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Prototyping the Mississippi Delta: Patents, alternative futures, and the design of complex environmental systems

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Abstract

The bird foot delta of the Mississippi River exists at the nexus of cultural and environmental forces. Attempts to build navigable channels through this dynamic deltaic landscape illustrate the tension between human necessity and transformation of river systems. Each channel cut through the delta served the dual function of facilitating navigation to the Mississippi's epic inland waterway, while simultaneously expediting the movement of valuable sediment to ever-deeper water, ultimately robbing the delta and its environs of life-sustaining substrata. Technological innovation paralleled transformation of the delta, and as the navigable channels advanced, so too did the methods and devices used to rake, exhume, and define new paths for ships. This 'modern' history is strikingly well preserved in the geomorphology of the river as well as in the archives of the United States Patent and Trademark Office (USPTO). A forensic look at patent documents for the period suggests that two unrealized site-specific inventions may have led to radically different futures for the delta through the engagement of fluvial processes and altered deposition of sediments.

Patent innovation / Mississippi River / Lewis M. Haupt / Juan Bautista Medici / James Buchanan Eads

Maintenance of navigable channels through the Mississippi River's bird foot delta, known as the Heads of Passes, is vital to the economy and culture of North America, yet every new channel cut through the delta since European settlement has also expedited the movement of valuable sediment to ever-deeper gulf waters. The pre-settlement delta, as described by early explorers, was a vast matrix of mud lumps, snags, natural levees, alligators, and migrating channels—a place formed over millennia (Fig. 1). [1] Diffuse networks of distributaries, lush vegetation, and wealth of sediments conspired in the creation of the modern delta, also known as the Plaquemines-Belize delta formation, which came into being over the last 1,300 years.

In the lifespan of the ever-changing Mississippi, a river that has been producing deltas of one form or another at its interface with the Gulf of Mexico for at least 7,500 years, the anthropogenic history of the delta is relatively short. Irrespective of timescales, the transformations catalyzed by human activity have been radical and potentially irreversible. David Muth summarizes the problem as follows: 'The Bird's Foot was perched in comparatively deep water when Europeans arrived, and every channel project undertaken for the last 300 years has pushed the river's mouth into deeper water.'[2] The pre-contact (that is, unimproved) delta acted as a massive sieve, capturing sediment and building land. Introductions of new channels, or perforations, in this fabric changed the flow of water and process of accretion. New channels, in combination with extensive modifications to the broader watershed by levees, dams, and other control structures, have essentially broken the delta-building capacity of the Mississippi. And, as the land subsides and channels lengthen, the river itself now threatens to carve a new course and renew its delta, as it has for centuries.

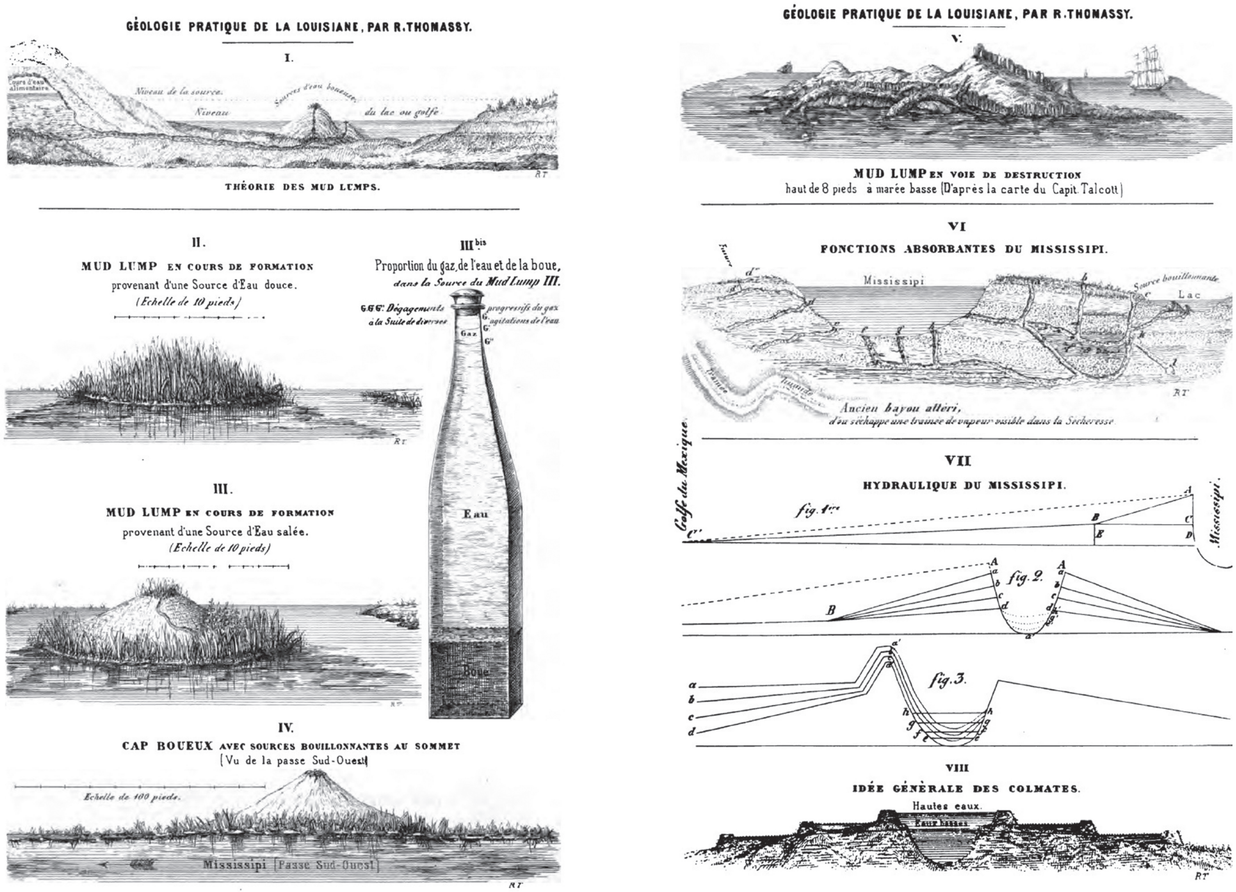

Figure 1 *Géologie pratique de la Louisiane*, a French language guide to the formation of the Mississippi River and Louisiana by Raymond Thomassy, published in 1860, was intended to accurately depict the geology of the region. Thomassy's observation of the mud lumps that form in the delta (shown here), reveal the complexity of the landscape that took shape through the subtle interplay of sediment, fresh and salt water, and vegetation over millennia. The images show actively shifting sediments, the composition of the water, subterranean veins, and the formation of natural levees.

Attempts to build navigable channels at the mouth of the Mississippi River date back to 1726 when French settlers dragged iron and timber harrows through natural passes to remove obstructions.[3] In 1837, thirty-four years after the Louisiana Purchase, the US Government commenced efforts to increase passable navigation depths in river channels using bucket dredges, initiating a long and costly process of maintaining fixed channel depths in one of the world's most dynamic deltaic landscapes.[4] Numerous proposals were developed, tested, and abandoned during the earliest years of experimentation at the Heads of Passes, including plans for permanent artificial ship channels, operation of bucket dredges to remove mud lumps, the stirring and agitation of bottom sediment, scraping of the bottom, closing of lateral outlets, and the construction of parallel jetties. Many of the machines and systems used to build navigable channels were also disclosed in patent and are now preserved in the archive of the United States Patent and Trademark Office (USPTO). This fact is not entirely coincidental, as patent rights in the United States are constitutional in origin, leading to an intricate weaving of entrepreneurial invention and environmental transformation.[5] Primacy of patent rights and the rapid rate of nation building in the nineteenth century reveal some curious anomalies and surprising narratives in patent documents, including a vivid recount of the formation of navigable channels at the mouth of the Mississippi.

Today, the primary navigable channel of the Mississippi is enormous. As ships increased in size, so did the shipping channels, culminating in the creation of parallel jetties and a permanent shipping channel at the Southwest Pass with depths of 45 feet (14.7 m). Persistence of the channel has drastically impacted the morphology of the delta, leading to rapid advancement of the Mississippi's bird foot into ever-deeper gulf waters, and necessitating levees and restrictions of outlets upstream to maintain water flow through the pass. Two parallel jetties and extensive levees expedite water and sediment beyond distributary bars and into the deep water at the delta front. A look back into the archives of the USPTO reveals that several alternative methods were patented for the construction of navigable channels through the Mississippi River Delta. In fact, as government plans were being developed for jetties at the Southwest Pass, two leading engineers, Lewis M. Haupt and Juan Bautista Medici, independently submitted patents for methods to maintain navigable channels at the pass, though neither was ever implemented. Each of the patents engages fluvial processes and delta building in unique ways, and invites us to imagine a different past and future for the delta.

A short history of innovation and the creation of navigable channels at the Heads of Passes 1837–1875

First attempts by the United States Government to maintain navigable channels through the Mississippi River Delta involved the removal of obstructions such as snags, and dredging by buckets, following recommendations made by Captain A. Talcott in his survey of the river made in 1837–1838. At the time of Talcott's survey, the natural channels of the Mississippi were littered with logs and other obstructions. Henry Shreve had been working on clearing the upper reaches of the river since the 1820s, untangling massive rafts that blocked navigation. As the government initiated its plan in 1837 to clear the passes at the mouth of the river, Shreve patented the technology for his famous snagboats *Heliopolis* (1828–1829), *Eradicator* (1836), and *Archimedes* (1837) (Fig. 2).[6] The patent, in combination with his appointment as Superintendent of Western Rivers, gave him a near monopoly on clearing the river and even led to royalty payments to his family after his death.

Shreve's innovative twin-hulled boat with central scaffolding and pulleys freed vast extents of the Mississippi's natural channels of obstructions to navigation, though the government's dredge activities proved to be less straightforward. The massive flows and fluvial forces of the river quickly reversed the bucket dredging initiated in 1837. The boat and bucket dredge used in these early dredge activities was known as the *Belize*, a massive vessel manufactured in Philadelphia by John Vaughn and Levi Morris & Co, and operated under the supervision of Captain Talcott.[7] The *Belize* was the most powerful dredge boat of its time, yet the steel of the outsized technology proved insufficient for the job and the chain links that joined the buckets failed. Once dredge activity stopped, the new channels created by the *Belize* were quickly filled by mud and silt, and dredging was put on hold until 1853.

A process of government-backed testing and prototyping occurred during the fifteen years between the cessation of bucket dredging in 1838 and contracts for harrowing in 1853. In 1845 the government approved tests and evaluation of 'J. R. Putnam's *Plan for Removing Bars at the Mouth of the Mississippi*', which involved the use of a patented harrow, or scraper, designed to dislodge and agitate bottom sediment.[8] An act of Congress authorized the Secretary of War to appoint a board of three officers to evaluate Putnam's plan and patented dredge device.[9] Putnam's plan ostensibly served as a test for future dredge technologies. His patent and published pamphlet describe a process of dragging steel plough-heads on a 24 x 30 foot (7.3 x 9.1 m) frame through passes of the river to dislodge sediment that would be carried away by river currents (Fig. 3).[10] This became the preferred method when dredge activities resumed in 1853.

The Tugboat Company of New Orleans resumed dredging in 1853 under government contract using a technology similar to Putnam's. The company employed powerful boats to drag massive harrows with iron teeth, or coulters (blades of a steel plough), through the channels using steamboats, just as Putnam had proposed in his plan and patent. Harrowing and scraping proved effective and Congress funded future schemes using modified, but similar, technology. For instance, Thomas McLallen was awarded a contract in 1860 to drag the channels with a new harrow, or scraper, invented by Steven H. Long. McLallen built and tested the highly successful 'Long's scraper' as per the specifications of the patent granted to Long in 1861.[11] Long's scraper was well regarded for its efficacy in clearing channels, though it only became the preferred method after evaluation and testing of other patented systems invented by E. B. Bishop of New Orleans,[12] and Nelson Van Deventer of New Albany, Indiana[13] (Fig. 4).[14] In this manner, the process of patenting and prototyping continued.

Success with harrowing and scraping at the Heads of Passes did not preclude the development of new and highly experimental technologies. For example, P. G. T. Beauregard, a government engineer and military officer, patented a system for a 'Self-acting bar-excavator' in 1853, which he believed focused the forces of river currents on sand bars.[15] Beauregard 'gave' his invention to the Federal Government in the hope it might help solve the problem of maintaining navigable channels (Fig. 5). Beauregard's patent claimed to deflect surface currents and erode sandbars using the energy of rivers, yet real-world tests were never recorded.[16] Unfortunately, the biggest impact of the patent may actually be one of legacy, as Beauregard's continued insistence on the merits of his invention in combination with his invention of a cure for bites from a mad dog ultimately contributed to his reputation as a 'crackpot'.[17]

By 1856/57 a plan to close lateral outlets and define a main channel with jetties was initiated with the hope that focusing the river's energy on a main channel might help remove sandbars. The contract for dam and jetty work was granted to Craig & Rightor, involving the utilization of wooden plank piles to stop water flowing through outlets upstream and a jetty constructed as necessary to remove bars in the river.[18] The system of construction utilized by the team was protected by patent, and it was also awarded a contract for implementation. The patent granted to Waldo P. Craig for a 'Dam' discloses the art of constructing wooden-plank dam walls for the closing of crevasses in levees, dikes, and other outlets of river water (Fig. 6).[19] Construction involved driving bevelled planks of alternating geometry along two sides of a wooden frame, and backfilling the void between the two parallel walls. The outlet dams and jetties did not function as planned, owing in part to weak materials, and work on closing the outlets was never fully completed.

The necessity to maintain and deepen navigable channels continued, and in 1867 the Federal Government advertised for proposals to build a dredge boat specifically designed for use at the mouth of the Mississippi. By 1869 US Government dredger *The Essayons*, French for 'let us try', was dredging the South Pass and Pass a l'Outre.[20] The dredge utilized a series of hull-mounted rotating blades to create a 'mud fan' or 'cutter head' that would cut and agitate sediment to be carried away by moving river water. The boat also utilized an adjustable water ballast to alter buoyancy, allowing the blades to reach the river bottom. A complex legal battle emerged concerning the intellectual property associated with the dredge boat technology. Edwin L. Brady claimed that *The Essayons*' design was in fact his invention, disclosed in Patent 72360, 'Dredge-Boat for Excavating River' (Fig. 7).[21] The courts ruled that design innovation for *The Essayons*' cutting head was in fact disclosed in an earlier patent by E. B. Bishop for a 'Dredging-Machine' (US Patent 19908), which was applied and tested on other dredgers. Additionally, the courts decided the innovations in hull design and other details may have also originated through older European precedents and were already in use by another vessel operating on the Mississippi River, known as the *Enoch Train*. It was therefore concluded that General

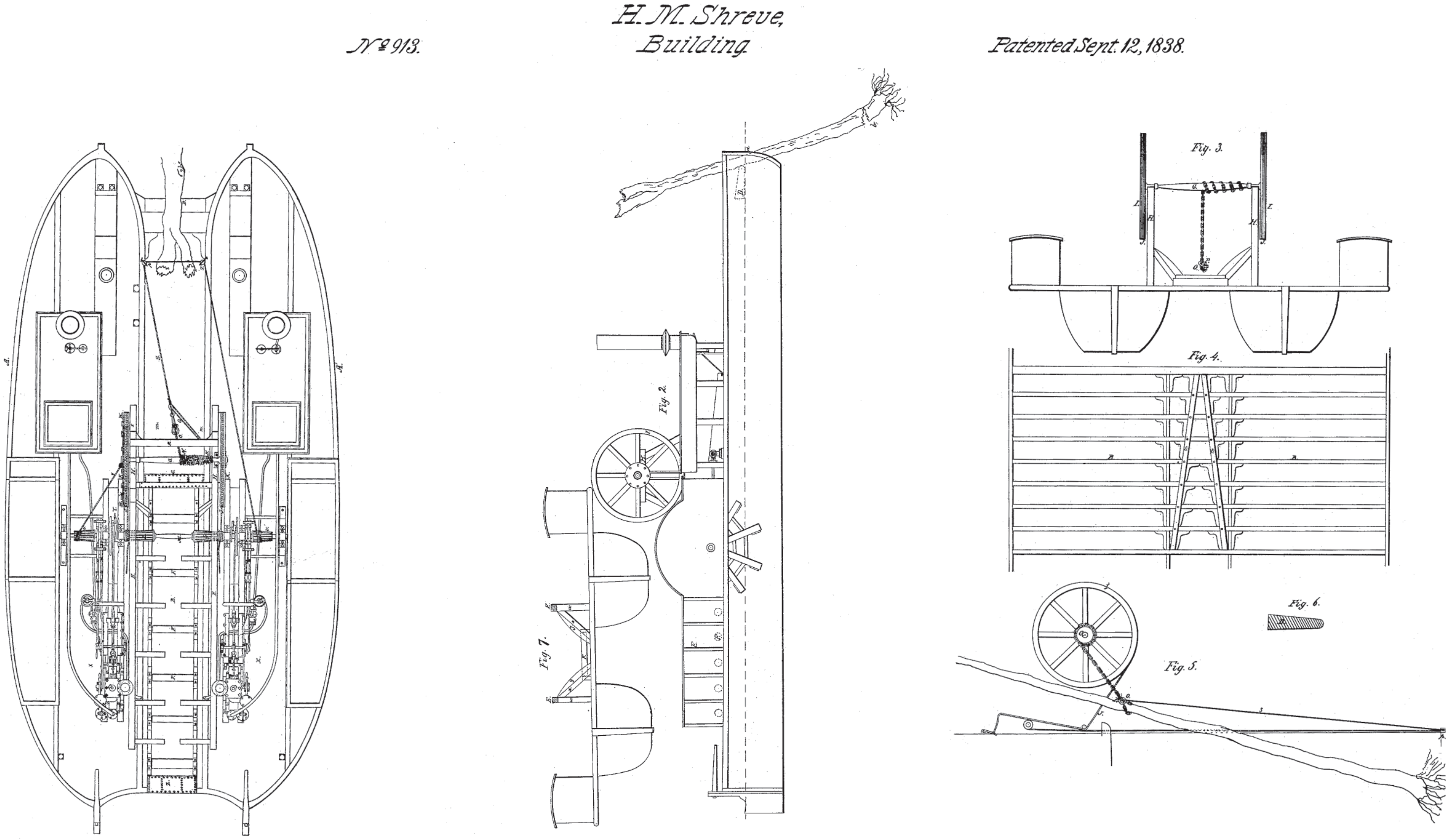

Figure 2 Henry M. Shreve patented his famous snagboat in 1838 (US Patent 913). The twin hull design made it possible to hoist large snags (for instance tree trunks) onto the vessel and clear the massive logjams that restricted navigation on the Mississippi.

The patent drawings show the process of extracting snags and the technical details of the ship designed by Shreve.

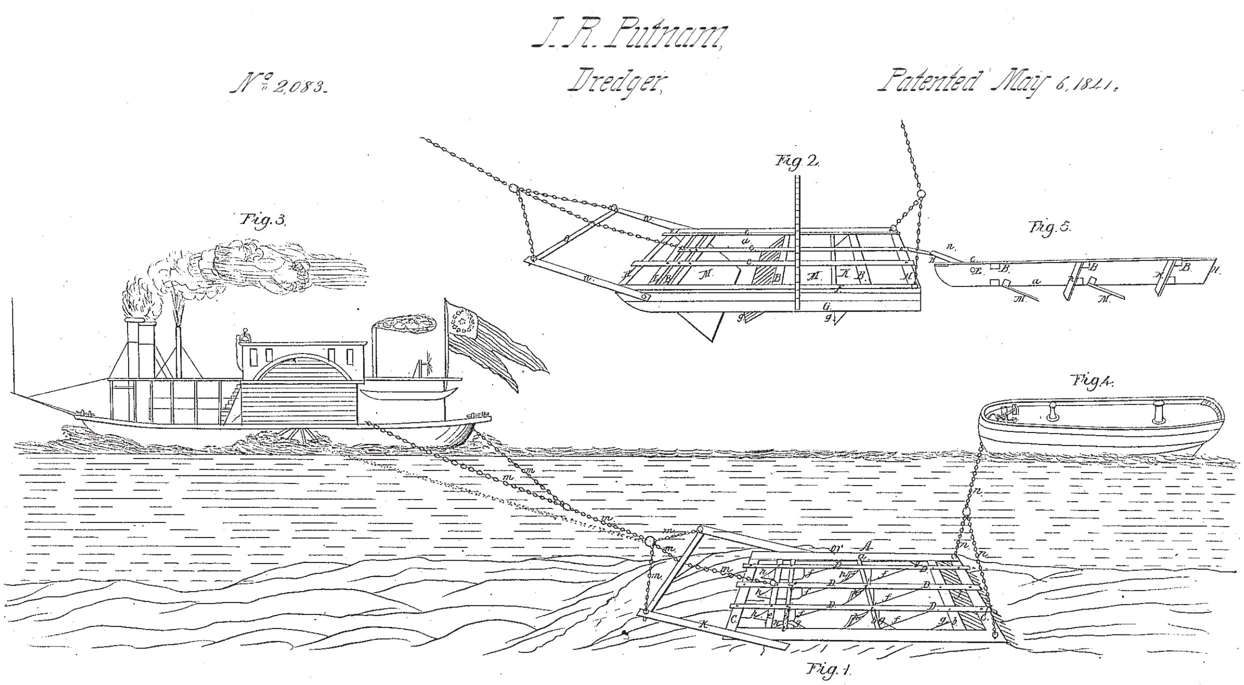

Figure 3 J. R. Putnam's technical brochure *Plan for Removing Bars at the Mouth of the Mississippi River and Other Harbors* was published in 1841 along with his patent for a dredge boat and method (US Patent 2083).

The drawings show the process of dragging massive harrows on the river bottom to dislodge sediment and cut a navigable channel.

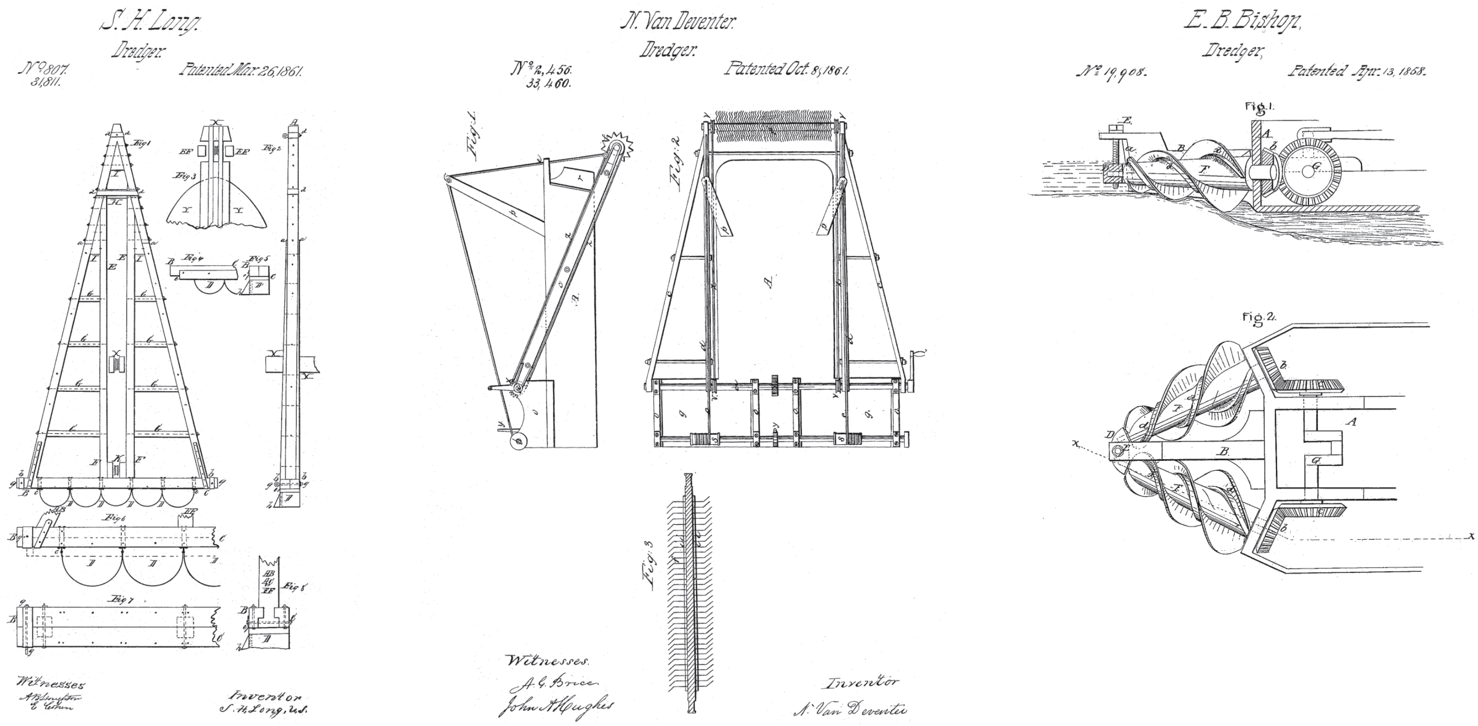

Figure 4 The process of prototyping and innovation was integral to developing new technologies for dredging the Mississippi. 'Long's Scraper' (US Patent 31811) became a preferred method and was used in the fulfilment of government contracts.

Alternative methods were also evaluated, including those disclosed in the mechanical dredge cutting heads invented by Van Deventer (US Patent 33460) and Bishop (US Patent 19908). Technical publications of the era compared these technologies and ultimately recommended the use of Long's invention.

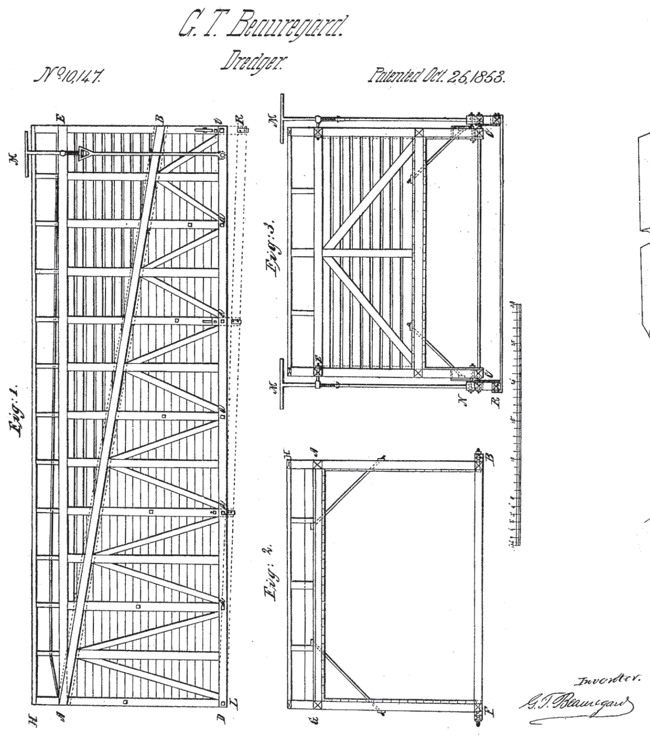

Figure 5 Mechanical devices and machines dominate the history of dredging the Mississippi. In this context, the 'Self-acting bar-excavator' invented by P. G. T. Beauregard (US Patent 10147) was novel for its use of flowing water to dredge navigable channels. The device proposed to deflect and focus river currents in an attempt to erode sandbars.

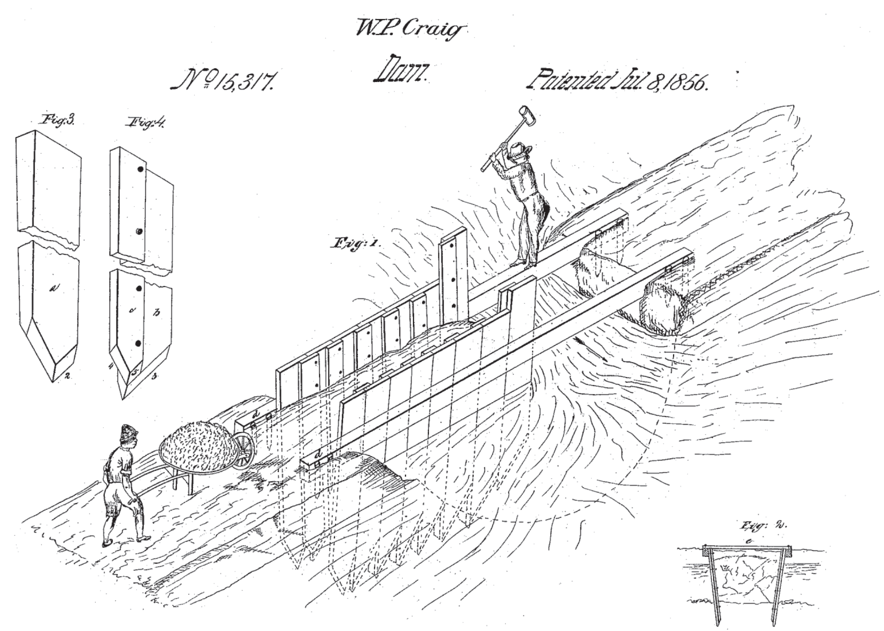

Figure 6 Craig & Rightor's plan to close lateral outlets along the lower reaches of the Mississippi River is depicted in the patent for a 'Dam' (US Patent 15317). The process involved driving parallel rows of wooden planks into the earth and backfilling the void with soil. The method, and contract, was abandoned after a few years when the technology proved too weak to withstand the force of the Mississippi and did not aid in stabilizing channel geometry.

McAlester, the ship's designer, originated plans for the dredge boat without Brady's patent. According to the ruling, Brady stole the idea and submitted a patent after learning of McAlester's plan. *The Essayons*' tenure as the primary dredge in the Southern Pass and the Pass a l'Outre extended until 1878 when the entire crew, including its captain, were lost at sea.

Four years before the tragedy on *The Essayons*, plans were already in process to build permanent parallel jetties through the Heads of Passes, as dredged channels require near-continuous maintenance in order to sustain navigable depths. The process of prototyping and testing new technology at the mouth of the Mississippi was expensive, ongoing, and largely ineffective, creating a unique opportunity for experimentation. In 1875, after a thirty-seven-year process of trial-and-error testing and patent prototyping, the US Government entered into a contractual agreement with James Buchanan Eads to prototype and test his patented jetty construction methods for the construction of navigable channels at the South Pass of the Mississippi. Eads' involvement in the Lower Mississippi changed the river forever, leading to the construction of jetties at the South and Southwest Passes and the formation of the Mississippi River Commission in 1879. This, however, did not stop the iterative process of patent innovation that defined the early American history of the delta.

Eads' prototype at the South Pass

The promise of permanent navigable channels at the Heads of Passes came closer to reality 1874 when Eads petitioned Congress with an innovative jetty plan involving the construction of parallel jetties at the Southwest Pass. Eads' patented jetties were to be made of wood and brush, placed in a parallel configuration to define a narrow channel cross section and therefore maintain navigable depths by increasing the velocity of water outletting at the pass.[22] The plan was attractive because of its cost reduction and limited financial risk for the government, yet it challenged the supremacy of the United States Army Corps of Engineers (USACE) in the improvement of rivers. Eads' proposal was eventually approved, but not for the Southwest Pass as he had intended. Instead a scaled-down version of the jetties was constructed at the smaller South Pass, leaving the massive Southwest Pass relatively unaltered until the early twentieth century.

A public battle ensued between Eads and Andrew Humphreys of the USACE, who had conflicting plans for permanent shipping channels.[23] The intricacies of the dispute are well documented, as Humphreys publicly challenged Eads' untested plan and worked to discredit the proposal for its lack of practicality and use of experiential technology. Eads and his team financed, built, and evaluated the experimental system for a period of four years (1875–1879), and when the jetties succeeded in maintaining adequate channels depths, they received their fee, estimated to have totalled 5 million dollars. Eads patented his methods, which in combination with a contract for the work based on successful maintenance of channel depth provided sufficient incentive to test their experimental technology. And, more importantly to the broader engineering community, he created a legal framework for challenging the monopoly of government engineers and agencies. The jetty prototypes were self-funded by Eads and his backers, using the principle of 'No Cure, No Pay',[24] which was heralded by the engineering community as a method to break the 'monopoly in the hands of the Army Engineer Corps'.[25] The patent, in essence, became a stick for engineers to protect their ideas, challenge government monopolies, and advance innovation with.[26]

Irrespective of the controversy, Eads and his partner James Andrews were granted patent rights for a 'Mattress for Embankments' on 8 December 1875, after petitioning Congress with their self-funded plan for jetty work (Fig. 8).[27] Eads and Andrews' experimental jetties employed floatable mattresses fabricated of wood and light brush materials that could be towed by boat into position at the desired channel geometry before sinking and anchoring them with stone and pilings. After fixing the lightweight structure in the desired location, the materials would become encased in silt that served to protect the wood from worms and rot. The river's sediment also fixed the jetty in place, in essence bonding the structure to the river.

Eads' modular, moveable, partially biodegradable jetty system challenged conventional construction practices and required evaluation and testing.[28] The process of prototyping was incentivized by paying an incremental fee for a period of four years, ultimately testing the experimental system by establishing benchmarks. Eads' jetty prototypes managed to maintain deep water for navigation, and after exhaustive surveys by the US Government the team received their fee by maintaining depths.[29] Even though Eads' system was widely considered a success, the parallel orientation of the jetties and construction methods were not perfect. The South Pass channel needed regular dredging to maintain appropriate channel depths, and the seaward extensions of the structure were repeatedly damaged by storms. Irrespective of these shortcomings, the USACE decided to replicate the same technology in the jetties at the Southwest Pass at the turn of the century as it planned channels to accommodate larger ships.

Parallel jetties at the Southwest Pass and the current morphology of the delta

The South Pass of the Mississippi was the primary navigation and shipping route of the delta for more than thirty years before a larger channel was planned at the Southwest Pass. Much had changed since the experimental period of the 1870s. The conflict between Eads and Humphreys exposed a schism between private and government engineers and led to the formation of the Mississippi River Commission (MRC) in 1879. Eads was an original member of the MRC, and had an outsized role and legacy at the Heads of Passes. Although Eads died in 1887, his inventiveness was not forgotten. In 1908, construction was completed at the Southwest Pass using similar, yet substantially reinforced, construction methods relying on the kind of bush mattresses employed by Eads more than thirty years earlier at the South Pass (Fig. 9). Importantly, the Southwest Pass was the original location suggested by Eads for the construction of his jetty system in his pamphlet *Mouth of the Mississippi: Jetty System Explained*, published and presented to Congress in 1874. Had no innovations occurred in the thirty-plus years since his initial proposal?

Parallel jetties have been in place at the Southwest Pass of the Mississippi for more than 110 years, providing an opportunity to evaluate the impact of the system on the delta. The original jetties were constructed approximately parallel and nearly half a mile apart for a length of 4 miles (6.5 km). The jetties acted like a nozzle to constrict flow, though sandbars have continuously formed in the channel and at the interface where the river water meets the gulf, requiring constant dredging. To ameliorate shoaling, the jetties have been lengthened into deeper water to promote the deposition of sediment beyond the channel entrance. The jetties now extend nearly to the continental shelf and the bulk of the sediment is expedited to an advanced delta front. Critics of the jetties argue that

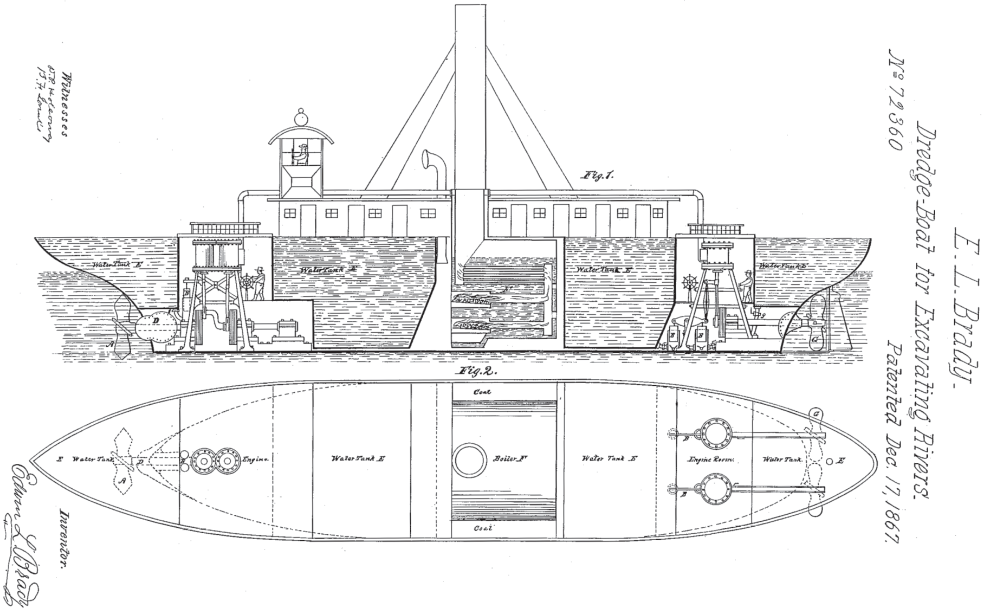

Figure 7 The purpose-built dredge boat *The Essayons* was constructed in 1869 to dredge channels at the Heads of Passes. Edwin Brady sued the US Government for infringement of his dredge boat invention (US Patent 72360), which discloses a dredger with dual cutter heads and adjustable water ballast used to control the displacement of the hull in the water column while the cutter head dislodges sediment at the bottom of the riverbed.

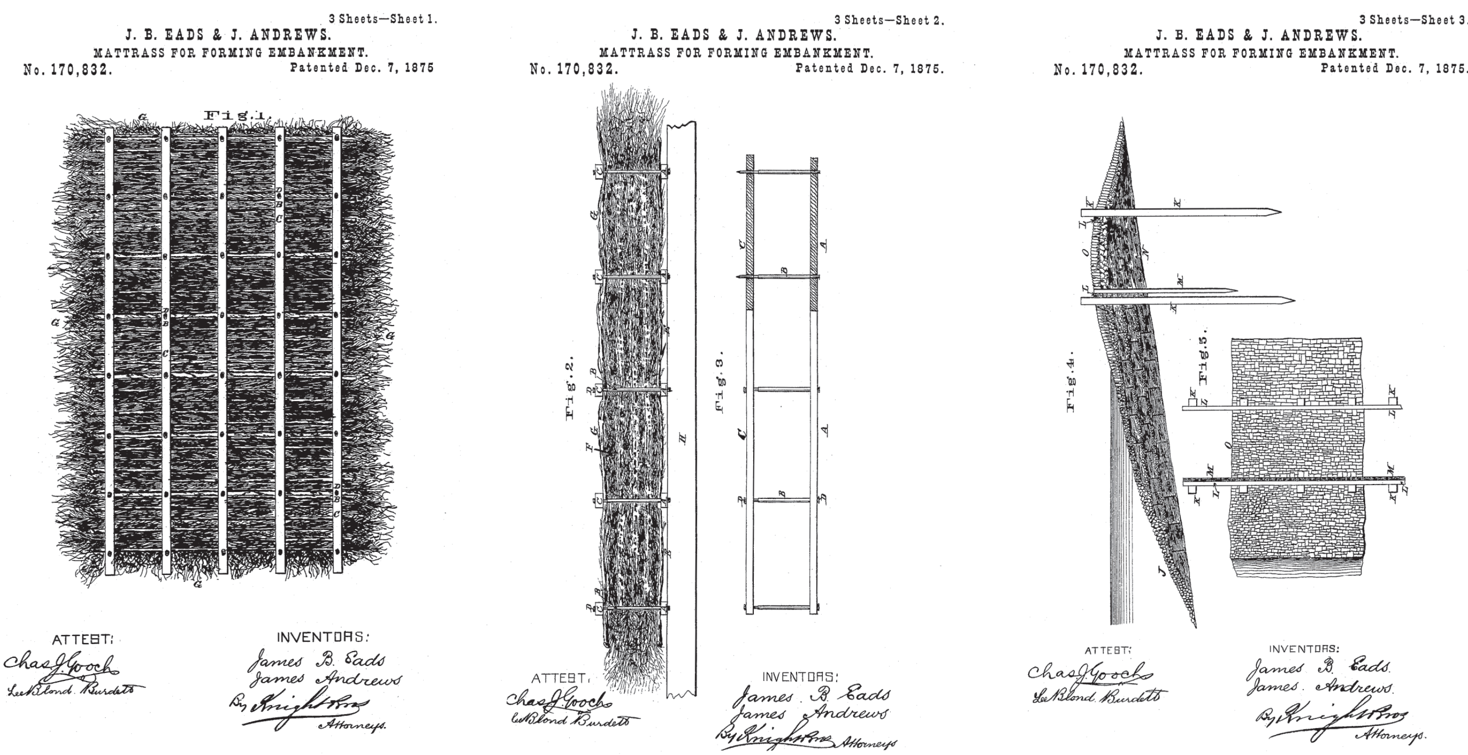

Figure 8 James Buchanan Eads' proposal to build jetties at the Southwest Pass (and later South Pass) was described in his report *Mouth of the Mississippi: Jetty System Explained* and fortified with a patent for the underlying technology. The jetty system (US Patent 170832) describes the use of floatable mattresses (shown in the left and centre drawings) composed of brush and wood that would be assembled and towed into position. The mattress would then be anchored in place using pilings and a layer of heavy stone (shown in the drawing on the right).

Figure 9 Burrwood, Louisiana, and Southwest Pass jetties construction photographs, circa 1905–1915. The photograph shows the construction process at the Southwest Pass using the mattress systems prototyped at the South Pass more than 30 years earlier by Eads. The wood and brush mattress was assembled on a platform and floated into position with tugboats. (Source: Burrwood, Louisiana, and Southwest Pass Jetties Construction Photographs, Mss. 5068, Louisiana and Lower Mississippi Valley Collections, LSU Libraries, Baton Rouge, Louisiana, USA)

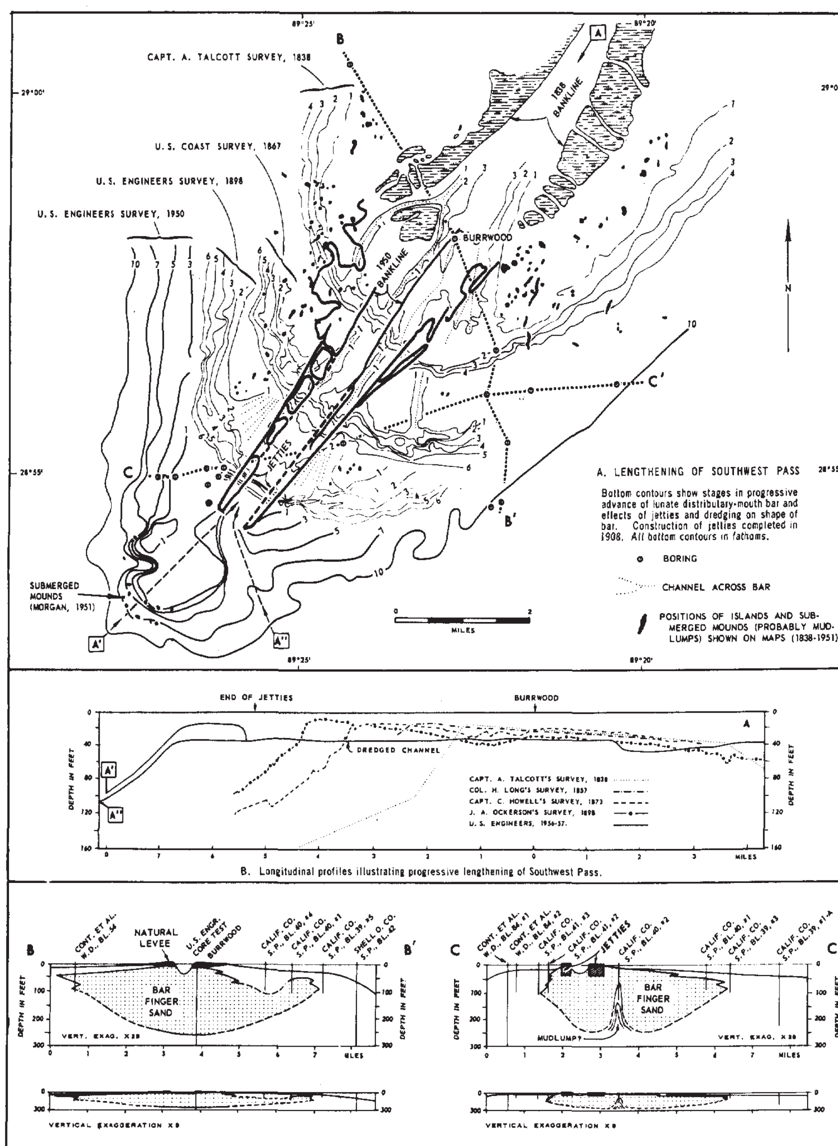

Figure 10 Historical development of the Southwest Pass showing the effects of jetties and dredging. Note the extension of the pass and channel into deeper water.
(Source: Harold Norman Fisk, 'Bar-Finger Sands of Mississippi Delta', in: J. A. and J. C. Osmond (eds.), *Geometry of Sandstone Bodies* (American Association of Petroleum Geologists, 1961), 29-52.

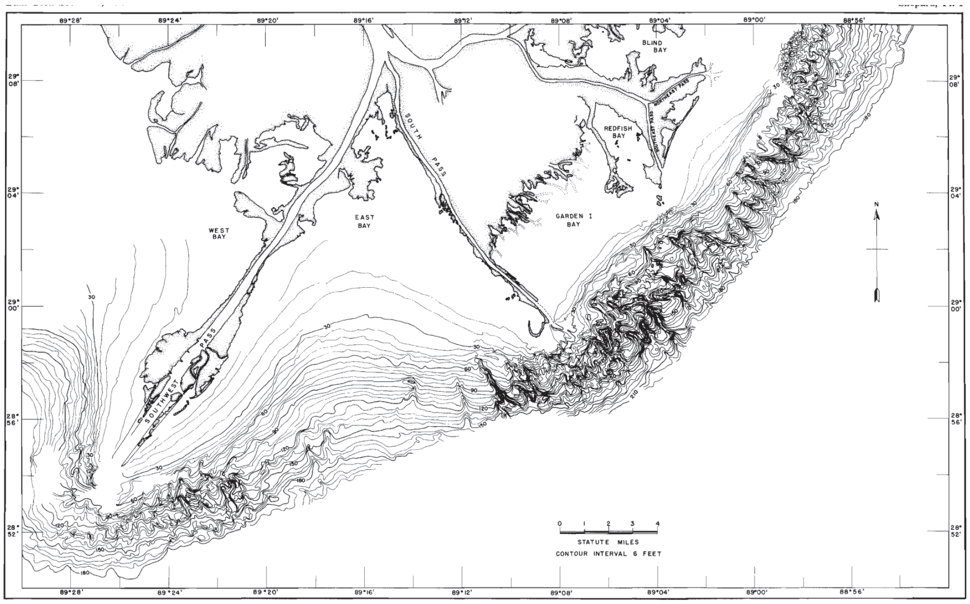

Figure 11 Submarine topography of the upper slope of the Mississippi River Delta from the Southwest Pass to the Northwest Pass. (Reprinted with permission from: Francis P. Shepard, 'Delta-Front Valleys Bordering the Mississippi Distributaries', *Geological Society of America Bulletin* 66/12 (1955), 1489–1498)

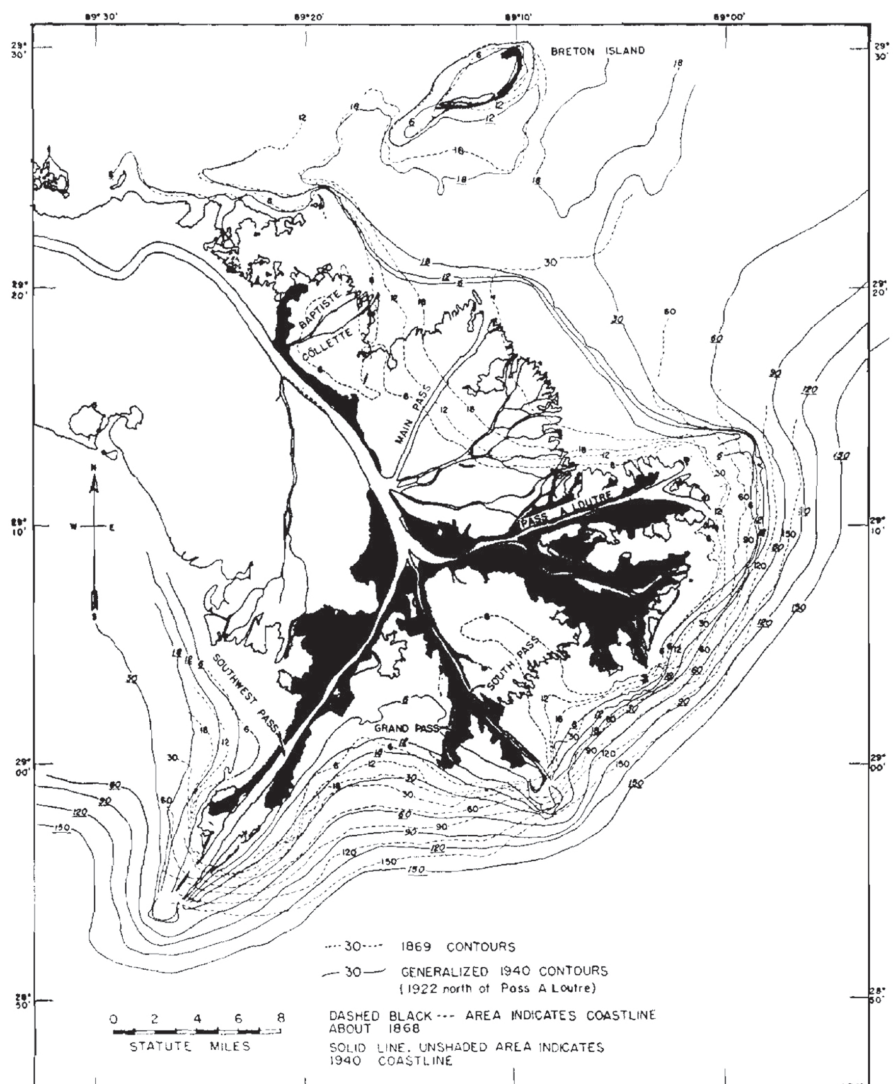

Figure 12 Comparison of old and new outer delta of the Mississippi River with generalized contours showing the depth changes between 1869 and 1955. (Reprinted with Permission from: Francis P. Shepard, 'Delta-Front Valleys Bordering the Mississippi Distributaries', *Geological Society of America Bulletin* 66/12 (1955), 1489–1498)

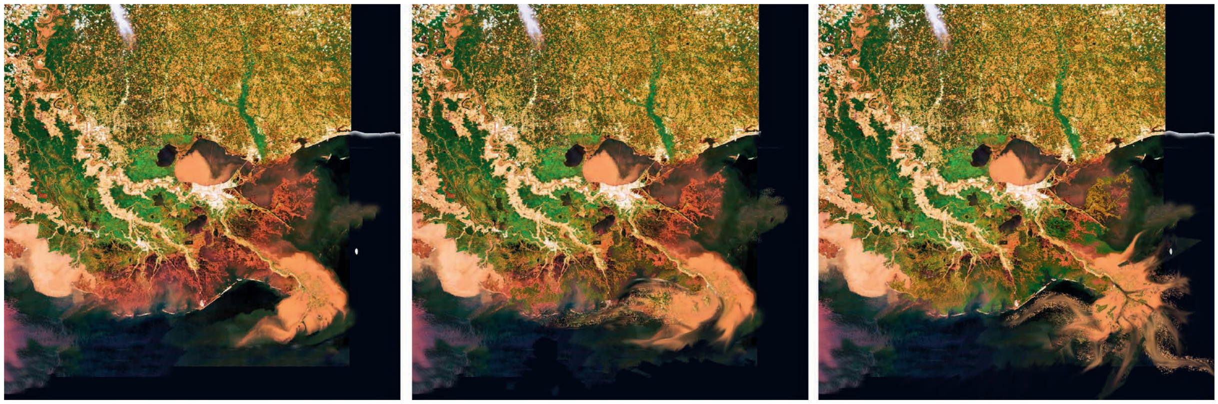

Figure 13 (Left) Existing NASA Satellite image showing areas of vegetation growth and sediment plume. (Centre) Rendering (by author) speculating on the morphology of the delta if Lewis M. Haupt's patent had been implemented in the early twentieth century and sediments had been directed westward towards the delta and barrier islands. (Right) Rendering (by author) speculating on the morphology of the delta if Juan Bautista Medici's patent had been implemented in the early twentieth century and sediment had been accumulated adjacent to navigation channels by a 'bathymetric forest'.

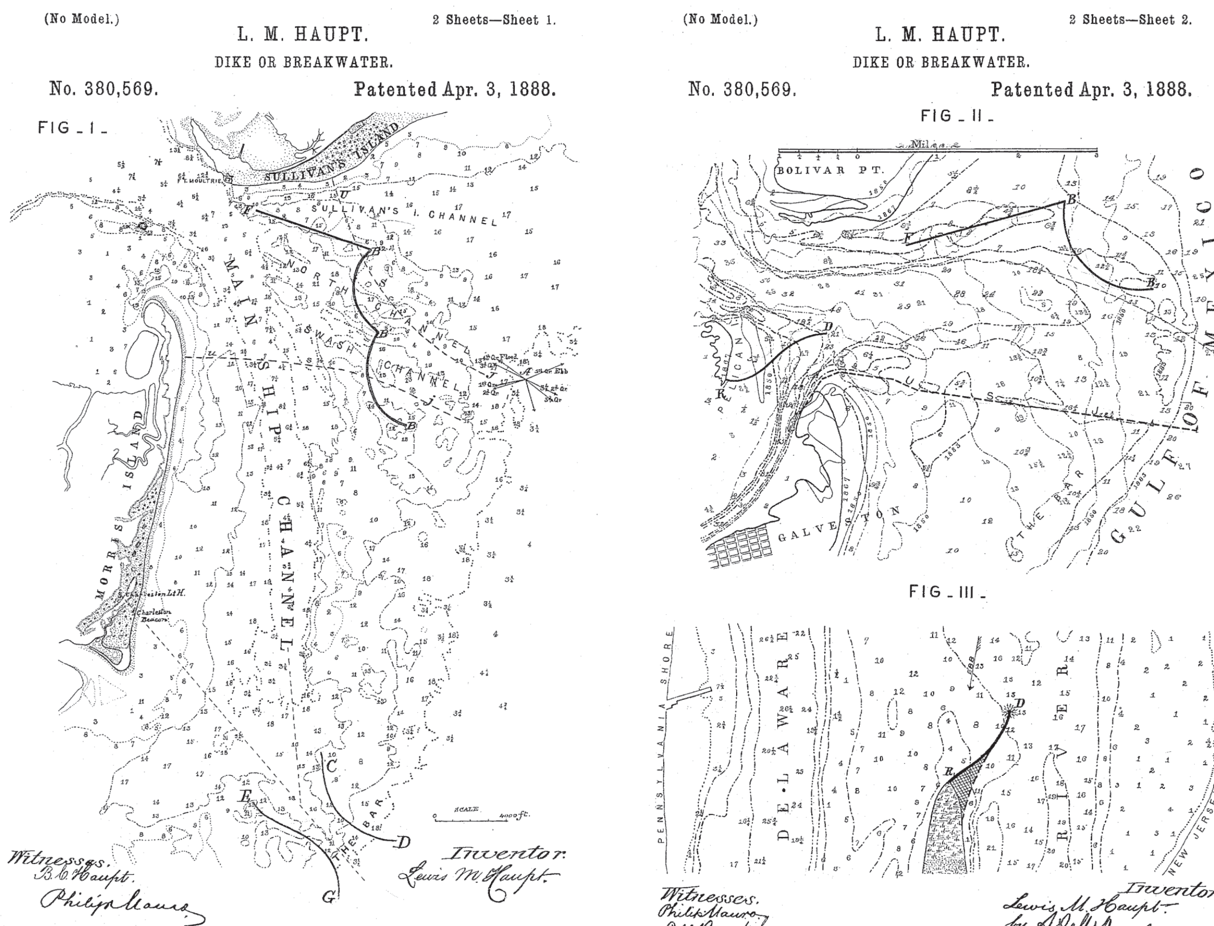

Figure 14 Lewis M. Haupt's patent for the reaction breakwater shows his invention sited at the entrance to Galveston Bay, in the Delaware River, and at the entrance to the Charleston Harbor (US Patent 380569). The breakwater was designed to maintain navigable channels at the mouths of rivers, harbours, and ports, or areas with active tidal changes where its double curved form would passively scour a channel to the required depths. The patent drawings show the proposed plan layout and projected bathymetry.

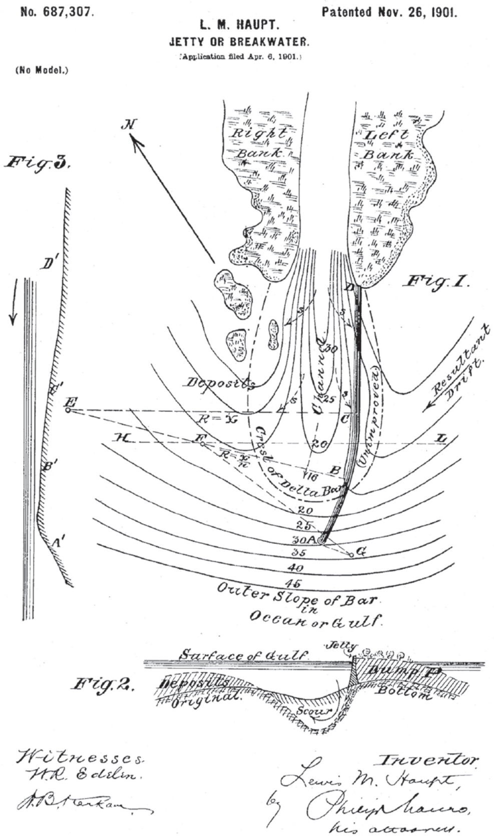

Figure 15a Lewis M. Haupt modified the reaction breakwater to fit conditions found in the deltas of sediment-laden rivers such as the Mississippi (US Patent 687307). The drawing shows the invention sited at the Southwest Pass of the Mississippi. Although it is somewhat uncommon to show specific sites in patent drawings, Haupt was actively promoting the breakwater at the Southwest Pass and used the patent image as a case study to describe the intended use.

Figure 15b Lewis M. Haupt's topographical models for the Southwest Pass of the Mississippi comparing the USACE plan requiring dredging (left) to his plan using the reaction breakwater without dredging (right). Notice the depth of the channel and deposition of sediment on the western bank. (Source: Lewis M Haupt, 'The Reaction Breakwater as Proposed for the Opening of the South-West Pass of the Mississippi River', *Journal of the Franklin Institute* 150/1 (1900), 1–17)

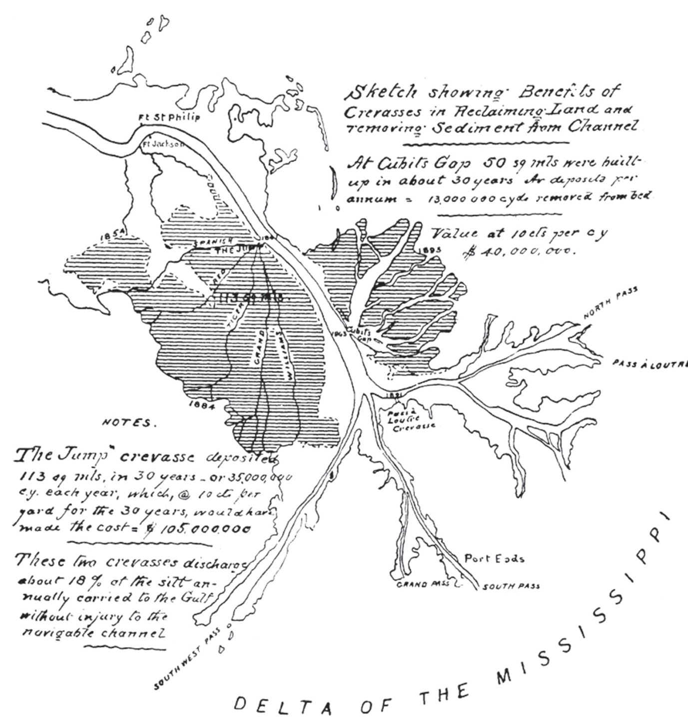

Figure 16 Lewis M. Haupt's drawing of outlets from his article on the 'Mississippi Problem' shows the recharge of the delta. He also argued that outlets would relieve the sediment load at the Southwest Pass and reduce the need for dredging, which in combination with the reaction breakwater would be self-sustaining and self-dredging. (Source: Lewis M. Haupt, 'The Mississippi River Problem', *Proceedings of the American Philosophical Society* 43/175 (1904), 71–96)

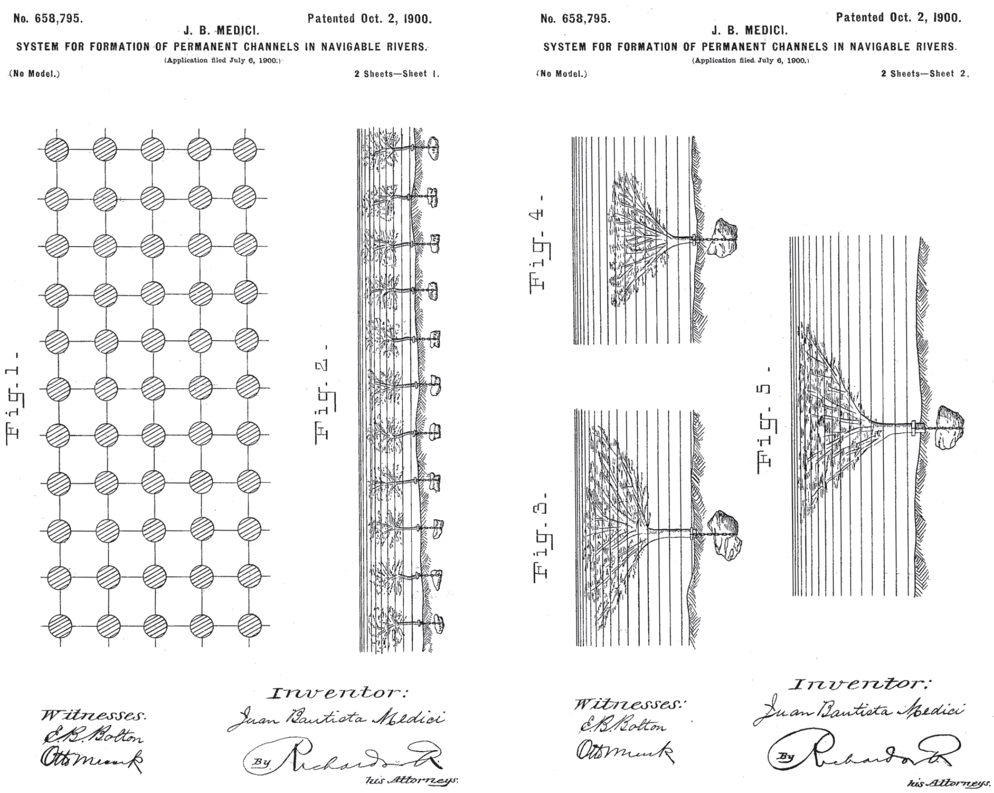

Figure 17a Juan Bautista Medici's patent drawings (US Patent 658795) show a system of establishing a subsurface 'forest' to define navigable channels. The right drawing shows the basic unit of construction anchoring trees with large boulders at variable heights in the water column. The left drawing shows the basic grid layout that arrays the anchored trees and a cross section through the array. Variable heights of trees in the gridded formation define channel geometry.

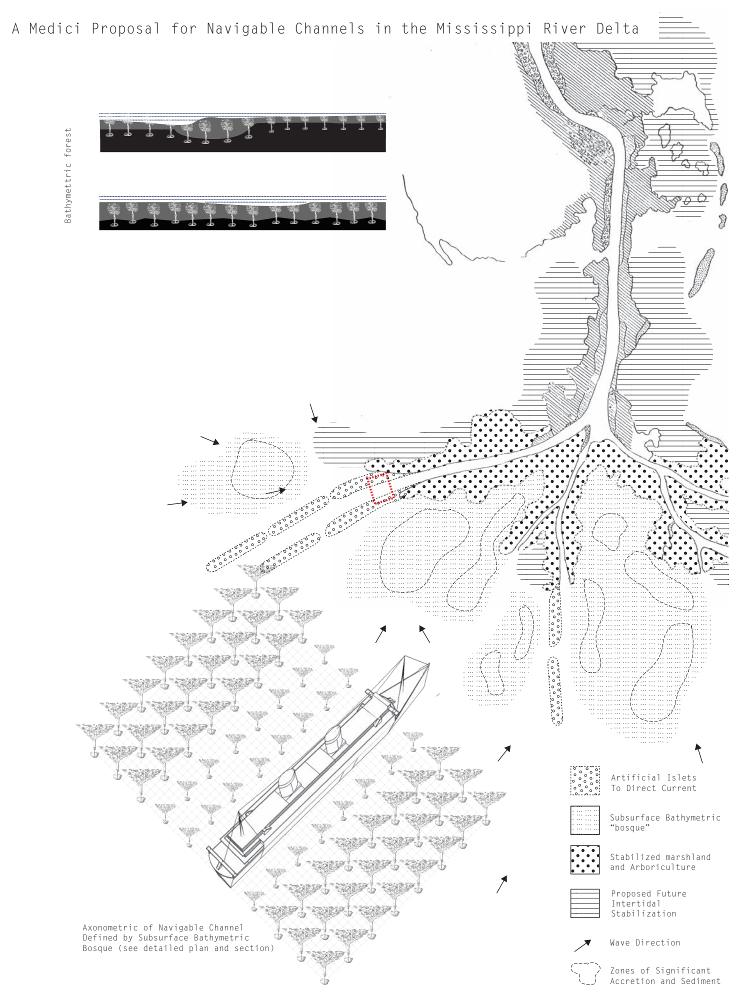

Figure 17b This diagram (by author) of Medici's invention deployed at the scale of the Mississippi River Delta speculates about the effect the invention would have had on the river and imagines a counterfactual history in which the subsidence was halted and the delta continued to grow over the last century. According to the patent, Medici's system is capable of spanning many kilometres, and would have continued to grow as the delta expanded through the accumulation of sediments and the placement of additional trees. Islets would have been created to direct currents and define the navigable channels. A vast bathymetric 'bosque' would have captured sediment and stabilized the deltaic landmass of the advancing delta. Arboriculture on high ground would have been used to grow trees to feed the delta-building process.

the system is destroying the delta and that we should move 'proactively towards building a navigation system that does not rely on nineteenth-century innovation and design (like jetties)'. [30]

At the time of construction it was estimated that the bar sediment deposited at the outlet of the jetties would extend seaward at a rate of 150 to 250 feet (45.7 to 76.2 m) annually, depositing the load from the Mississippi into ever-deeper waters of the Gulf of Mexico. This estimate proved remarkably accurate, as later surveys confirmed that the Southwest Pass has progressed towards the Gulf at the rate of 250 feet (76.2 m) per year (Fig. 10). [31] It is also the case that the straightening of the pass led to an abnormal growth of the southwest lobe of the delta. [32] To date, the Southwest Pass jetties of the Mississippi have extended more than 6.7 miles (10.8 km) into the Gulf, and the channel is continuously dredged to maintain navigable depths in excess of 45 feet (13.7 m). Sediments accumulate in the channel, and those that do make it to the Gulf are deposited in the deep water of the delta front and are not available to form natural levees or even recharge adjacent wetlands (Figs. 11 & 12).[33] Of course there are other factors to consider when evaluating the jetties' effect on the delta, including the ubiquity of levees throughout the watershed and the series of dams in the upper reaches of the river that block sediment. But even with these current impediments to fluvial processes, the Mississippi carries an estimated 500 million tonnes of sediment to the gulf annually, and an estimated 200 million reach the delta plain, enough to conservatively build 2,740 km^2 of new land in the next century when combined with vegetation and organic production. [34]

Patent alternatives to parallel jetties at the Southwest Pass

Parallel jetties have been in place at the Southwest Pass for more than a century, and are now intertwined with the fabric of our economy, culture, and the morphology of the Mississippi River Delta. Returning to the point of conception of the jetties, conceived as eighteenth-century innovations, we found that two successive alternatives were submitted by leading engineers for the construction of navigable channels at the Southwest Pass. The patents were granted in 1900 and 1901 to Juan Bautista Medici (1843–1903) of Buenos Aires, Argentina, and Lewis M. Haupt (1849–1923) of Philadelphia, Pennsylvania, United States. Both uniquely engage the fluvial processes, of rivers and the processes of delta building, and would have produced a radically different relationship between navigation and the landscape of southern Louisiana.

Haupt's patent was an evolution of his world-famous 'reaction breakwater', which earned him a Magellanic Premium Award from the American Philosophical Society in 1887. The patent proposals were documented and disseminated in USPTO patent bulletins, and published in *Scientific American* in addition to his numerous lectures on the subject. Medici's proposal is a lesser-known, yet radical alternative. The patent was granted to Medici as a foreign national living in Argentina. Medici's theories are not as well-documented, but his ideas seem to originate from his experience as an engineer for Buenos Aires and La Plata. The patent suggests a highly speculative form of delta building that blurs the boundary between the construction of navigable channels and the construction of natural deltaic formations. Both suggest alternative futures for the Mississippi River Delta, including the halting of subsidence and the re-establishment of the delta-building capacity of the Mississippi (Fig. 13).

The Haupt proposal

Lewis M. Haupt was considered, by some, to be the natural successor to the legacy of James Buchanan Eads as the preeminent American hydrologic engineer.[35] During his lifetime he worked as a topographical engineer for Fairmont Park, a patent examiner at the USPTO, a Professor of Civil Engineering at the University of Pennsylvania, and consultant to the Nicaraguan Canal Commission. Haupt's theories of hydrologic engineering earned him a Magellanic Premium Award from the American Philosophical Society in 1887 for his research on the 'Physical Phenomena of Harbor Entrances'. His findings were revolutionary when published, and led to the invention of the reaction breakwater, a self-dredging breakwater system that he patented in 1887 under the title 'Dike or breakwater' (Fig. 14).[36]

Haupt's proposal for the Southwest Pass was adapted from his patent and prior research. The reaction breakwater was to be constructed and tested (that is, prototyped) at Aransas Pass, Texas, by the Reaction Breakwater Company in the late 1880s, but the process did not go smoothly. His proposal was aggressively dismissed by the US Government's War Department, which claimed that the patent and research were 'purely theoretical [. . .] unconfirmed by experience, and contain nothing not already well known, and which has a useful application in the improvement of our harbors'. [37] The War Department's attempt to discredit Haupt's innovation also inadvertently cast doubts on the Philosophical Society's Magellanic Premium Award, creating an interesting tension in Haupt's lectures to the society. Whether the intention of the statement was to stifle innovation, avoid paying patent royalties, or simply to award a contract to other parties may never be known. But, after a series of failed plans and contracts for a breakwater at the Aransas Pass, Lewis Haupt's curved reaction breakwater was partially constructed, proving its efficacy in maintaining a navigable channel depth within fifteen months even without meeting Haupt's complete specifications.

News of plans for jetties at the Southwest Pass of the Mississippi spread, and by 1901 Haupt had adapted his reaction breakwater design to the specific hydrologic and fluvial conditions at the Southwest Pass. Haupt's patent (US 687307) for a 'Jetty or breakwater' was granted on 26 November 1901 and intended to revise and update claims made in his previous patents for use at the Southwest Pass of the Mississippi and in other deltas of sediment-laden rivers (Fig. 15a).[38] Haupt summarizes his invention as following:

> In this improvement the purpose is more particularly to apply the energy of the fluvial waters, charged with their own sediment, in such manner as to create erosion, produced by the concentration and reaction of a permanent opposing medium placed in or near their path and resulting in the deposition of sediment upon the opposite flank of the channel from that upon which the artificial structure is erected. [39]

In its simplest form, Haupt's 'Jetty or breakwater' maintains navigable channels through the force of river water and the littoral drift amplified by the curvature of the jetty. These two interacting forces are mediated by the geometry of the jetty, and ultimately work by scouring a channel adjacent to the structure and allowing for the accretion of river sediment on the opposing bank to the constructed jetty.

Haupt's patent is site-specific yet capable of being adapted to diverse contingencies, and includes details about the conditions of the Southwest Pass. He claims the invention:

> [. . .] is designed to make the jetty the tool through which the potential energy of the natural forces is applied to secure and maintain commercial channels, and the results are inseparably connected not only with the form of the tool, but with the manner of its application. Under these circumstances a drawing would seem to be unnecessary; but to aid in the interpretation of my invention a diagram is submitted based upon the physical conditions existing at the Southwest Pass of the Mississippi River, taken as a type. [40]

Though it remains unclear if the MRC or the USACE were aware of the patent, a draft act of Congress in Haupt's archives at the American Philosophical Society suggests that it was considered at the highest levels of government, and his detailed article in *Scientific American* ensured the principle and technology were widely disseminated, including technical details and a detailed critique of the proposed plan. [41] Haupt also lectured widely on the subject of the reaction breakwater at the mouth of the Mississippi. He believed the government jetties would impound silt and cause bars to form, which would require constant dredging. He also warned of bar migration into ever-deeper water, a problem that the reaction breakwater was well designed to address as the curvature of the breakwater would deposit sand and silt on a western bank, and ultimately towards the adjacent wetlands (Fig. 15b).

Haupt was well aware of issues of land loss and the important role of sediments in recharging and stabilizing the delta. During one of his speeches to the American Philosophical Society in 1904, he convincingly argued for the use of outlets in conjunction with his single concaved jetty, stating that the outlets would nourish the delta and reduce the need for dredging, while the curvature of the jetty would deposit sediment and maintain depth. [42] What emerges from Haupt's patent, lecture, and writings is an image of the delta in which sediment budgets are balanced by outlets and the navigable channels are passively maintained by engaging the fluvial forces of the Mississippi to scour a permanent channel (Fig. 16). The sediment-laden water would be directed towards the western bank of the channel and deposited in the adjacent wetlands. When combined with the littoral drift of sediments, the reaction breakwater would replenish sediments closer to shore, and contribute to land-building instead of the advancement of the Southwest Pass into deeper water.

The Medici proposal

Juan Bautista Medici of Buenos Aires, Argentina, submitted a radical proposal to the USPTO in the early summer of 1900 for the creation of navigable channels. The *Official Patent Office Gazette*, published that summer, unceremoniously states of the invention:

> The herein described means for the formation and of channels in navigable streams consisting of trees placed in position therein said trees being placed in two series the tops of one series extending to the water level and the other series terminating a distance below the water level. [43]

This difficult to understand description was accompanied by a single drawing of two trees at varying heights in a water column, masking the scale and potential impact of the invention. The basic unit, comprised of trees anchored to heavy boulders, is unremarkable and may have led to a misreading of the patent. Yet the scale of the proposal evokes the scale of deltas and engages the intrinsic process of their formation, and defies conventional classifications of technology such as dike, breakwater, groin, etc., suggesting an entirely new scale and strategy for technological innovation in the construction of river systems.

Medici was 57 years old when he received his patent, and one gets a sense that it is a swansong of sorts, after a lifetime of work in civil and hydrologic engineering (Fig. 17a).[44] Medici was certainly not as well known in the American engineering community as Haupt, and in fact nothing is documented in english about Medici except for his patent. He was born in Piedmont, Italy, in 1843 and died in Buenos Aires in 1903. While residing in Italy he worked on domestic railroad projects and the potable water network of Montevideo, Uruguay. After immigrating to Argentina in 1870, Medici was involved in the detailed survey of Buenos Aires. He then became director of hydraulic sanitation of the city and built the seawall at the Río de la Plata and Catalinas docks. Later, together with Argentinian engineer Lavalle, Medici graded 175,000 km^2 of the province of Buenos Aires. The grading work was followed by the construction of an extensive network of channels to drain the area in addition to the design of two navigable channels. This project was awarded a gold medal at the Esposizione italo-americana in 1892 in Genoa.[45] During his illustrious career in Argentina, Medici was also involved in the layout, planning, waterworks, and construction of the State Capitol at La Plata.[46]

Medici was granted his patent for a 'System for the formation of permanent channels in navigable rivers' (US 658795) on 2 October 1900, as a solution to the creation of navigable channels in deltaic landscapes. Medici's patent was intended as an improvement on Eads' jetties at the South Pass of the Mississippi River. Medici's patent claims even include a description of the jetties:

> The system of jetties or artificial islets formed of brush and earth employed, for example, in the delta of the Mississippi [referring to Eads' jetties] has fallen short of desired results, owing to the rigid nature of the resistance thus offered to the tremendous force of wave and current, before which force such rigid bodies must eventually give way. I have therefore sought to overcome the defects of such systems in the manner which I will now proceed to describe.[47]

What follows is a description of an invention that defies reduction to a singular object. Instead Medici discloses a method of channel creation that establishes entirely new bathymetries by anchoring cut trees in grids of varying depth that extend kilometres, configured to direct the movement of water and define new channels.

In its simplest form, Medici's patent involves the anchoring of a subsurface 'forest' or 'orchard' of large cut trees with variable depths relative to the surface, to guide flowing water and capture sediment. The field or matrix of vertical trunks and branched canopies would alter the speed and direction of the water by establishing a new bathymetry of tree canopies that define channels, islets, and bars in the river delta. The basic unit of construction is trees of varying sizes, from 2 to 7 m high with up to 9 m of canopy spread, arranged in a grid of 20 m on centre. The height of the trees varies in relation to the water's surface, and their depth defines the desired channel geometry. Just as in wild deltas, friction and the accretion of sediment define channel location and geometry. Medici's system operationalizes this process, essentially building a delta as a delta might build itself. The scale of the intervention is commensurate with the scale of the world's great deltas, varying in overall dimension, from 50 to 1,000 m in width and 1,000 to 40,000 m in length, though there is no preconceived formal layout for the bathymetric forest. In fact, the system may adapt and grow over time, adapting and evolving as the bird foot of the Mississippi extends to the gulf and new channels are required.

Medici's system invites us to imagine a vast deltaic landscape constructed on principles observed in nature, yet designed to meet the human necessity to navigate (Fig. 17b). Medici's proposed structure is expansive, potentially spanning kilometres, functioning at a scale commensurate with the deltaic landscapes of large rivers. When compared with conventional technologies for engineering of navigable channels, such as jetties, Medici's proposal precludes object-oriented descriptions, evoking conditions found in naturally forming delta systems. Envisioning the system implemented at the Southwest Pass suggests the creation of a subsurface bathymetric field of trees aligned vertically and horizontally to direct the current of the Mississippi, while capturing sediment in a kilometre-thick matrix of tree limbs and trunks. The branches of the trees would become thick with silt and ossified by molluscs, further edifying the structure and catalyzing the formation of new ecological assemblages. Extension of the delta using Medici's principles would also require the cultivation of trees on the bank of the river to harvest as the basic building blocks of the deltaic system. The image that emerges is a quixotic kaleidoscope of sediment of vegetation, not dissimilar to the pre-contact delta, adapted to meet the needs of navigation—a tectonic delta that precludes simplistic binaries between manmade and natural.

Conclusion

The Mississippi River Delta is one of the most dynamic environments on earth. Extensive levees and fixed navigation channels have shackled the river, broken its delta-building capacity, and now the river threatens to change course and continue building deltas as it has for millennia. As we consider how to build the delta of the future, a recount of the past becomes increasingly valuable. Not only as a heuristic method for problem solving, but also as a precedent for innovation in complex environmental systems. The process of creating channels through the Mississippi River Delta provides but one example of this dynamic process, illuminating an important relationship between innovation and environmental transformation, while warning us of the frailty of technology and the environment. Archives of the USPTO chronicle the evolution of technology used to transform the delta, from the simple Victorian-era devices employed to scrape new channels, to the speculative delta-building processes envisioned by Juan Bautista Medici. What becomes evident is that the delta of today came into being through the iterative process of innovation in the nineteenth century, and a failure of innovation in the twentieth and twenty-first centuries. Had the process of prototyping and testing continued, we might have discovered a system to delay subsidence of the delta, or found a method to build a productive habitat while constructing navigable channels. The existing patents by Juan Bautista Medici and Lewis M. Haupt suggest that the next evolution of technology may engage fluvial processes and build novel ecologies, but we may never know for certain, and so we will pick up where they left off more than a century ago. Would their inventions have changed the future? The answer is irrelevant, yet the process of innovation is as vital today as it has been for centuries, and their patents provide us with a magic mirror, reflecting the possibility of a foretold, yet unrealized, modern delta.

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BIOGRAPHICAL NOTES

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