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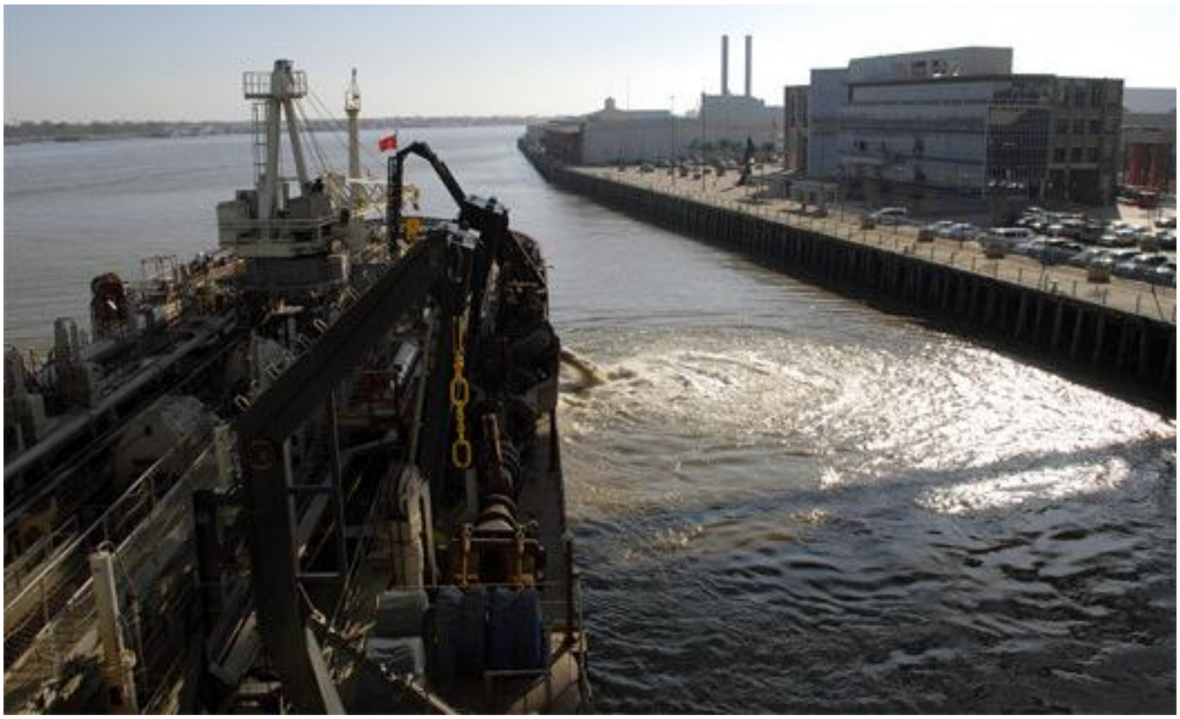
January 2013

Beneficial Use:
Toward Balancing America's (Sediment) Budget


Hopper dredge, New Orleans Harbor. [Photo by Ricky Boyett, courtesy of the USACE]

Of all the anthropogenic transformations occasioned upon the North American continent, few garner less attention than the shift in the dynamics of sediment transport: in essence, in the large-scale movement of huge quantities of earth. Yet the impacts of this profound alteration are all around us — literally, around the North American littoral — and what is at stake is nothing less than the survival of coastal places and spaces, and the peoples and processes that depend on them.

Some background, both historic and technical. For millennia the movement of sediment was governed by natural processes; wind and water would erode and mobilize mineral particles across the topographic surface, and then deposit a share of these particles into the currents of rivers. The coarsest sediments would settle out upstream, while the finer particles would either disperse along the rivers' broad meander belts, forming rich riparian zones in alluvial valleys, or else would move downstream suspended in the water column or tumbling along in the bedload. As the rivers disembogued into the seas, their currents would slow, lose kinetic energy and dump their sediment load at the continent's edge. There, the billions of tons of sand, silt and clay particles would accumulate in the form of deltaic lobes and coastal wetlands, or get swept sidelong by offshore currents to accrete on beaches, dunes, salt marshes and barrier islands along curving bights. The pedological loss of the continent's interior thus begot the geomorphological and ecological gain of its edge. The resulting littorals — including the delta of America's greatest river — have long ranked among the most productive environments for an extraordinary range of life forms, including humans.

Fast-forward to modern times, and much has changed. We came to view the natural tendency of rivers to store surplus water laterally as an intolerable problematic — "flooding," we called it — and so we strait-jacketed the channels within levees and floodwalls. We denuded forests, broke prairie sod, replaced biodiversity with monoculture, and augmented the fluvial and aeolian erosion of fertile topsoil. We routed water from wet to dry places via aqueducts, canals, pipelines and reservoirs, to be used for hydroelectricity, irrigation, municipal and industrial purposes, and upon these systems we built the world's largest economy. Getting this abundance to market required efficient navigation, and that meant straightening and stabilizing key arteries like the Mississippi and its tributaries, building locks and canals to allow vessels to step-ladder upriver, and dredging constantly to maintain requisite depths. And on deltaic plains such as that of the Mississippi River in southern Louisiana, we scored and scoured the landscape to enable vessels to call more efficiently at ports, and to extract fossil fuels more effectively.

Inner Harbor Navigation Canal, New Orleans. Top left: Dredging, ca. 1918. Top right: Lock, 1957. Bottom left: After Hurricane Katrina, September 2005. Bottom right: Construction of the IHNC Surge Barrier, 2009. [Photos by the USACE]

For all the economic gains — and there were plenty — 20th-century hydrological interventions also altered the flux of terrestrial sediment to ocean systems. Particles that once pulsated messily but beneficially from the continent's interior to its coasts now piled up uselessly behind locks and dams, or in the bedload of slackened currents. Or else they got jettisoned onto the continental shelf, sans any geomorphological or ecological benefit whatsoever. And as the century wore on, ocean currents continued to gnaw away at fragile beaches and barrier islands, and rising sea levels inundated coastal wetlands which were already subsiding under deprivation of fresh water. New residential and commercial development, meanwhile, crept ever closer to surge-prone coasts and deeper into flood plains, egged on by the availability of federal flood insurance and a false sense of security imparted by flood-control structures.

The Spatial Mismatch of the Sediment Budget

Today, early in the 21st century, we are confronting the consequences: many of our major river systems find themselves with too much sediment where we don't want it, and too little where we desperately need it. Six major reservoirs constructed in the mid-20th century on the Missouri River, which historically transported 320,000,000 tons of suspended sediment annually to the Gulf Coast, now impound over three-quarters of that load behind their dams, where it reduces reservoir storage capacity and necessitates costly removal. On the downstream side of the dams, the unnaturally clear and swift-moving current (what hydrologists term "hungry water") incises the channel and scrapes clean the banks of the carbon-rich fine-grain material needed for healthy fisheries. Similarly, eight locks and dams built between the 1870s and 1930s have converted what used to be the free-flowing Illinois River into a series of placid "pools" connected by mere trickles. The slowing of water therein has caused sediments to settle and fill backwater lakes and side channels, diminishing ecological productivity and recreational uses while increasing dredging costs for navigation. Similar scenarios occur on the Arkansas, Tennessee, and Upper Mississippi branches — indeed, on nearly every major river system nationwide. [1]

Sediment at a dredging site on the Upper Mississippi River, Wabasha, Minnesota. [Photo by Laura Bremer, courtesy of the USACE]

Some historical measurements will help illustrate these phenomena. In 1835, a visitor to New Orleans reported that "a glass filled with [the Mississippi's] water appears to deposit in a short time a sediment nearly equal to one-twelfth of its bulk." [2] An investigation conducted in the same spot in 1846 quantified that deposition at 890 milligrams per liter. [3] Today, the Mississippi carries past New Orleans well under one-third the sediment it transported when those observations were made. The change is visible to the naked eye: waters that were once an opaque rusty brown are now a translucent, cloudy gray. The 890 milligrams of particles measured in 1846 now typically weigh in around 125 milligrams per liter, which, if one were to repeat the drinking-glass observation, would deposit a film immeasurably thin to the naked eye. By no means should this clarity be interpreted as purity, or as evidence that we've successfully curtailed the detrimental loss of fertile farmland soil. Rather, in many major watersheds, we find ourselves with increased topsoil erosion rates and decreased sediment loads reaching coasts. Worse yet, it is the highest-quality sediment needed for coastal land-building — sand, the coarsest particle — that is likeliest to end up trapped upstream because it is the heaviest. With minimal amounts of silt and clay alluvium deposited into the deltaic bank account, but withdrawals being made at ever-mounting rates, a dire future looms for our coasts, especially for those of the Mississippi River Delta. [4] Scientists at Louisiana State University have estimated that, even with modest estimates of soil subsidence and sea level rise and generous approximations of future sediment supply, the Delta will run a nearly insurmountable sediment deficit of 1 to 5 billion tons, possibly up to 17 billion tons, by the year 2100. [5]

Lower Louisiana suffers an extreme case of coastal sediment deficit, but not the only one. Twenty-eight percent of all Americans occupy counties or parishes with seashores, and when adjacent areas with nearly as much vulnerability are included, the figure rises to over 53 percent of the population — and an even greater share of our critical infrastructure. According to one study, over 75 percent of the ocean shoreline of the United States is "retreating landward," and much of the degradation can be attributed to "fundamental changes in depositional patterns" of recent origin and by anthropogenic agency. [6] Shoreline erosion has forced the relocation of assets, necessitated the repeated re-nourishment of white sandy beaches, and occasioned the wholesale deterioration of rich ecosystems. By one estimate, North America historically sent 2,350 million tons of terrestrial sediment annually into the sea; now it sends 1,910 million tons, with most of the remainder impounded in reservoirs. And the dilemma is global; all other landmasses except Indonesia have witnessed comparable changes in sediment transport. According to earth systems scientist James Syvitski, "humans have simultaneously increased the sediment transport by global rivers through soil erosion … yet reduced the flux of sediment reaching the world's coasts … because of retention within reservoirs. Over 100

billion metric tons of sediment and 1 to 3 billion metric tons of carbon are now sequestered in reservoirs constructed largely within the past 50 years." [7] All this material formerly enriched our coasts.

Eroded shoreline at mouth of Dog River, near Mobile, Alabama. [Photo by Cesar Harada]

Coastal land loss increasingly positions human communities in harm's way. Witness how eroded marshes and saltwater-killed cypress swamps allowed Hurricane Katrina's storm surge (2005) to intrude inland with minimal impedence, and how federal levees failed to prevent it from inundating the subsided metropolis of New Orleans. Note also how "superstorm" Sandy (2012) wreaked havoc on developments nearest to New York and New Jersey shores but generally spared those that were buffered by sand dunes and barrier islands.

In the wake of Katrina and Sandy, and with dire predictions of sea level rise threatening coastal metropolises worldwide, we finally find ourselves engaged in a civic conversation on coastal risk-reduction strategies. Some argue for depopulating high-risk areas, or at least ending the underwriting of that risk through the liberal availability of federal flood insurance — but this line of reasoning currently gains little favor among either the citizenry or the body politic. A more popular argument is to install Dutch-style barriers, Galveston-style sea walls, or Louisiana-style levees, but these "hard" interventions are wildly expensive, environmentally damaging, and potentially exacerbating, in that they introduce further structural rigidity to coasts that work best when they are fluid and fluvial. A third way — rebuilding barrier islands, beaches, marshes, and wetlands to create a soft natural buffer between volatile seas and humanized shores — emerges as the optimal solution. Except, that is, for one nagging problem: the sediment needed for such projects lies in the wrong place, and the means by which it formerly moved from continent to coast — rivers — no longer flow freely.

Human Sediment-Moving

Enter the industry of sediment mining. Digging for dirt takes many forms and goes by various names. On terrestrial surfaces, "aggregate operators" excavate topsoil, sand, crushed limestone, gravel and rocks. "Earthworks engineers" remove soil from borrow pits, road cuts, channel or building excavations. "Sand miners" position themselves along low-velocity riverbanks to extract coarse alluvium, then wait for the river to "trap" more sediment as dump trucks cart off the spoil. Most notably for our purposes, "dredgers" on specialized vessels cut, augur, blast or scoop sediment from the bottom of rivers, harbors, bays or offshore shoals, and make it available for onshore use.

Enter next the industry of sediment transportation. If the material comes from water bodies intended for local use, it is processed into a slurry and pumped or siphoned through pipelines to its destination. If the dirt needs to move longer distances, trucks haul it from borrow pits to fill sites. For farthest distances, barges float it to bulk-cargo storage facilities, from which it is trucked or railroaded to its final destination, which is usually in the purview of the real estate or construction sectors.

If — as in the case of certain farmlands or wetlands restoration projects — the sediment-deprived area abuts a major river, then "dedicated dredging" is an option. One successful case study of dedicated dredging for land building is the federally funded, state administered Bayou Dupont Mississippi River Marsh Creation Project. Located downriver from New Orleans on the west bank of the Mississippi, this project uses a hydraulic cutter-suction dredger, the Florida, to mine silt from a borrow area on a shallow, stable point bar on the non-navigation side of the river channel. It then pumps the spoil material as a watery slurry through a series of 72-inch-wide bankside siphons; the slurry then flows by gravity through a steel pipeline laid along a three-mile right-of-way. A jacking and boring system gets the slurry below and back above a railroad and highway-crossing grade. As the mud arrives at two marsh-creation areas in the Barataria Basin, the pipeline bifurcates and the slurry splays out at each nozzle. After dewatering, the remaining silt is spread about by backhoes and earthmovers.

Students plant native grasses in newly created wetlands at Bayou Dupont, Louisiana. [Photo by Louisiana Governor's Office of Homeland Security and Emergency Preparedness]

As a result, in just a few months in 2009–2010, over 570 acres of new wetlands were created where previously stood three feet of salt water. Adjacent sites are currently targeted for restoration. [8] Similar projects at Scofield Island, Shell Island and other eroded areas near the mouth of the Mississippi promise equal success. All of which raises the question: Can dedicated dredging be the answer to our sediment flux problem? The problem is in the "dedicated" part. Dedicated dredging means that the alluvial delivery happens only when the project is active and the machinery is running. Unfortunately, erosive long-shore currents and rising seas are relentless; sediment must constantly replenish coastal lands, as they did historically, to keep apace of withdrawals. Any long-term solution to the sediment budget problem cannot have a project end-date.

What about another potential solution: Can we barge our way out of our sediment imbalance? Only to a limited extent. A decade ago, for example, authorities dredged the over-sedimented Illinois River at a wide spot called Peoria Lake, and barged the soil to Chicago to cover the old U.S. Steel South Works along the Lake Michigan. The "Mud to Parks" program, which has counterparts nationwide, is a fine prototype for spot projects. It made economic sense for Chicago because the barges had to travel only 150 miles from Peoria, and the project required only 1,500 tons of sediment. But sediment-bearing barges cannot be deployed en masse to shore up eroding coasts and deltas nationwide, particularly in the extreme case of southern Louisiana, because it would be impossibly cost-prohibitive.

Ditto for trucking soil from terrestrial borrow pits. This option works for the construction of levees, which are long and narrow and require pure, cohesive, binding clays. Dump trucks by the hundreds buzzed around New Orleans constantly during 2006–2011, transporting clay to build the $15 billion Hurricane and Storm Damage Risk Reduction System (note that it's no longer called the *flood-protection* system) in the wake of the Katrina levee failures. But for wetlands restoration, which requires far more material, digging from a borrow pit is environmentally damaging and often pedologically inappropriate. If the borrow pit is too far away, costs go up; if it is too close, then it may represent a case of robbing of Peter to pay Paul. Barrier islands, meanwhile, are best shored up from offshore sand deposits, which may be dredged and directed to islands via pipeline slurries, as beach nourishment has been done for decades.

What's left, then, for large-scale ongoing coastal and shoreline restoration?

Post-Panamax container ships pass in the Houston Ship Channel. [Photo by Louis Vest]

Beneficial Use of Dredged Sediments

Enter the (potential) industry of beneficial-use maintenance dredging. Unlike dedicated or capital-projects dredging, the process of maintenance dredging happens continually, to keep key waterways navigable to a stipulated depth for the vessels that depend on them. Over one-quarter of a billion cubic yards of sediment are dredged annually to maintain U.S. waterways and harbors, yielding enough soil to create 242 square miles of land at a depth of one foot. [9] That figure will rise as American ports race to become "Post-Panamax ready" — that is, deep enough to accommodate the maximum-sized ships (bearing up to 12,500 containers) that will be able to use the Panama Canal following its circa-2015 widening. Among other criteria, according to a recent study, "a port is considered post-Panamax ready when it has [a] channel depth of 50 feet with sufficient channel width and turning basin size." [10] For the Port of New Orleans, post-Panamax means digging a 750-foot-wide swath throughout the 95 lowermost miles of the Mississippi that will be five feet deeper than its current 45-foot standard. Not doing so would disastrously deny the Port the next major wave of global commerce, while also increasing the cost of agricultural exports and petroleum imports because vessels would have to lighten their cargo to evade shallow draft. [11] American ports are currently racing to deepen their harbors; as of late 2012, only Norfolk, Virginia, is post-Panamax ready.

For the lower Mississippi to be dredged and maintained at 50 feet of depth, it will require the mobilization of a vast quantity of sediment in the very heart of the nation's most sediment-starved region. The Mississippi River Deltaic Plain has lost over 1,880 square miles of land since the 1930s, and stands to lose another 1,750 square miles by 2060, due mostly to levee-building and canal excavation. [12] The crisis, brewing since the early 1900s, caught scientists' attention in the 1960s; by the 1990s, most experts held out hope that unleashing river water via controlled diversions would solve the problem. Pulsations of fresh water, the thinking went, would push back saltwater intrusion, and the suspended sediments would settle and shore up sinking wetlands. But then came three pieces of bad news: new data on just how much the deltaic plain had subsided, new information on how much sea level had risen, and new understanding of just how little sediment remained in the Mississippi. Which is why maintenance dredging might be key to meeting the challenge: The beneficial use of alluvium dredged for channel-maintenance purposes has the potential to reduce significantly the last of these problems, and ameliorate the other two. River diversions or even full-blown crevasses alone will not solve the sediment problem. The freshwater they unleash is critical because it pushes back seawater, but it must be fortified with an anthropogenic injection of sediment for it to build new land — and that's where the dredged materials come in.

Newly created marshes near the mouth of the Mississippi River, West Bay, Louisiana. [Photo by eustatic]

Engineering and Environmental Policy

So, how do we get there? The bureaucratic path to beneficial use starts with the Clean Water Act, which stipulates that any disposition of sediments into U.S. wetlands or waters requires a permit from the Army Corps of Engineers. The Corps, which is responsible for maintaining the navigability of American waterways, involves the U.S. Environmental Protection Agency and sometimes state counterparts to review the ecological and human health impacts of the proposed disposition. Both the Corps and the EPA, to various degrees, have been traditionally disinclined to green-light dredged sediment for land reclamation, for a mix of institutional and environmental reasons. Institutionally, the Corps' central mission has historically focused on "internal improvements." Its engineers were trained at West Point in the military rather than in the civil tradition, and as such, tended to view natural forces as something to be subdued through science and technology rather than nurtured and sustained. Taming wild Western rivers to enable the development of the Republic meant channel straightening, bank control, debris removal and depth maintenance. It did not mean making swamps and rebuilding islands. The very last step of the Corps' navigation mission entailed the dispensing of worthless dredged sediments, which they did as quickly and cheaply as possible, almost as an afterthought. It was garbage, after all. Being a compliance organization, the Corps must be authorized and funded by Congress before it can change any of its policies, and politicians were no more inclined to value mud than were engineers. Most Corps dredging contractors to this day are instructed, and compensated, to dispose of the muck by releasing it into the top of the water column and letting the current sweep it seaward. The release of this sediment — the travesty of the wasted resource — is as irrational as it is common along the lower Mississippi: a dredge positions itself off a selected bank, a stiff pipe extends into mid-channel, and a muddy splay gushes from the terminus — all within sight of the most sediment-deprived lands in North America.

Received environmental wisdom has also worked against the beneficial-use argument. River sediments sequester varying quantities of municipal, industrial and agricultural contaminants, including the pesticide DDT, the herbicide atrazine, industrial PCBs, heavy metals, arsenic and potentially endocrine-disrupting hormones. The compounds bind to sediment grains and settle into the bedload. Re-suspending and relocating the particles into riparian ecosystems near human populations could pose a serious health risk. The EPA estimates that between one and four percent of all maintenance-dredged material in the U.S. is sufficiently contaminated to warrant special handling. [13] Environmental activists, for their part, have long invoked concerns about remobilizing contaminants to fight unwanted waterways projects nationwide, and traditionally recoil at the notion of using dredged soils (and, similarly, sewerage effluent) for ecological restoration.

West Bay, Louisiana. [Photo by eustatic]

Evolving awareness has led both the Corps and the EPA to recalibrate over the past two decades. The Water Resources Development Acts of 1986, 1990 and 1992 increasingly directed the Corps to include environmental protection and redress environmental damages in its mission, and the 1996 Act authorized the department to develop beneficial uses of dredged sediment in civil works navigation projects. The EPA, and the environmental community in general, have come to recognize that land loss warrants as much concern as polluted sediment. In the past decade, the Corps and the EPA have collaborated in creating a framework for dredged material management and guidelines for identifying, planning and financing beneficial use projects. [14]

Yet, to the frustration of Louisiana officials, the Corps has lagged in making beneficial use the rule rather than the exception. While Congress authorized the department to spend $100 million on beneficial use projects, it neglected to appropriate funds to carry out that directive. The disconnect shines light on an underlying problem: sediment budgets in general, and beneficial use in particular, have never been meaningfully integrated into the federal oversight of the Mississippi and other river systems, which privileges the activities of navigation, agriculture, hydroelectricity and recreation. Until that mindset changes, and the sediment needs of the nation’s margins are factored into the management of its rivers, the Corps has little choice but to comply with authorizations and appropriations reflecting outdated priorities. Meanwhile, interior sediment slips beyond the grasp of the continent, unnecessarily exacerbating the predicament of sea level rise. [15]

The State of Louisiana, for its part, betrays its own brand of sediment disconnect. Even as state officials urge the Corps to use dredged material for land-building, authorities at the Port of New Orleans — a state agency — operate their own custom-made state-of-the-art dredge, the Edward S. "Ned" Reed — and regularly scour wharf-side river bottoms to a depth of 100 feet to accommodate deep-draft cruise ships and containerized vessels. Just like the federally contracted dredgers, the Reed jettisons the silt into the current. The State of Louisiana would do well to demonstrate its commitment to beneficial use by beneficially using its own dredged sediments.

Beneficial use of dredged sediment east of the Inner Harbor Navigation Canal Lake Borgne Surge Barrier, New Orleans. [Photo by USACE]

Legal and Economic Tactics

Legal muscle might be one way to regularize beneficial use. Mark Davis, director of the Tulane Institute on Water Resources Law and Policy, points to a key clause in the Coastal Wetlands Planning and Protection Act, the 1990 federal law that legally birthed the effort to save coastal Louisiana. CWPPRA, which established a partnership between federal and state government toward developing a comprehensive plan to fight land loss in Louisiana, stipulated that the envisioned plan "shall coordinate and integrate coastal wetlands restoration projects in a manner that will ensure the long-term conservation of the coastal wetlands of Louisiana." The resulting plan, first issued in 1993 and a predecessor of today's Louisiana Master Plan, stated that the Secretary of the Army must "*ensure* [that] navigation, flood control, or irrigation projects" carried out upriver "are consistent with the purposes of the restoration plan" for Louisiana (emphasis added). Davis contends that this provision "could be used to force Corps action" on sediment supply and beneficial-use questions, "even without going to court, if the state were to routinely insist on its use." [16] Even then, Congressional appropriations would still be critical, because marsh creation projects are a legally complicated and technically costly undertaking.

Another tactic could entail embedding beneficial use into port and navigation legislation. A recent example is the proposed (and now defeated) Realize America's Maritime Promise Act. The RAMP Act, as one prominent legislator explained, would have "direct[ed] taxes that the maritime industry pays to run our ports and our channels [into] the pot to fund dredging, [to] help our ports, keeping them open, keeping them dredged…." [17] That legislator was Senator Mary Landrieu of Louisiana, who understands all too well her state's erosion problem, as well as its sediment deficit. Inserting a clause encouraging or mandating beneficial use into future dredging legislation would serve everyone's best interests.


Land restoration project, East Timbalier Island, Louisiana. [Photo by Erik Zobrist, courtesy of the NOAA Restoration Center]

Given the upcoming post-Panamax dredging boom and the need to buffer the national coastline, perhaps the time has come for a bold new approach toward balancing America's sediment budget. So I'll conclude by proposing a policy whereby contractors may take legal possession of all sediments they dredge under federal contracts. An "if-you-dredge-it-you-own-it" policy would deploy market forces toward upgrading the fiscal value of sediment and moving it to where it's needed. Contractors, under my proposal, may do anything they wish with the muck, including dumping it into the river as is done now — or, better, selling it back to state or federal governments for coastal restoration, at a cost below what authorities would have spent on alternate sources. Hoppers could be established at the riverside docks of scores of restoration projects, like Bayou Dupont, and a steady stream of dredging barges would keep them supplied with the alluvium mined via their contracted channel-maintenance work. If a hiccup in federal funding deprives the contractors of their customer, or if higher prices beckon elsewhere, the dredgers would be free to sell the soil on the private market as fill, and keep the revenue. What difference does it make? The material is utterly wasted right now; anything would be an improvement. Privatizing dredged sediment might give an incentive to save and deliver the valuable mud to wherever it is needed on the coastal landscape — and if in the process wealth is made and jobs created, all the better.

America's sediment budget did not get knocked off balance by sinister or incompetent forces, but rather as an unforeseen consequence of promethean engineering projects that have produced great wealth for American society for generations. No more can we decommission dams and locks for the sake of increasing sediment supply than we can remove levees from the lower Mississippi for the sake of fast-tracking coastal restoration; millions of Americans rely on these engineering structures, and they are here to stay. Nevertheless, we should recognize that they come with a cost, and strategically augmenting the sediment load of rivers as they flow to coasts, particularly by maximizing the beneficial use of dredged sediments, is a good way to reduce that cost. Human intervention skewed North America's sediment dynamics, and only human intervention can rebalance them.