya Rivers at the time of the failure, the possible remedial actions that might be undertaken or the conditions resulting from these actions.

The scenario for this study is to suppose that the failure did in fact occur, and the occurrence took place during a major flood. The resulting diversion of flood waters through the outflow channel, down the Red River channel and thence down the Atchafalaya would develop a much larger channel immediately. The main channel of the Atchafalaya would enlarge its cross section in a short period of time to a dimension adequate to carry the main flow of the Mississippi. While some flow would continue in the main lower Mississippi channel during subsequent periods of high water, the discharge of the Mississippi River would essentially be captured by the Atchafalaya. During low flow periods that would occur after the flood, the discharge to the Lower Mississippi River channel might be negligible. All of this would take place in spite of efforts which might be taken to restrict the diversion at Old River and keep the Mississippi River channel open.

Consequences of Failure of Low Sill Structure

Some of the economic burdens that would result from the capture of the Mississippi River, and the probable benefits to be derived from preventing it, were outlined for Congress in 1954 by the then Secretary of the Army in a recommendation for the construction of the ORCS (House Document 478, 83rd Congress, 1954, pp 16-17). The Secretary pointed out that if the Atchafalaya continued to capture an ever larger portion of the Mississippi's flow, the Mississippi River channel would eventually fill with silt for a considerable distance below Old River and the total flow of the river would pass through the Atchafalaya except during floods. Navigation on the Mississippi would have to be routed through the Atchafalaya River system and the intracoastal waterway to New Orleans, unless a lock and dam were constructed below Old River and a dredged channel were maintained from the lock to near Baton Rouge. The cost of the first alternative would be high because of the improvements that would be required in the Gulf Intracoastal Waterway and in the Atchafalaya River. Construction of a lock and dam and dredging to maintain a navigation channel would likewise be costly.

In addition to the economic burden pointed out by the Secretary, other effects of the diversion of the Mississippi River at Old River would be the disturbance of equilibrium conditions in the river as far upstream as Vicksburg, and increased flooding in the Atchafalaya basin. Increased stream velocities upstream from Old River (and lower stages) would result from the increased gradient through the Atchafalaya. The increased stream velocity would cause the river to meander more and would make navigation more difficult. Many of the present locks, flood-gates, levees and floodwalls would be ineffective for the altered stages along the Mississippi and Atchafalaya. Existing transportation facili-ties and communication and utility lines across the Atchafalaya Basin might be severed during increased flows.

The major effect on the quality of the water would be an increase in the extent and frequency of salt water intrusion from the Gulf into the main stem of the Mississippi River. Salt water encroachment would tend to make the river an unreliable source of fresh water for the many industries and municipalities located south of Baton Rouge along both banks of the Lower Mississippi River. If fresh water flow stopped completely, the river would become a slack water, salty estuary of the Gulf of Mexico, with all that this implies for industries, municipalities and nuclear-fueled power plants that now use, or plan to use, river water as their supply.

IV

EFFECTS OF FAILURE ON WATER QUALITY

Salt Water Intrusion

The quality of the water of the Lower Mississippi River would be changed by the loss or significant reduction in flow of water following the failure of the Old River control structure. The most important effect would be the change in salinity caused by salt water intrusion into the channel as the fresh water was displaced by salt water entering from the Gulf of Mexico. This change would be more than merely a slight increase in salinity from its present level. It would tend to be a total conversion from fresh to salt water.

Uner existing conditions there is a dynamic equilibrium in the Mississippi channel between the fresh water flowing downstream and the salt water of the Gulf of Mexico. The dense salt water tends to displace the fresh river water and flow upstream along the river bottom. The flow of fresh water erodes the salt water - fresh water interface and retards the salt water intrusion. Thus, the continuing intrusion results in a wedge of salt water along the bottom of the channel, with its narrow end upstream.

The interface between the salt and fresh water in the Mississippi River is well defined. It has been found that the salinity content changes from fresh water with concentrations of a few hundred parts per million (ppm) chloride to saline water which contains 10,000 to 15,000 ppm of chloride with a depth change of a few feet. There is little mixing along the interface at the small end of the wedge. Maximum chloride concentration in the Mississippi River upstream from the salt water wedge is about 50 ppm (Everett, 1971, p. 25).

Because the thalweg of the Mississippi is below sea level, salt water intrudes into the mouths of the river at all times except during the largest floods. The extent to which salt water penetrates depends upon the discharge from the stream, tidal conditions and the elevation of the bottom of the river channel.

Analytical methods of predicting the length of the salt water wedge above the mouth of the river have not been successful because of the changes in the forces which influence the extent of the intrusion (Everett, 1971, pp. 22-28; Kazmann and Arguello, 1973, p. 43). The discharges, depth and width of the river, tides and the distribution of flow in the river's various outlets to the Gulf are all factors in determining the extent of salt water intrusion.

The maximum recorded intrusion occurred in October, 1939, when the river discharge reached a record low of 75,000 cfs and ranged from 75,000 to 100,000 cfs for thirty consecutive days. The upper end of the salt water wedge reached Norco, Louisiana which is 120 miles from the Gulf and 15 miles above New Orleans. In October, 1940, the wedge penetrated past Kenner Hump at mile 115 (AHP) though flow was less than 100,000 cfs for only a few days. Concentrations of chloride have been as high as 620 ppm at the Algiers water treatment plant intake at mile 95.5 (AHP) (Everett, 1971, pp. 22, 29).

Whereas low discharges in the Mississippi permit a salt water wedge to penetrate upstream along the channel bottom, the complete loss of freshwater flow into the Lower Mississippi River at the latitude of Old River would result in the present channel completely filling with salt water. The heavier salt water would flow inland from the Gulf of Mexico along the bottom of the channel, displacing the freshwater and forcing it up to the surface, thus forming a two-layered stratified system. The freshwater on the surface would move downstream, its total depth decreasing as it moved downstream. Eventually all the fresh water would be lost and the channel would become completely filled with salt water to an elevation approximately equal to the Gulf level. This resulting water body would be tidal at its lower end, with positive and negative waves alternatively traveling up the old channel as the Gulf tides rose and fell.

The present channel bottom of the Mississippi is below sea level upstream from the Gulf to a point well above Old River, as shown on Figure 3. At some locations between Baton Rouge and New Orleans, the salt water would be well over 150 feet deep.

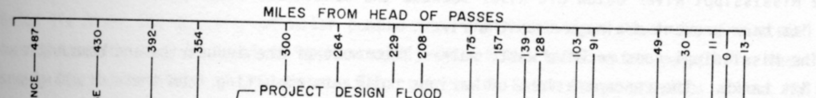


FIGURE 3. PROFILE OF THE LOWER MISSISSIPPI RIVER FROM THE GULF OF MEXICO TO MILE 500 FROM HEAD OF PASSES

Even if there were a complete diversion at Old River, fresh water flow into the present channel of the Mississippi River would not stop altogether. Precipitation falling between the levees would pass down-stream. Also, there are two minor tributaries to the Lower Mississippi: Thompson Creek and Bayou Sara. These streams, that drain an area of approximately 425 square miles, enter the river just above Baton Rouge at Miles 256 (AHP) and 266 (AHP) respectively. The streams are ungaged, but an estimate of their flow can be made by assuming their discharges would be similar to other gaged streams in the area. The mean annual discharge of similar streams in this area is about 1.4 cfs per square mile of watershed. The two tributaries would thus contribute an annual flow averaging approximately 600 cfs to the Mississippi Channel. It is also quite possible that, in time, runoff from lands which now drain away from the river might be redirected into the channel, since the water level in the channel would be at sea level, and thus lower than the land to be drained.

With a complete cessation of fresh water flow at Old River, the quantities of fresh water entering the river from all other sources would not be enough to cause a significant reduction in the salinity of the water from the Gulf.

Pollution

The Mississippi River receives wastes produced in about 41 percent of the area of the Continental United States. Bacteria, nitrogen and phosphorous compounds, pesticides, organic chemicals and various heavy metals from countless sources are all present in ever-varying concentrations. A number of recent publications have discussed the water quality of the Lower Mississippi and have described the variations in concentration of specific pollutants and indicators of water quality (EPA, 1972, 1974; LSCC, 1973, 1974, 1977). Loss of the flow from up river would divert these materials away from the channel of the Lower Mississippi. However, the overall mass of materials carried to Louisiana's wetlands and the Gulf of Mexico would remain unchanged.

Pollutants from minor creeks, rivulets and overland flow are not a significant problem on the Mississippi River below Old River because the continuous flood protection levees along its bank prevent drainage into the river.

The Mississippi does receive waste waters from most of the industries and communities along its banks. The concentrations of various polutants resulting from these discharges depend on the quantities discharged, the volume of receiving water with which they are mixed, the rate of transport of the waste away from the point source and the rate at which the material is removed from the water or is changed in form.

Significance of Water Quality Changes

The change of water quality in the Lower Mississippi River from fresh to saline would be more than a variation in water quality. It would be a complete change in character. This change would affect all of the industries and municipalities which depend on the Mississippi as a source of fresh water. The loss of the Mississippi River as a fresh water source for even a few weeks each year would cause severe problems to the users, such as potability and pipe corrosion, because of the absence of readily available alternative fresh-water sources.

This change in water quality would not, of course, affect navigation or recreation on the the Mississippi River.

There would be other effects: industries that use river water for once-through cooling would find that their river intakes and the outlets for spent water were too close together. Consequently the cooling water would be contaminated by water that had passed through the condensers and was much hotter than normal river temperatures. The effect would be to reduce the production of power.

Industries and municipalities that dispose of treated wastes into the river might find that the degree of treatment was inadequate. On the other hand, industries that produced waste streams of chlorides or other minerals found in sea water would find that they had, effectively, stopped polluting the river: if the water is already too salty, a little more salt would not be noticeable.

V

FRESH WATER USAGE AND REQUIREMENTS

Present Uses

Below Old River the quantity of water pumped from the Mississippi River for industrial and power generation uses is equal to approximately 65% of the total water pumped for these purposes in the entire state of Louisiana. The river below Baton Rouge provides almost half the quantity of water used for public supply in Louisiana. More than 150 industries, power plants and municipalities pumped water from the Lower Mississippi in 1975. Large industrial plants utilizing the river's water included almost fifty chemical plants, some twenty synthetic rubber and plastics producers, more than twenty petroleum refineries and about twenty processors of food and kindred products (U.S. Geological Survey unpublished data, 1977).

Table I shows total pumpage for public supplies and thermoelectric and industrial uses by parishes along the river. Lafourche Parish is included since fresh water from the Mississippi is pumped into Bayou Lafourche at Donaldsonville and provides fresh water for this parish. Fresh water pumpage for thermo-electric uses accounts for 57% of the total pumpage. Table II lists industrial use of fresh water by type of industry. The chemical and plastics industries account for 85% of the total industrial usage.

TABLE I
PUBLIC SUPPLY, INDUSTRIAL AND THERMOELECTRIC PUMPAGE IN 1975
(Parishes along the Mississippi River Downstream from Old River, Rounded to the nearest MGD)

	Public Supply		Industrial		Thermoelectric	
Parish	Ground	Surface	Ground	Surface	Ground	Surface
Ascension	1	1	1	115	0	0
Assumption	0	2	0	10	0	0
East Baton Rouge	40	0	85	114	8	5
Iberville	1	0	30	643	1	388
Jefferson	0	58	2	34	3	1498
Lafourche	0	8	0	29	0	0
Orleans	0	131	19	0	16	594
Plaquemines	0	6	0	51	0	0
Point Coupee	1	0	5	1	0	0
St. Bernard	0	9	0	566	0	0
St. Charles	0	5	2	604	0	1541
St. James	0	2	4	275	0	0
St. John the Baptist	1	1	3	88	0	0
West Baton Rouge	4	0	3	0	0	0
West Feliciana	2	0	2	35	0	0
TOTAL	50	223	156	2565	28	4026

Total Ground Water = 235 MGD   Total Surface Water = 6814 MGD   Grand Total = 7049 MGD

Figures based on U.S. Geological Survey files for water pumpage in 1975.

Total withdrawal of fresh water in 1975 in the parishes below Old River using the Mississippi River's water was more than 7.0 billion gallons per day (BGD). Of this amount, slightly more than 6.8 BGD was taken from surface sources, with almost all of this being taken from the Mississippi. Approximately 6.4 BGD of the water used was returned to the river as wastewater.

TABLE II
FRESHWATER WITHDRAWALS, IN MILLIONS OF GALLONS A DAY FROM THE LOWER MISSISSIPPI FOR VARIOUS INDUSTRIES IN 1975

	Ground water	Surface water	Total
Chemical, plastics and synthetic rubber	78	2224	2302
Petroleum refining and petroleum products	21	179	200
Food and kindred products	37	32	69
Wood and paper products	3	58	61
Others or industrial withdrawals not identified by type product	18	71	89
TOTAL	157	2564	2721

Source: U.S. Geological Survey data for water pumpage in 1975.

Table III is a list of the major power generation facilities along the Mississippi below Old River in 1975. All but two of the facilities withdrawing water in 1975 used cooling water, once through. Additionally, small municipal power plants are located along this reach with a total capacity of 100 MW as well as private industrial generating plants having a total capacity in excess of 400 MW. Total pumpage for power generation was 4 BGD in 1975, almost all of which was from the Mississippi River. At least one nuclear fueled power plant, owned by the La. Power & Light Company at Taft, La., will be utilizing river water for cooling by 1984. As of this writing (1980) it is more than 50 percent complete and making application for permission to load fuel.

TABLE III
ELECTRIC GENERATION FACILITIES ALONG THE MISSISSIPPI RIVER BELOW OLD RIVER

Plant	Owner[3]	Approximate 1975 capacity (MW)	Fresh water withdrawals (MGD)[1,2] Ground	Surface
Big Cajun[4]	Cajun Electric	230	17	0
Louisiana	GSU	428	5	5
Willow Glen	GSU	1586	1	388
Little Gypsy	La. P&L	1251	0	930
Market Street	NOPSI	96	2	112
Nine Mile Point	La. P&L	1917	0	1500
Waterford	La. P&L	860	0	605

Source: Lower Mississippi Region Comprehensive Study, 1974, Volume D-11, pp. 292, 410.
1. U.S. Geological Survey, unpublished data of pumpage of water in Louisiana, 1975, unpaginated.
2. Corps of Engineers, 1975, p. 161.
3. Owners: GSU--Gulf States Utilities, inc.; La. P&L--Louisiana Power & Light, Inc.; NOPSI--New Orleans Public Service, Inc.
4. Projected maximum withdrawal rate, Environmental Impact Statement Bovay Engineers, Inc.,--Burns and Roe Inc., 1975. p. 4-20.

Effects of Loss of Fresh Water Flow on Water Use

Since the water withdrawn from the Mississippi is used for a myriad of purposes, the required quality of the raw water and the treatment requirements are not uniform. In some instances brackish or saline water could be used in place of fresh water with few, if any, problems. Total dissolved solids over about 500 ppm, including 250 ppm of chlorides, would make the water undesirable for public consumption according to drinking water standards. There are, in addition, many industrial processes in use along the lower Mississippi which require water of higher quality than that suitable for public water supply.

To further complicate the analysis of the effects of the failure of the ORCS on water use on the lower Mississippi is the likelihood that in the years immediately following failure, the salinity of the river would be quite variable throughout the year and along the length of the channel. To reduce the complexity of this problem to a worst-case basis the assumption was made that the flow of fresh water had stopped completely. Provisions would then have to be made to satisfy water demand by developing alternate sources.

As in any study dealing with water supplies, the first requirement is to determine water demands. The major difference between this study and other studies is that demand projections have been based on the assumptions that water usage would decrease rather than increase. The basis for this assumption is discussed at length in the following pages.

Recent federal regulations have forced industries to reduce the quantities of waste materials discharged into receiving waters, and the expressed goal of "zero discharge" is to eliminate the discharge of all pollutants and make the streams suitable for swimming and fishing. If this goal, unrealistic as it may be, remains in effect, and there is, at present, no reason to assume otherwise, the recycling of water would approach 100 percent by the mid 1980's and the only water demand would be to replace water actually consumed or lost by evaporation.

Should the fresh water flow in the Mississippi cease, the cost of obtaining fresh water would clearly increase. In many instances, it might be more economical to recycle wastewater than to develop alternate sources. If recycling were already being practiced in response to federal requirements, the demand would remain nearly constant at the present level of consumption. If recycling were not yet practiced by industries, the necessity to develop an alternate source coupled with the federal requirements, would be a strong incentive to reduce water demands to the maximum extent.

An increase in the price of water could be expected to reduce the municipal demand. It has been observed that water consumption in communities decreased by approximately 6 percent for a 10 percent increase in price (Clark, 1976, p 372). Thus the total demand on the public water supplies along the Mississippi could be expected to decrease somewhat, even with a slight increase in population. An assumption that requirements of municipal water supply systems would remain constant is therefore reasonable.

In summary then, water demands have been based on the assumptions that (1) municipal requirements would not change, and (2) industrial requirements would reflect the actual consumptive use requirements.

Consumptive use requirements differ widely between different industrial categories and even between plants using the same basic processes. In thermoelectric power generation consumptive losses are approximately one and one half percent of the condenser flow for plants using cooling ponds, and about two percent for plants using evaporative cooling towers and spray ponds. The average condenser water requirement for fossil-fueled, steam electric power plants was about 40 gallons per kilowatt-hour in 1965 (Water Resources Council, 1968, p. 4-3-3). Using these figures and assuming condenser cooling water will be passed through evaporative cooling towers, it is possible to estimate the consumptive water requirements for the thermoelectric plants on the lower Mississippi. Of the 7550 MW capacity shown in Table III, the capacity of the plants dependent on the Mississippi for fresh water is about 6370 MW. The consumption of these plants, based on the two percent of 40 gallons per kilowatt-hour would be approximately 120 MGD.

Most water used by industry is for cooling purposes, and the plants located along the lower Mississippi are no exceptions. Reductions in water use can be accomplished by reusing water by the use of cooling devices such as forced or natural draft cooling towers or cooling ponds.

While each plant has its own characteristics and potential for water conservation, generalizations can be made concerning the overall level of consumption, or minimum water requirements. The U.S. Environmental Protection Agency published an estimate of water intake and consumption in 1968 for a number of standard industrial classes. This informat presented in Table IV, shows the wide variation which would be expected, with from 6.2% to 21.2% of the total volume of intake actually being consumed.

TABLE IV.

VOLUME OF INTAKE AND PERCENT CONSUMED BY INDUSTRY GROUPS, 1968

Industry	Intake, Billion gallons	% Consumed
Food & Kindred Products	811	7.2
Lumber	118	21.2
Paper	2252	7.7
Chemicals	4476	6.7
Petroleum & Coal	1453	15.2
Stone, clay, glass	251	13.1
Primary metals	5005	6.2
All manufacturers	15467	9.6

Source: US EPA "The Economics of Clean Water", Vol I, 1972, p. 37.

In general, the consumptive use by an industry would increase somewhat when it changed from once-through cooling systems (which increase the temperature of cooling water but do not directly evaporate any) to closed-cycle cooling systems because of the evaporative losses associated with most cooling processes. Once-through cooling systems have essentiall no water losses. Cooling towers consume about 0.2 percent of the recirculated volume throug spray losses, and about 1.0 percent through evaporation for each 10½ F decrease in cooling temperature (Durfor, 1963, p 236). Thus, the consumption data presented above would have to be increased somewhat if all industries practiced closed-cycle cooling.

It was assumed that the minimum water requirements of various industries using the Mississippi as a fresh water source would be 20 percent of the total water usage for wood products, 15 percent for petroleum refineries, and 10 percent for the remainder. Applying these percentages to the figures for 1975 industrial surface water pumpage shown in Table I, gives a total consumption of 270 MGD for all industries using the river as a source of supply.

The total public water supply obtained from surface streams was 227 MGD. Assuming this full amount would have to be provided, along with the consumptive requirements of thermo-electric generating plants and industries, the total demand for fresh water by present users of the Mississippi below Old River would be some 620 MGD. This is the demand used for cost estimates in this study. Despite the seeming accuracy of the figures, no guarantee is given or implied that the second and third significant figures are reliable. It is possible to round off these numbers to 200 MGD and 600 MGD respectively without losing accuracy.

VI

POSSIBLE FRESH WATER SOURCES

General

Should the discharge of the Mississippi River be essentially captured by the Atchafalaya, the flow in the Lower Mississippi would progressively decrease as the channel just below the point of diversion filled with sediments. Salt water intrusion into the entire river channel would probably occur during the first period of low discharge that occurred after the failure of the low-sill structure. Thus in a relatively short period of time the fresh water flow in the lower Mississippi would cease almost entirely and alternate sources of fresh water would be needed to satisfy the present users of fresh water. Other sources of surface water, as well as ground-water supplies, are the most likely alternatives. Less likely, but possible, are the desalting of brackish or saline waters, the capture and storage of local runoff, and water reclamation and reuse.

Exclusive of the Mississippi River, the most important sources of surface water in southeastern Louisiana include the Atchafalaya River, the streams flowing into Lake Pontchartrain and Lake Maurepas, and the Pearl River. The area between the Atchafalaya basin and the Pearl River covers over 13,000 square miles of which about 11,000 square miles is land. The runoff from this area averages from 18 to 24 inches per year.

In the same area there is an abundance of fresh ground water, although its distribution is not uniform. Vast quantities of potable ground water are available in the parishes east of the Mississippi and north of Lake Pontchartrain. Below Baton Rouge, along the banks of the Mississippi, the ground water is usually potable. In the vicinity of New Orleans and further south, the salinity of the ground water is too high for most uses.

River and stream beds in southeast Louisiana are below sea level from their outlets for some distance upstream. Consequently near the outlets of such rivers the channels contain saline water at times. For this reason the quantity of fresh water which may be withdrawn is often limited by the upstream movement of salt water into the river--the "Salt Water Wedge".

Surface Waters

East of the Mississippi

East of the Mississippi river and south of Lake Pontchartrain, the bayous are characterized by low minimum flows and intrusion of salt water into the streams and marshes. The bayous drain low wetlands that are very flat, and such lands are subject to flooding by tides. Major hurricanes may produce tides in many of these areas in excess of 10 feet MSL. Such streams must be excluded from consideration as sources of fresh water.

The major streams east of the Mississippi that are potential sources of fresh water are the Amite, Tickfaw, Tangipahoa, Tchefuncte and Pearl Rivers.

The Amite River drains an area of 1,819 square miles from its source in southwestern Mississippi to Lake Maurepas. Principal tributaries include Bayou Manchac and the Comite River. The annual average discharge of the Amite River is about 2,600 cfs at its mouth. The mean flow of the river at Denahm Springs is 1,900 cfs. The minimum flow recorded for the Amite between 1938 and 1976 at Denham Springs was 271 cfs, from a drainage area of about 1,280 square miles (U.S. Geological Survey, 1976, p. 231).

The Tickfaw River also originates in southwestern Mississippi and flows into Lake Maurepas. Principal tributaries are the Blood, Natalbany, and Pontchartrain Rivers. Average annual discharge is approximately 1,300 cfs from a drainage area of 945 square miles. Minimum flow recorded at Holden, Louisiana for a period from 1940 to 1976 was 65 cfs from a drainage area of 247 square miles. This minimum flow occurred in October, 1969 (U.S. Geological Survey, 1976, p. 196).

The Tangipahoa River has an average flow of about 1,300 cfs at its mouth. The source of the river is in southwest Mississippi and it drains approximately 771 square miles. The minimum recorded flow of 245 cfs in the Tangipahoa, for the period from 1938 to 1976 occurred at Robert, Louisiana where the drainage area is 646 square miles, from October 30 to November 3, 1968 (U.S. Geological Survey, 1976, p. 192). To prevent the movement of salt water upstream, the minimum flow required twelve miles upstream from the mouth of the Tangipahoa is approximately 100 cfs. This requirement means that, at low flow, the maximum rate of withdrawal should not exceed 150 cfs.

The Tchefuncte River's mean flow at its mouth at Lake Pontchartrain is about 700 cfs from a drainage area of 450 square miles. The mean flow at Folsum, Louisiana for the period of record 1943-1976 is 159 cfs. The minimum recorded flow of the Tchefuncte near Folsum was 26 cfs in September, 1968 where the drainage area is 95.5 square miles. (U.S. Geological Survey, 1976, p. 190).

The Pearl River, which flows along the state line between south-eastern Louisiana and southwestern Mississippi drains an area of 6,630 square miles at Bogalusa, Louisiana and has an average flow of 9,300 cfs at that point. Below Bogalusa, the Pearl River consists of a system of tributary, distributary and interconnecting channels. About 15 miles south of Bogalusa the Bogue Chitto joins the Pearl from the west. Farther downstream the channel branches into the Pearl River and a western branch, appropriately called the West Pearl River. Still farther south, the Middle Pearl River distributary leaves the West Pearl River. Minimum flow in the West Pearl River at U.S. Highway 11 above the junction with the Middle Pearl distributary is 1,300 cfs, which is approximately 75% of the total flow of the system during minimum flows (Cardwell, et. al, 1966, pp. 13-14).

Development of the Pearl River as a source of water for towns and industries along the Mississippi River is presently restricted by a Louisiana State Stutute prohibiting transport of water from St. Tammany Parish. The Louisiana Revised Statute Act of 1968, No. 284 paragraphs 1 and 2 as amended by an Act of 1972, No. 42, paragraph 1 provides that:

> No person, firm, corporation, public body, quasi-public body or political subdivision shall transport underground or surface water from the Parsih of St. Tammany to any person, firm, corporation, municipality or city located outside of said Parish; provided, however, that the provision of this section shall not be construed to prohibit any person, firm or corporation engaged in the business of selling or furnishing to consumer bottled water from wells which are situated within the said Parish.

Revision of this law would be required prior to embarking on any project to export water from the Pearl River or ground water from St. Tammany Parish.

Salt water intrusion may be a critical parameter on the lower Pearl River. For a withdrawal rate of 150 cfs from the West Pearl River below U.S. Highway 90, salt water could be expected to intrude to the point of withdrawal and remain for a seven-day period at least once every six years and remain for a fourteen-day period at least once every 7½ years (Cardwell, et. al, 1967, pp. 44-47). Withdrawals made farther upstream on the Pearl River would be limited by minimum flows rather than salt water intrusion. Above mile 29.9 on the Pearl River, where a lock is located, withdrawals equal to the minimum flow could be made. As a result of large and sustained withdrawals, however, the river downstream from the lock would become a salt water estuary during low flows.

West of the Mississippi

Surface drainage in the basin lying between the west bank of the Mississippi and east of the Bayou Lafourche ridge is characterized by sluggish canals and bayous. The Barataria Bay Basin extends from Donaldsonville, Louisiana, from mile 175 AHP down to the Gulf of Mexico. The dominant water bodies in the area are Barataria Bay at the lower end, Lakes Salvador and Cataouatche, and Lac des Allemands, which is near mile 130 AHP on the Mississippi. The water level record of the gaging station on Bayou des Allemands, which is about seven miles below Lac des Allemands, shows that flows into and out of the lake are tidally influenced. The water surface at the gaging station normally ranges between -0.5 and 2.0 feet MSL. Water surfaces in the swamps and marshes south of Lac des Allemands would be even closer to the level of the Gulf of Mexico. There are no surface water supplies in this basin which could provide a significant amount of fresh water suitable for a potable water supply on a continual basis.

Between the Bayou Lafourche ridge and the East Atchafalaya Basin Floodway Levee sources of surface water closely resemble those in the Barataria Bay basin. Sluggish bayous and drainage canals carry surface water to the Gulf. North of Donaldsonville the land is low and wet except for the natural levee banks of the Mississippi. The narrow strip of land between the Mississippi River and the Atchafalaya Basin is drained through a random pattern of bayous and drainage canals, none of which could qualify as a major source of fresh water.

The Atchafalaya will become a principal source of fresh water in south Louisiana should the Old River Control Structure be destroyed. A system of channels, pipelines and pumping stations to divert water from the Atchafalaya to satisfy the demands of the existing municipal and industrial users on the Lower Mississippi would be feasible.

Quality

The water in streams which flow into Lakes Pontchartrain and Maurepas is of satisfactory quality for use as sources of potable water. High rates of discharge are derived from surface runoff while dry weather flows consist of ground-water discharge. The concentrations of dissolved solds are generally lower than such concentrations in Mississippi River water and the water is generally softer. Color, turbidity and sediment are present (Cardwell, 1967, pp. 47-74), but pose no unusual water treatment problems.

The quality of the fresh water in the Atchafalaya basin would be essentially that of the Mississippi River. Any difference in quality would be caused by inflows from the Red River.

Ground Water

General

Three principal aquifer groups have been identified in southeastern Louisiana. They are the Miocene-Pliocene sands, Pleistocene sands, and the Mississippi River alluvium. Miocene and Pliocene sands form a vast aquifer complex in southeastern Louisiana. The system of sand layers formed by these deposits consists of fine to medium well-sorted sands with interbedded layers of clay. The Mio-Pliocene sands outcrop in Mississippi and dip and thicken to the south where they are covered by Pleistocene deposits. Sand layers range in thickness from 50 to a few hundred feet. Transmissivities usually range from 100,000 to 300,000 gpd per foot. The unconsolidated formations are many thousands of feet thick, but fresh water is found only to a maximum depth of 3500 feet in Tangipahoa Parish. Southward from Lake Pontchartrain the base of fresh water becomes increasingly shallow and is underlain by saline aquifers (LMRC, 1974, Vol. C-II, pp. 477, 481, pp. 528-531).

Pleistocene deposits overlie the Mio-Pliocene sands throughout southeastern Louisiana. These sands have not been completely flushed of salt water, and south of New Orleans they generally contain saline water. The sands are not well sorted and their transmissivities are less than 200,000 gpd per foot. Well yields of fresh water are generally low to moderate, possibly a few hundred gallons per minute. Larger yields are often obtained where the local aquifer is hydraulically connected to, and recharged by, the Mississippi River alluvium and the point-bar deposits which receive water from the Mississippi.

Total Potential Supply

Figures 4 and 5, taken from the Lower Mississippi Region Comprehensive Study, summarize the groundwater situation in the lower Mississippi Region. This study contains an estimate that the potential yield of the aquifers in Water Resources Planning Areas 8 and 10 (which include most of southeastern Louisiana from the Atchafalaya Basin to the Pearl River and a part of Amite, Wilkinson and Pike Counties, Mississippi) is 460 MGD from water table aquifers and 850 MGD from artesian aquifers (LMRC, 1974, Vol. C-1, p. 150). Pumpage of fresh ground

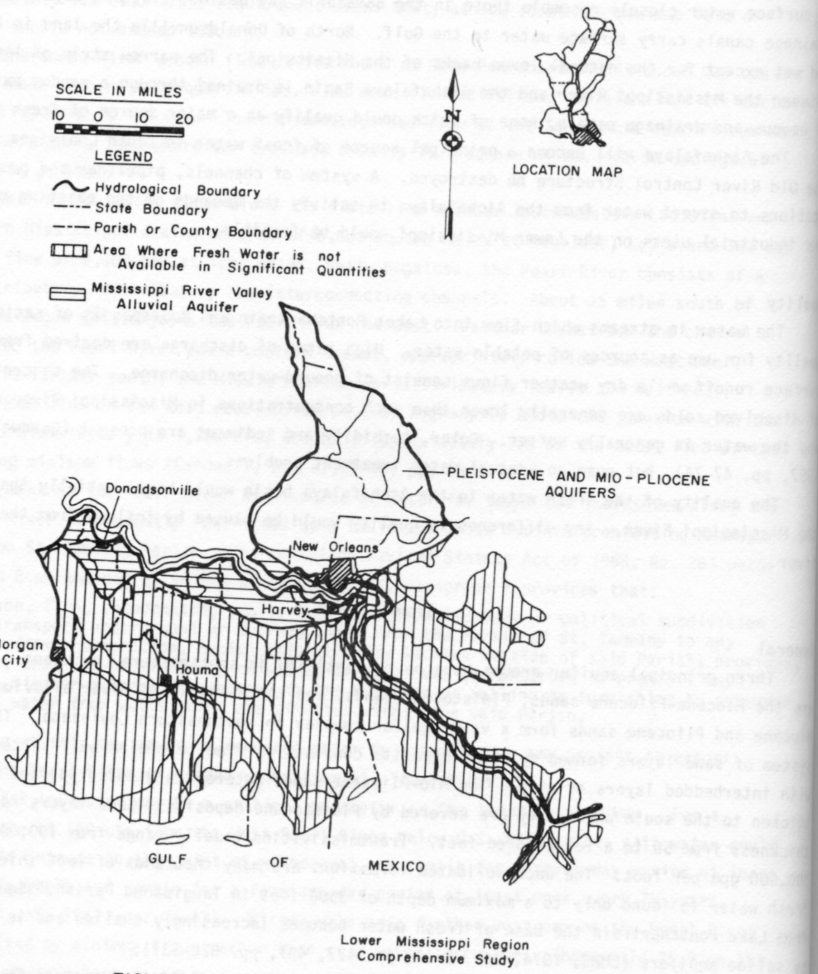


FIGURE 4. GEOLOGIC SOURCES OF GROUND WATER

water in southeastern Louisiana was about 415 MGD in 1975. The estimate of groundwater requirements in the area for 1980 is more than 600 MGD (Louisiana Department of Public Works, 1971, pp. 46, 48). Estimates of potential yield were based on pumping rates which would cause a lowering of water levels an average of 200 feet, or to the top of the aquifer in artesian aquifers, and water level declines of forty feet in water table aquifers after fifty years of pumping. The decline of water levels assumed in these estimates of potential yields included such parameters as increases in pumping costs as water levels decline, land subsidence, contamination by salt water and the effect of lowered water levels on the outcrop or recharge area. The estimates obtained are crude average values for all of southeastern Louisaina and should be used with this qualification in mind at all times.

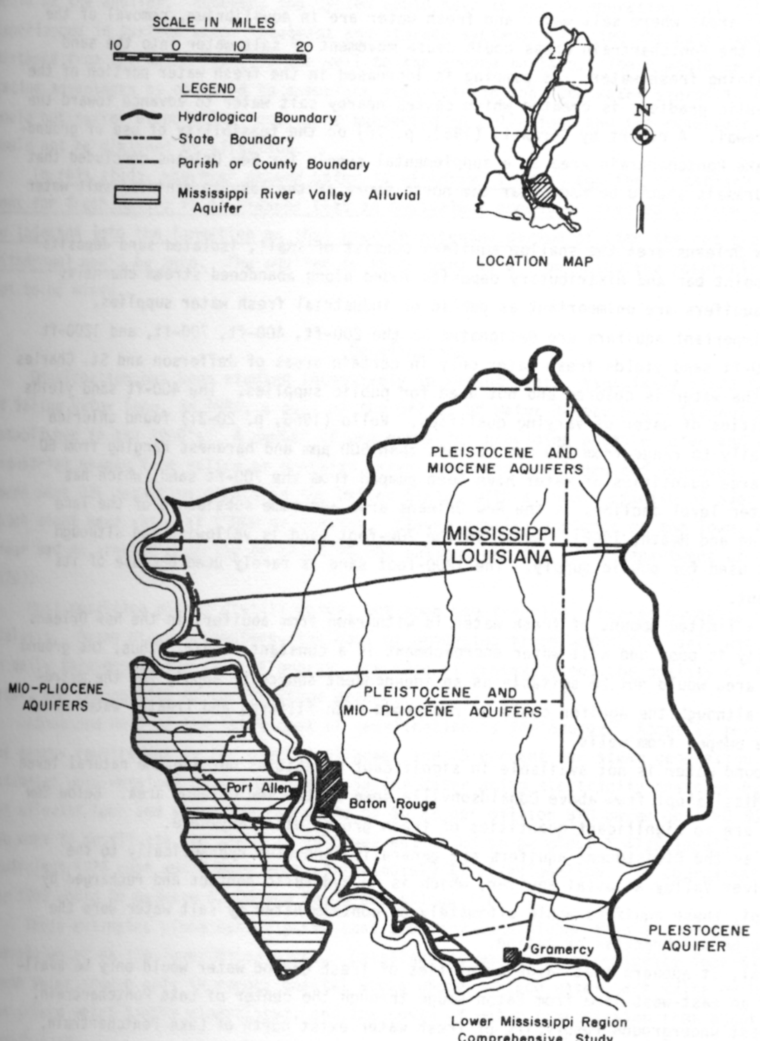


FIGURE 5. GEOLOGIC SOURCES OF GROUND WATER

In the Florida Parishes, the area north of Lake Pontchartrain, vast groundwater resources exist and flowing wells are common. There is an estimated 2×10^{14} gallons (two hundred thousand billion gallons) of fresh water underground, enough to fill a lake 100 times the area of Lake Pontchartrain to a depth of 15 feet (Winner, 1963, p. 19). These artesian aquifers have been developed as sources of fresh water for public supplies, industrial use, irrigation and rural domestic use. The fresh water aquifers are underlain by salt water throughout Louisiana. In the Florida Parishes, the deepest fresh water bearing sand is about 3500 feet below MSL. Under most of the area fresh water occurs to a depth of at least 2400 feet below MSL.

Lake Pontchartrain lies just south of the Florida Parishes. Aquifers under this lake contain both fresh and saline waters. The interface between salt water and fresh water decreases from a depth of about 3000 feet near the north shore of the lake to about 1000 feet in the south.

As in other areas where salt water and fresh water are in equilibrium, removal of the ground water in the Pontchartrain areas could cause movement of salt water into the sand presently containing fresh water. As pumping is increased in the fresh water portion of the aquifer a hydraulic gradient is created which causes nearby salt water to advance toward the point of withdrawal. A report by Cardwell (1967, p. 70) on the feasibility of use of groundwater in the Lake Pontchartrain area as a supplemental supply for New Orleans concluded that any large withdrawals should be made near the north shore of the lake to minimize salt water encroachment.

In the New Orleans area the shallow aquifers consist of small, isolated sand deposits including the point bar and distributary deposits found along abandoned stream channels. These shallow aquifers are unimportant as public or industrial fresh water supplies.

The most important aquifers are designated as the 200-ft, 400-ft, 700-ft, and 1200-ft sands. The 200-ft sand yields fresh water only in certain areas of Jefferson and St. Charles Parishes, and the water is colored and not used for public supplies. The 400-ft sand yields moderate quantities of water of varying qualities. Rollo (1966, p. 20-21) found chloride contents generally to range from 250 ppm to less than 500 ppm and hardness ranging from 80 to 268 ppm. Large quantities of water have been pumped from the 700-ft sand, which has resulted in water level declines in the New Orleans area and some subsidence of the land surface (Kazmann and Heath, 1968). Water in the 700-foot sand is yellowish and although potable is not used for public supply. The 1200-foot sand is rarely used because of its chloride content.

Although a limited amount of fresh water is withdrawn from aquifers in the New Orleans area the quality is poor and salt water encroachment is a constant threat. Thus, the ground water in this area would not be suitable as an independent source of supply for the metropolitan area, although the aquifer could be recharged with filtered and treated water which could later be pumped from wells.

Fresh ground water is not available in significant quantities outside the natural levee ridge of the Mississippi from above Donaldsonville down to the New Orleans area. Below New Orleans there are no significant quantities of fresh ground water anywhere.

Inasmuch as the Pleistocene aquifers are generally connected hydraulically to the Mississippi River Valley alluvial aquifer, which is in hydraulic contact and recharged by the Mississippi, these aquifers would ultimately be contaiminated by salt water were the Mississippi to become brackish or saline.

In general, it appears that large quantities of fresh ground water would only be available north of an east-west line from Baton Rouge through the center of Lake Pontchartrain. Even though vast underground reservoirs of fresh water exist north of Lake Pontchartrain, continuous withdrawals at rates large enough to meet all or a substantial part of the demand along the Mississippi River could eventually deplete the aquifers unless artificial recharge were undertaken.

In order to provide for a permanent water supply and to maintain water levels in the wells, the aquifers would have to be recharged artificially through a system of injection wells. Essentially, equilibrium would have to be created between withdrawal and injection. This requirement of artificial recharge increases the costs of ground water supply systems.

A fresh water surface source capable of producing at a rate equal to the total demand must be located (including the water to be used for recharge to replenish the water taken from storage). Since the water injected into aquifers must be free of solids, filtration of the water from the surface source must be provided. Finally, a transmission network and a series of injection wells would be required. It is, of course, possible that some of the wells used to produce water could be utilized as injection wells.

A ground-water production and injection system such as this would be equivalent to a normal surface water supply. It would produce water at the mean rate, with a storage reservoir of sufficient capacity to meet fluctuations in demand. In this instance the storage reservoir would be the aquifer. However, the system would have to pay an operating cost not normally experienced in surface water treatment and storage systems: lifting the water the vertical distance from the water level in the well to the ground surface. There would be some compensating advantages as compared to a surface reservoir in that the water stored in the aquifer would not suffer evaporation losses, be subjected to pollution, and the reservoir capacity would not be dimished by siltation.

In this study, wherever ground water is withdrawn from an aquifer to satisfy a requirement for fresh water, it is planned that an equivalent amount of treated surface water would be injected into the formation so that over an extended period of time the net ground water withdrawal would be zero. The aquifer is to be used as a flow balancing reservoir and is not to be mined.

Desalination

Desalination has been studied intensively in recent years, especially since the Office of Saline Water (now, in 1980, a part of the Office of Water Research and Technology) was established in the 1950's. A number of processes for providing potable water and water for industrial usages from saline or brackish water have been developed and improved. In 1971 there were 301 desalting plants in the United States with a total capacity of over 43 MGD of which eight were rated at 1 MGD or greater. Eleven desalting plants on the lower Mississippi River had an average capacity of about 90,000 gallons per day (U.S. Department of the Interior, 1970).

Most desalting plants distill water, but some use freezing, reverse osmosis, or electrodialysis. Among other parameters, the cost of producing fresh water from salt water depends on daily throughput, the cost of energy, the type of process used, the quality of feed water, and the quality of the finished product.

About one half of the total cost of desalination is for energy. About 25 percent of the energy requirement is for electrical power and 75 percent for steam generation. Cost estimates were obtained by the Office of Saline Water using electricity costs of 6.2 mils per kilowatt hour and steam heating costs of $0.22 per million BTU based on a 50 MGD unit. The cost to desalinate sea water in 1965 was estimated to be about $.47/kilogallon. The equivalent 1976 cost would have been approximately $1.25/kilogallon. An approximate estimate for 1980 would be between $2.00 and $3.00 per kilogallon.

These estimates yield cost figures that are very much higher than the present cost of potable water on the lower Mississippi. Desalination would be economically feasible as a fresh water source only in remote coastal areas where surface waters are salty or brackish, the ground water highly mineralized, and the costs of water transmission from other locations prohibitive.

Water Reuse

Continuous water reuse is already practicied in a number of processes such as in closed cycle cooling towers and in the steam generation-condensation cycle. It may find an even more widespread application if effluent limitations for wastewater discharges become more restricive. However, direct recycling of a community water supply by the use of treated sewage effluent is so rare as to be virtually nonexistent. Treated industrial waste-water could be used as a community water supply in some instances, and treated municipal wastewater could be used by some industries, but recycling of a community water supply through a waste-water treatment system would be practiced only if no other alternative were available.

There are several advanced methods of water and wastewater treatment available which can make almost any water source safe to drink. However, these methods are quite expensive and are generally considered to be practical only in the most unusual circumstances (Metcalf and Eddy, 1972 and Clark et. al, 1977).

If the Mississippi River's flow should be diverted, industries using river water would be forced to practice reuse by recycling their water supplies to the maximum extent possible because the cost of fresh water would increase, and this added cost would improve the economic desirability of conservation. It is, however, highly unlikely that any of the communities along the lower Mississippi would attempt to recycle wastewater for municipal use since alternate sources of fresh water are available.

VII

ALTERNATE FRESH WATER SUPPLIES

Introduction

Most of the industries and population centers in southeastern Louisiana which utilize the fresh water of the Mississippi are located along its banks and on the narrow natural levees of Bayou Lafourche. Few alternative surface water sources have been developed because the Mississippi has been a dependable source in the past, although ground water is used in limited quantities through the region.

The demand for fresh water is unevenly distributed along the river banks from just above Baton Rouge to below Venice. Consequently, the feasibility of alternatives varies from place to place along the river. The immediate solution to a fresh water crisis would most probably consist of a number of local solutions rather than a single, regional one. It is possible that in time a water authority might be established to develop a region-wide supply, but this would be accomplished by the cooperation of local organizations in response to economic and physical circumstances.

This study addresses the initial problems that would be studied by any planning organization whose task it would be to delineate feasible alternate, and permanent, water supplies for the large numbers of users along the Mississippi. This study is actually an initial screening of possible alternative sources of fresh water to determine which of them might be suitable for more detailed investigation.

The dominant geologic feature of the region is the Mississippi River trench. With the freshwater flow reduced or eliminated, scour and deposition would virtually cease and the River would no longer be a formidable barrier to water transmission lines. Water could be transferred from one side of the river to the other with few complications. This would eliminate the necessity of having to maintain a strict division between supplies for the East bank and West bank.

Clearly a number of alternative arrangement can be made to transfer various quantities of fresh water from several locations to the customers. Although no attempt has been made to determine the optimum course of action, preliminary cost estimates have been made for some of the more feasible alternatives.

North of Baton Rouge and in the Baton Rouge Metropolitan area, ground water is a logical alternative source of the total fresh water supply for both public and industrial consumption because of its quality and availability. It is already the principal source of potable water as shown by the pumpage data in Table I. In East and West Baton Rouge Parishes, West Feliciana, and Point Coupee, all 47.0 MGD of the public water supply is derived from ground water. For industries and electric generating stations, about 40 percent of the water used was ground-water. If total demand by industry were reduced by 90 percent through various conservation practices, the present rate of groundwater withdrawals would, theoretically, meet the total industrial and thermo-electric consumption requirements. The water is available in the aquifers but wells would have to be installed in locations where the water is used, or it would have to be piped from existing well sites to the consumer.

In the Baton Rouge area and the parishes upstream, the replacement of the Mississippi as a surface water source would pose no serious problems, nor would it be an expensive matter.

Two alternative approaches to the problem of supplying fresh water to users of the Mississippi River downstream from the Baton Rouge area were considered. Both alternatives consisted of providing water from several sources. The fresh water supply for the New Orleans metropolitan area and those consumers downstream from New Orleans would be obtained from the Pearl River, supplemented by well fields northeast of Lake Pontchartrain. This source was the same in both alternatives.

Alternate Water Supply Plan A

For this analysis the region below East and West Baton Rouge Parishes was divided into four segments as shown in Figure 6. Segment 1 encompasses the New Orleans metropolitan area: the parishes of Jefferson, Orleans, and St. Bernard. Segment 2 consists of both banks of the Mississippi in St. James, Ascension, Assumption, Plaquemines, and Iberville Parishes, and Bayou Lafourche. Segment 3 is composed of the sparsely populated areas along the Mississippi south of New Orleans. St. Charles and St. John the Baptist Parishes made up Segment 4. Breakdown of water demands by parishes and segments, as well as type are shown in Tables V and VI.

TABLE V.
WATER REQUIREMENTS BY PARISH AND TYPE

Parish	Public	Industrial	Thermoelectric
Ascension	1.8	12.7	0.0
Assumption	1.6	1.1	0.0
Iberville	1.4	73.4	11.8
Jefferson	58.4	3.9	45.3
Lafourche	7.6	3.2	0.0
Orleans	131.3	2.1	18.4
Plaquemines	6.4	5.5	0.0
St. Bernard	9.0	61.7	0.0
St. Charles	5.0	66.1	46.5
St. James	1.7	30.4	0.0
St. John the Baptist	2.4	9.9	0.0
Totals	226.6	270.0	122.0

Requirements given in MGD (Million gallons per day)

Source: U.S. Geological Survey Files for Water Pumpage in 1975.

TABLE VI.
WATER REQUIREMENTS BY SEGMENTS
(Million Gallons a Day, Rounded Figures)

Segment No.	Public	Industrial	Thermoelectric	Total
1	200	70	60	330
2	15	120	10	145
3	5	5	0	10
4	10	75	45	130
TOTALS	230	270	115	615

Combined by segments from Table V.

Segment No. 1 - New Orleans Metropolitan Area

As shown in Table VI, the New Orleans metropolitan area would have an average requirement of approximately 330 MGD. Municipal requirements would be 200 MGD, industrial 70 MGD and thermoelectric 60 MGD.

Ground water and alternate surface water supplies have been studied intermittently as sources to satisfy the fresh water requirements of the New Orleans Metropolitan area. The total dependence of the metropolitan area on the Mississippi River has caused operational problems in the past because of salt water intrusion from the Gulf to the river intakes on the Mississippi during periods of low flow in the river. Moreover there exists a constant

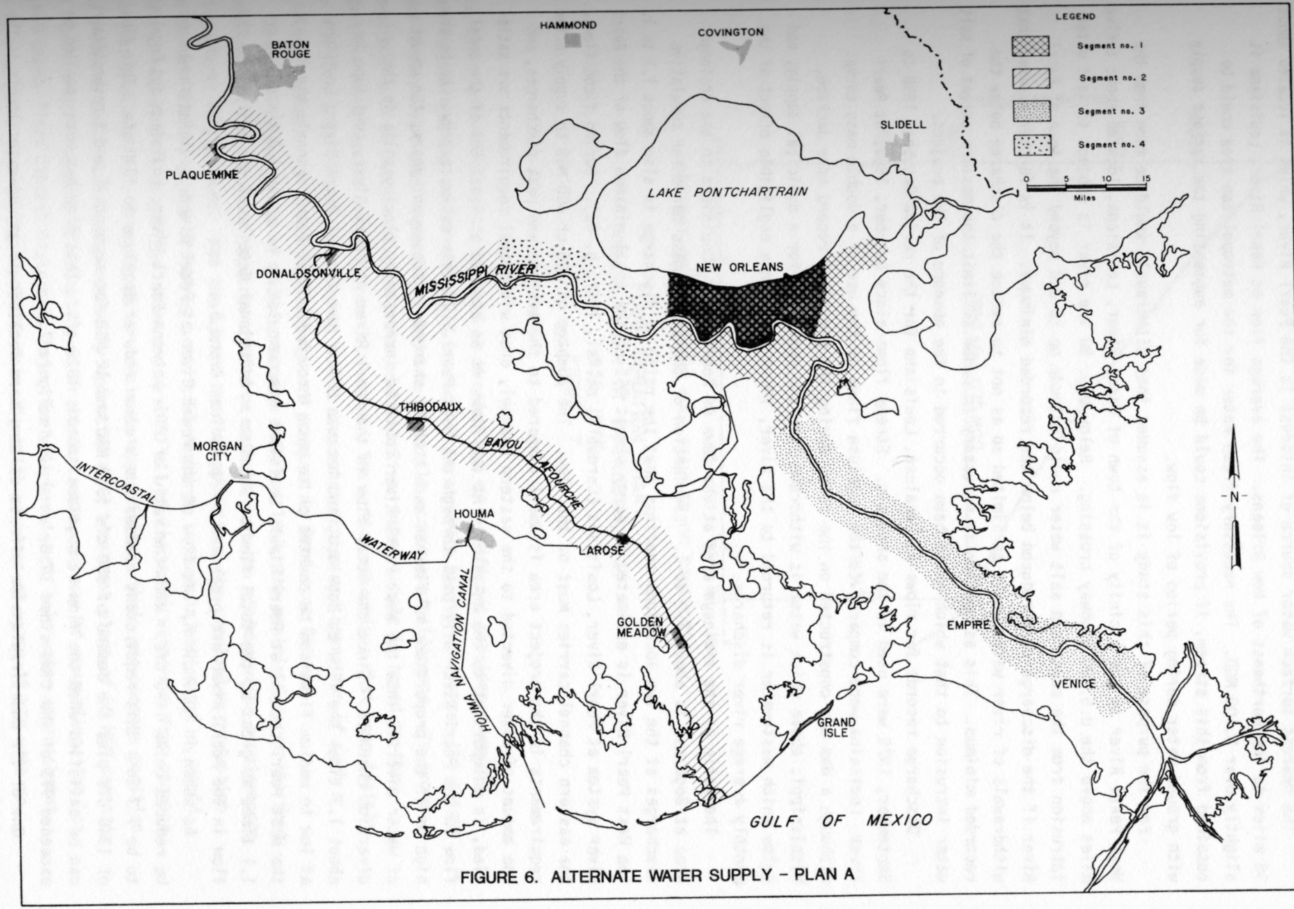


FIGURE 6. ALTERNATE WATER SUPPLY - PLAN A

hazard from pollution due to industrial or shipping accidents, not to mention the gradual increase in concentration of various pollutants in the river water, despite the best effor of local, state and Federal agencies.

The nearest surface water source of interest is the Pearl River, which is located abo 35 miles to the northeast of New Orleans. The average flow at Pearl River, Louisiana is slightly over 6,100 MGD. The necessary fresh water for the metropolitan area could be obtained from this stream, if provisions could be made for augmenting the surface supply with ground water during period of low flow.

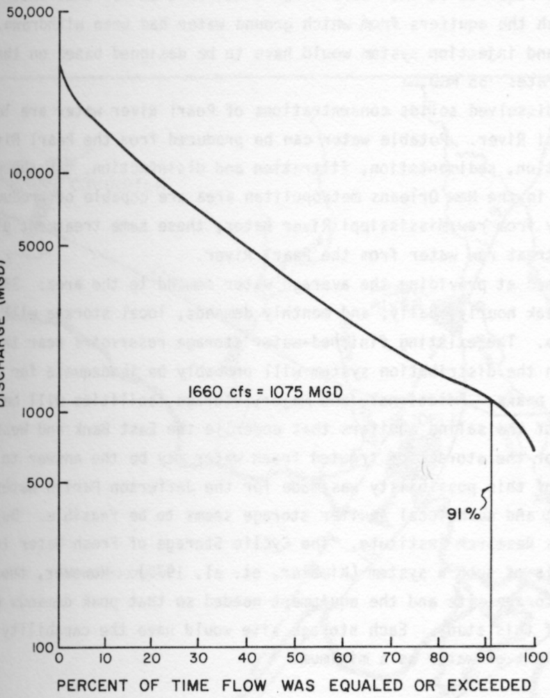
For the purpose of this study it is assumed that withdrawals would be made from the West Pearl River in the vicinity of the town of Pearl River, Louisiana, located about twel miles above the U.S. 90 highway crossing. Below U.S. 90 the river is subject to salt water intrusion from the south and salt water could intrude up to and beyond the town of Pearl River if the discharge were reduced below the recorded minimums. It is further assumed tha withdrawals of river water would be limited so as not to reduce the discharge below the recorded minimum. This assumption is necessary in order to limit the maximum extent of sal water intrusion to that which would have occurred in the absence of the project.

Discharge records for flows at Bogalusa, Louisiana for the period October, 1938 to September, 1975 were used in the analysis. Stream flows since October, 1963, at Pearl River, Louisaina were compared to the Bogalusa flows by the use of a double mass curve. Although a dam was constructed on the river during the period of record near Jackson, Mississippi, above which water is withdrawn from the reservoir for a municipal supply, and below which wastewater is returned to the river, there has been a negligible effect of the monthly average river discharge.

The ratio of the drainage area at the town of Pearl River, Louisiana to the drainage area at Bogalusa is about 1.3 to 1. Examination of the double mass curve for cumulative discharges at the two locations confirms that the ratio of discharge is also about 1.3 to 1. The West Pearl River is estimated to carry almost 95% of the total minimum flow of the Pearl River system at Pearl River, Louisiana (Cardwell, et. al, 1967, p. 43). During flood flows, the eastern channel carries most of the flow. The pumpage of 300 or 400 MGD to supply water requirements in the project area is small compared to the average and peak discharges, and the amount of water diverted to the eastern channel, once withdrawal requirements are satisfied, is unimportant to the anlyasis. At low flows it is assumed at least 85% of the total flow in the Pearl River will pass through the West Pearl. If this estimate proves to be too high or if the proportions of flow in each channel changed in subsequent years, the amount of water diverted into the West Pearl River could be increased by placing sills in the diversion channels. Since the total flow in the Pearl River at Pearl River, Louisiana is about 1.3 times the flow at Bogalusa, and because 85% of the flow at Pearl River, Louisiana at low to medium flows can be counted on to pass through the West Pearl channel, the flow in the West Pearl channel at Pearl River, Louisiana was computed to be about 1.3 times 85%, or 1.1 times as great as the total flow at Bogalusa. Additional details of the analysis of the flow in the Pearl River are presented in Appendices A and B.

As shown in Appendix A, the flow of the Pearl River at Pearl River, Louisina should not be reduced below 1470 cfs. With the ratio of flow between Pearl River, Louisiana and Bogalusa to be 1.3 to 1 this requirement reduces the minimum flow at Bogalusa to 1340 cfs. This flow of 1340 cfs plus the demand of 530 cfs (330 MGD and 12 MGD for segments 1 and 3 respectively) can be satisfied when the flow at Bogalusa exceeds 1870 cfs. This flow has been equalled or exceeded 91% of the time since 1938, as shown in Figure 7.

One of the undesirable side effects of long term declines in ground-water levels is the gradual subsidence of the land surface. Consequently any scheme of surface water use which involves the use of ground-water storage should include the replenishment of the aquifers when surplus surface water is available. Thus over relatively short periods, say five



FLOW DURATION CHART
PEARL RIVER AT BOGALUSA, LA.
1938-1975
FIGURE 7.

years, major water-level declines would be avoided and no significant subsidence would occur. Moreover, as the well field would be located in a rural, unurbanized area, the slight amount of subsidence that might occur would be of little economic significance. To avoid side-effects such as subsidence, the proposed Pearl River water supply is based on the conjunctive use of ground water and surface water. The writer recognizes that some legislation will have to be altered in order to permit the construction and operation of such a conjunctive system. The following analysis was prepared by Professor Kazmann.

During the driest period of record, between 1954 and 1957, the monthly flow of the West Pearl River was less than the required discharge rate to meet the minimum water requirements during several long periods. Had the system been in operation, the cumulative production from the well fields, partly offset by artificial recharge through injection wells, would have been some 60 billion gallons. However, by 1960 all of the water withdrawn from storage would have been replaced, bringing water levels to approximately their pre-pumpage position. This condition would have been produced by operation of a treatment plant of 55 MGD capactiy and injection wells capable of accepting water at that rate. By way of comparison, the Los Angeles County Flood Control District's injection well barrier to salt water encroachment has injected water from the Metropolitan Water District at rates of up to 40 MGD with no operating difficulties. Of course if a larger treatment plant were built, recharge could be maintained at a higher rate and the cumulative amount taken from groundwater storage would be less. The exact size of the treatment plant will have to be determined after detailed studies have been completed.

The only treatment required at the Pearl River site would be for that water which must be injected to replenish the aquifers from which ground water had been withdrawn. This water treatment plant and injection system would have to be designed based on the long term average replenishment rate: 55 MGD.

The hardness and dissolved solids concentrations of Pearl River water are lower than those of the Mississippi River. Potable water can be produced from the Pearl River with the application of coagulation, sedimentation, filtration and disinfection. As the existing water treatment plants in the New Orleans metropolitan area are capable of producing a water of satisfactory quality from raw Mississippi River water, these same treatment plants could readily be adapted to treat raw water from the Pearl River.

This study has aimed at providing the average water demand to the area: 330 MGD. In order to satisfy the peak hourly, daily, and monthly demands, local storage will be required in the New Orleans area. The existing finished-water storage reservoirs near the New Orleans treatment plants and in the distribution system will probably be inadequate for anything except hourly or daily peaks. Adidtional, and major, storage facilities will be needed.

The use of parts of the saline aquifers that underlie the East Bank and West Bank of the New Orleans area for the storage of treated fresh water may be the answer to the storage requirement. A study of this possibility was made for the Jefferson Parish Water Department (Kazmann et. al., 1974) and such local aquifer storage seems to be feasible. Bulletin 10 of the La. Water Resources Research Institute, "The Cyclic Storage of Fresh Water in Saline Aquifers", gives details of such a system (Kimbler, et. al. 1975). However, the capacity and location of each storage site and the equipment needed so that peak demands can be met are beyond the scope of this study. Each storage site would have the capability of storing one or two billion gallons of water as a minimum.

Costs

Water from Pearl River and from wells in St. Tammany Parish would have to be treated, delivered, and paid for by the water users in the project area. A preliminary general estimate of the cost of such a project is useful in comparing the cost of this alternative water source to other possible actions which may be taken to insure that an adequate supply of fresh water is always available.

Cost data were obtained from several sources. Estimates from contractors and actual construction estimates from bids on facilities comparable to portions of this project were used. A local utility company provided a schedule of rates which was used to compute power costs. Additional cost information is presented in Appendix C.

The system would have to deliver the 330 MGD for Segment 1, and 10 MGD for Segment 3 to the New Orleans metropolitan area. A possible location for the transmission pipe lines from Pearl River to the metropolitan area is shown in Figure 8. A dual pipe line would run from the Pearl River about 1.1 miles above the U.S. Highway 11 bridge, to the southeast shore of Lake Pontchartrain in the vicinity of Little Woods. It would then follow Parish Road south across the Intracoastal Waterway to Chalmette where it would supply the St. Bernard Water Works and local industries. Also at this point the requirements for Segment 3 would be obtained from the feeder line. The dual main lines would then cross the Mississippi and follow the west bank levee right of way upstream to serve the Algiers, Gretna, Westwego and Marrero Water Works, and the various industrial users along this reach. The lines would continue upstream to the vicinity of Nine Mile Point where they would supply the water for the power generating plant, then cross the Mississippi back to the East Bank to supply the Carrollton Water Works (New Orleans Metropolitan area treatment plant) and the Jefferson Parish Water Works.

Although this is probably the more expensive routing, it has the advantage that it would supply the water to the users at their existing intakes and thus would minimize the

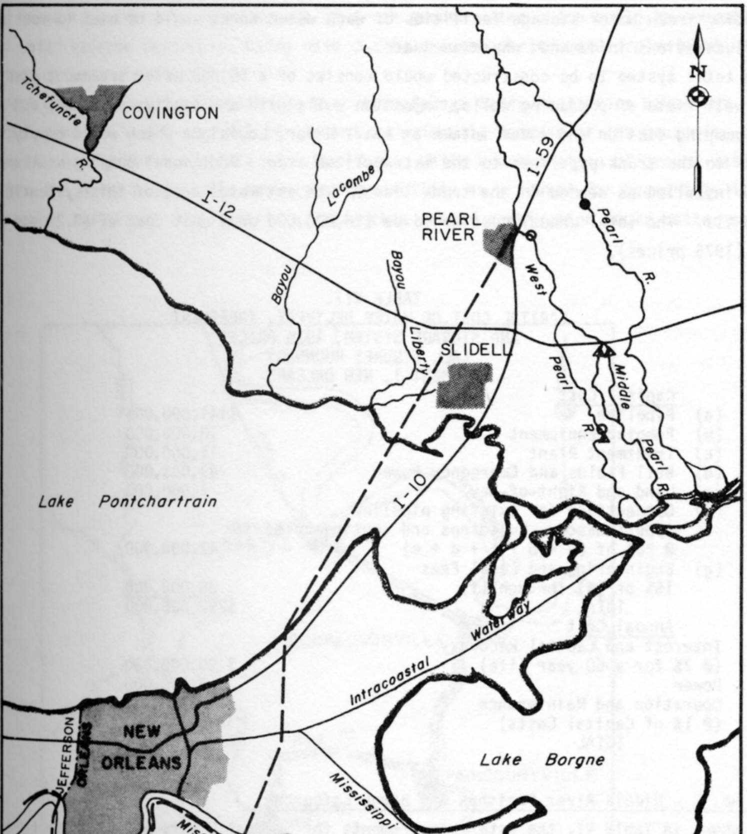


FIGURE 8. ALTERNATE A, SEGMENTS 1 AND 3

need of modifying existing facilities. These savings would more than justify the additional cost for this routing system. Also, since the Mississippi River levee rights of way would be used, there would be a minimal amount of disruption or dislocation in the communities. The existing fresh water storage facilities of each water works would be used to meet part of the fluctuations in demand, where adequate.

The total system to be constructed would consist of a 55 MGD water treatment plant, a 340 MGD well field of producing wells, injection wells with a capacity of 55 MGD, and a 340 MGD pumping station and river intake at Pearl River, Louisiana which would supply the raw water to the trunk pipelines to the metropolitan area. Additional pumping stations would be installed as needed in the trunk lines. The estimated cost of this system is shown in Table VII. The total annual cost would be $26,000,000 or a unit cost of $0.22 per 1000 gallons (1976 prices).

TABLE VII.
CAPITAL COST OF WATER DELIVERY, TREATMENT AND STORAGE SYSTEM, 1976 PRICES
(ALL FIGURES ROUNDED)
SEGMENT 1, NEW ORLEANS

Capital Cost	
(a) Pipeline	$141,000,000
(b) Pumping Equipment	10,000,000
(c) Treatment Plant	11,000,000
(d) Well Fields and Emergency Power	49,000,000
(e) Land and Right-of-Way	1,000,000
(f) Connections for existing pipeline, Appurtenances, buildings and contingencies @ 20% of (a + b + c + d + e)	42,000,000
(g) Engineering and Legal Fees 15% of (a) through (f)	38,000,000
TOTAL	$292,000,000
Annual Cost	
Interest and Capital Recovery (@ 7% for a 50 year life)	$ 20,000,000
Power	3,500,000
Operation and Maintenance (@ 1% of Capital Costs)	2,500,000
TOTAL	$ 26,000,000

Segment No. 2 - Middle River Parishes and Bayou Lafourche

As shown in Table VI, the water requirements for Segment 2 were estimated to be 15 MGD for public, 120 for industrial and 10 for thermo-electric plants, for a total of 145 MGD.

To the northeast, the nearest major surface water stream is the Amite River, which has an average daily flow of about 1675 MGD at its mouth. It is about fifteen miles east of the Mississippi River. The minimum flow on the lower river is about 230 MGD, which is slightly more than the average water requirements for this area.

The nearest substantial stream to the west would be in the Atchafalaya Basin. The East Atchafalaya Basin Protection Levee lies about twelve miles away from the Mississippi in the vicinity of Plaquemine. The distance to this levee increases gradually to about twenty-five miles in central St. James Parish. With the Mississippi River flow passing through the Atchafalaya Basin, a substantial discharge could be maintained in the Grand River and the Intracoastal Waterway which both pass along the inside of the East Atchafalaya Basin Protection Levee. The freshwater requirement for Segment 2 could be satisfied with a withdrawal from any location along this waterway.

Groundwater in Segment 2 is found in the Mio-Pliocene deposits and the Mississippi alluvium as discussed earler in the paper. To the east, beneath Lake Pontchartrain and in the parishes to the north and east, vast quantities of ground water of relatively good quality are available.

Fresh ground water along the Mississippi between Baton Rouge and New Orleans is found in relatively shallow sands which are thought to be hydraulically connected to the Mississippi

River. Salt water intrusion into the river channel would probably increase the salinities of these aquifers in a very short time, especially if they were pumped at the needed rates of withdrawals to meet the demand of Segment 2. Thus, it is believed that the deeper aquifers to the east constitute the only large source of fresh ground water which could be operated as a cyclic water storage reservoir, being used during drought periods and replenished during periods of adequate flow.

The fresh water stream just inside the East Atchafalaya Basin Protection Levee was chosen as the source of supply for all of Segment 2, primarily because of its proximity to Bayou Lafourche and Iberville and Ascension Parishes. While a combination of ground water and water from the Amite River would be another possibility as a source for Segment 2, it is believed, pending additional investigations, that this latter combination would better serve Segment 4.

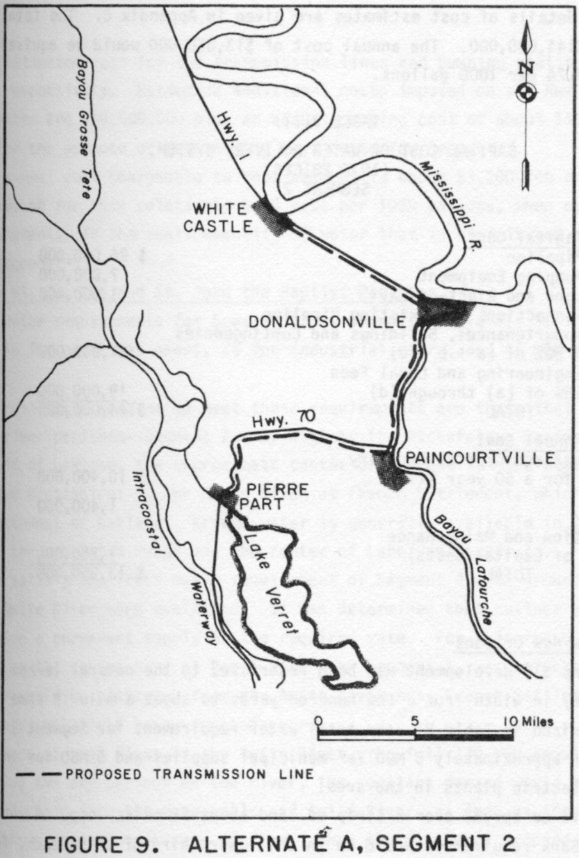


FIGURE 9. ALTERNATE A, SEGMENT 2

The fresh water supply system for Segment 2 includes a single 150.0 MGD pumping station (145 MGD requirement, rounded off) at the East Atchafala Basin Protection Levee near Pierre Part, with transmission lines from there generally following the roadways and railroad lines to Bayou Lafourche, to the Mississippi River at White Castle, all as shown in Figure 9. The untreated water is then delivered up and down stream from these points to the existing fresh water intakes of all users. Along the Mississippi the water transmission lines are placed in the right of way of the levees (which would be allowable if the Mississippi no longer reached flood stage downstream of ORCS). This would be done in order to minimize disruptions to communities and existing facilities. Lack of information as to the exact location of the sites of fresh water demand along the reach made the actual design of a functional distribution system impossible. Some existing intake structures were located, such as municipal water treatment plants and some steam electric generating plants. Representative average flows were assumed using these exact locations and demands, combined with estimated flows for the rest of the users to determine transmission line sizes.

Costs

The cost estimates for the fresh water delivery system for Segment 2 are summarized in Table VIII. Further details of cost estimates are given in Appendix C. The total capital cost would be about $144,000,000. The annual cost of $13,050,000 would be equivalent to a unit cost of about $0.24 per 1000 gallons.

TABLE VIII.
CAPITAL COST OF WATER DELIVERY SYSTEM,
(1976 PRICES)
SEGMENT 2

Capital Cost	
(a) Pipeline	$ 96,000,000
(b) Pumping Equipment	7,000,000
(c) Land and Right-of-Way	1,000,000
(d) Connections for Existing Pipeline, Appurtenances, Buildings and Contingencies @ 20% of (a + b + c)	21,000,000
(e) Engineering and Legal Fees 15% of (a) through (d)	19,000,000
TOTAL	$144,000,000
Annual Cost	
Interest and Capital Recovery (@ 7% for a 50 year life)	$ 10,400,000
Power	1,400,000
Operation and Maintenance (@ 1% of Capital Costs)	1,250,000
TOTAL	$ 13,050,000

Segment No. 3 - Below New Orleans

Below New Orleans all development has been restricted to the natural levees of the Mississippi which vary in width from a few hundred yards to about a mile in some locations. Using the data summarized in Table VI, the total water requirement for Segment 3 would be 10 MGD, consisting of approximately 5 MGD for municipal supplies and 5 MGD for industry. There are no thermoelectric plants in the area.

This demand would be spread over a strip of land about 65 miles long. A substantial portion of the West Bank requirement would be in the lower third of this reach, from Empire at mile 30 AHP down to Venice at mile 10 AHP. There are no communities on the east bank of the Mississippi below Pointe a la Hache at mile 50 AHP.

In Plaquemines Parish no significant quantities of fresh groundwater are available anywhere. The few shallow sands that do contain fresh water are connected hydraulically to the Mississippi River and thus would become saline should the river become a salt water estuary. There is no fresh surface water available in the area due to the low relief of the land and its proximity to the Gulf of Mexico. The nearest surface water stream that could provide an adequate amount of fresh water to Segment 3 is the Pearl River. As outlined in the discussion for Segment 1, the water requirement of Segment 3 would be met with water from the Pearl River - New Orleans transmission system. The water would be transported by pipeline from Algiers, down the west bank of the Mississippi to Venice, and delivered to the existing intakes of the water users.

The cost of furnishing the water to the point of offtake described above was included in the cost analysis for Segment 1. The additional costs for Segment 3 are for a transmission line down the west bank of the Mississippi levee to serve all customers, with river crossings to Dalcour and Pointe a la Hache on the east bank. With the Mississippi River water diverted, these river crossings could be made at reasonable cost.

From Algiers to Belle Chasse the line would carry the full 10 MGD. The Belle Chasse water plant serves about 40 percent of the total population. To meet the requirements for the remainder of the population and industries south of Belle Chasse, a line of 9 MGD capacity would suffice.

Costs

The total estimated cost for the transmission lines and pumping stations are $19,600,000 and $1,200,000 respectively. Estimated additional costs imposed on the New Orleans Metropolitan System are $10,500,000 plus an annual pumping cost of about $500,000, and are included here for the purpose of determining unit costs for Segment 3.

The total annual cost chargeable to this segment is about $3,200,000 or $0.89 per 1000 gallons. The reason for this relatively high cost per 1000 gallons, when compared to costs for the other segments, is the small quantity of water that is distributed over the long reach of this segment.

Segment No. 4 - St. Charles and St. John the Baptist Parishes

The total water requirements for Segment 4, as shown in Table VI, is 130 MGD. Of this amount, 10 MGD is for municipal users, 75 for industrial users, and 45 MGD for thermoelectric plants.

Possible fresh water sources to meet these requirements are those that are available for the middle river parishes--Segment 2. By highway the Atchafalaya Basin lies some 65 miles to the west of LaPlace, the approximate center of Segment 4. The nearest surface water east of the Mississippi is the Amite River at French Settlement, which is about 40 miles to the northwest of LaPlace. Ground water is generally available in large quantities north of a line through Baton Rouge and the center of Lake Pontchartrain.

Systems to satisfy the fresh water requirement of Segment 4 with groundwater and with water from the Amite River were evaluated. It was determined that neither would be sufficient to provide a permanent supply at the required rate. For this reason a combined system, similar to the system used at Pearl River for Segment 1, was selected as the most feasible. Water would be withdrawn from the Amite River near French Settlement, with a large dual-purpose well field being located nearby.

During periods of high flows on the Amite River, the full 130 MGD requirement could be withdrawn. During the dry periods on the river, the constant demand would be supplied from the combined production from the deep wells and Amite River, as long as the discharge of the river remained above some minimal rate of flow. When the discharge dropped to or below this minimum, the total demand would be satisfied by the wells. During the periods of sufficiently high discharge in the Amite River, water that would otherwise be wasted would be withdrawn from the river, treated, and injected into the aquifers to replenish them. Figure 10 shows the route of the distribution line.

The nearest gaging station on the Amite River for which stream-flows are published is at Denham Springs, some 25 miles upstream from French Settlement. While there are several tributaries to the river between these two locations, they are minor and the flows at French

Settlement are properly represented by the record of discharge at Denham Springs.

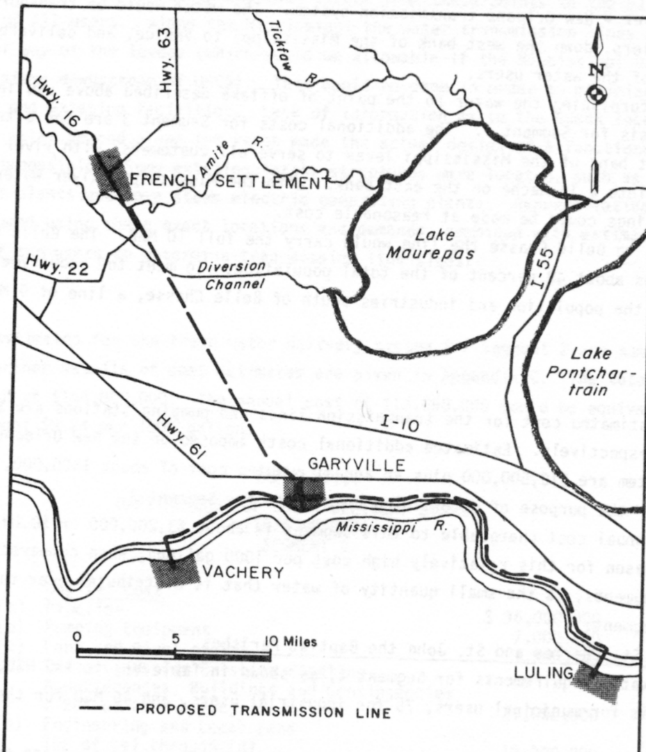


FIGURE 10. ALTERNATE A, SEGMENT 4

The minimum recorded daily flow at Denham Springs was 270 cfs. On the assumption that withdrawals at French Settlement for this project should not decrease the natural flow below 300 cfs, the average demand of 200 cfs (130 MGD), could be completely satisfied from the Amite River whenever the stream flow was more than 500 cfs.

A frequency analysis of streamflows between 1938 and 1970 (LMRCSCC, 1974) shows that the average flow for a 30 day period would be less than 300 cfs about once every 20 years. The average streamflow for a seven day period would be less than 300 cfs about once every eight years. Similar analyses show that on the average the discharge would not satisfy the 200 cfs demand and still leave 300 cfs as unregulated flow for 30 days about twice every three years.

To determine the size of the water treatment plant necessary to process the Amite River water for injection a mass curve analysis was made. The minimum withdrawal rate from the Amite River was determined which would provide enough water during the wet months to offset the steady demand on the aquifers during the dry months of the worst four-year period of record. The worst four-year period was determined to be the years 1966 through 1969. During these four years the monthly average stream flows in the dry months would have resulted in the greatest cumulative shortage: 14 billion gallons over a 13-month period. The aquifers in the area would be mined at this rate to make up the surface water shortage. To replenish the aquifers during the other 35 months of the four year period would require recharge at an average rate of about 15 Million gallons a day, about 25 cubic ft/sec.

For the system to be adequate, it would require a 15 MGD water treatment plant and injection well system, a 225 cfs pumping station (200 cfs demand and 25 cfs for well replenishment), and 50 production wells. A single 78-inch diameter transmission line would carry the 200 cfs to the Mississippi river bank at Garyville, 30 miles away. From that point a 10-inch line would run upstream to a point opposite Vacherie, and a 72-inch line would carry the water downstream as shown in Figure 10. River crossings would be located as needed to get water to users on the West Bank.

The production well system would consist of a series of 50 wells in the vicinity of French Settlement, each producing 1800 gpm. Although it is not possible to pinpoint exactly where the wells might be located, a general area where substantial fresh water aquifers occur was outlined (Cardwell and Rollo, 1960; Winner, 1963), and cost estimates are based on those assumed locations. Small changes in the location of the well field or in the alignment of the transmission lines would not alter the overall estimated costs significantly.

As in the other segments, the raw untreated water would be delivered to the customers at their existing water intakes. Water treatment and storage would be provided by the individual customers according to their needs.

Costs

The cost estimates for this segment are presented in Table IX. Additional details of the costs estimated are presented in Appendix C. The total annual cost of $11,800,000 for this portion of the project is equivalent to about $0.25 per 1000 gallons.

TABLE IX.
COST ESTIMATES OF WATER WITHDRAWALS, REPLENISHMENT, AND DELIVERY (1976 PRICES ALL FIGURES ROUNDED)
SEGMENT 4

	Capital Cost	
(a)	Pipeline	$ 58,000,000
(b)	Pumping Equipment	3,000,000
(c)	Treatment Plant	4,000,000
(d)	Well Fields, Emergency Power	32,000,000
(e)	Land & Right-of-Way	1,000,000
(f)	Connections to Existing Systems, Appurtenances, Contingencies @ 20% of (a + b + c + d + e)	20,000,000
(g)	Engineering & Legal Fees @ 15% of (a + b + c + d + e + f)	18,000,000
	TOTAL	$136,000,000
	Annual Costs	
	Interest & Capital Recovery (@ 7%, 50 year life)	$ 9,800,000
	Power	800,000
	Operation & Maintenance (@ 1% of Capital Costs)	1,200,000
		$ 11,800,000

Alternate Water Supply Plan B

Several other alternate water supplies were evaluated, independently, by other researchers. Some were eliminated as not being feasible. Alternate B finally selected consisted of a combination of portions of Alternate A, modifications of other portions of Alternate A, and completely different systems for other portions.

The system developed in Alternate A for segments 1 and 3 were used in Alternate Plan B as the most practicable solution. All other water requirements for the East Bank would be taken from Amite River deep well system as described in Segment 4 of Alternate A. All water for the West Bank users would come from the Atchafalaya Basin.

East Bank Requirements

Other than those parishes included in Segments 1 and 3 of Alternate A, water requirements on the East Bank in the study area are those in Ascension, Iberville, St. Charles, St. James, and St. John the Baptist Parishes. The total requirement for these parishes on the East Bank (some of the parishes are located on both banks) was estimated at about 140 MGD. This estimate was based on an investigation of industrial and municipal site locations on maps furnished by Illinois Central Gulf, Industrial Development Department, revised March, 1976 and Waste Discharge Data furnished in the State of Louisiana Water Quality Management Plan of the Lower Mississippi River Basin, revised March 1974, pp. 39-43, and therefore are considered quite reasonable.

This total requirement of 140 MGD (220 cfs) is slightly more than required at the Amite River deep well system detailed in Segment 4 of Alternate A. This would require four or five additional 1800 gpm deep wells above the 50 required in Alternate A. A similar study of the mass curves indicates that during this period requiring a recharge rate of about 18 MGD during the 35 wetter months of the four year period.

The system at the Amite River would consist of a water treatment plant (18-20 MGD) and an injection well system, a 245 cfs pumping station to supply the current demand plus water for aquifer replenishment and 54 production wells. Each well would be capable of producing at a rate of 1800 gpm, and be located in the vicinity of French Settlement.

The transmission line would follow Louisiana Highway 22 from French Settlement to Burnside, approximately 16 miles. At Burnside, part of the flow would be diverted upstream and the remainder downstream to supply all users in the five parishes included in this phase of the study. The transmission lines would follow the Old River Road so that the water would be supplied to all users at their present intake structures. Locations of the intakes of major users were estimated from maps and the flow passing downstream was reduced accordingly. This made possible a reduction in pipe sizes along the 29 mile stretch upstream and 55 mile stretch downstream. Since the intakes could not be precisely pinpointed, nor actual demands determined, the flows and pipe sizes determined are, at best, reasonable estimates.

Costs

The cost estimates for this phase are presented in Table X. Additional details of cost estimates are presented in Appendix C. The total annual costs of $13,300,000 for this phase of the study gives a unit rate of $0.26 per 1000 gallons.

TABLE X.
COST ESTIMATES OF WATER WITHDRAWALS,
REPLENISHMENT, AND DELIVERY
(1976 PRICES, ALL FIGURES ROUNDED)
Alternate Plan B--East Bank

	Capital Cost	
(a)	Pipeline	$ 71,000,000
(b)	Pumping Equipment	5,000,000
(c)	Well Fields and Emergency Power	33,000,000
(d)	Land and Right-of-Way	1,000,000
(e)	Connections to Existing Systems, Appurtenances, Contingencies @ 20% of (a + b + c + d)	22,000,000
(f)	Engineering & Legal Fees @ 15% of (a + b + c + d + e)	20,000,000
	TOTAL	$152,000,000
	Annual Costs	
	Interest & Capital Recovery (@ 7%, 50 year life)	$10,600,000
	Power	1,400,000
	Operation and Maintenance (@ 1% of Capital Costs)	1,300,000
	TOTAL	$13,300,000

West Bank Requirements

Should the Atchafalaya capture the Mississippi River, it is only reasonable to look to the Atchafalaya River to meet the total demands of all users of fresh water on the West Bank of the Mississippi River. The problem is to find the most feasible method to get this water to the respective users. One possibility is to pump water from the Atchafalaya at Bayou Sorrell Lock into the Intracoastal Waterway. This would bring water to Plaquemine, Louisiana and close to Bayou Lafourche. However, the Intracoastal Waterway is not a reliable source of fresh water if it continues to serve as a navigable waterway for barge traffic.

Several alternates to this scheme were investigated, and it was decided to bring the water from the Atchafalaya Basin to the Mississippi River by two routes.

Plaquemines to White Castle:

To serve industrial and domestic users south of Plaquemines to White Castle would require 39 MGD. This water could be supplied to Plaquemines through the Intracoastal Waterway at relatively low cost. However, as discussed previously, this water source is probably unsatisfactory. A better method seems to be to pump water through a transmission line along Louisiana Highway 75 from the Bayou Sorrell Lock, a distance of 13 miles. The water would then be pumped through 9 miles of transmission line to White Castle, with the industries receiving water from the pipeline where it is nearest their property. After making two cost estimates it was determined it would be more economical to run the transmission lines down Louisiana Highway 1 to White Castle, which would require the industrial users to install pipe lines from Highway 1 to their present intake facilities along the River Road. To follow the River Road with the main transmission line would approximately double its length due to the bend in the river in this reach, with the consequent increase in total costs.

The cost estimate for this phase is predicated on a 39 MGD pumping station at the Bayou Sorrell Lock, 13 miles of transmission line along Louisiana Highway 75, and 9 miles of transmission line along Louisiana Highway 1, along with necessary booster stations in the transmission lines.

White Castle to Jefferson Parish, and Including Bayou Lafourche

To satisfy the remaining fresh water requirement of the West Bank, water would first be pumped into Bayou Lafourche from the Atchafalaya Basin. Water requirements in Assumption and Lafourche Parishes, 14 MGD, would be taken from the bayou at present intake structures. Users north of Donaldsonville in Ascension and Iberville Parishes would be served through 5 miles of transmission line along the river road. 5 MGD would be required for this area. The 16 MGD requirement south of Donaldsonville in Ascension, St. James and St. John the Baptist Parishes would be served through 46 miles of transmission line from Donaldsonville also along the river road.

The 62 MGD requirement for St. Charles Parish would be met by pumping through 19 miles of transmission line along U.S. Highway 90 from Bayou Lafourche to Boutte. At Boutte the flow would be diverted up and down the river to meet the requirements in those respective areas. All water, the 42 MGD going north as well as the 20 MGD going south, would be brought directly to present intake structures of users.

With the loss of the Mississippi River, Bayou Lafourche would no longer be a source of fresh water to its present users since the bayou is supplied with water from the Mississippi river through a pumping station at Donaldsonville. It will thus be necessary to pump all the water required into the bayou. Since the bayou is navigable below Thibodaux, is heavily used and is a definite economic asset to the area, additional water must be pumped into Bayou Lafourche to maintain this capability.

At present the pumping station at Donaldsonville has the capability of pumping 200 MGD of Mississippi River water into Bayou Lafourche. Any substitute system of water supply must satisfy this requirement after all consumptive withdrawals have been made. Since the total requirements placed on the bayou under this phase of the study is 97 MGD, the designed system is calculated to furnish 300 MGD to Bayou Lafourche.

This total system would include a 300 MGD capacity pumping station in the Atchafalaya Basin, a dual transmission line of 36 miles, generally along U.S. Highway 90 and Louisiana Highway 20 to Thibodaux, to pump the water into Bayou Lafourche at that point, preferably just north of the weir in Thibodaux. It is probable the bayou north to Donaldsonville may have to be deepened and channeled to handle the flow to that town.

In addition there is a need for two pumping stations at Donaldsonville, one to pump 5 MGD north and one to pump 16 MGD south. A 62 MGD pumping station in the vicinity of Raceland will be required to pump the water from Bayou Lafourche to Boutte. At Boutte two stations with capacities of 42 MGD and 20 MGD will be required to pump the water north and south, respectively. Of course the system would have to include all necessary transmission lines and booster stations.

Costs

The total cost estimates for the West Bank include these, and those listed for the area between Plaquemines and White Castle. Table XI gives the breakdown of costs for this phase. Additional details of the costs estimates are given in Appendix C. The total annual cost of $22,200,000 yields a unit cost of $0.45 per 1000 gallons.

TABLE XI.
ALTERNATE PLAN B--WEST BANK
TRANSMISSION COSTS

	Capital Cost	
(a)	Pipeline	$174,000,000
(b)	Pumping Equipment	8,900,000
(c)	Land and Right-of-Way	1,000,000
(d)	Connections to Existing Systems, Appurtenances, Contingencies @ 20% of (a + b + c)	36,900,000
(e)	Engineering and Legal Fees @ 15% of (a + b + c + d)	33,200,000
	TOTAL	$254,000,000
	Annual Costs	
	Interest and Capital Recovery (@ 7% for a 50 year life)	$ 17,800,000
	Power	2,200,000
	Operation and Maintenance (@ 1% of Capital Costs)	2,200,000
	TOTAL	$ 22,200,000

VIII

COST COMPARISONS AND SUMMARIES

One major difference in the water requirements between the two alternates makes a direct comparison of costs between the two impossible without a modification to one or the other.

In Alternate A water was furnished to the users along Bayou Lafourche through a system of pipe lines and the present freshwater flow in Bayou Lafourche was not maintained. Alternate B took into account the importance of the navigability of this bayou to the South Central portion of Louisiana and the costs shown in Table XI included an additional 200 MGD for this purpose.

Note: Bayou Lafourche flows in a generally southerly direction from Donaldsonville, on the Mississippi River to the Gulf of Mexico. Water in the bayou is furnished from the Mississippi River, through a pumping station in Donaldsonville. With the exception of rainfall and some runoff, this is the only source of water for the bayou. Loss of flow past Donaldsonville by virtue of the Atchafalaya capturing the Mississippi would eliminate this major source of fresh water. The pumping station at Donaldsonville is rated at 200 MGD.

TABLE XII.
COST SUMMARY FOR ALTERNATE A
(Rounded Numbers)

Segment No.	Total Capital Cost	Total Annual Cost	Flow (MGD)	Cost $/1000 gals.
1.	$292,000,000	$26,000,000	330	0.22
2.	144,000,000	13,000,000	147	0.24
3.	31,000,000	3,200,000	10	0.89
4.	136,000,000	11,800,000	130	0.25
	$603,000,000	$54,000,000	617	0.24

The summary of costs for Alternate A are given in Table XII. Table XIII gives the costs for Alternate B, including the additional costs for maintaining the freshwater discharge of Bayou Lafourche. In order that the costs between the two alternates may be compared, additional calculations were made for Alternate B to isolate the cost of furnishing the water to the users, using the same route, and neglecting those costs directly attributable to maintaining the flow in Bayou Lafourche. These costs are summarized in Table XIV.

TABLE XIII.
COST SUMMARY FOR ALTERNATE B
INCLUDING COSTS FOR BAYOU LAFOURCHE
(Rounded Numbers)

Segment	Total Capital Cost	Total Annual Cost	Flow (MGD)	Cost $/1000 gals.
1 and 3	$323,000,000	$29,200,000	340	0.23
East Bank	152,000,000	13,300,000	141	0.26
West Bank	254,000,000	22,200,000	340*	0.45**
	$729,000,000	$64,700,000	821*	0.28

NOTES: * Includes approximately 200 MGD flow for Bayou Lafourche in addition to approximately 140 MGD for Municipalities, commerce and industry.
** Based on the water sold to the industrial, commercial and municipal users.

From Tables XII and XIV the costs for furnishing approximately 620 MGD to the consumers along the river and Bayou Lafourche are essentially the same. When rounded off to $/1000 gallons the two alternates give virtually the same unit costs.

TABLE XIV.
COST SUMMARY FOR ALTERNATE B
EXCLUDING COSTS FOR BAYOU LAFOURCHE
(Rounded Numbers)

Segment	Total Capital Cost	Total Annual Cost	Flow (MGD)	Cost $/1000 gals.
1 and 3	$323,000,000	$29,200,000	342	0.23
East Bank	152,000,000	13,300,000	141	0.26
West Bank	128,000,000	11,500,000	136	0.23
	$603,000,000	$54,000,000	619	0.24

Table XIII shows that the cost for furnishing water to the West Bank users was $0.45/1000 gallons when the costs included furnishing the 200 MGD to maintain the navigability of Bayou Lafourche. This unit cost is about double the cost that it would be in the absence of bayou navigation. The total cost for Alternate B under this condition was $0.28/1000 gallons, or about 16 percent higher than if navigation were neglected. Both of these figures would seem to indicate that maintenance of Bayou Lafourche as a navigable body of fresh water is economically questionable. It might, however, be possible to maintain navigation at a smaller cost by using pumped seawater for this purpose.

Bayou Lafourche is a very important waterway artery in South Central Louisiana, as it is kept navigable from just below Thibodaux to the Gulf of Mexico. Along its banks are several industries that rely on boat and barge traffic to bring in raw materials and carry out finished products. Of prime importance is the shellfish industry, so vital to the economy of Lafourche Parish. Most of the boats that make up the Lafourche Parish shrimping fleet are docked on both banks of Bayou Lafourche north of Golden Meadow, as well as those boats used to harvest oysters. The loss of the bayou would be a severe blow to the economics of these two industries in Lafourche Parish. In addition, the bayou is presently used for recreational boating and fishing.

The analysis indicates that maintenance of fresh-water navigation in Bayou Lafourche (and the decreased salinity in the Lafourche outlet) would cost approximately $10,000,000 per year. Such an annual expenditure would result in a number of direct benefits, benefits that should be evaluated before a final judgment can be made. Such an evaluation is beyond the scope of this report.

IX

CONCLUSIONS

Should the Old River Control Structure fail, and the Mississippi River be captured by the Atchafalaya, the present Mississippi River as we know it would be lost as a source of water supply for the many users of its water along the reach south of East and West Baton Rouge Parishes. Navigation of ocean going vessels would be slightly affected, if at all, but barge traffic above Baton Rouge would stop. Additional sources of water supply would have to be found to serve the many domestic, industrial and thermoelectric users. Assuming that the industrial and thermoelectric users would reduce their demands by appropriate technology, the costs to all users would undoubtedly be much higher than they are at present.

However, the additional cost for the water is not the only consequence of a possible collapse of the structure. To reduce their requirements, which will be an absolute necessity, the industries would have to alter their present processes, and the industries and thermoelectric plants would have to install elaborate recycling units. These additional costs would have to be included in the overall cost analysis, and would certainly be a major component of their new, and increased, costs.

Another concern, and probably more critical than costs, is the time lag between the collapse of the Old River Control Structure and the construction of the pumping stations, well fields, and transmission lines required in either alternate. A project of either magnitude would take years to complete. The users have two options:

Option A would be to trust the integrity of the Old River Control Structure and hope that it never fails. If, and when it did fail the industrial and thermoelectric plants would soon have to shut down until construction of one or more of the systems outlined in the two alternates were completed. For a short while water for the domestic users might have to be hauled in by truck or other methods. Option B would require that work be initiated on a number of the systems outlined in the alternates so that they would be immediately available when the structure failed. Option A is to do nothing. Option B might be undertaken to improve the quality and reliability of present water supplies.

Considering Option A, it seems doubtful that water for domestic users in the quantities required could be supplied by any means other than large diameter transmission lines. Secondly, the loss of water to the many industrial users, for even a small period of time, would require them to shut down their operations, and would be a financial burden from which some could never recover. It could result in many of them moving to new locations. Such an exodus would be an economic disaster to the many parishes along the Mississippi River that depend upon these industries for their livelihood.

Option B remains. However, a combination of leadership and persuasion would be needed to motivate the various users to invest in the proposed construction on the assumption it will be needed in the future. Among the unanswered questions: how would the costs be prorated between domestic, industrial, and thermoelectric users? The benefit to one would certainly be of benefit to the other. Some sort of coordinating agency would have to be created to arbitrate the cost allocations. Lawsuits could develop which might delay any construction, and with protracted litigation it seems unlikely that timely action would be undertaken. Of course the New Orleans water supply is not presently of satisfactory quality and it may be that regardless of the ORCS existence a new source will be sought from the Pearl River. Such an action would alert the municipalities and industries of the area to the possibilities of alternate water sources as well as improve the quality of water in the New Orleans area and decrease its vulnerability.

There is, of course, another and parallel possibility--a vigorous effort should be made to preserve the Old River Control Structure. The Corps of Engineers is presently studying methods to reduce the stress on the structure and hope to have an auxilliary structure operating by 1985. But they make no guarantees as to the longevity of the system.

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APPENDIX A

PEARL RIVER FLOW AT BOGALUSA AND PEARL RIVER, LOUISIANA

During the 38 years of record, the minimum average daily flow in the Pearl River at Bogalusa, Louisiana was found to be 1020 cfs, occuring during several days in October, 1963. The minimum recorded average daily flow in the Pearl River at Pearl River, Louisiana during this period occurred in 1963 when it reached a low of 1580 cfs. The assumption that the flow in the West Pearl River at Pearl River, Louisiana is approximately 85 percent of the total Pearl River discharge during periods of low flow, would establish the minimum flow in the West Pearl as 1340 cfs.

If it is assumed that, as a result of withdrawals, the flow in the West Pearl should not be reduced below 110 percent of this minimum value, the limiting flow in the West Pearl would be 1.1 x 1340 cfs, or 1470 cfs. The demand of 340 MGD (330 and 10 MGD for Segments 1 and 3 respectively) could be completely satisfied whenever the discharge in the West Pearl was greater than 1470 + 530, or 2000 cfs.

The ratio between the total discharge at Bogalusa and the discharge in the West Pearl at Pearl River averages about 1.1. Thus, the corresponding discharge at Bogalusa which would limit fresh water withdrawals from the West Pearl would be 2000/1.1, or 1820 cfs.

APPENDIX B

WATER REQUIRED FROM STORAGE AT PEARL RIVER DURING THE DRIEST PERIOD OF RECORD

The daily streamflow records at Bogalusa for January through December, 1954 indicate that there was a period of 135 days during which the flow was less than 1820 cfs, the minimum which would allow the withdrawal of the full 530 cfs (340 MGD) at Pearl River, Louisaina. For each of these days the flow at Pearl River, Louisiana withdrawal point was determined as 1.1 times the flow at Bogalusa. It was then assumed that water could be withdrawn at a rate that would reduce the flow in the West Pearl River down to its minimum acceptable of 1470 cfs. When flows in the West Pearl were below 1470 cfs no water would be withdrawn. The 340 MGD would then have to be withdrawn from another source. This source would be a well field. Withdrawals from the well field would have to be replenished during periods of adequate flows in the Pearl River.

Over the entire period of record, an operational analysis shows that with a filter plant capacity of 55 MGD, the maximum withdrawals from storage would have amounted to 60 billion gallons. A larger filter plant capacity would reduce this maximum, a smaller filter plant capacity would increase the amount of ground-water withdrawal from storage. Detailed engineering and economic studies are needed to determine the optimum capacity of filter plant and the well field for injection purposes.

One such field and treatment facility was included in the costs analysis for Segment 1 of Alternates A and B.

APPENDIX C

ASSUMPTIONS USED IN COST ESTIMATES

The cost estimates used in this study were developed from a variety of sources. Published literature on costs were used whenever possible. Old data were updated using appropriate cost indexes published by Engineering News Record (ENR). Where no appropriate cost estimates for a particular item could be found, estimated costs were made based on data for similar items and conditions.

Capital cost estimates for pumping stations, transmission lines and booster stations were obtained from expressions developed by Singh, et. al (Singh, et. al, JAWWA, October, 1974). The costs presented by Singh, et. al were based on 1964 dollars and included all items involved in cost of materials, transportation and installation. The 1964 dollars were updated to 1976 dollars using the ENR Construction Cost Index for the United States. The multiplication factor was 2401/936 or 2.57.

The capital cost for construction of a water treatment plant using chemical coagulation, sedimentation, rapid sand filtration and chlorination was also obtained by a modified expression by Singh, et. al. adjusted to 1976 dollars. A water well producing 2.2 MGD (or an injection well of the same capacity) was assumed to cost $175,000. Pumping costs for pumping and booster stations, as well as for well fields were estimated to average $97 per year for each installed horsepower. This value was obtained by calculating the average cost of power per year for a large power service with a constant demand of 36,000 KW, using the graduated utility rates of a local power company. No attempt was made to account for rising power costs or for the effects of variation in power demands throughout the months of the years.

Finally, right-of-way costs were estimated as $5,000 per mile of transmission on public property. Right-of-way along the Mississippi River between the levee and River Road was assumed to be free of charge.

A computer program on a Wang computer unit was developed. The program was set to receive flow requirements and length of transmission lines. The computer then calculated the head requirements and subsequent pumping station costs for a various range of pipes believed to be economical. Included in the costs were annual pumping power costs. The construction costs were broken down for a 50-year life and added to the annual power costs. This resulted in annual cost for power, and transportation and pumping station (over the 50-year life), for each pipe diameter included in the range. The pipe diameter yielding the lowest annual costs was considered to be the optimum and those costs were used in the final estimates for each phase.

It should be pointed out that these costs at best are informed estimates. However, since the same data, assumptions and mathematical input to the same computer program were used, the relative costs are probably valid.