Missouri S&T

Missouri University of Science and Technology

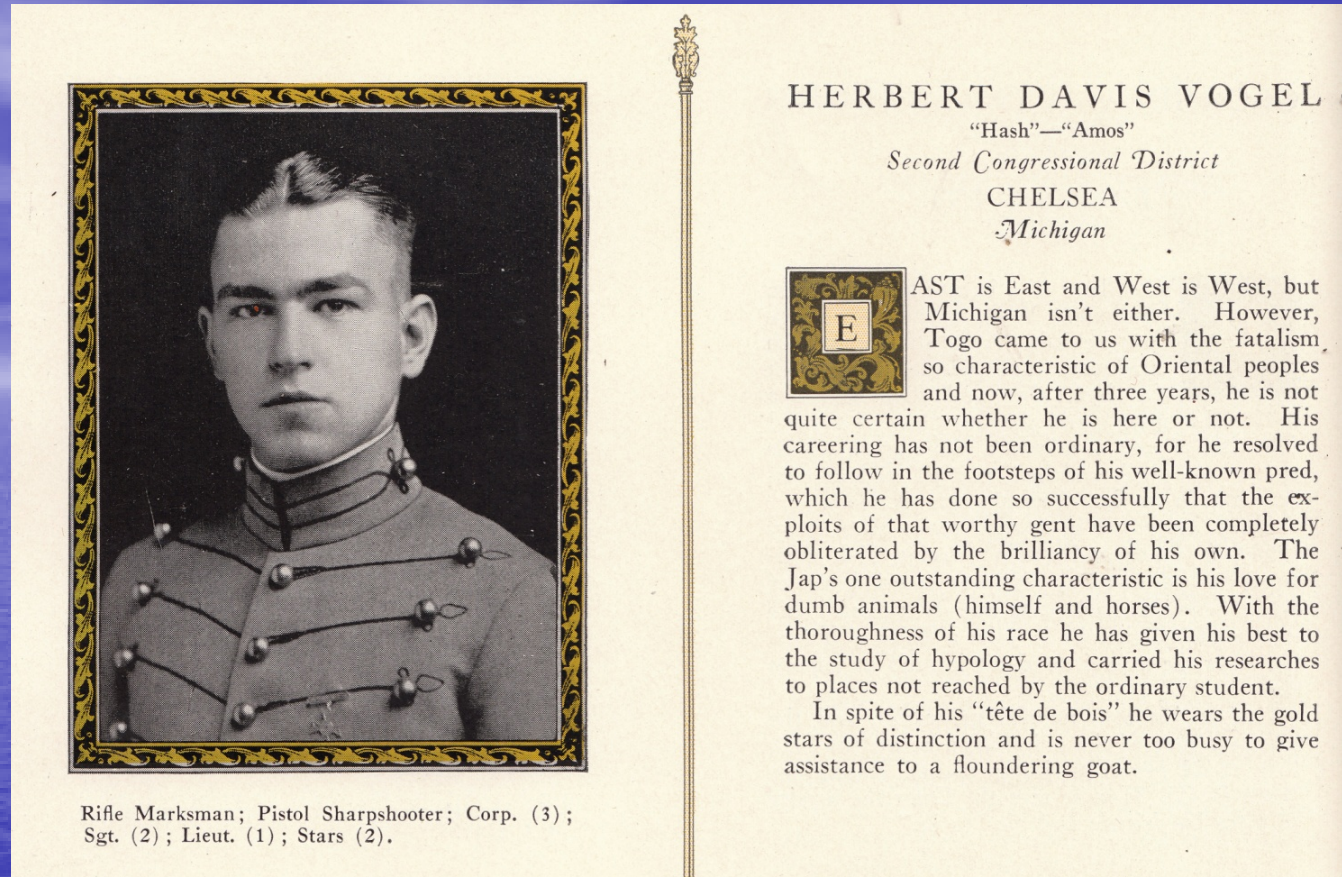
Development of the Flood Protection System in the Mississippi Delta

J. David Rogers, Ph.D., P.E., P.G.
Professor and Karl F. Hasselmann Chair in Geological Engineering
Missouri University of Science & Technology
for the
AWG Webinar
September 30, 2020

Mississippi River watershed

Funnel-shaped basin drains 41% of the continental United States

Average flow 640,000 cfs. Suspended sediment flux 180 million yds^3/yr, one third of all US rivers. Long duration floods transport enormous volumes of sediment



HERBERT DAVIS VOGEL

"Hash"—"Amos"

Second Congressional District

CHELSEA

Michigan

EAST is East and West is West, but Michigan isn't either. However, Togo came to us with the fatalism so characteristic of Oriental peoples and now, after three years, he is not quite certain whether he is here or not. His careering has not been ordinary, for he resolved to follow in the footsteps of his well-known pred, which he has done so successfully that the exploits of that worthy gent have been completely obliterated by the brilliancy of his own. The Jap's one outstanding characteristic is his love for dumb animals (himself and horses). With the thoroughness of his race he has given his best to the study of hypology and carried his researches to places not reached by the ordinary student.

In spite of his "tête de bois" he wears the gold stars of distinction and is never too busy to give assistance to a floundering goat.

Rifle Marksman; Pistol Sharpshooter; Corp. (3); Sgt. (2); Lieut. (1); Stars (2).

- **Herbert D. Vogel graduated West Point's Class of 1924 with a major in civil engineering and received a commission in the Corps of Engineers.**
- **Only 10% of a graduating class received engineer appointments, and all of these came from the top 20% of the class. This choice provided more options for alternative employment outside of the Army.**

- The disastrous **Flood of 1927** along the Mississippi River changed everything
- The Corps of Engineers was charged with solving the flood control woes of the Mississippi River, set forth in their **Jadwin Plan**, which was incorporated into the sweeping **Flood Control Act of 1928**
- Part of the act called for the establishment of a river hydraulics laboratory along the lower Mississippi River that would be under the Corps of Engineers control.

Graduate work at Cal Berkeley 1927-28

Charles Derleth, Jr.
Dean of the College of Civil Engineering

California Civil Engineering Building

- Herbert Vogel was one of six Army Engineers working on master's degrees at the University of California (Berkeley) in 1927-28, under **Charles Derleth.** In the spring of 1928 Vogel noticed an announcement of fellowships for foreign study in Germany through the **Institute of International Education.** He had grown up speaking some German and had taken two years of advanced German at Michigan.
- He received an offer to study at the hydraulic laboratory at the **Berliner Technical Hochschule** in Charlottenburg, beginning his studies on Nov 1, 1928

Vogel (second from right) with other American scholars in Germany in 1929. Freeman Scholar Clarence Bardsley is fourth from left.

Outdoor hydraulic model at Dresden, photographed by Vogel

- The Freeman Scholars were studying at the Prussian Institute for Hydraulic and Marine Engineering, located in Lock Island, next to the Berlin Technical Hochschule. Vogel worked with Prof. George Henry de Thierry, who had lectured at MIT in 1927.
- During the semester break in March-April 1929, he visited the hydraulic laboratories at Delft, Lyon, Zurich, Karlsruhe, Dresden, Vienna, Munich, Gratz, and Brunn. His per diem allotment from the Army was $6/day.
- He received his Doctor of Engineering degree on August 1, 1929, and was posted to the Memphis District of the Army Corps of Engineers.

Major General Lytle Brown, Chief of Engineers, 1929-1933

Major General Lytle Brown succeeded Edwin Jadwin as Chief of Engineers on October 1, 1929. He switched the site of the new hydraulics laboratory from Memphis to Vicksburg because the Corps' new Lower Mississippi Valley Division was to be based there.

- The new 147 acre laboratory was christened the **"Waterways Experiment Station,"** or **WES**, to placate President Hoover, who still favored a national hydraulics laboratory in Washington, DC.
- In May 1930 Hoover signed the act establishing a **National Hydraulics Laboratory** at the Bureau of Standards in Washington, DC, but it never received sufficient funding to establish itself as a prominent research facility.

Brigadier General Thomas Jackson,
MRC President, 1929-1932

- When Vogel was assigned the role of developing WES he was given a budget of only $50,000 per annum.
- From 1929-32 Brigadier General Thomas Jackson served as President of the Mississippi River Commission (MRC).
- He funneled close to $1 million to Vogel during the first year (1929-30), through the new Mississippi River & Tributaries Project
- This allowed Vogel to construct a real facility, purchasing holding tanks, flumes, weirs, and traps inside the main buildings.
- The administration building shown here cost $122,000.

- **Aerial oblique view of the new Administration Building at WES and the earth dam impounding a 40 acre lake with sufficient storage to run all the hydraulic models. Note concrete apron for spillway at extreme left.**

First Lieutenant Herbert D. Vogel, WES Director from 1929-34

- Vogel christened the reservoir "Lake Brown," after the Corps Commanding General Lytle Brown.
- This shows the Vogel's home overlooking the lake, from just above the dam's right abutment.

- The silty loess soils in Vicksburg were perfectly suited to outdoor models with vertical exaggeration, as shown here. Note vertical cuts in the loess for the reservoir spillway at extreme right background. The new Administration Building is at left.

- **During 1930-31 Vogel employed former Freeman Scholar Clarence Bardsley of the Missouri School of Mines (shown here with Vogel) to assist him in developing the first hydraulic models at WES.**

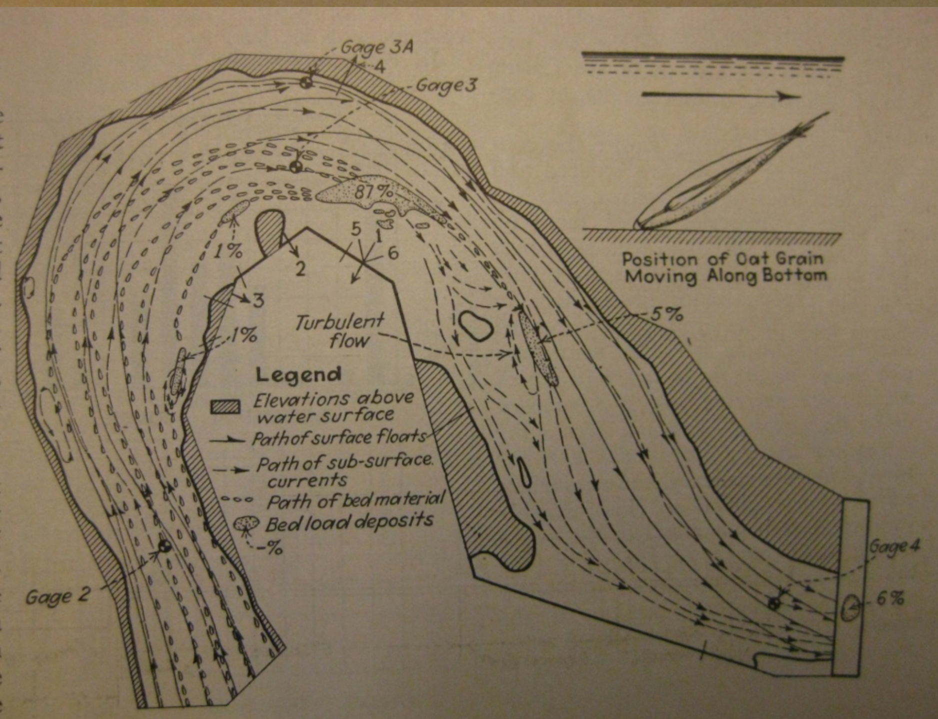
Vogel (left) and Prof. Clarence Bardsley (right) of the Missouri School of Mines

Vogel employed the principles of similitude that had been pioneered by hydraulic modelers in Europe to examine various means to make the Mississippi River channel more hydraulically efficient

Geometric Versus Hydraulic Similitude

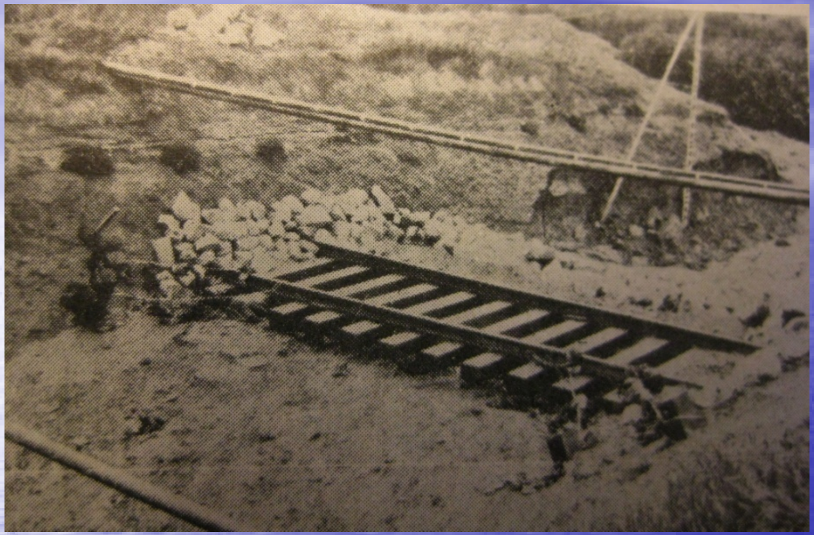
Factors to Be Considered When Using Models to Study Flow in Open Channels

By Herbert D. Vogel
Director, U.S. Waterways Experiment Station, Vicksburg, Miss.
First Lieutenant, Corps of Engineers, U.S. Army
and John Paul Dean
Assistant to District Engineer, First Lieutenant, Corps of Engineers,
U.S. Army, New Orleans, La.



One aspect the hydraulic models that was difficult to predict were long-term bed and bank adjustments, engendered over decades by dramatically different flows. Vogel mentioned these limitations, but no one seemed to take note of them until after the 1973 flood.

Full scale overflow tests



Full scale overflow tests on railroad levee embankments, showing results after 226 hours (lower left)

Railroad levee embankment overflow tests

Full-size railroad embankment

Observers at railroad embankment test, 1931; note WES building in background

- The rail ballast overflow tests drew considerable attention because everyone could understand their significance
- They reinforced the idea of "armored" levee crests, but failed to examine toe undercutting impacts, which are often exacerbated by underseepage

General Ferguson as President of the MRC

Colonel Harley B. Ferguson

Brigadier General Harley Ferguson (West Point '97) succeeded General Jackson as President of the Mississippi River Commission from 1932-39, during the formative years of the Corps' Mississippi River & Tributaries Project

Ferguson was the Corps most outspoken advocate of channel cutoffs to improve hydraulic efficiency. In November 1930 he released a report calling for a series of cutoffs between the White River and Old River, the first of 16 cutoffs, all of which were modeled at WES. Ferguson established WES an integral part of the MRC and the MR&T project.

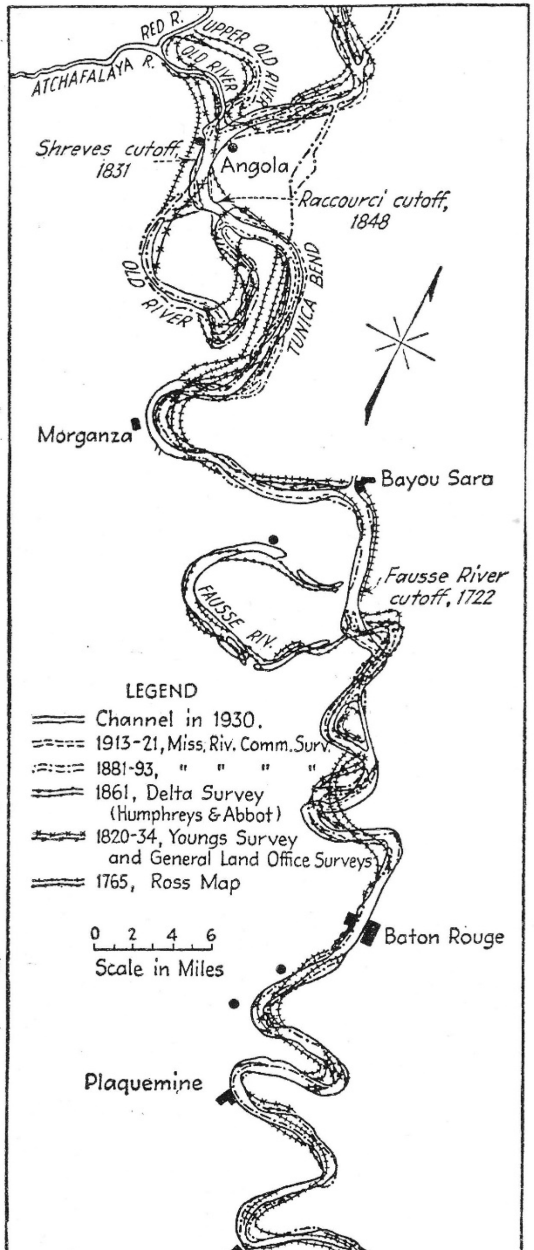


Fig. 5—Records of 165 years of channel changes below Baton Rouge reflect a high degree of stability. Compare with Fig. 4, which is typical above Red River.

Levee set-backs used for first time

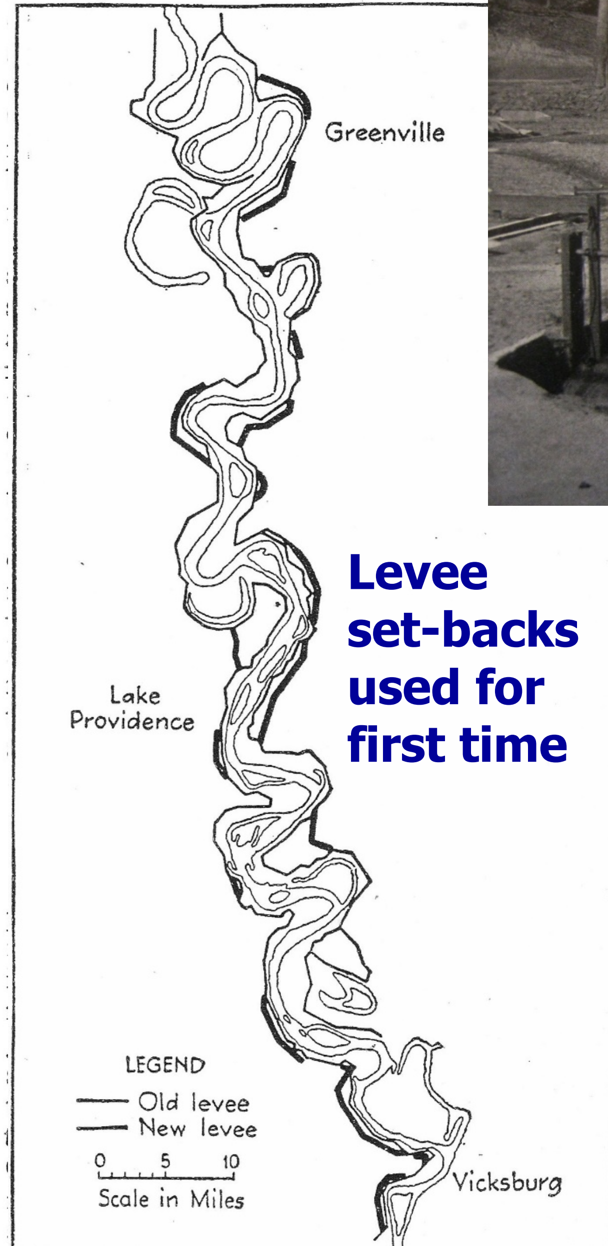
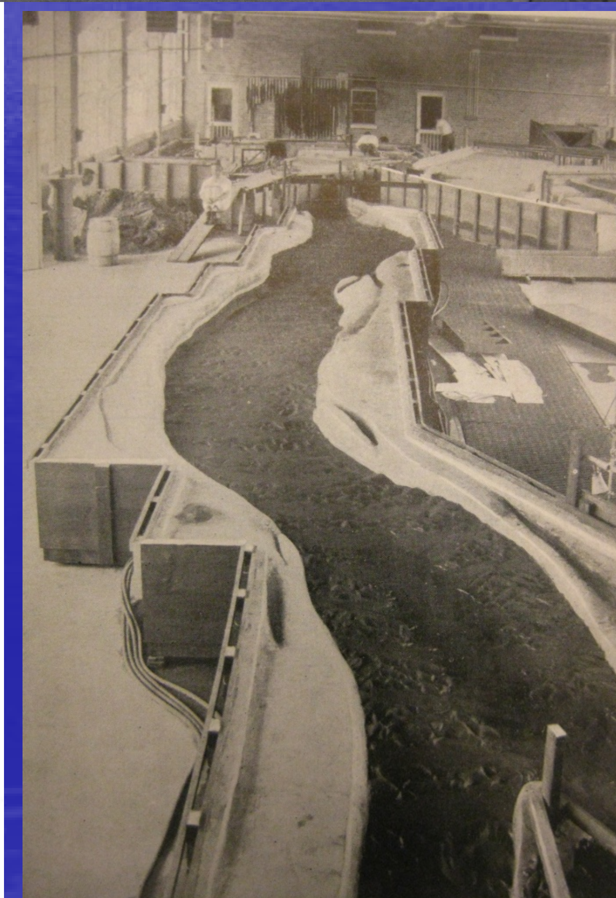


Fig. 6—Much rectification of the high-water channel has been accomplished by setting back the levee line at projecting points, as shown in this stretch between Greenville and Vicksburg.



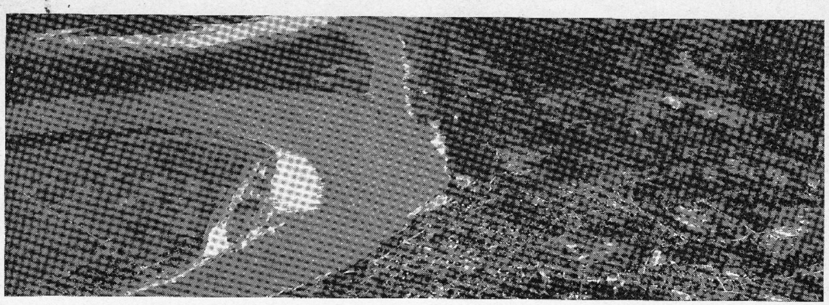


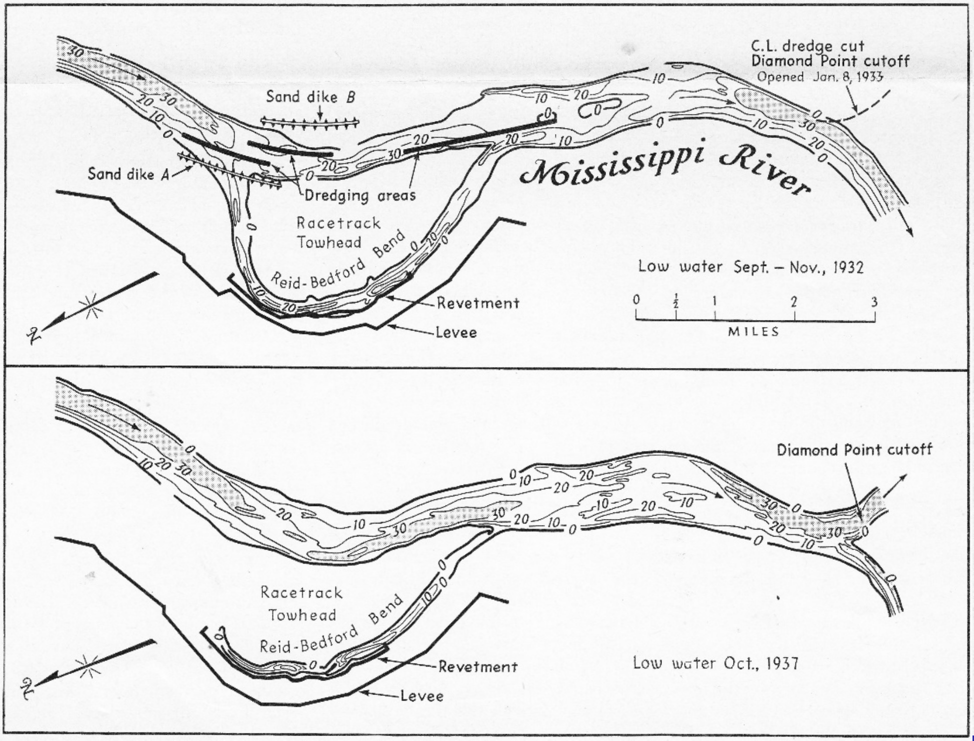
FIG. 1. INCREASING THE MISSISSIPPI'S CAPACITY: GILES CUTOFF IS BEING DREDGED AND VIDALIA POINT CUT BACK.

Mississippi River Cutoffs Effective

Cutoffs Lower Flood Crests

George R. Clemens
Mississippi River Commission, Vicksburg, Miss.

Fifteen cutoffs are rapidly redistributing the flow of the Mississippi River and have materially lowered flood crests above Red River Landing



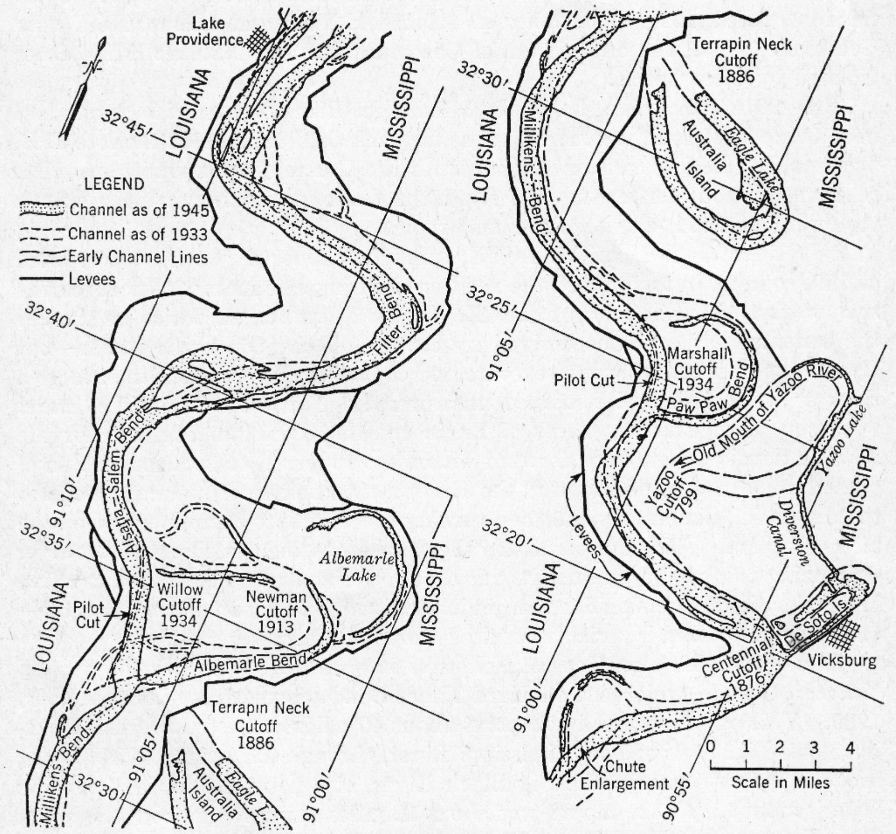


Fig. 2.—Cutoffs in the 50-Mile Section Upstream from Vicksburg

Goal: reduce flood height thru increased channel efficiency. **16 cutoffs were made along the lower Mississippi River to increase grades and channel efficiency.**

April, 1934 THE MILITARY ENGINEER

Organization and Operation of the Waterways Experiment Station

H. D. Vogel

First Lieutenant, Corps of Engineers

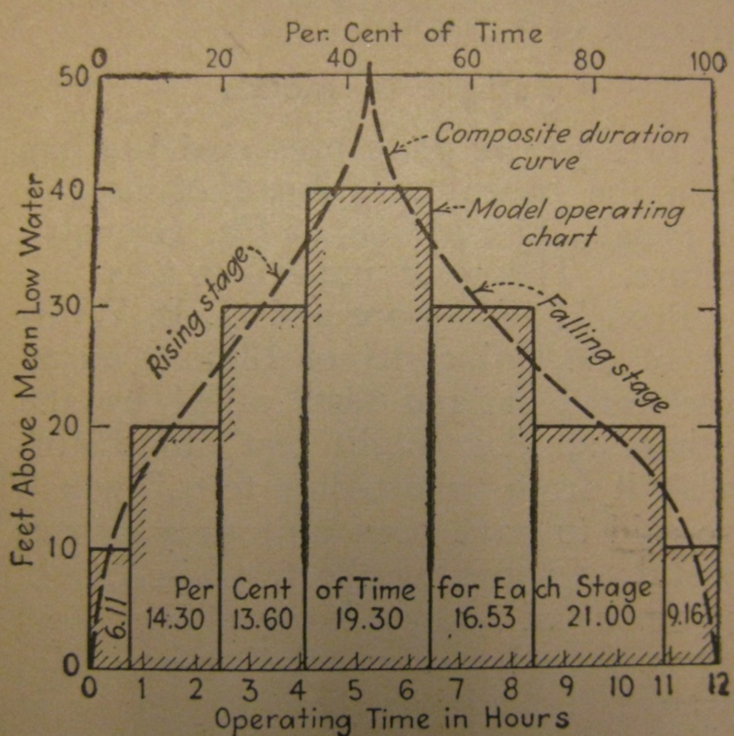


Fig. 7—Operating chart for a model based on hydrographs of river ranging over a five-year period.

The loess soils at Vicksburg were perfect for sculpting outdoor models. Vogel prepared a series of notable articles explaining the program of research at WES

Model of Birds Point-New Madrid floodway under test

- The **Birds Point-New Madrid Floodway** was located in Missouri west of the confluence of the Mississippi and Ohio Rivers at Cairo, IL. It incorporates an area of about 206 square miles.
- In 1932 WES performed a model study to determine the effects of operating the floodway on the lands lying within it and to predict the draw-down on the Mississippi River with the floodway in use.
- With more than 100 miles of river to simulate, Vogel built an 80-foot-long outdoor concrete model of the river channel, the overbank between levees, backwater areas, and the floodway.
- Vog took special care to correctly place drainage ditches, levee borrow pits, and other details that would affect water levels, and raised miniature levees with soil taken from actual on-site levee borings. These tests indicated that the new levees were of sufficient height to contain any projected flood

Design Intent of the Bird's Point Floodway

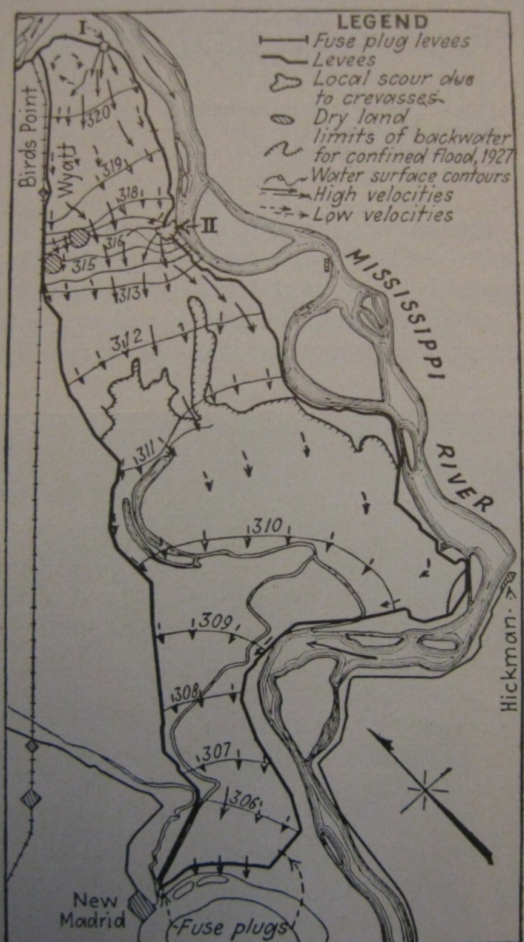


Fig. 4—Model map of New Madrid floodway, showing crevasses, backwater limits, current velocities and water-surface contours resulting from a simulated 1927 flood.

The Corps of Engineers designed the floodway to save Cairo, IL, a key rail and highway junction
They also designed a drainage system to reclaim floodway lands for agriculture

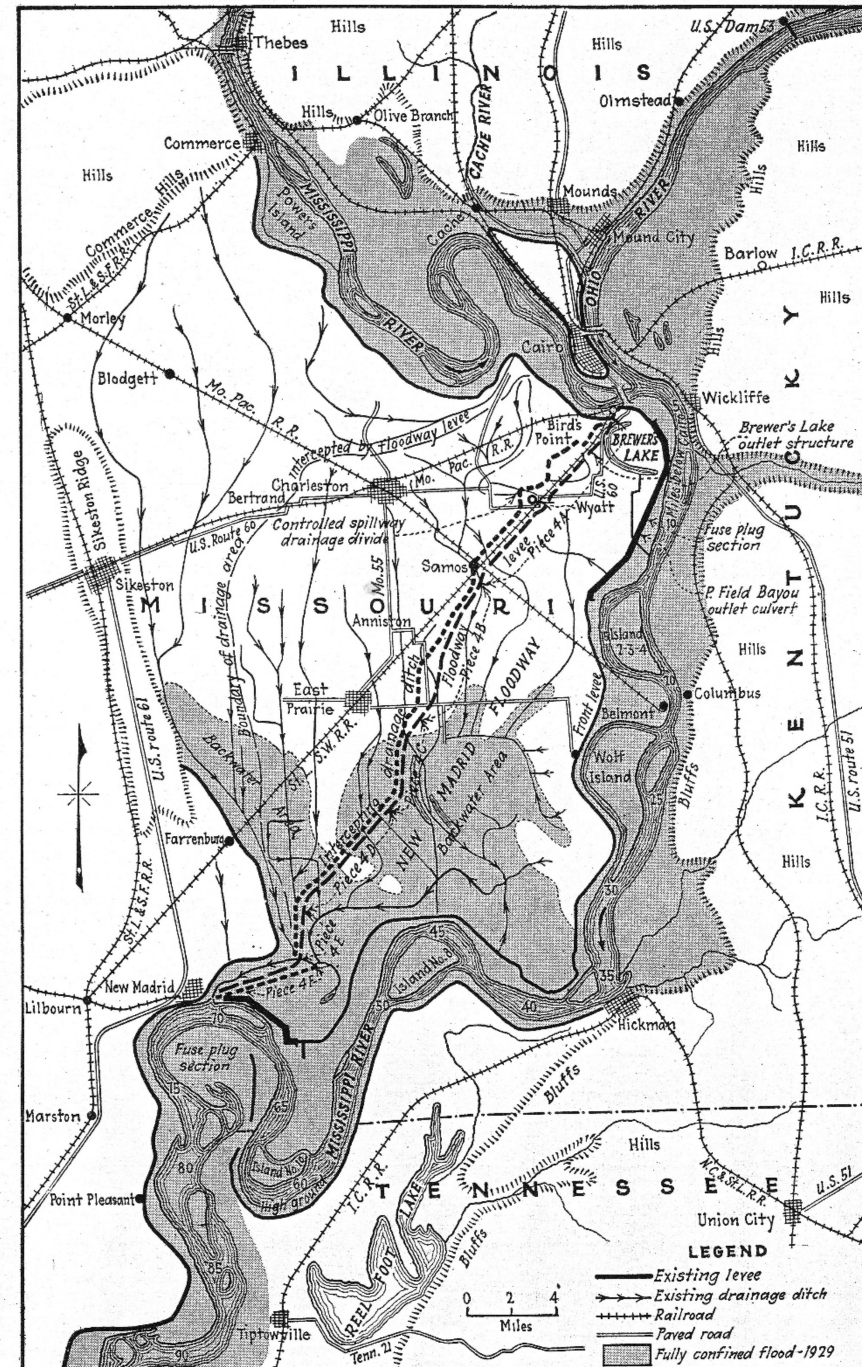
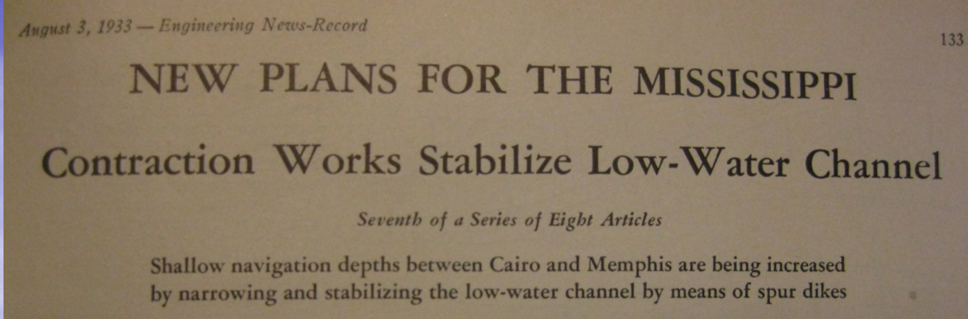


Fig. 1—Levee and drainage system of New Madrid floodway

WES strove to improve channel efficiency

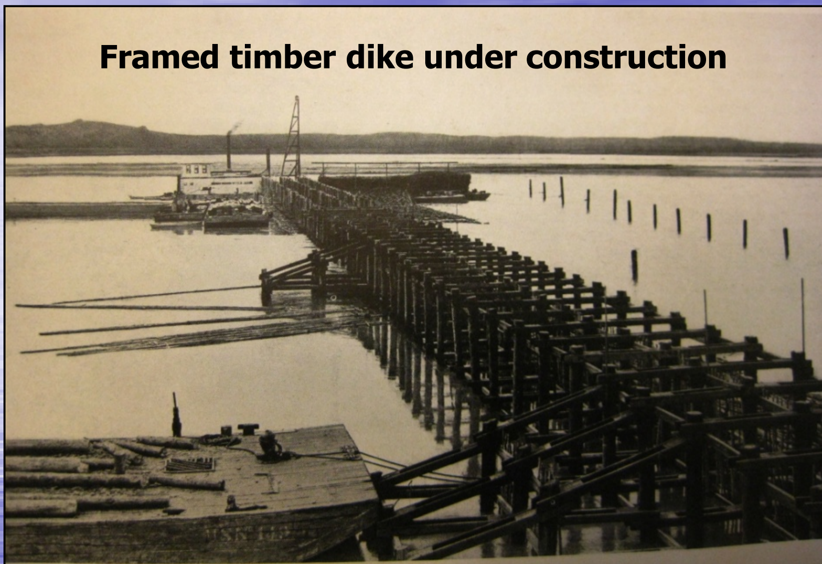


NEW PLANS FOR THE MISSISSIPPI

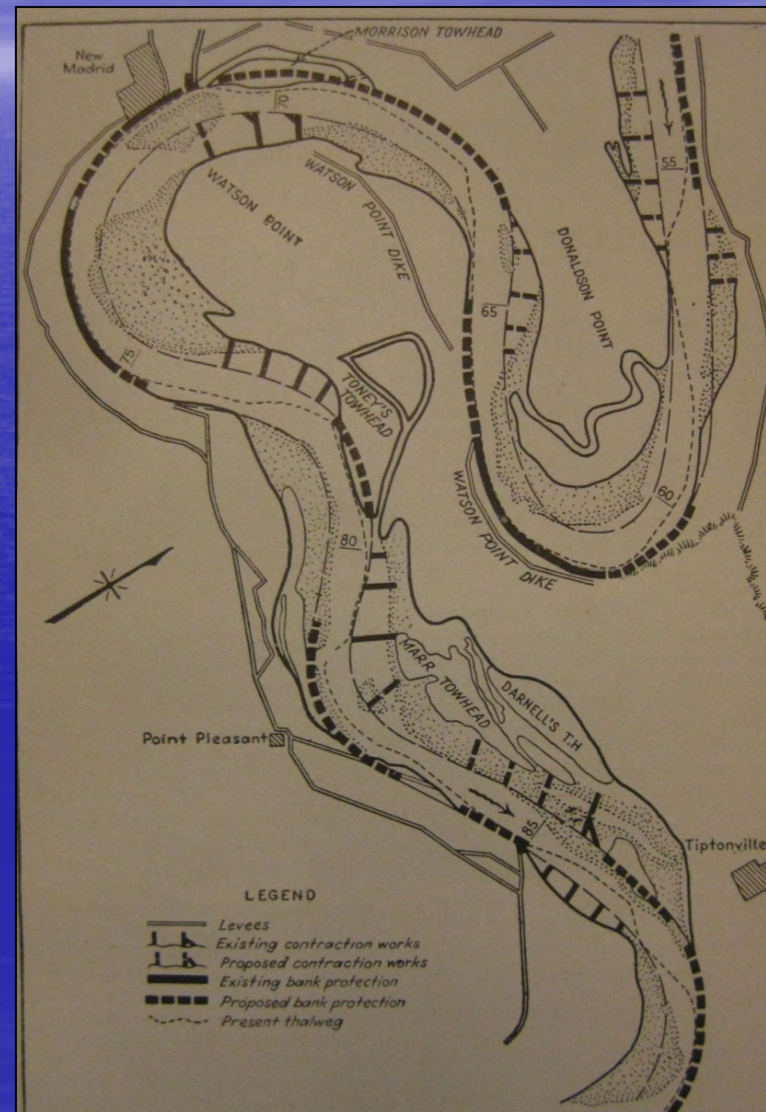
Contraction Works Stabilize Low-Water Channel

Seventh of a Series of Eight Articles

Shallow navigation depths between Cairo and Memphis are being increased by narrowing and stabilizing the low-water channel by means of spur dikes



Framed timber dike under construction



Effects of Mississippi River Cut-Offs

By HARLEY B. FERGUSON

MEMBER AMERICAN SOCIETY OF CIVIL ENGINEERS

BRIGADIER GENERAL, CORPS OF ENGINEERS; PRESIDENT, MISSISSIPPI RIVER COMMISSION, VICKSBURG, MISS.

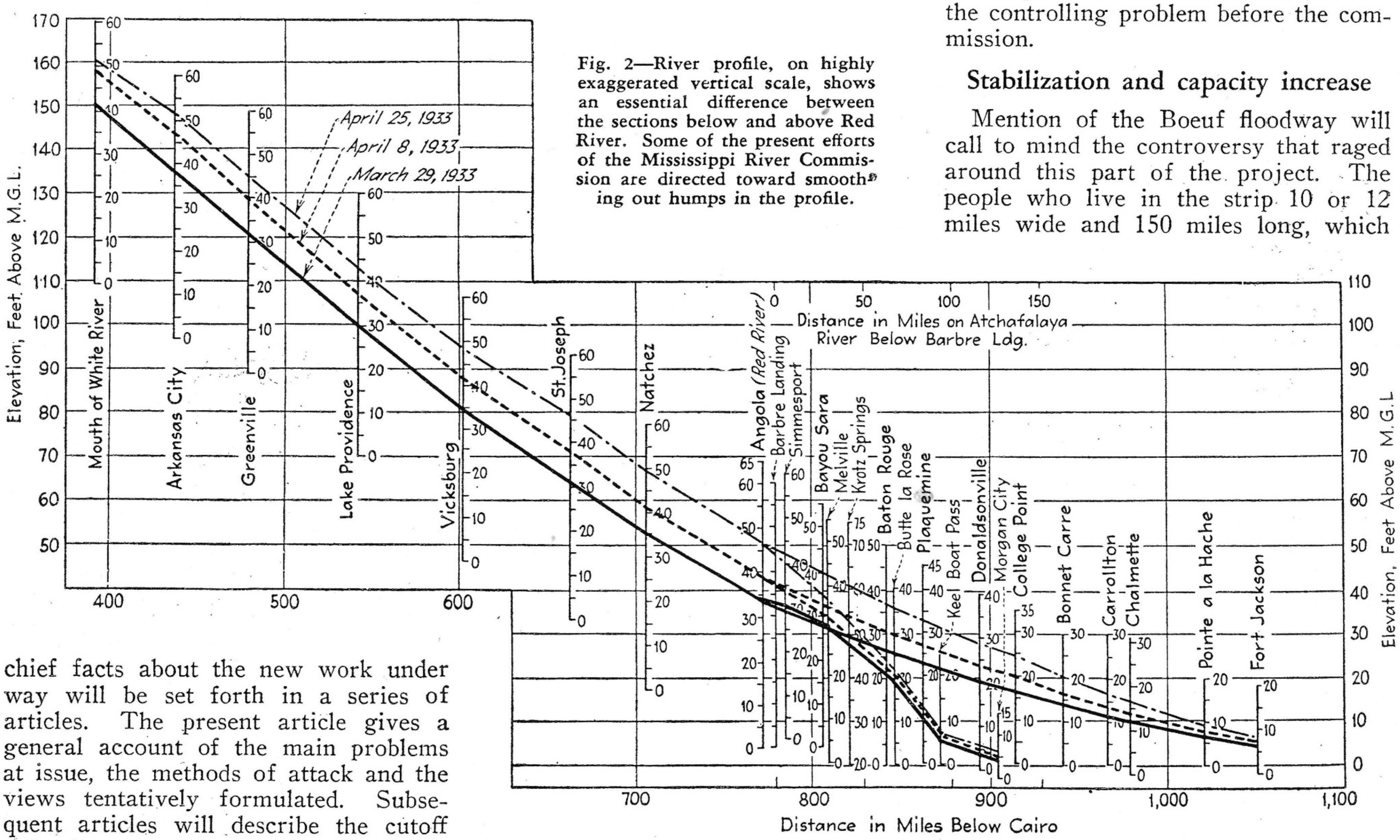


Fig. 2—River profile, on highly exaggerated vertical scale, shows an essential difference between the sections below and above Red River. Some of the present efforts of the Mississippi River Commission are directed toward smoothing out humps in the profile.

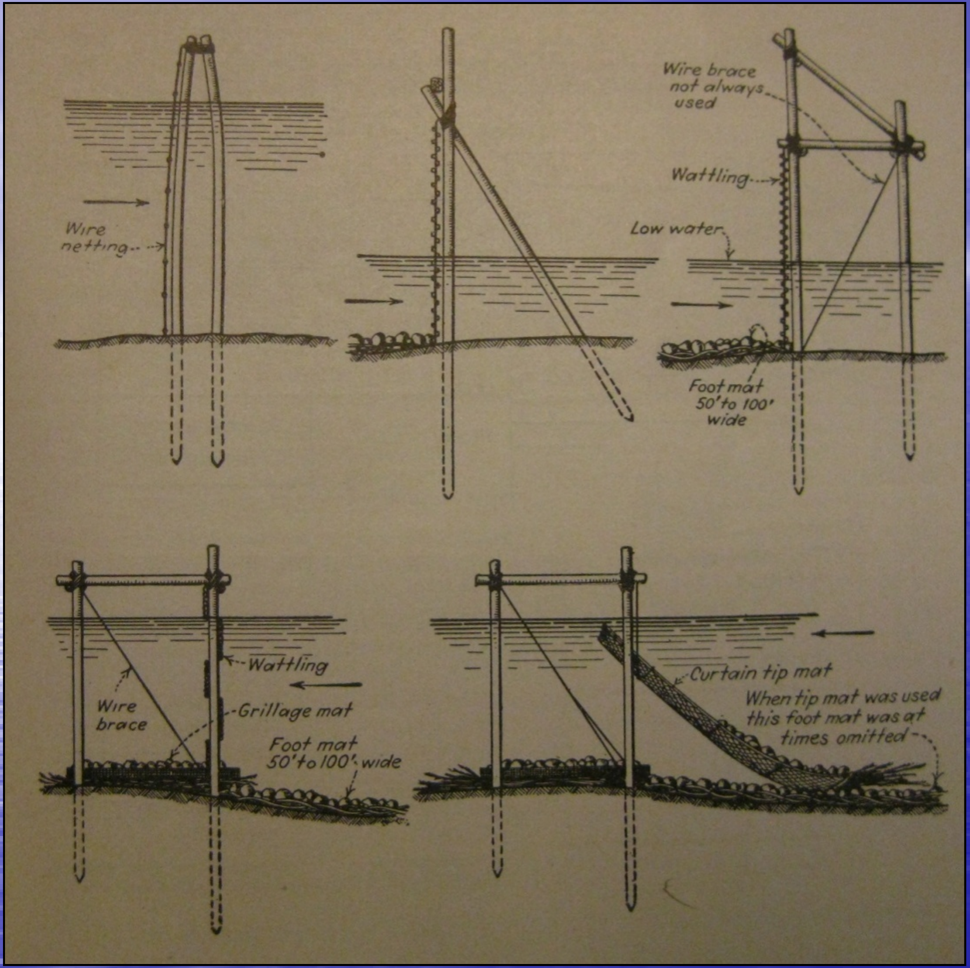
chief facts about the new work under way will be set forth in a series of articles. The present article gives a general account of the main problems at issue, the methods of attack and the views tentatively formulated. Subsequent articles will describe the cutoff operations, contraction works, new

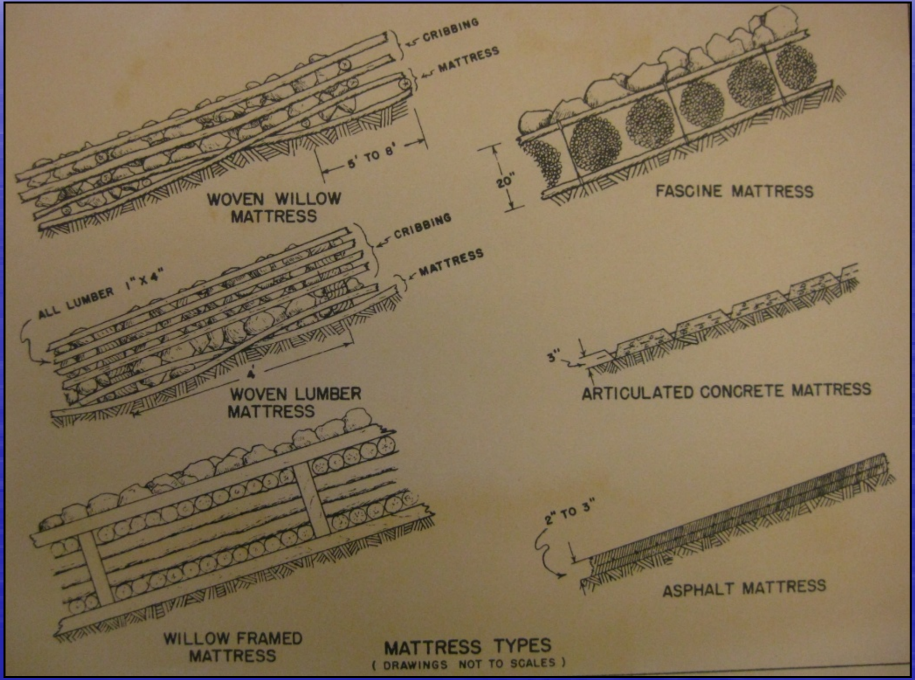
the controlling problem before the commission.

Stabilization and capacity increase

Mention of the Boeuf floodway will call to mind the controversy that raged around this part of the project. The people who live in the strip 10 or 12 miles wide and 150 miles long, which

Developing design standards for brush dikes





- **WES also developed schemes for timber dikes and submerged brush foot mats and curtain tip mats**

Timber framed dikes

- The Corps also employed framed dikes to assist in construction of channel cutoffs
- Flotsam collected against these timber dikes during spring floods, forming reinforced brush dikes that were effective in trapping sediment

- **Framed dikes** were employed along the Mississippi River to confine flow and increase velocity along a **preferred navigation channel.** These dikes caught organic debris which aided in their becoming backfilled with sediment.

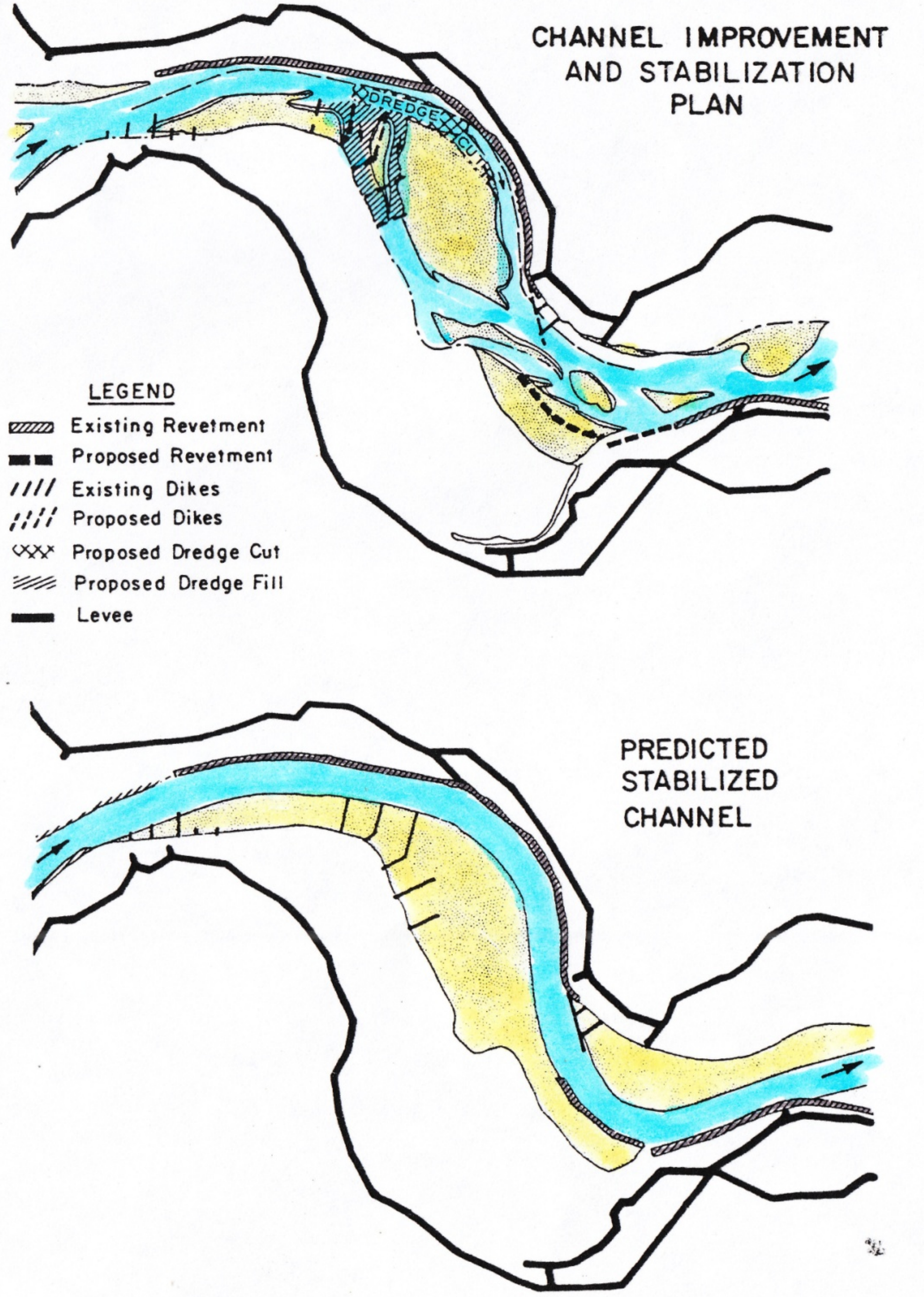
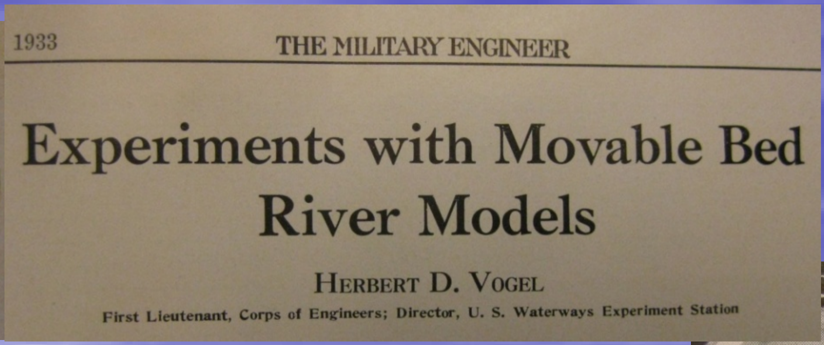


FIGURE 5 *Example of corrective works used to alleviate a troublesome divided-flow condition along a selected Mississippi River reach.*

Split Flow Conditions

- **Channel improvements included 16 cutoffs and two major chutes; and bank revetments (damaged during high flows).**
- **These improvements initially lowered flood stages 16 ft at Ark City and 10 ft at Vicksburg**
- **Discovered this required corrective dredging**

Examining transient bed effects at constant flow values

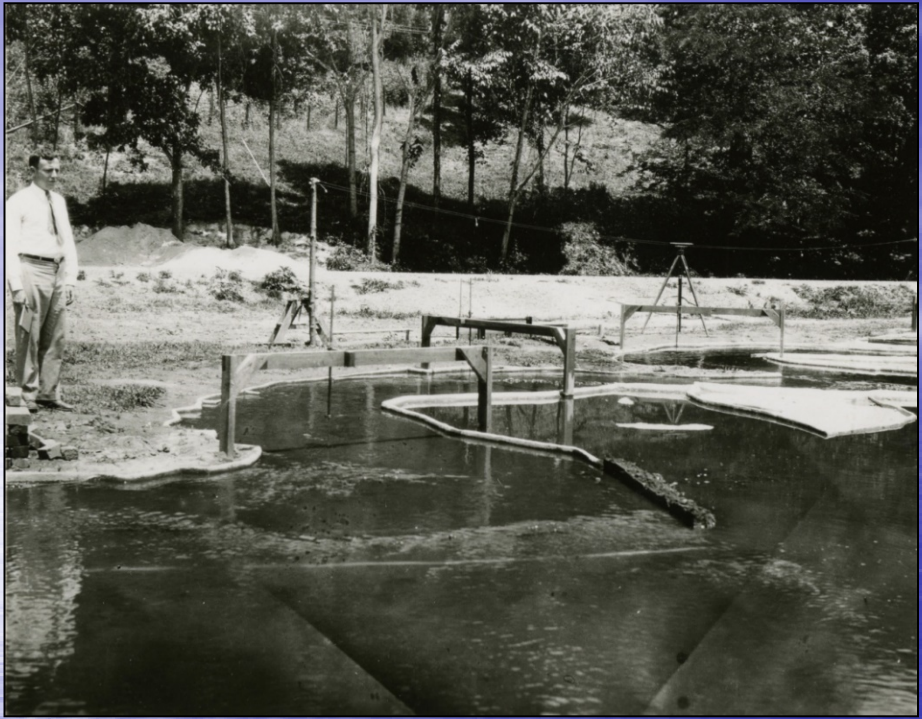

1933 THE MILITARY ENGINEER

Experiments with Movable Bed River Models

HERBERT D. VOGEL

First Lieutenant, Corps of Engineers; Director, U. S. Waterways Experiment Station

Natural sand bed channel (lower left); dredged channel (upper right); and impact of structural dikes (lower right)



- In the summer of 1934 Vogel made a special trip to Europe to tour their hydraulic laboratories. He found that WES had progressed far beyond anything in Europe
- He then reported to the Army's Command and & General Staff School at Fort Leavenworth, one of the most junior officers to ever attend this two-year course.
- Vogel was promoted to Captain in August 1935, eleven years after graduating from West Point.

Major Elements of the MR&T

- 2,200 miles of levees and floodwalls (avg 30 ft high) below Cape Girardeau
- Bypass floodways: Bird's Pt-New Madrid (1931); Bonne Carre (1931); Morganza Diversion (1954); Old River Diversion (1960/1977)
- Channel improvements; incl. 16 cutoffs and two major chutes; and bank revetments. Initially lowered flood stages 16 ft at Ark City and 10 ft at Vicksburg
- Major tributary improvements, 4 dams in Yazoo Basin (Enid, Arkabutla, Sardis, Grenada) and Wappapello on the St Francis River

Levee construction techniques before the introduction of self-propelled earth moving machinery

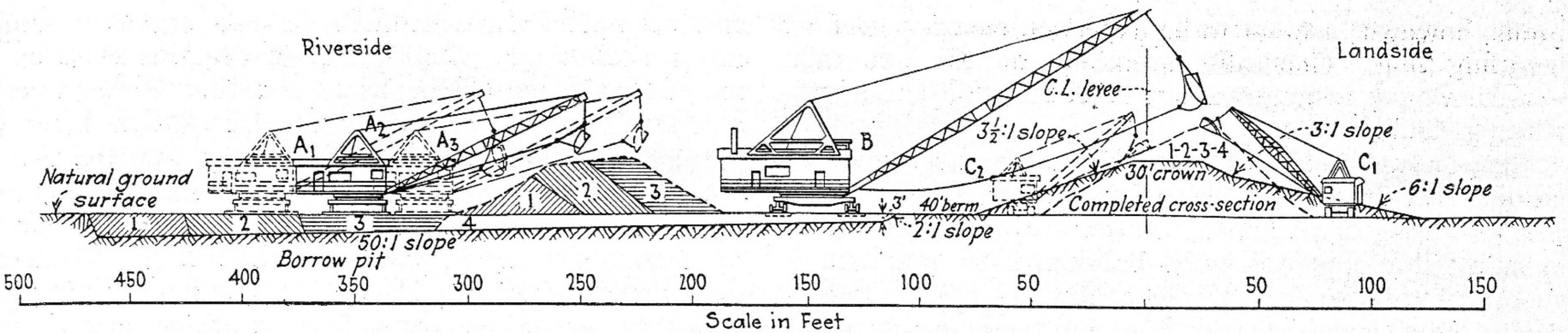


Fig. 3—Levee construction with draglines operated in series

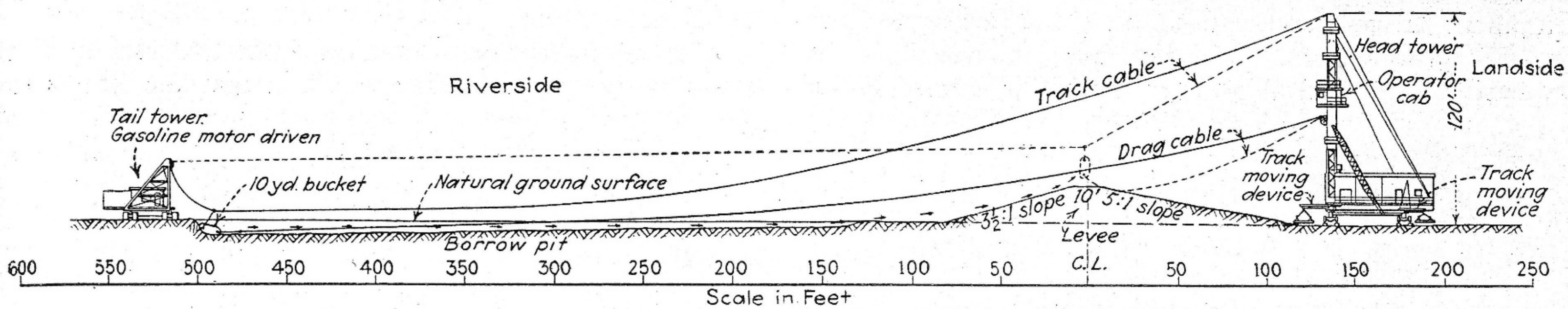


Fig. 4—Levee construction with electric tower excavator

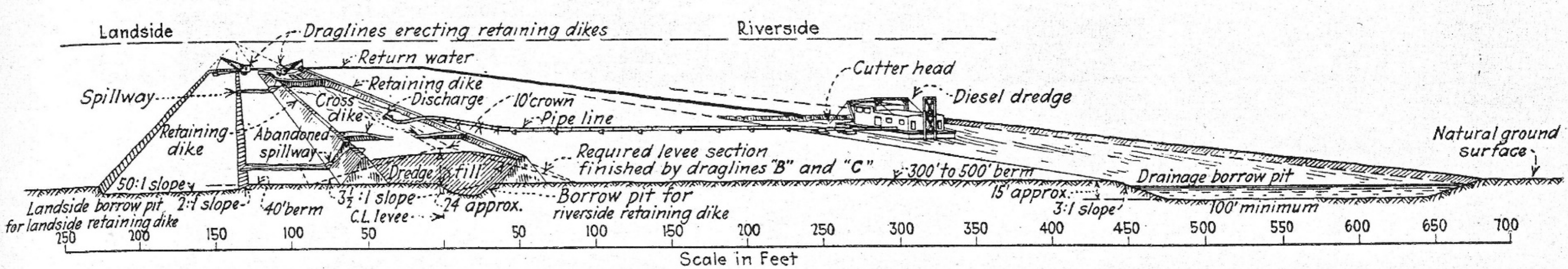
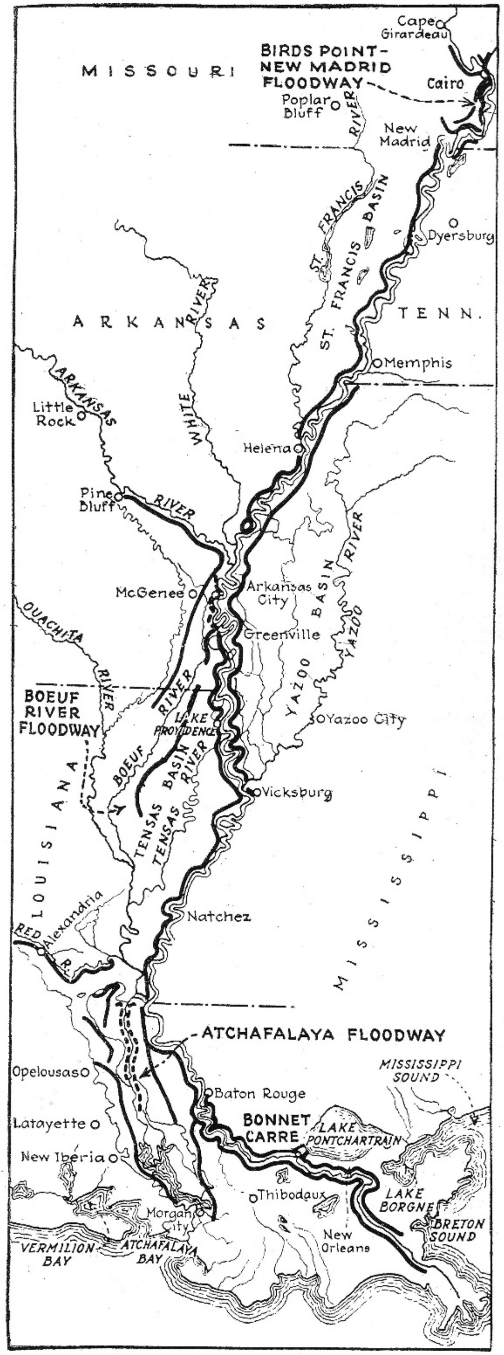


Fig. 7—Hydraulic-fill levee construction with pipe-line dredge

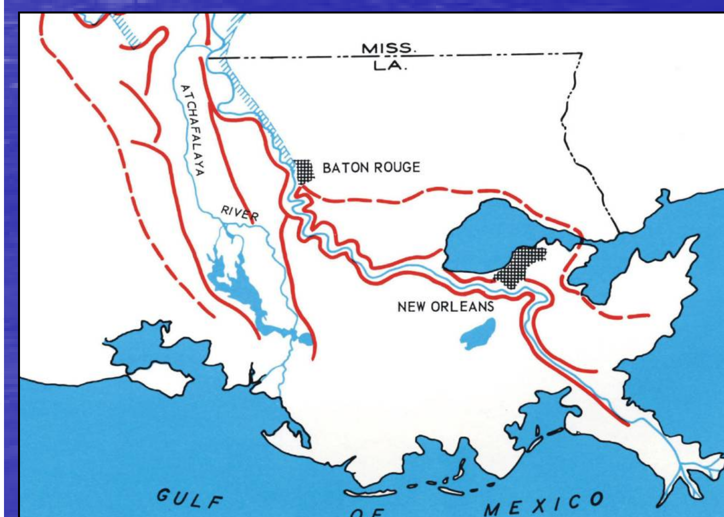
Channel stabilization measures often increase boundary shear, increasing friction and “lifting” flood stages



Levee and diversion system of Mississippi flood control adopted by act of Congress approved May 15, 1928

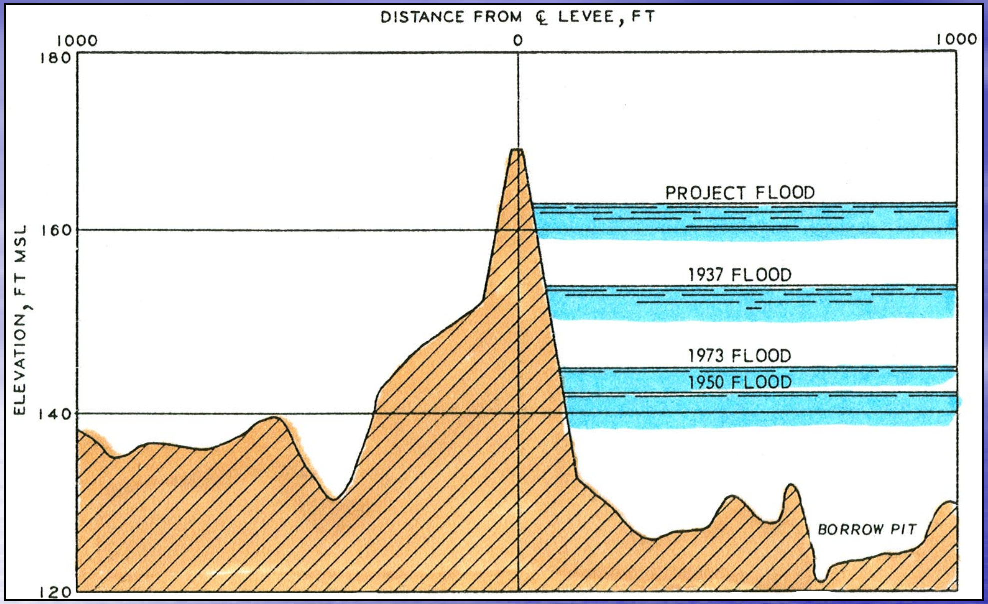
Levees, Floodwalls, and the Atchafalaya

Prof H. N. Fisk briefs BGEN Max C. Tyler, of the Mississippi River Commission in 1942

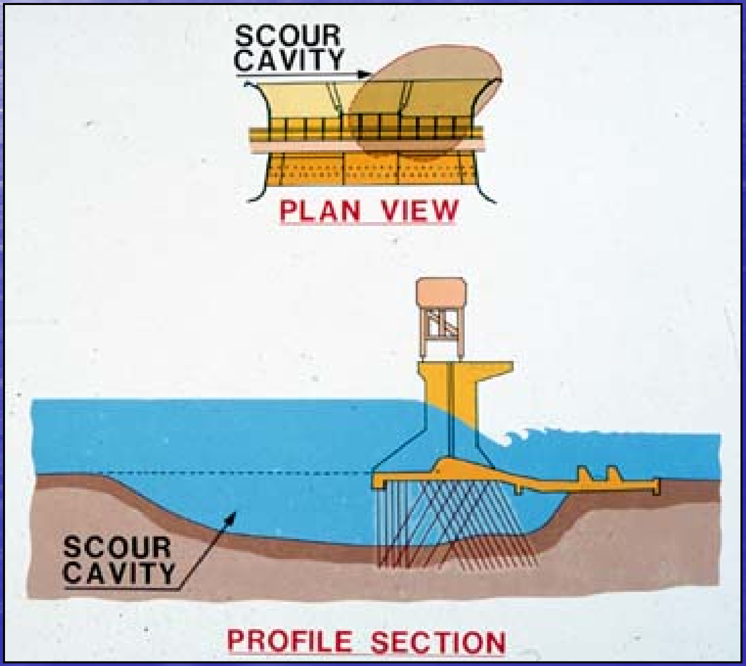


- **The MR&T employs 2,200 miles of levees and floodwalls below Cape Girardeau, which average 30 ft high**
- **In 1952 Prof. Fisk told the Corps of Engineers that under natural conditions the Mississippi River would divert itself down the Atchafalaya River, sometime by 1973**

The big test came in 1973



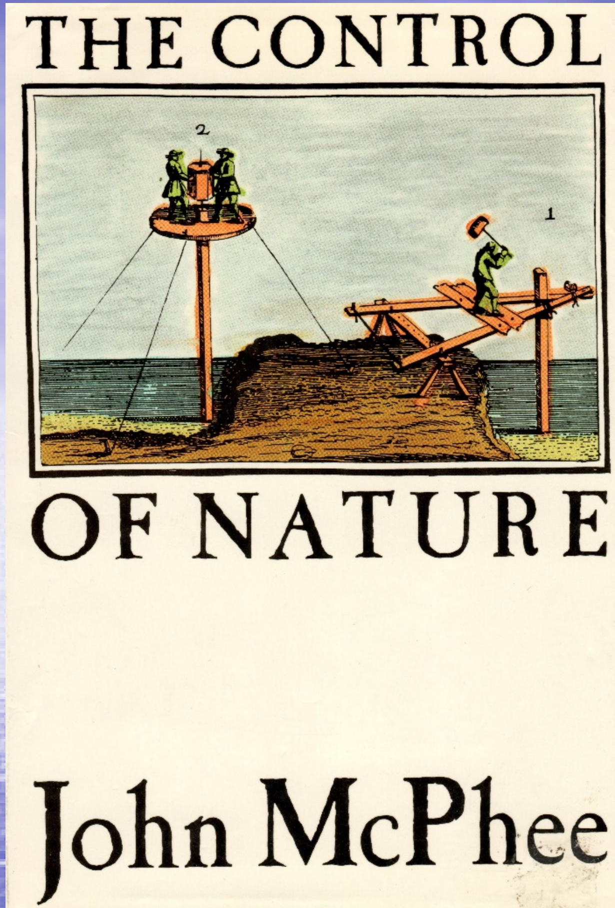
- The Corps of Engineers came perilously close to losing the Old River Diversion structure connecting to with the Atchafalaya Bypass during the 1973 flood. Its capacity was doubled afterward.

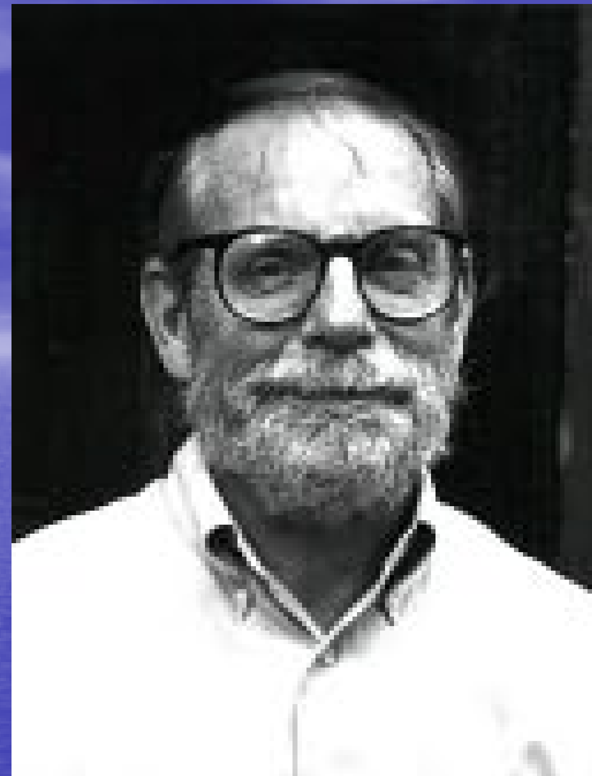


Collapsed Wing Wall on Old River Diversion Structure

- Scour cavities developed on both sides of the Low Sill Diversion Structure during the Flood of 1973.
- If these scour holes had conjoined, the structure would have failed, and a new Mississippi River channel would have been carved down the Atchafalaya River to the Gulf of Mexico.

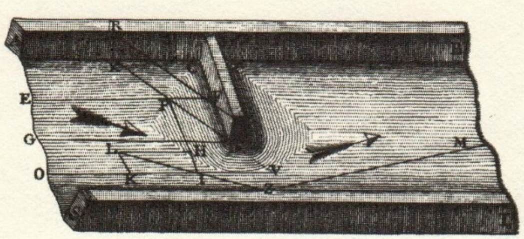
The Old River Control Structure Complex was rebuilt following the '73 flood



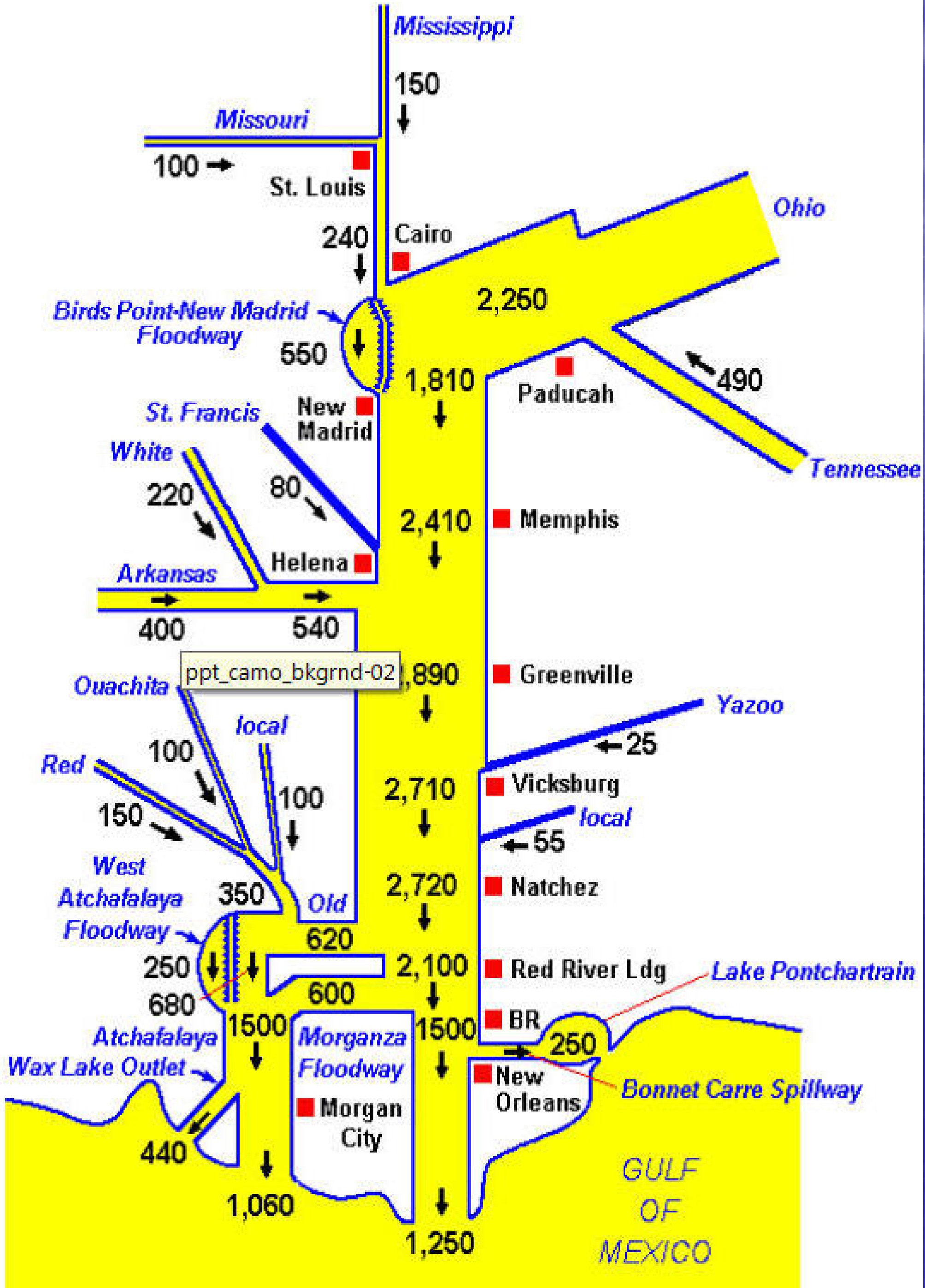


Pulitzer Prize winning author John McPhee

Atchafalaya



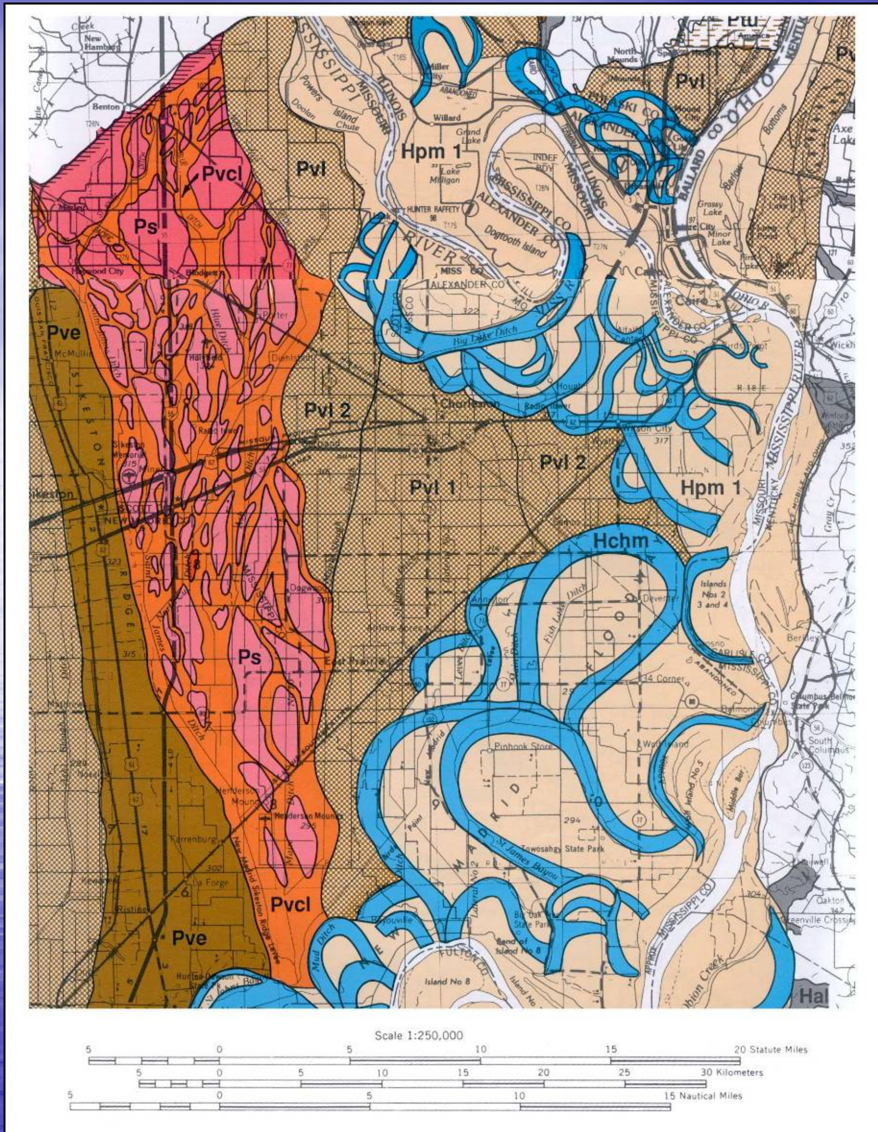
THREE HUNDRED MILES up the Mississippi River from its mouth—many parishes above New Orleans and well north of Baton Rouge—a navigation lock in the Mississippi's right bank allows ships to drop out of the river. In evident defiance of nature, they descend as much as thirty-three feet, then go off to the west or south. This, to say the least, bespeaks a rare relationship between a river and adjacent terrain—any river, anywhere, let alone the third-ranking river on earth. The ad-



MR&T Design Flood

- The **Project Flood** was developed in 1956. It combines Jan 1937, Jan 1950, and Feb 1938 storms over the Ohio and Mississippi Basins
- The peak flow of the Project Flood is **3,000,000 cfs** at Red River landing
- The MR & T was constructed by the Army Corps of Engineers between 1928-60 for $8 billion
- Numerous additions since 1960
- Major diversions at Old River, Morganza Floodway, and Bonne Carre; which siphon off 54% of the maximum flow

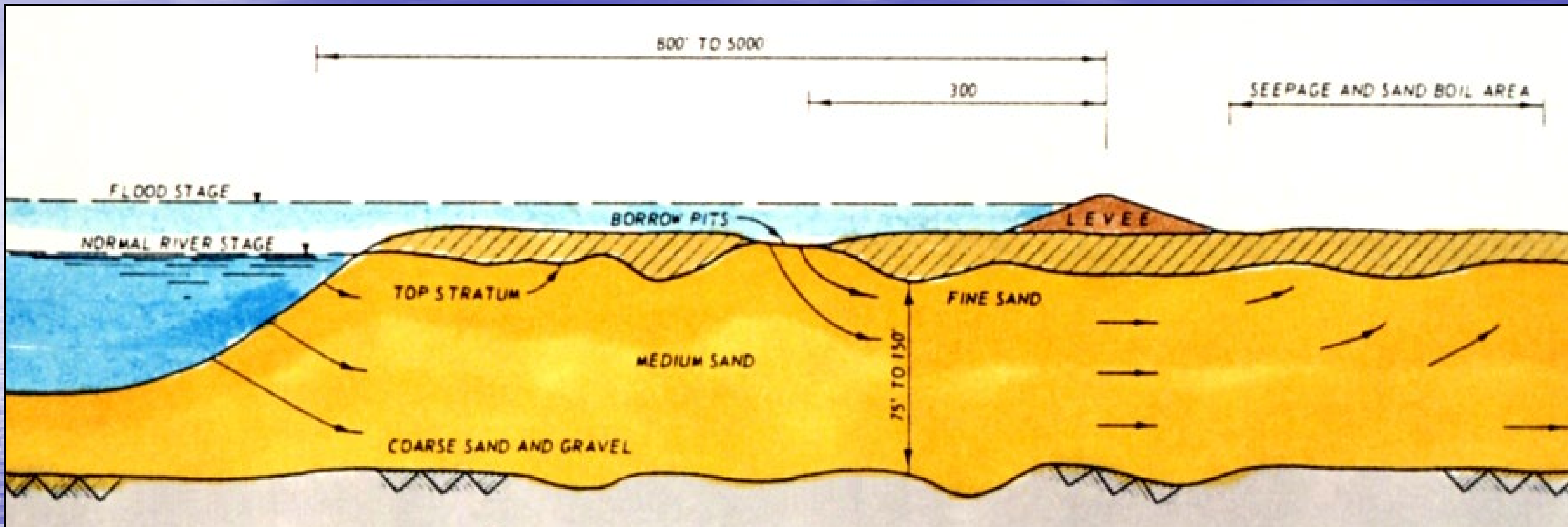
Why are levees 1000X more likely to fail than dams?



Map of Mississippi River Valley showing abandoned meanders.

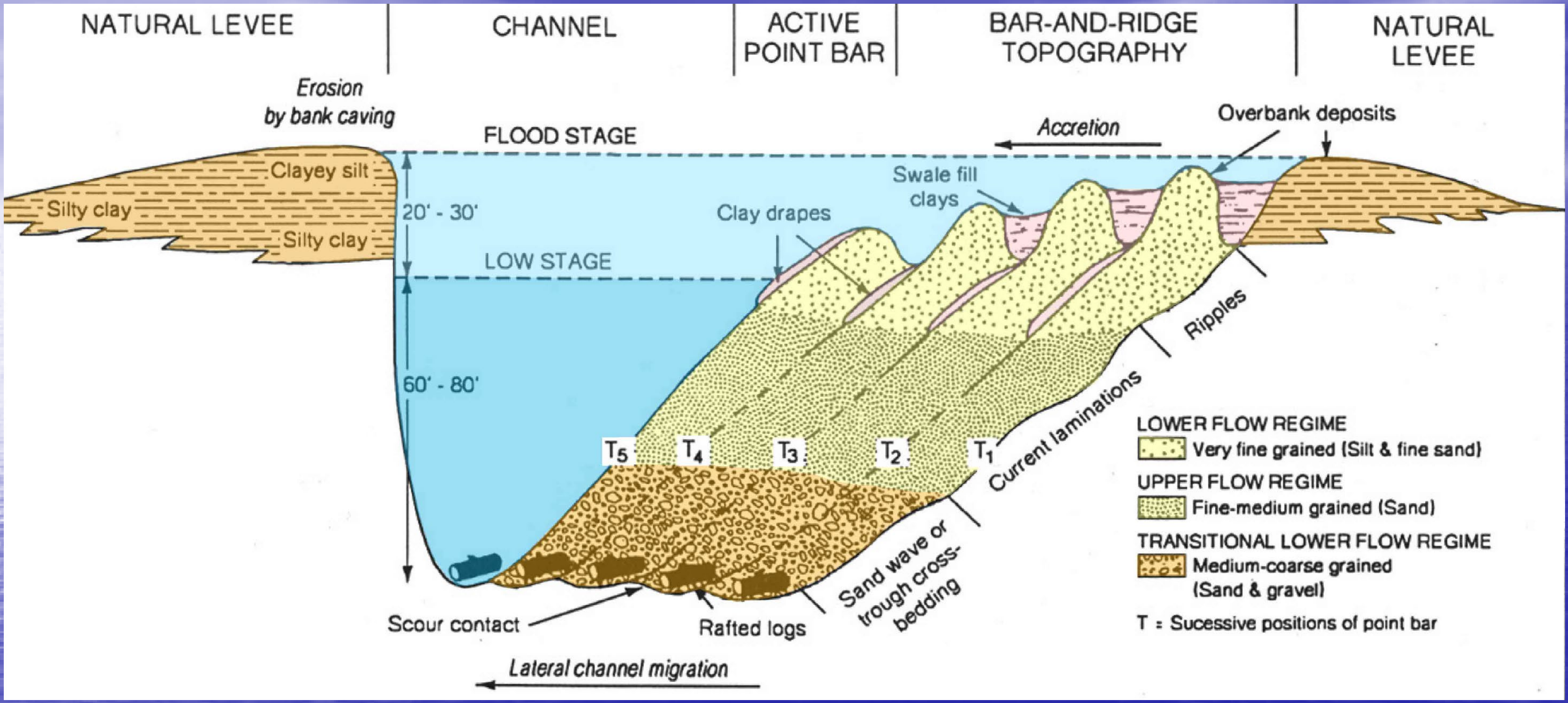
- A major shortcoming of levee is the differing foundation conditions upon which they are founded.

Underseepage problematic in permeable point bar sands



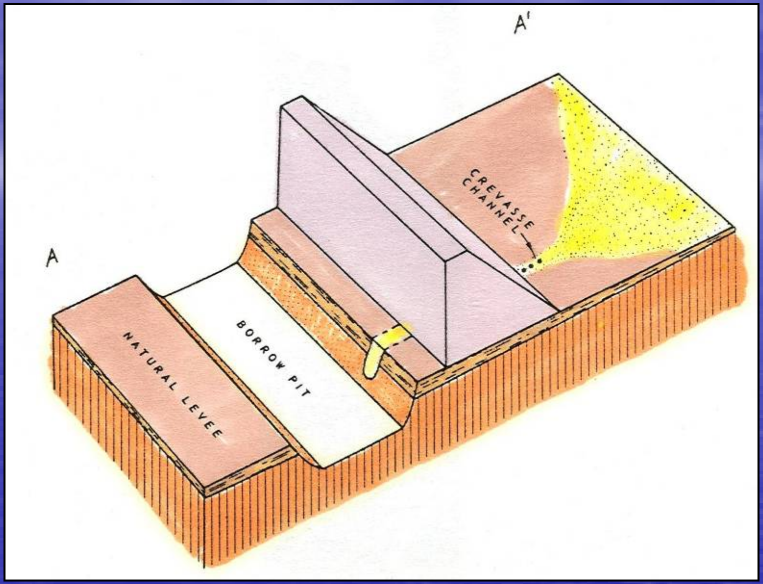
- Saturated pervious foundations respond quickly to increased hydraulic pressure, leading to development of sand boils.
- Site geology and flood duration two most important factors.

Danger of horizontal correlations



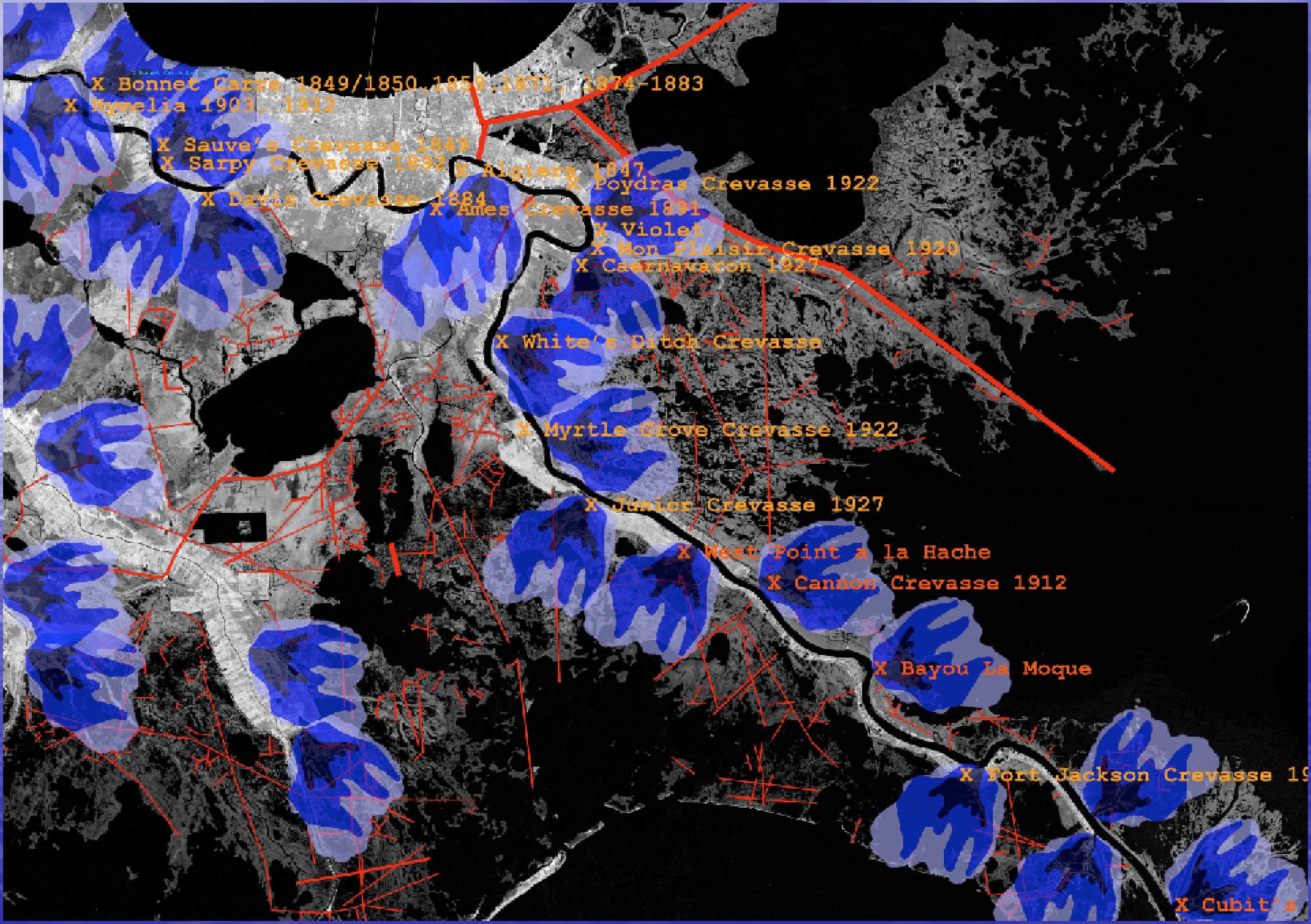
- **Inclined character of point bar deposits in a sinuous channel system. Note clay drapes; and how these might easily be mis-characterized by straight line correlations between adjacent borings.**

Natural crevasses beneath levees

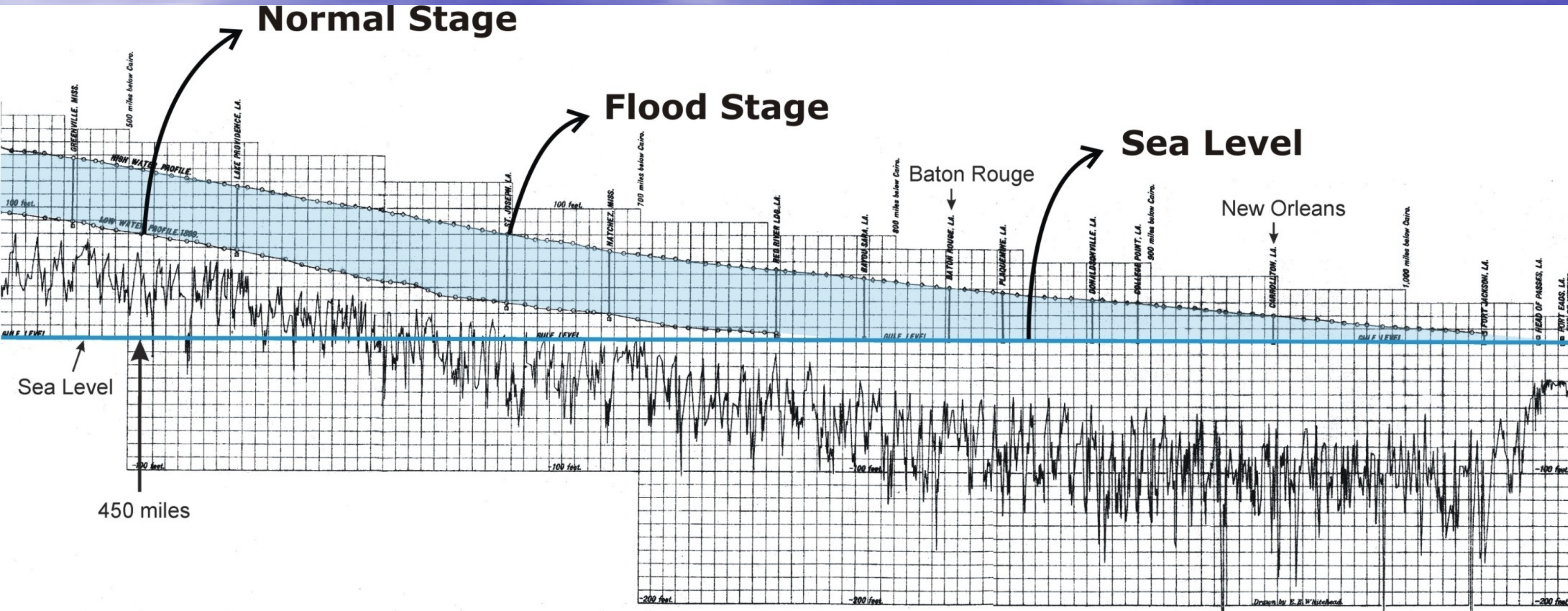


Crevasses lie beneath earthen levees like ***ticking time bombs***, waiting to explode.

Major crevasse splays along lower Mississippi River channel (from John Day at LSU)

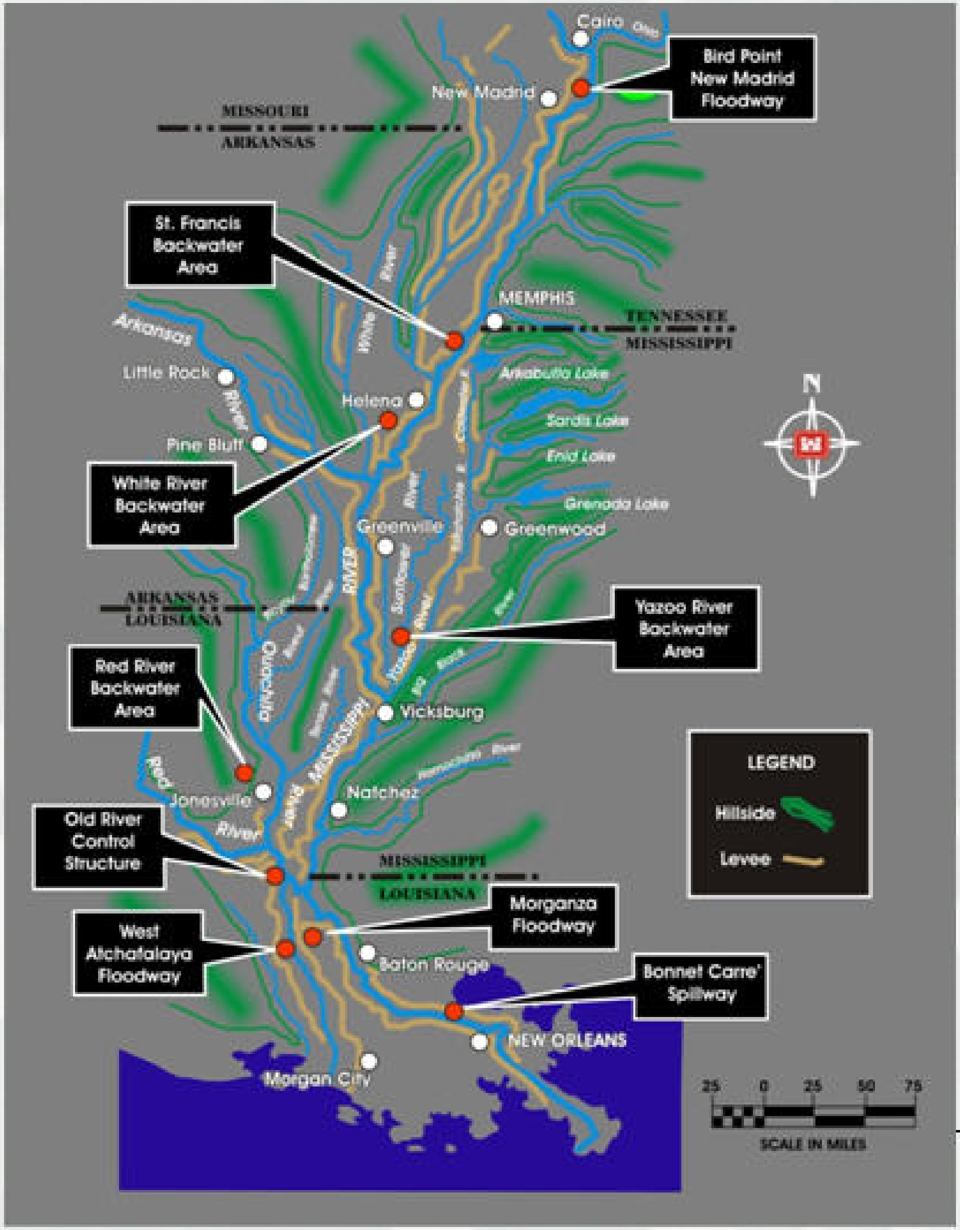


Rising Profile of the Lower Mississippi

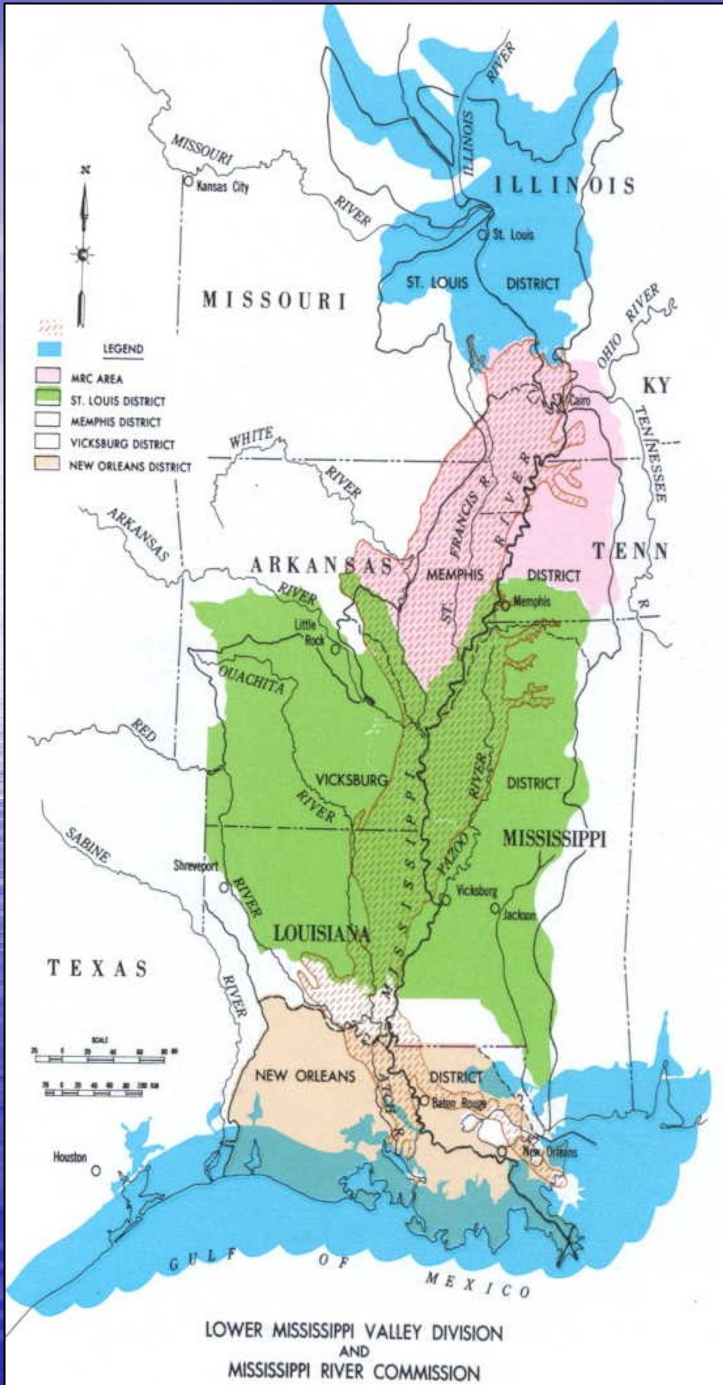


The bed of the Mississippi River dips below sea level during the last 450 miles of its course, up to Greenville, Mississippi.

Mississippi River and Tributaries Project



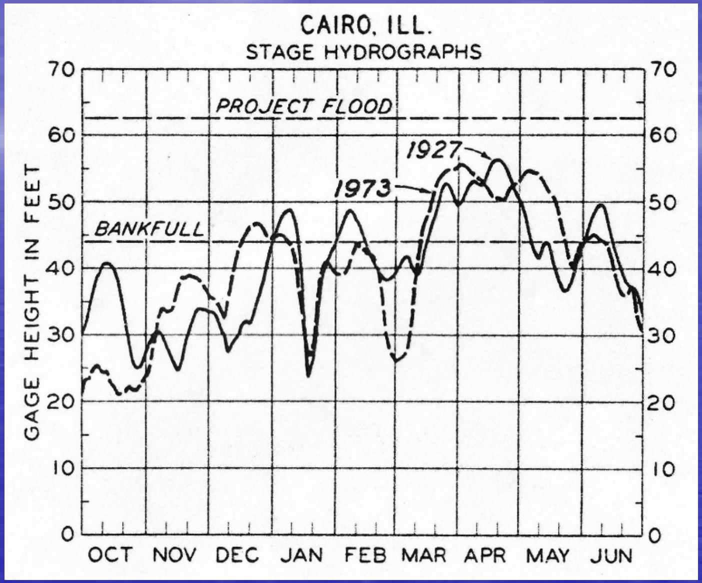
- 3400+ miles of levees
- 4 backwater areas
- 4 floodways / spillways
- 5 dams



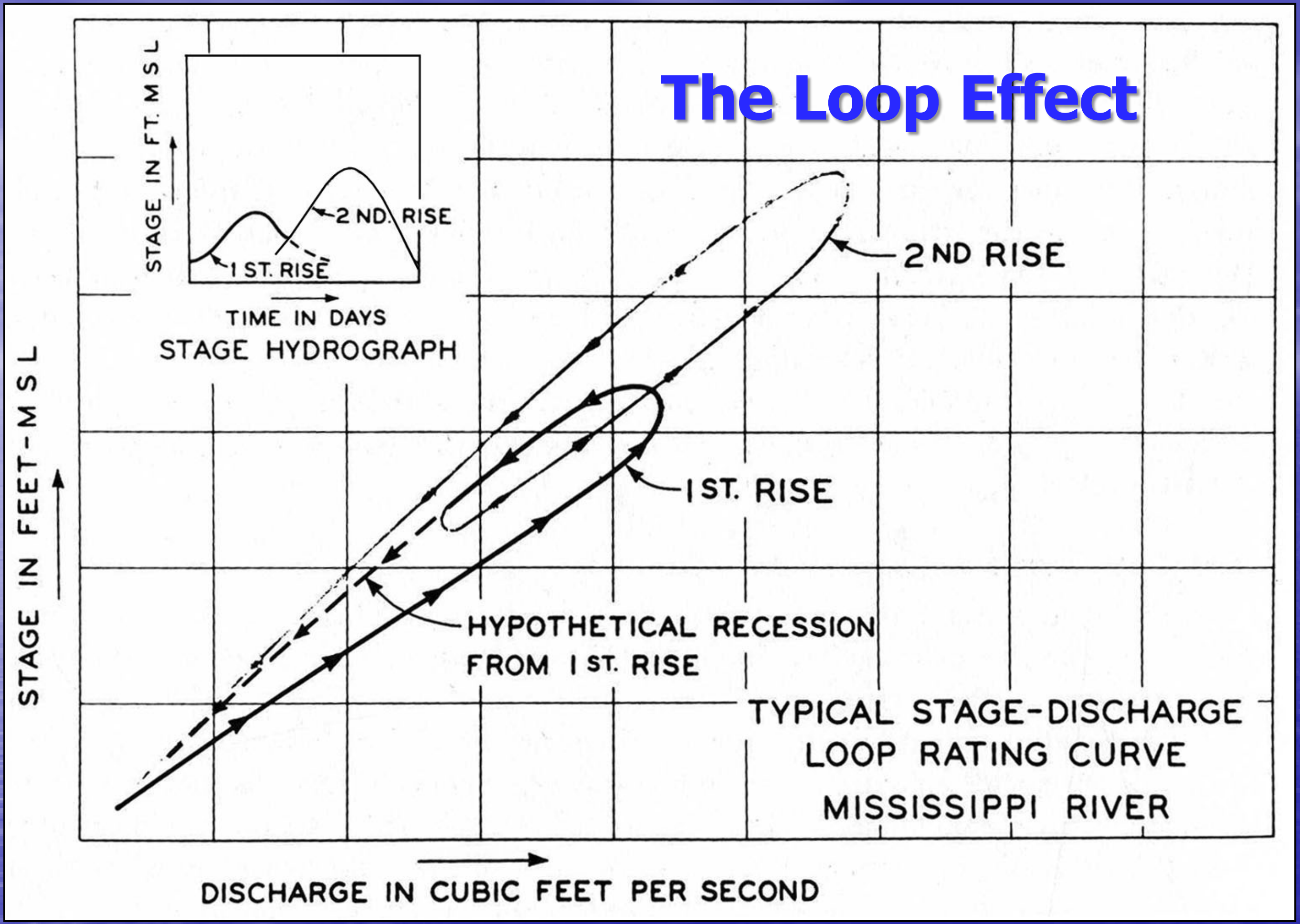
Operations and Maintenance

- O & M is handled by the respective Corps of Engineers Districts located along the Mississippi River Valley, shown here.
- The district's O&M budgets have been slashed to nothing in recent years, due to shifting Federal budget shortfalls

Rapid Drawdown induced failures

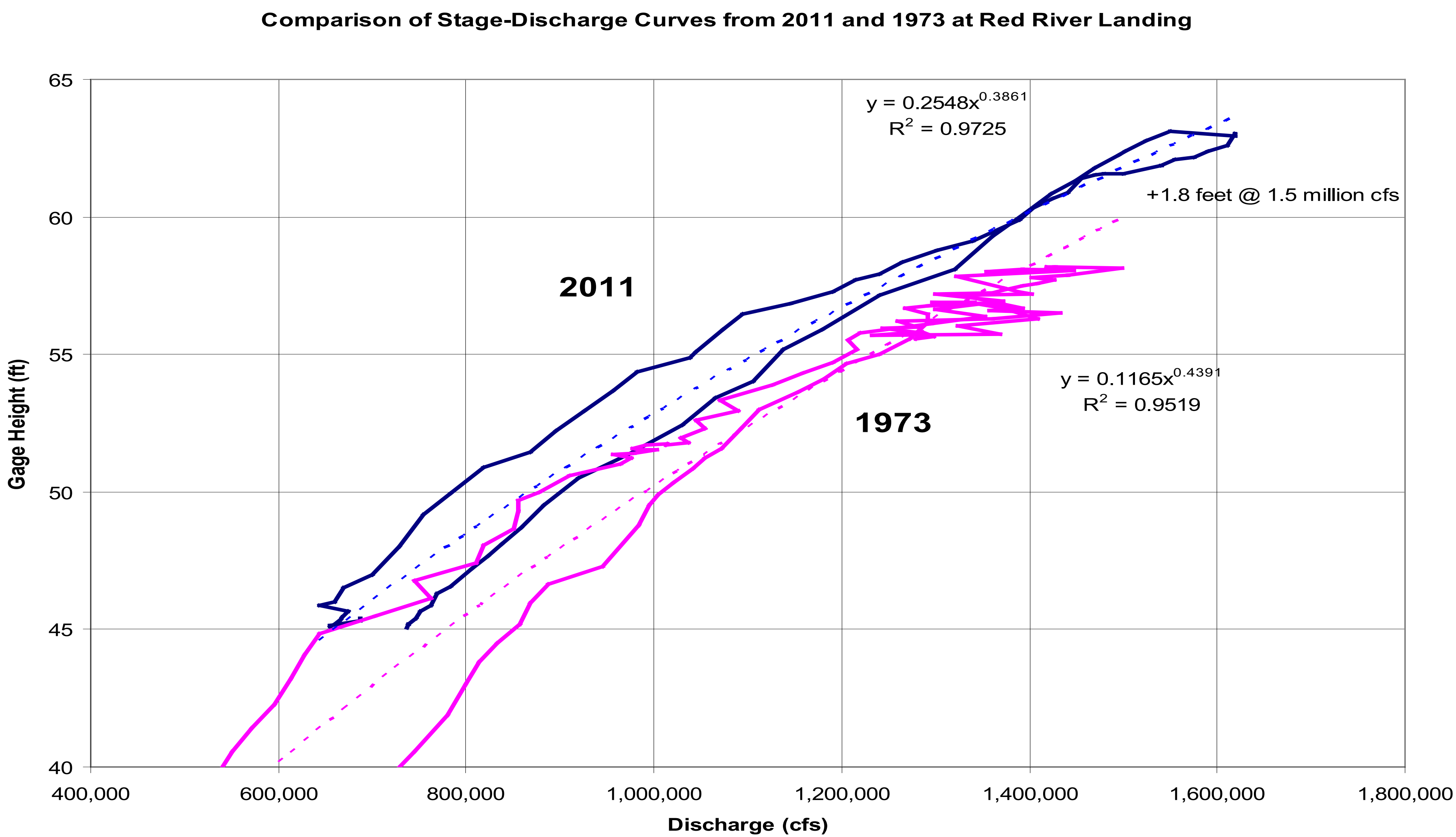


- The 1973 flood was unusual in its duration (62 to 90 days), and its multiple cycles (loop effect)
- Levees resisted peak flows, but many failed when the river dropped precipitously, after its initial early season peak, in January, February, and April

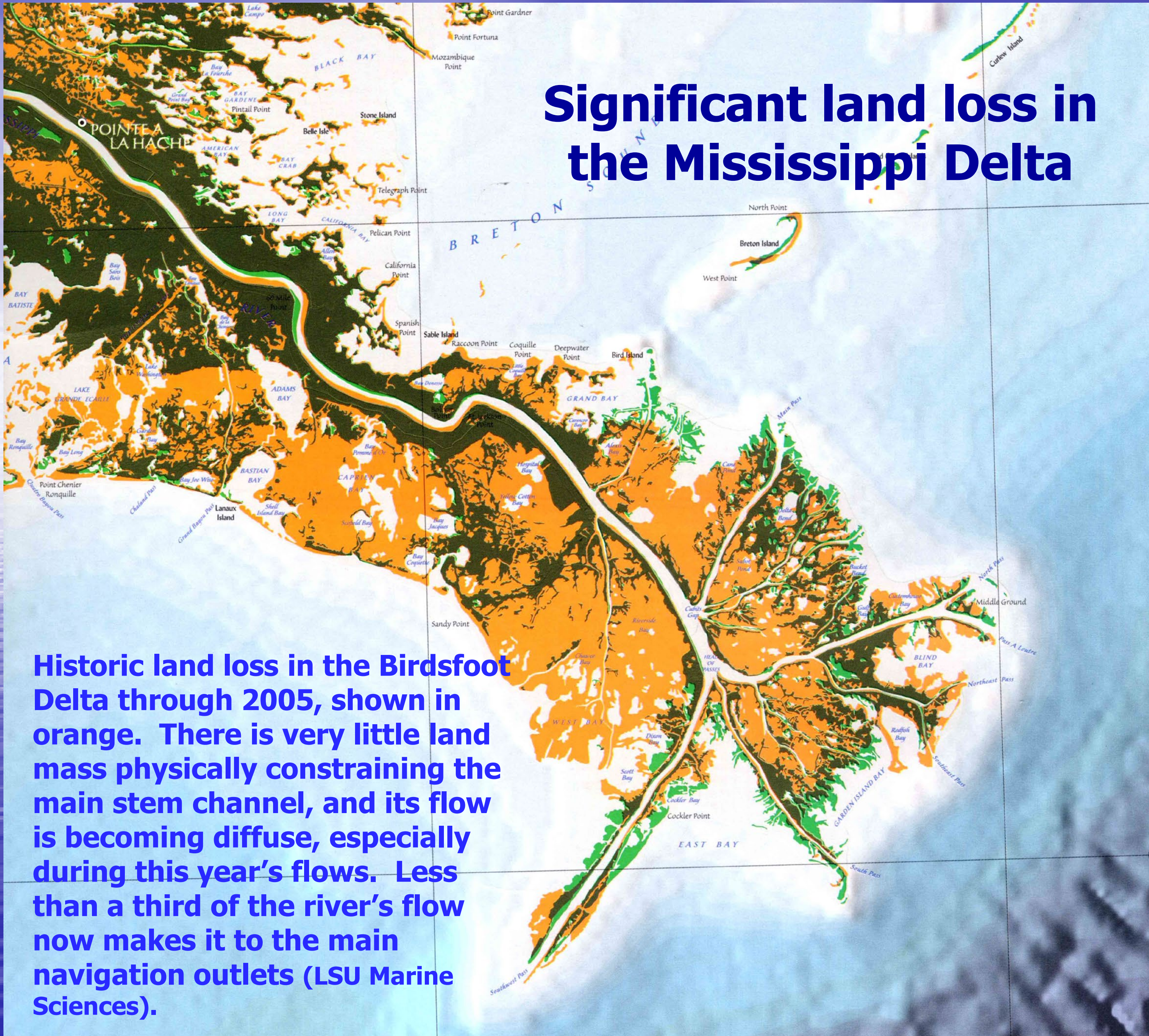


- **Stage-Discharge 'Loop Rating Curve:' Typical increases in flow stage that accompanies successive peak flows, as observed in the 1973 Flood.**

Comparison of 1973 & 2011 flood levels at Red River Landing



Significant land loss in the Mississippi Delta



Historic land loss in the Birdsfoot Delta through 2005, shown in orange. There is very little land mass physically constraining the main stem channel, and its flow is becoming diffuse, especially during this year's flows. Less than a third of the river's flow now makes it to the main navigation outlets (LSU Marine Sciences).

- Land loss shown in orange
- During the next large runoff event, the river will likely jump its banks somewhere above Head-of-Passes
- We'll be stuck with wherever it decides to go

- **During the record flows of 2011 only 22% of the river’s discharge passed through Southwest Pass, the other navigation channels being filled with silt.**