Part II

Explosion and Aftermath: The Causes and Consequences of the Disaster

The loss of control of the Macondo well; the resulting explosion, fire, and destruction of the *Deepwater Horizon* rig; and the ensuing spill of nearly 5 million barrels of oil before the well was capped on July 15 reflect specific decisions about well design, construction, monitoring, and testing. The Commission's detailed analysis (Chapter 4) explains those actions in the context of this specific reservoir and subsurface geology as well as the regulatory framework and practices that affected those business decisions. Once the rig was destroyed and the uncontrolled flow of oil began leaking into the Gulf, industry and government struggled to contain and respond to the spill—prompting important questions about public and private authority, technical capability and capacity, and the current state of the art in addressing such crises. Understanding of the Gulf ecosystem and the regional economy underlies an early assessment of the spill's impacts and how to restore damaged natural resources, respond to economic losses, and address adverse impacts on human health. Chapters 4, 5, 6, and 7 address the related issues of containment and response, impact assessment, recovery, and restoration.


MONICA ANN

Chapter Four

"But, who cares, it's done, end of story, [we] will probably be fine and we'll get a good cement job."

The Macondo Well and the Blowout

In March 2008, BP paid a little over $34 million to the Minerals Management Service for an exclusive lease to drill in Mississippi Canyon Block 252, a nine-square-mile plot in the Gulf of Mexico. Although the Mississippi Canyon area has many productive oil fields, BP knew relatively little about the geology of Block 252: Macondo would be its first well on the new lease. BP planned to drill the well to 20,200 feet, both to learn more about the geology of the area and because it thought—based on available geological data—that it might find an oil and gas reservoir that would warrant installing production equipment at the well.[1] At the time, BP would have had good reason to expect that the well would be capable of generating a large profit.

Little more than two years later, however, BP found itself paying out tens of billions of dollars to

Fighting a losing battle, fireboats pour water onto the doomed rig in the hours after the Macondo well blowout. The tragic loss of the *Deepwater Horizon* at the close of the complex drilling project resulted from a series of missteps and oversights and an overall failure of management.

< *U.S. Coast Guard photo*

contain a blowout at the Macondo well, mitigate the damage resulting from the millions of gallons of oil flowing from that well into the Gulf of Mexico, and compensate the hundreds of thousands of individuals and businesses harmed by the spill. And that is likely just the beginning. BP, its partners (Anadarko and MOEX), and its key contractors (particularly Halliburton and Transocean) face potential liability for the billions more necessary to restore natural resources harmed by the spill.

The well blew out because a number of separate risk factors, oversights, and outright mistakes combined to overwhelm the safeguards meant to prevent just such an event from happening. But most of the mistakes and oversights at Macondo can be traced back to a single overarching failure—a failure of management. Better management by BP, Halliburton, and Transocean would almost certainly have prevented the blowout by improving the ability of individuals involved to identify the risks they faced, and to properly evaluate, communicate, and address them. A blowout in deepwater was not a statistical inevitability.

The Challenges of Deepwater Drilling at the Macondo Well

High Pressures and Risk of a Well Blowout

Oil forms deep beneath the Earth's surface when organic materials deposited in ancient sediments slowly transform in response to intense heat and pressure. Over the course of millions of years, these materials "cook" into liquid and gaseous hydrocarbons. The transformed materials can flow through porous mineral layers, and tend to migrate upward because they are lighter than other fluids in the pore spaces. If there is a path that leads to the surface, the hydrocarbons will emerge above ground in a seep or tar pit. If an impermeable layer instead blocks the way, the hydrocarbons can collect in porous rock beneath the impermeable layer. The business of drilling for oil consists of finding and tapping these "pay zones" of porous hydrocarbon-filled rock.

Pore Pressure and Fracture Gradient

Pore pressure is the pressure exerted by fluids in the pore space of rock. If drillers do not balance pore pressure with pressure from drilling fluids, hydrocarbons can flow into the wellbore (the hole drilled by the rig, including the casing) and unprotected sections of the well can collapse. The pore-pressure gradient, expressed as an equivalent mud weight, is a curve that shows the increase of pore pressure in a well by depth.

Fracture pressure is the pressure at which the geologic formation is not strong enough to withstand the pressure of the drilling fluids in a well and hence will fracture. When fracture occurs, drilling fluids flow out of the wellbore into the formation instead of circulating back to the surface. This causes what is known as "lost returns" or "lost circulation." The fracture gradient, expressed as an equivalent mud weight, is a curve that shows the fracture pressure of rocks in a well by depth.

The weight of the rocks above a pay zone can generate tremendous pressure on the hydrocarbons. Typically, the deeper the well, the higher the pressure—and the higher the pressure, the greater the challenges in safely tapping those hydrocarbons. The first oil wells were drilled on land and involved relatively low-pressure oil reservoirs. As oil companies drilled farther offshore, they encountered large hydrocarbon deposits, often in more porous and permeable geologic formations, and, like at the Macondo well, at ever-higher pressures.

The principal challenge in deepwater drilling is to drill a path to the hydrocarbon-filled pay zone in a manner that simultaneously controls these enormous pressures and avoids fracturing the geologic formation in which the reservoir is found. It is a delicate balance. The drillers must balance the reservoir pressure (pore pressure) pushing hydrocarbons into the well with counter-pressure from inside the wellbore. If too much counter-pressure is used, the formation can be fractured. But if too little counter-pressure is used, the result can be an uncontrolled intrusion of hydrocarbons into the well, and a discharge from the well itself as the oil and gas rush up and out of the well. An uncontrolled discharge is known as a blowout.

Drill Pipe, Mud, Casing, Cement, and Well Control

Those drilling in deepwater, just like those drilling on land, use drill pipe, casing, mud, and cement in a series of carefully calibrated steps to control pressure while drilling thousands of feet below the seafloor to reach the pay zone. Drilling mud, which is used to lubricate and cool the drill bit during drilling, plays a critical role in controlling the hydrocarbon pressure in a well. The weight of the column of mud in a well exerts pressure that counterbalances the pressure in the hydrocarbon formation. If the mud weight is too low, fluids such as oil and gas can enter the well, causing what is known as a "kick." But if the mud weight is too high, it can fracture the surrounding rock, potentially leading to "lost returns"—leakage of the mud into the formation. The rig crew therefore monitors and adjusts the weight (density) of the drilling mud as the well is being drilled—one of many sensitive, technical tasks requiring special equipment and the interpretation of data from difficult drilling environments.

Drilling Terminology

Drilling through the seafloor does not differ fundamentally from drilling on land. The crews on any drilling rig use rotary drill bits that they lubricate and cool with drilling mud—an ordinary name for what is today a sophisticated blend of synthetic fluids, polymers, and weighting agents that often costs over $100 per barrel. The rig crews pump the mud down through a drill pipe that connects with and turns the bit. The mud flows out holes in the bit and then circulates back to the rig through the space between the drill pipe and the sides of the well (the annulus), carrying to the surface bits of rock called cuttings that the drill bit has removed from the bottom of the well. When the mud returns to the rig at the surface, the cuttings are sieved out and the mud is sent back down the drill string. The mud thus travels in a closed loop.

As the well deepens, the crew lines its walls with a series of steel tubes called *casing*. The casing creates a foundation for continued drilling by reinforcing upper portions of the hole as drilling progresses. After installing a casing string, the crews drill farther, sending each successive string of casing down through the prior ones, so the well's diameter becomes progressively smaller as it gets deeper. A completed deepwater well typically telescopes down from a starting casing diameter of three feet or more at the wellhead to a diameter of 10 inches or less at the bottom.

Casing strings, which are a series of steel tubes installed to line the well as the drilling progresses, also help to control pressures. First, they protect more fragile sections of the well structure outside the casing from the pressure of the mud inside. Second, they prevent high-pressure fluids (like hydrocarbons) outside the casing from entering the wellbore and flowing up the well. To secure the casing, crews pump in cement to seal the space between the casing and the wellbore. If a completed well can yield economically valuable oil and gas, the crews can initiate production by punching holes through the casing and surrounding cement to allow hydrocarbons to flow into the well.

Designed and used properly, drilling mud, cement, and casing work together to enable the crew to control wellbore pressure. If they fail, the crew can, in an emergency, close powerful blowout-preventer valves that should seal off the well at the wellhead.

Deepwater Horizon Arrives and Resumes Drilling the Well

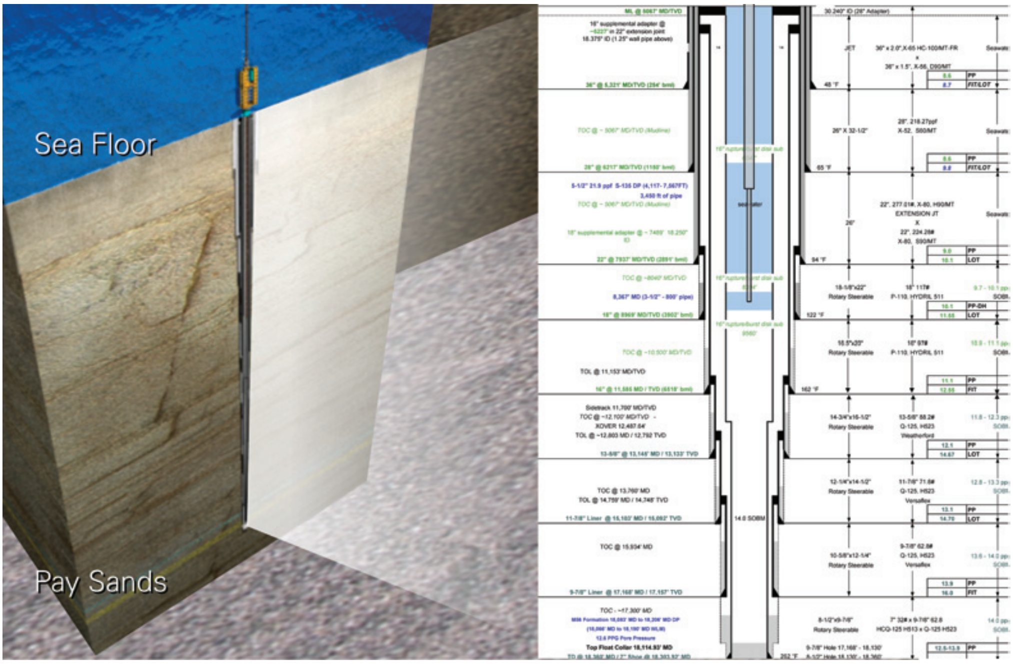
After purchasing the rights to drill in Block 252, BP became the legal "operator" for any activities on that block. But BP neither owned the rigs, nor operated them in the normal sense of the word. Rather, the company's Houston-based engineering team designed the well and specified in detail how it was to be drilled. A team of specialized contractors would then do the physical work of actually drilling the well—a common industry practice. Transocean, a leading owner of deepwater drilling rigs, would provide BP with a rig and the crew to run it. Two BP "Well Site Leaders" (the "company men") would be on the rig at all times to direct the crew and contractors and their work, and would maintain regular contact with the BP engineers on shore.

BP actually used two Transocean rigs to drill the Macondo well. The *Marianas* began work in October 2009 and drilled for 34 days, reaching a depth of 9,090 feet, before it had to stop drilling and move off-site to avoid Hurricane Ida. As described in Chapter 1, the storm nevertheless damaged the rig badly enough that BP called in the *Deepwater Horizon* to take over.

While the *Marianas* had been anchored in place with huge mooring chains, the *Deepwater Horizon* was a dynamically positioned mobile offshore drilling unit (MODU).[2] It relied on thrusters and satellite-positioning technology to stay in place over the well. Once the rig arrived on January 31, 2010, and began drilling operations, Transocean's Offshore Installation Manager Jimmy Harrell took over responsibility as the top Transocean employee on the rig.

When the *Deepwater Horizon* arrived, its first task was to lower its giant blowout preventer (BOP) onto the wellhead that the *Marianas* had left behind. The BOP is a stack of enormous valves that rig crews use both as a drilling tool and as an emergency safety device. Once it is put in place, everything needed in the well—drilling pipe, bits, casing, and mud—passes through the BOP. Every drilling rig has its own BOP, which its crew must test before and during drilling operations. After a week of surface testing, the *Deepwater*

FIGURE 4.1: Macondo Well Schematic



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Horizon rig crew lowered the 400-ton device down through a mile of seawater and used a remotely operated vehicle (ROV) to guide it so that it could be latched onto the wellhead below.

The *Deepwater Horizon*'s blowout preventer had several features that could be used to seal the well. The top two were large, donut-shaped rubber elements called "annular preventers" that encircled drill pipe or casing inside the BOP. When squeezed shut, they sealed off the annular space around the drill pipe. The BOP also contained five sets of metal rams. The "blind shear ram" was designed to cut through drill pipe inside the BOP to seal off the well in emergency situations. It could be activated manually by drillers on the rig, by an ROV, or by an automated emergency "deadman system." A casing shear ram was designed to cut through casing; and three sets of pipe rams were in place to close off the space around the drill pipe.

Below the wellhead stretched four telescopic casing strings installed by the *Marianas* to reinforce the hole it had begun drilling. The *Deepwater Horizon* crew proceeded to drill deeper into the Earth, setting progressively smaller-diameter casing strings along the way as required. (Figure 4.1) They cemented each new string into place, anchoring the well to—and sealing the well off from—the surrounding rock.

"Lost Circulation" Event at the Pay Zone, and a Revised Plan for the Well

By early April, the *Deepwater Horizon* crew had begun to penetrate the pay zone—the porous hydrocarbon-bearing rock that BP had hoped to find. But on April 9, they suffered a setback. At 18,193 feet below sea level, the pressure exerted by the drilling mud exceeded the strength of the formation. Mud began flowing into cracks in the formation instead of returning to the rig. The rig had to stop drilling until the crew could seal the fracture and restore mud circulation.[3]

Lost circulation events are a fact of life in the oil business. The crew responded with a standard industry tactic. They pumped 172 barrels of thick, viscous fluid known as a "lost circulation pill" down the drill string, hoping it would plug the fractures in the formation.[4] The approach worked, but BP's on-shore engineering team realized the situation had become delicate. They had to maintain the weight of the mud in the wellbore at approximately 14.0 pounds per gallon (ppg) in order to balance the pressure exerted by hydrocarbons in the pay zone.[5] But drilling deeper would exert even more pressure on the formation, pressure that the BP team measured in terms of equivalent circulating density (ECD). The engineers calculated that drilling with 14.0 ppg mud in the wellbore would yield an ECD of nearly 14.5 ppg—enough of an increase that they risked further fracturing of the rock and more lost returns.

Equivalent Circulating Density (ECD)

A column of fluid will exert an amount of pressure on its surroundings that can be calculated if one knows the height of the column and the density of the fluid. If one pumps the fluid to make it circulate through the column, it will exert even more pressure. Equivalent circulating density or ECD is used to describe the total effective pressure that a column of drilling mud exerts on a formation as it is circulated through the drill string and back up the wellbore. To pump a given fluid faster or through narrower restrictions, it has to be pumped at greater pressure, and this, in turn, increases the ECD.

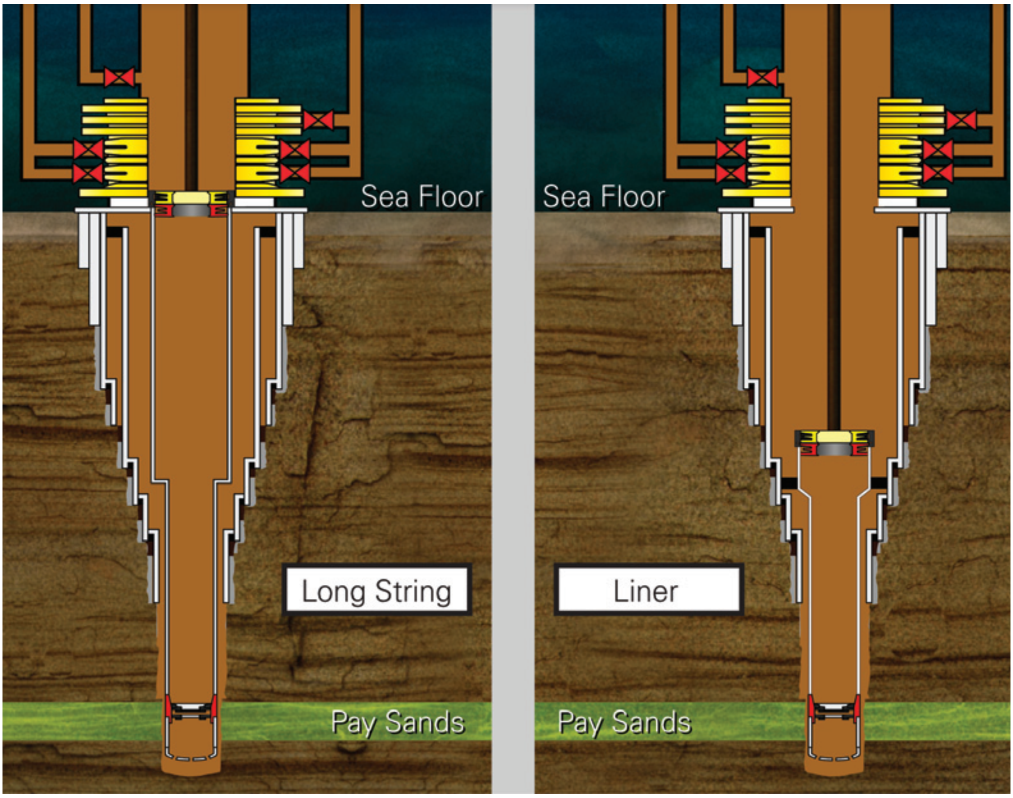
The engineers concluded they had "run out of drilling margin": the well would have to stop short of its original objective of 20,200 feet.[6] After cautiously drilling to a total depth of 18,360 feet, BP informed its lease partners Anadarko and MOEX that "well integrity and safety" issues required the rig to stop drilling further.[7]

At that point, Macondo was stable. Because the column of drilling mud in the wellbore was heavy enough to balance the hydrocarbon pressure, BP and its contractors, including Transocean, were able to spend the next five days[8] between April 11 and 15 "logging" the open hole with sophisticated instruments. Based on the logging data, BP concluded that it had drilled into a hydrocarbon reservoir of sufficient size (at least 50 million barrels[9]) and pressure that it was economically worthwhile to install a final "production casing" string that BP would eventually use to recover the oil and gas.

Preparing the Well for Subsequent Production

The engineers recognized that the lost circulation problems and delicacy of the rock formation at the bottom of the well would make it challenging to install the production casing.[10] After the rig crew lowered the casing into its final position, Halliburton would cement it into place. Halliburton would pump a specialized cement blend down the inside of the casing string; when it reached the end of the casing, cement would flow out the bottom and up into the annular space between the casing and the sides of the open hole. Once cured, the cement would bond to the formation and the casing and—if all went

FIGURE 4.2: "Long String" vs. "Liner"



Two options for the Macondo production casing.

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well—seal off the annular space. BP and Halliburton had cemented the previous casing strings at Macondo, and this cement job would be particularly important. The first attempt at cementing any casing string is commonly called the primary cement job. For a primary cement job to be successful, it must seal off, or "isolate," the hydrocarbon-bearing zone from the annular space around the casing and from the inside of the casing itself.

The Engineers Select a "Long String" Casing

BP's design team originally had planned to use a "long string" production casing—a single continuous wall of steel between the wellhead on the seafloor, and the oil and gas zone at the bottom of the well. But after the lost circulation event, they were forced to reconsider. As another option, they evaluated a "liner"—a shorter string of casing hung lower in the well and anchored to the next higher string. (Figure 4.2) A liner would result in a more complex—and theoretically more leak-prone—system over the life of the well. But it would be easier to cement into place at Macondo.

On April 14 and 15, BP's engineers, working with a Halliburton engineer, used sophisticated computer programs to model the likely outcome of the cementing process. When early results suggested the long string could not be cemented reliably, BP's design team switched to a liner. But that shift met resistance within BP.[11] The engineers were encouraged to engage an in-house BP cementing expert to review Halliburton's recommendations. That BP expert determined that certain inputs should be corrected. Calculations with the new inputs showed that a long string could be cemented properly. The BP engineers accordingly decided that installing a long string was "*again* the primary option."[12]

Centralizers and the Risk of Channeling

Installing the agreed-upon casing was a major job. Even moving at top speed, the crew on the *Deepwater Horizon* needed more than 18 hours just to lower a tool, such as a drill bit, from the rig floor to the bottom of the well, 18,000 feet below sea level. Assembling the production casing section-by-section and lowering the lengthening string down into the well below would require roughly 37 hours.[13]

As the crew gradually assembled and lowered the casing, they paused several times to install centralizers (Figure 4.3) at predetermined points along the casing string. Centralizers are critical components in ensuring a good cement job. When a casing string hangs in the center of the wellbore, cement pumped down the casing will flow evenly back up the annulus, displacing any mud and debris that were previously in that space and leaving a clean column of cement. If the casing is not centered, the cement will flow preferentially up the path of least resistance—the larger spaces in the annulus—and slowly or not at all in the narrower annular space. That can leave behind channels of drilling mud that can severely compromise a primary cement job by creating paths and gaps through which pressurized hydrocarbons can flow.

BP's original designs had called for 16 or more centralizers to be placed along the long string.[14] But on April 1, team member Brian Morel learned that BP's supplier (Weatherford) had in stock only six "subs"[15]—centralizers designed to screw securely into place between sections of casing. The alternative was to use "slip-on" centralizers—devices that slide onto the exterior of a piece of casing where they are normally secured in place by mechanical "stop collars" on either side. These collars can either be welded directly to the centralizers or supplied as separate pieces. The BP team—and Wells Team Leader John Guide in particular—distrusted slip-on centralizers with separate stop collars because the pieces can slide out of position or, worse, catch on other equipment as the casing is lowered.[16]

Shortly after the BP team decided on the long string, Halliburton engineer Jesse Gagliano ran computer simulations using proprietary software called OptiCem, in part to predict whether mud channeling would occur. OptiCem calculates the likely outcome of a cement job based on a number of variables, including the geometry of the wellbore and casing, the size and location of centralizers, the rate at which cement will be pumped, and the relative weight and viscosity of the cement

FIGURE 4.3: Centralizer Sub

Centralizer "subs" screw into place between sections of casing.

Weatherford

compared to the mud it displaces. Gagliano's calculations suggested that the Macondo production casing would need more than six centralizers to avoid channeling.

Gagliano told BP engineers Mark Hafle and Brett Cocales about the problem on the afternoon of April 15.[17] With de facto leader John Guide out of the office, Gregory Walz, the BP Drilling Engineering Team Leader, obtained permission from senior manager David Sims to order 15 additional slip-on centralizers—the most BP could transport immediately in a helicopter. That evening, Gagliano reran his simulations and found that channeling due to gas flow would be less severe with 21 centralizers in place. Late that night, Walz sent an e-mail to Guide explaining that he and Sims felt that BP needed to "honor the [OptiCem] modeling to be consistent with our previous decisions to go with the long string."[18]

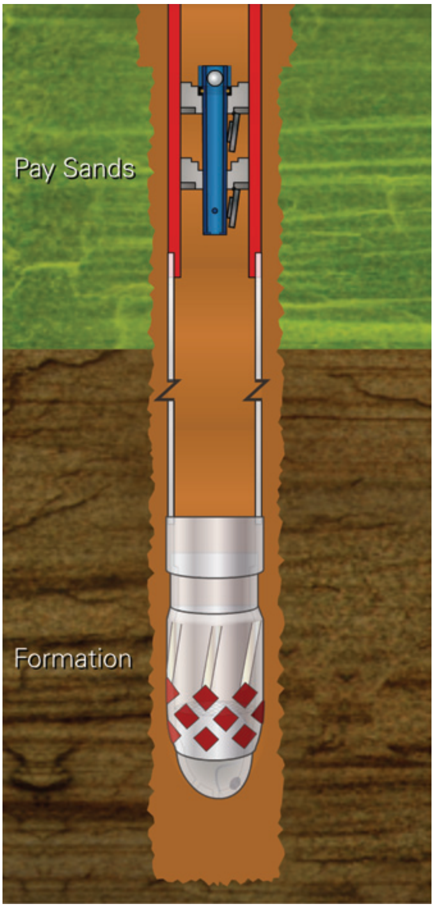
When Guide learned the next day of the decision to add more centralizers, he initially deferred, but then challenged the decision. Walz had earlier assured Guide that the 15 additional centralizers would be custom-designed one-piece units that BP had used on a prior well and would limit the potential for centralizer "hang up."[19] But when the centralizers arrived, BP engineer Brian Morel, who happened to be out on the rig, reported that the centralizers were of conventional design with separate stop collars. Morel e-mailed BP drilling engineer Brett Cocales to question the need for additional centralizers.[20] Cocales responded that the team would "probably be fine" even without the additional centralizers and that "Guide is right on the risk/reward equation."[21]

Guide pointed out to Walz that the new centralizers were not custom-made as specified.[22] "Also," he noted, "it will take 10 hrs to install them." He complained that the "last minute addition" of centralizers would add 45 pieces of equipment to the casing that could come off during installation, and concluded by saying that he was "very concerned." In the end, Guide's view prevailed; BP installed only the six centralizer subs on the Macondo production casing.

Lowering the Casing String Into Position

Early on the morning of April 18, with a centralizer plan in hand, the rig crew finally began assembling and lowering the long string into position. The leading end of the casing,

FIGURE 4.4: Shoe Track



The shoe track, showing the float collar assembly at the top and the reamer shoe at the bottom.

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the "shoe track," began with a "reamer shoe"—a bullet-shaped piece of metal with three holes designed to help guide the casing down the hole. (Figure 4.4) The reamer shoe was followed by 180 feet of seven-inch-diameter steel casing. Then came a Weatherford-manufactured "float collar," a simple arrangement of two flapper (float) valves, spaced one after the other, held open by a short "auto-fill tube" through which the mud in the well could flow. As the long string was lowered down the wellbore, the mud passed through the holes in the reamer shoe and auto-fill tube that propped open the float valves, giving it a clear flow path upward.

Preparation for Cementing—and Unexpected Pressure Anomalies in the Well

The long string was installed in its final position early on the afternoon of April 19. With the top end of the string seated in the wellhead and its bottom end located just above the bottom of the wellbore, the crew's next job was to prepare the float-valve system for cementing. During the cementing process, fluids pumped into the well should flow in a one-way path: *down* the center of the last casing string, *out* the bottom, and *up* the annulus (between the exterior of the steel casing and the surrounding rock formations). To ensure unidirectional flow, the crew needed to push the auto-fill tube downward, so it would no longer prop open the float valves. With the tube out of the way, the flapper valves would spring shut and convert from two-way valves into one-way valves that would allow mud and cement to flow *down* the casing into the shoe track, but prevent any fluid from reversing direction and coming back *up* the casing. Once the float valves had converted, Halliburton could pump cement down through the casing and up around the annulus; the valves would keep cement from flowing back up the casing once the crew stopped pumping.

To convert the float valves, that evening the crew began pumping mud down through the casing. Based on Weatherford's specifications, the valves should convert once the rate of flow though holes in the auto-fill tube had reached roughly 6 barrels per minute (bpm), causing a differential pressure on the tube of approximately 600 pounds per square inch (psi).[23] But the crew hit a stumbling block. They pumped fluids into the well, eventually pressuring up to 1,800 psi, but could not establish flow.

Well Site Leader Bob Kaluza and BP engineer Morel[24] called Guide, their supervisor on shore. In consultation with Guide and Weatherford staff, the rig team decided to increase the pump pressure in discrete increments, hoping eventually to dislodge the auto-fill tube.[25] On their ninth attempt, pump pressure peaked at 3,142 psi and then suddenly dropped as mud finally began to flow. Significantly, however, the pump rate of mud into the well and through the shoe track thereafter never exceeded approximately 4 bpm.[26]

BP's team concluded that the float valves had converted, but noted another anomaly. The drilling-mud subcontractor, M-I SWACO, had predicted that it would take a pressure of 570 psi to circulate mud after converting the float valves.[27] Instead, the rig crew reported that circulation pressure was much lower: only 340 psi. BP's Well Site Leader Bob Kaluza expressed concern about low circulating pressure.[28] He and the Transocean crew switched circulating pumps to see if that made a difference, and eventually concluded that the pressure gauge they had been relying on was broken.[29] Believing they had converted the float valves and reestablished mud circulation in the well, BP was ready at last to pump cement down the production casing and complete the primary cement job.

The Inherently Uncertain Cementing Process

Cementing an oil well is an inherently uncertain process. To establish isolation across a hydrocarbon zone at the bottom of a well, engineers must send a slug of cement down the inside of the well. They then pump mud in after it to push the cement down until it "turns the corner" at the bottom of the well and flows up into the annular space. If done properly, the slug of cement will create a long and continuous seal around the production casing, and will fill the shoe track in the bottom of the final casing string. But things can go wrong even under optimal conditions. If the cement is pumped too far or not far enough, it may not isolate the hydrocarbon zones. If oil-based drilling mud contaminates the water-based cement as the cement flows down the well, the cement can set slowly or not at all. And, as previously noted, the cement can "channel," filling the annulus unevenly and allowing hydrocarbons to bypass cement in the annular space. Given the variety of things that can go wrong with a cement job, it is hardly surprising that a 2007 MMS study identified cementing problems as one of the "most significant factors" leading to blowouts between 1992 and 2006.[30]

Even following best practices, a cement crew can never be certain how a cement job at the bottom of the well is proceeding as it is pumped. Cement does its work literally miles away from the rig floor, and the crew has no direct way to see where it is, whether it is contaminated, or whether it has sealed off the well. To gauge progress, the crew must instead rely on subtle, indirect indicators like pressure and volume: they know how much cement and mud they have sent down the well and how hard the pumps are working to push it. The crew can use these readings to check whether each barrel of cement pumped into the well displaces an equal volume of drilling mud—producing "full returns." They can also check for pressure spikes to confirm that "wiper plugs" (used to separate the cement from the surrounding drilling mud) have landed on time as expected at the bottom of the well. And they can look for "lift pressure"—a steady increase in pump pressure signifying that the cement has turned the corner at the bottom of the well and is being pushed up into the annular space against gravity.

While they suggest generally that the job has gone as planned, these indicators say little specific about the location and quality of the cement at the bottom of the well. None of them can take the place of pressure testing and cement evaluation logging (see below).

The Cementing Design: Critical Decisions for a Fragile Formation

In the days leading up to the final cementing process, BP engineers focused heavily on the biggest challenge: the risk of fracturing the formation and losing returns. John Guide explained after the incident that losing returns "was the No. 1 risk."[31] He and the other BP engineers worried that if their cementing procedure placed too much pressure on the geologic formation below, it might trigger another lost-returns event similar to the one on April 9. In this case, critical cement—not mud—might flow into the formation and be lost, potentially leaving the annular space at the bottom of the well open to hydrocarbon flow.

The BP team's concerns led them to place a number of significant constraints on Halliburton's cementing design. The first compromise in BP's plan was to limit the circulation of drilling mud through the wellbore before cementing. Optimally, mud in the wellbore would have been circulated "bottoms up"—meaning the rig crew would have pumped enough mud down the wellbore to bring mud originally at the bottom of the well all the way back up to the rig. There are at least two benefits to bottoms up circulation. Such extensive circulation cleans the wellbore and reduces the likelihood of channeling. And circulating bottoms up allows technicians on the rig to examine mud from the bottom of the well for hydrocarbon content before cementing. But the BP engineers feared that the longer the rig crew circulated mud through the casing before cementing, the greater the risk of another lost-returns event. Accordingly, BP circulated approximately 350 barrels of mud before cementing, rather than the 2,760 barrels needed to do a full bottoms up circulation.[32]

BP compromised again by deciding to pump cement down the well at the relatively low rate of 4 barrels or less per minute.[33] Higher flow rates tend to increase the efficiency with which cement displaces mud from the annular space. But the increased pump pressure required to move the cement quickly would mean more pressure on the formation (ECD) and an increased risk of lost returns. BP decided to reduce the risk of lost returns in exchange for a less-than-optimal rate of cement flow.

BP made a third compromise by limiting the volume of cement that Halliburton would pump down the well. Pumping more cement is a standard industry practice to insure against uncertain cementing conditions: more cement means less risk of contamination and less risk that the cement job will be compromised by slight errors in placement. But more cement at Macondo would mean a higher cement column in the annulus, which in turn would exert more pressure on the fragile formation below. Accordingly, BP determined that the annular cement column should extend only 500 feet above the uppermost hydrocarbon-bearing zone (and 800 feet above the main hydrocarbon zones), and that this would be sufficient to fulfill MMS regulations of "500 feet above the uppermost hydrocarbon-bearing zone."[34] However, it did *not* satisfy BP's own internal guidelines, which specify that the top of the annular cement should be 1,000 feet above the uppermost hydrocarbon zone.[35] As designed, BP would have Halliburton pump a total of approximately 60 barrels of cement down the well—a volume that its own engineers recognized would provide little margin for error.[36]

Finally, in close consultation with Halliburton, BP chose to use "nitrogen foam cement"—a cement formula that has been leavened with tiny bubbles of nitrogen gas, injected into the cement slurry just before it goes down the well. This formula was chosen to lighten the resulting slurry from approximately 16.7 ppg to 14.5 ppg—thereby reducing the pressure the cement would exert on the fragile formation. The bubbles, in theory, would also help to balance the pore pressure in the formation and clear the annular space of mud as the cement flowed upward. Halliburton is an industry leader in foam cementing, but BP appears to have had little experience with foam technology for cementing production casing in the Gulf of Mexico.[37]

The Cement Slurry: Laboratory Analyses

A cement slurry must be tested before it is used in a cement job. Because the pressure and temperature at the bottom of a well can significantly alter the strength and curing rate of a given cement slurry—and because storing cement on a rig can alter its chemical composition over time—companies like Halliburton normally fly cement samples from the rig back to a laboratory shortly before pumping a job to make sure the cement will work under the conditions in the well. The laboratory conducts a number of tests to evaluate the slurry's viscosity and flow characteristics, the rate at which it will cure, and its eventual compressive strength.

When testing a slurry that will be foamed with nitrogen, the lab also evaluates the stability of the cement that results. A stable foam slurry will retain its bubbles and overall density long enough to allow the cement to cure. The result is hardened cement that has tiny, evenly dispersed, and unconnected nitrogen bubbles throughout. If the foam does not remain stable up until the time the cement cures, the small nitrogen bubbles may coalesce into larger ones, rendering the hardened cement porous and permeable.[38] If the instability is particularly severe, the nitrogen can "break out" of the cement, with unpredictable consequences.

On February 10, soon after the *Deepwater Horizon* began work on the well, Jesse Gagliano asked Halliburton laboratory personnel to run a series of "pilot tests" on the cement blend stored on the *Deepwater Horizon* that Halliburton planned to use at Macondo.[39] They tested the slurry[40] and reported the results to Gagliano. He sent the laboratory report to BP on March 8 as an attachment to an e-mail in which he discussed his recommended plan for cementing an earlier Macondo casing string.[41]

The reported data that Gagliano sent to BP on March 8 included the results of a single foam stability test. To the trained eye, that test showed that the February foam slurry design was unstable. Gagliano did not comment on the evidence of the cement slurry's instability, and there is no evidence that BP examined the foam stability data in the report at all.

Documents identified after the blowout reveal that Halliburton personnel had also conducted another foam stability test earlier in February. The earlier test had been conducted under slightly different conditions than the later one and had failed more severely.[42] It appears that Halliburton never reported the results of the earlier February test to BP.

Halliburton conducted another round of tests in mid-April, just before pumping the final cement job. By then, the BP team had given Halliburton more accurate information about the temperatures and pressures at the bottom of the Macondo well, and Halliburton had progressed further with its cementing plan. Using this information, the laboratory personnel conducted several tests, including a foam stability test, starting on approximately April 13. The first test Halliburton conducted showed once again that the cement slurry would be unstable.[43] The Commission does not believe that Halliburton ever reported this information to BP. Instead, it appears that Halliburton personnel subsequently ran a second foam stability test, this time doubling the pre-test "conditioning time" to three hours.[44]

The evidence suggests that Halliburton began the second test at approximately 2:00 a.m. on April 18.[45] That test would normally take 48 hours. Halliburton finished pumping the cement job just before 48 hours would have elapsed.[46] Although the second test at least arguably suggests the foam cement design used at Macondo would be stable, it is unclear whether Halliburton had results from that test in hand before it pumped the job. Halliburton did not send the results of the final test to BP until April 26, six days after the blowout.[47]

Evaluating the Cementing Job

Transocean's rig crew and Halliburton's cementers finished pumping the primary cement job at 12:40 a.m. on April 20.[48] Once the pumps were off, a BP representative and Vincent Tabler of Halliburton performed a check to see whether the float valves were closed and holding. They opened a valve at the cementing unit to see whether any fluid flowed from the well. If more fluid came back than expected, that would indicate that cement was migrating back up into the casing and pushing the fluids above it out of the top of the well. Models had predicted 5 barrels of flow back. According to Brian Morel, the two men observed 5.5 barrels of flow, tapering off to a "finger tip trickle."[49] According to Morel, 5.5 barrels of flow-back volume was within the acceptable margin for error.[50] Tabler testified that they watched flow "until it was probably what we call a pencil stream," which stopped, started up again, and then stopped altogether.[51] While it is not clear how long the two men actually watched for potential flow, they eventually concluded the float valves were holding.

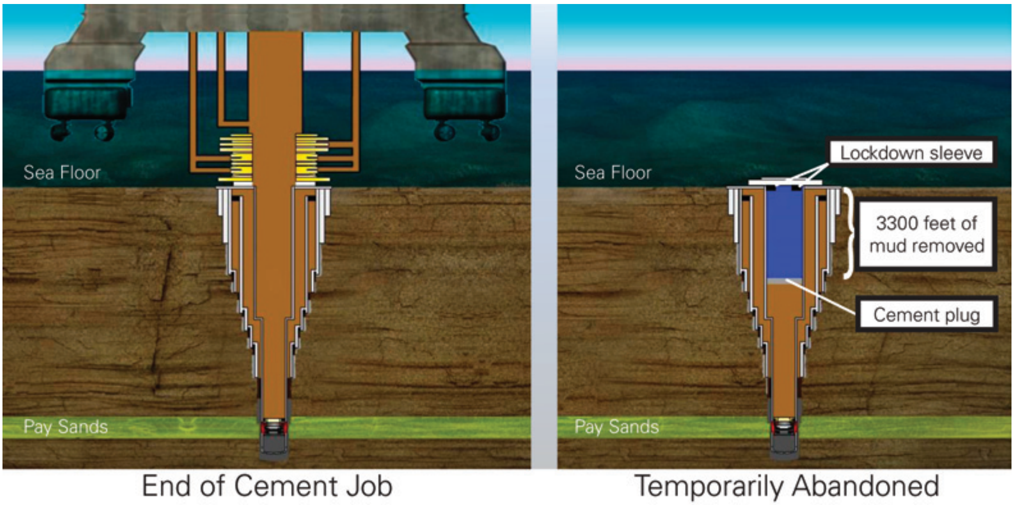
With no lost returns, BP and Halliburton declared the job a success. Nathaniel Chaisson, one of Halliburton's crew on the rig, sent an e-mail to Jesse Gagliano at 5:45 a.m. saying, "We have completed the job and it went well."[52] He attached a detailed report stating that the job had been "pumped as planned" and that he had seen full returns throughout the process.[53] And just before leaving the rig, Morel e-mailed the rest of the BP team to say "the Halliburton cement team . . . did a great job."[54]

Cement Evaluation Tools

Cement evaluation tools (including "cement bond logs") test the integrity of cement in the annular space around a casing. The tools measure whether and to what extent cement has bonded to the outside of the casing and formation, and the location and severity of any channels through the cement. Although a modern cement evaluation combines several different instruments, the primary approach is to analyze the casing's response to acoustic signals. Just as a muffled bell sounds different than a free-swinging bell, a well casing will respond differently depending on the volume and quality of cement around it. Cement evaluation tools do have important limits. Among other things, they work better after the cement has had time to cure completely. They also cannot evaluate cement in the shoe track of a casing, or in the annular space below the float valves.

At the 7:30 a.m. morning meeting with contractors on the rig, the BP team concluded the cement job went well enough to send home a team of technicians from Schlumberger who had been standing by on the rig for at least one day already[55] waiting to perform a suite of cement evaluation tests on the primary cement job, including cement bond logs.[56] The BP team relied on a "decision tree" that Guide and BP engineers had prepared beforehand. The

FIGURE 4.5: Temporary Abandonment



The status of the well before and after temporary abandonment.

TrialGraphix

primary criterion BP appears to have used to determine whether to perform the cement evaluation test was whether there were "[l]osses while cementing [the] long string."[57] Having seen no lost returns during the cement job, BP sent the Schlumberger team home and moved on to prepare the well for temporary abandonment.

Temporary Abandonment and Preparing to Move On to the Next Job

Once BP decided to send the Schlumberger team home, *Deepwater Horizon*'s crew began the final phase of its work. Drilling the Macondo well had required a giant offshore rig of *Deepwater Horizon*'s capabilities. By contrast, BP, like most operators, would give the job of "completing" the well to a smaller (and less costly) rig, which would install hydrocarbon-collection and -production equipment. To make way for the new rig, the *Deepwater Horizon* would have to remove its riser* and blowout preventer from the wellhead—and before it could do those things, the crew had to secure the well through a process called "temporary abandonment."

Four features of the temporarily abandoned well are worth noting. First is the single 300-foot-long cement plug inside the wellbore. MMS regulations required BP to install a cement plug as a backup for the cement job at the bottom of the well. Second is the location of the cement plug: BP planned to put it 3,300 feet below the ocean floor, or "mud line" (which was deeper than MMS regulations allowed without dispensation, and deeper than usual).[58] Third is the presence of seawater in the well below the sea floor: BP planned to replace 3,000 feet of mud in the wellbore above the cement plug with much

* The riser is the piping that connects the drilling rig at the surface with the BOP at the wellhead on the seafloor.

lighter seawater (seawater weighs roughly 8.6 ppg, while the mud in the wellbore weighed roughly 14.5 ppg). Fourth is the lockdown sleeve—a mechanical device that locks the long casing string to the wellhead to prevent it from lifting out of place during subsequent production operations. (Figure 4.5)

At 10:43 a.m., Morel e-mailed an "Ops Note" to the rest of the Macondo team listing the temporary abandonment procedures for the well.[59] It was the first time the BP Well Site Leaders on the rig had seen the procedures they would use that day. BP first shared the procedures with the rig crew at the 11 a.m. pre-tour meeting that morning.[60] The basic sequence was as follows:

Lockdown Sleeve

Before the Macondo blowout, a *lockdown sleeve* was not generally considered a safety mechanism or barrier to flow prior to the production phase of the well. Drilling rigs did not generally set lockdown sleeves. Rather, completion or production rigs did so after the drilling phase. BP decided to have the Deepwater Horizon set the lockdown sleeve because the Horizon could do the job more quickly than the completion rig. Based on the Macondo event, and given early concerns that upward forces during the blowout had approached or exceeded the force needed to lift the production casing up out of its seat in the wellhead, the Commission believes operators should consider installing a lockdown sleeve or other device to lock the casing hanger in place as part of drilling operations (or, at the very least, at the outset of temporary abandonment).

1. Perform a positive-pressure test to test the integrity of the production casing;
2. Run the drill pipe into the well to 8,367 feet (3,300 feet below the mud line);
3. Displace 3,300 feet of mud in the well with seawater, lifting the mud above the BOP and into the riser;
4. Perform a negative-pressure test to assess the integrity of the well and bottom-hole cement job to ensure *outside* fluids (such as hydrocarbons) are not leaking *into* the well;
5. Displace the mud in the riser with seawater;
6. Set the surface cement plug at 8,367 feet; and
7. Set the lockdown sleeve.[61]

The crew would never get through all of the steps in the procedure.

BP's Macondo team had made numerous changes to the temporary abandonment procedures in the two weeks leading up to the April 20 "Ops Note." For example, in its April 12 drilling plan, BP had planned (1) to set the lockdown sleeve before setting the surface cement plug and (2) to set the surface cement plug in seawater only 6,000 feet below sea level (as opposed to 8,367 feet). The April 12 plan did not include a negative-pressure test.[62] On April 14, Morel sent an e-mail entitled "Forward Ops" setting forth a different procedure, which included a negative-pressure test but would require setting the surface cement plug in mud before displacement of the riser with seawater.[63] On April 16, BP sent an Application for Permit to Modify to MMS describing a temporary abandonment procedure that was different from the procedure in either the April 12 drilling plan, the April 14 e-mail, or the April 20 "Ops Note."[64] There is no evidence that these changes went through *any* sort of formal risk assessment or management of change process.

Countdown to Blowout

The first step in the temporary abandonment was to test well integrity: to make sure there were no leaks in the well.

The Positive-Pressure Test

The positive-pressure test evaluates, among other things, the ability of the casing in the well to hold in pressure. MMS regulations require a positive-pressure test prior to temporary abandonment.[65] To perform the test at Macondo, the *Deepwater Horizon*'s crew first closed off the well below the BOP by shutting the blind shear ram (there was no drill pipe in the well at the time).[66] Then, much like pumping air into a bike tire to check for leaks, the rig crew pumped fluids into the well (through pipes running from the rig to the BOP) to generate pressure and then checked to see if it would hold.

The crew started the positive-pressure test at noon.[67] They pressured the well up to 250 psi for 5 minutes, and then pressured up to 2,500 psi and watched for 30 minutes. The pressure inside the well remained steady during both tests, showing there were no leaks in the production casing through which fluids could pass from inside the well to the outside. The drilling crew and BP's Well Site Leader Bob Kaluza considered the test successful. Later in the afternoon, Kaluza showed visiting BP executive Pat O'Bryan the pressure chart from the test; O'Bryan remarked, "Things looked good with the positive test."[68]

The Negative-Pressure Test: Unexpected Pressure Readings

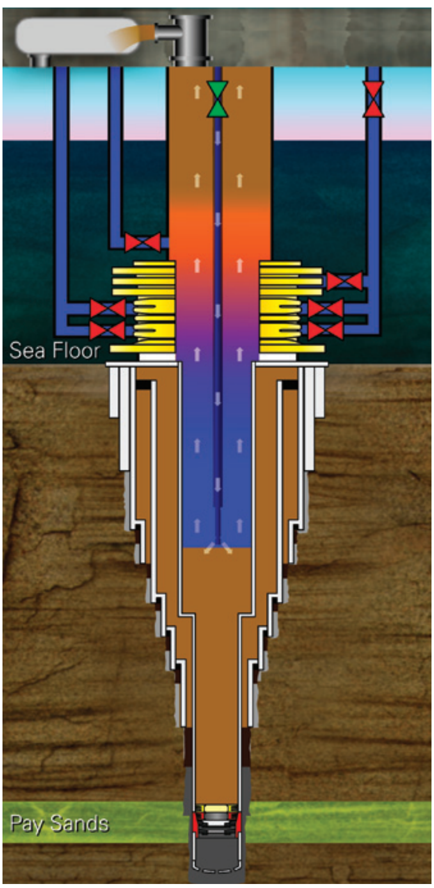
The negative-pressure test checks not only the integrity of the casing, like the positive-pressure test, but also the integrity of the bottomhole cement job. At the Macondo well, the negative-pressure test was the *only* test performed that would have checked the integrity of the bottomhole cement job.

Instead of pumping pressure into the wellbore to see if fluids leak out, the crew *removes* pressure from inside the well to see if fluids, such as hydrocarbons, leak in, past or through the bottomhole cement job. In so doing, the crew simulates the effect of removing the mud in the wellbore and the riser (and the pressure exerted by that mud) during temporary abandonment. If the casing and primary cement have been designed and installed properly, they will prevent hydrocarbons from intruding even when that "overbalancing" pressure is removed.[69] First, the crew sets up the well to simulate the expected hydrostatic pressure exerted by the column of fluids on the bottom of the well in its abandoned state. Second, the crew bleeds off any pent-up pressure that remains in the well, taking it down to 0 psi. Third, the crew and Well Site Leaders watch to make sure that nothing flows up from and out of the well and that no pressure builds back up inside of the well. If there is no flow or pressure buildup, that means that the casing and primary cement have sealed the well off from external fluid pressure and flow. A negative-pressure test is successful if there is no flow out of the well for a sustained period and if there is no pressure build-up inside the well when it is closed at the surface.

To conduct a proper negative test at Macondo, BP would have to isolate the well from the effect of the 5,000-foot-plus column of drilling mud in the riser and a further 3,300-foot column of drilling mud below the seafloor. Those heavy columns of mud exerted much more pressure on the well than the seawater that would replace them after temporary abandonment. Specifically, the pressure at the bottom of the well would be approximately 2,350 psi *lower* after temporary abandonment than before.[70] Once this pressure was removed, the downward force of the column of fluids in the well would be less than the pressure of the hydrocarbons in the reservoir, so the well would be in what is called an "underbalanced" state. It was therefore critical to test and confirm the ability of the well (including the primary cement job) to withstand the underbalance. If the test showed that hydrocarbons would leak into the well once it was underbalanced, BP would need to diagnose and fix the problem (perhaps remediating the cement job) before moving on, a process that could take many days.

The crew began the negative test of Macondo at 5:00 p.m. Earlier in the day, the crew had prepared for the negative test by setting up the well to simulate the planned removal of the mud in the riser and 3,300 feet of drilling mud in the wellbore. The crew ran the drill pipe down to approximately 8,367 feet below sea level and then pumped a "spacer"—a liquid mixture that serves to separate the heavy drilling mud from the seawater—followed by seawater down the drill pipe to push (displace) 3,300 feet of mud from below the mud line to above the BOP. (Figure 4.6)

FIGURE 4.6: Displacing Mud With Spacer and Seawater Before the Negative Pressure Test



Seawater (blue) displaces mud (brown) from wellbore and riser, with spacer fluid separating the two.

TrialGraphix

While drilling crews routinely use water-based spacer fluids to separate oil-based drilling mud from seawater, the spacer BP chose to use during the negative pressure test was unusual. BP had directed M-I SWACO mud engineers on the rig to create a spacer out of two different lost-circulation materials left over on the rig—the heavy, viscous drilling fluids used to patch fractures in the formation when the crew experiences lost returns.[71] M-I SWACO had previously mixed two different unused batches, or "pills," of lost-circulation materials in case there were further lost returns.[72] BP wanted to use these materials as spacer in order to avoid having to dispose of them onshore as hazardous waste pursuant to the Resource and Conservation Recovery Act, exploiting an exception that allows companies to dump water-based "drilling fluids" overboard if they have been circulated down through a well.[73] At BP's direction, M-I SWACO combined the materials to create an unusually large volume of spacer that had never previously been used by anyone on the rig or by BP as a spacer, nor been thoroughly tested for that purpose.[74]

Once the crew had displaced the mud to above the BOP, they shut an annular preventer in the BOP, isolating the well from the downward pressure exerted by the heavy mud and spacer in the riser. The crew could now perform the negative-pressure test using the drill pipe: it would open the top of the drill pipe on the rig, bleed the drill pipe pressure to zero, and then watch for flow. The crew opened the drill pipe at the rig to bleed off any pressure that had built up in the well during the mud-displacement process. The crew tried to bleed the pressure down to zero, but could not get it below 266 psi. When the drill pipe was closed, the pressure jumped back up to 1,262 psi.

Around this time, the driller's shack was growing crowded. The night crew was arriving in preparation for the 6:00 p.m. shift change, which meant that both toolpushers—Wyman Wheeler and Jason Anderson—and both Well Site Leaders—Bob Kaluza and Don Vidrine—were present. In addition, a group of visiting BP and Transocean executives entered as part of a rig tour escorted by Transocean Offshore Installation Manager Jimmy Harrell.[75] It was apparent to at least one member of the tour that the crew was having a "little bit of a problem."[76]

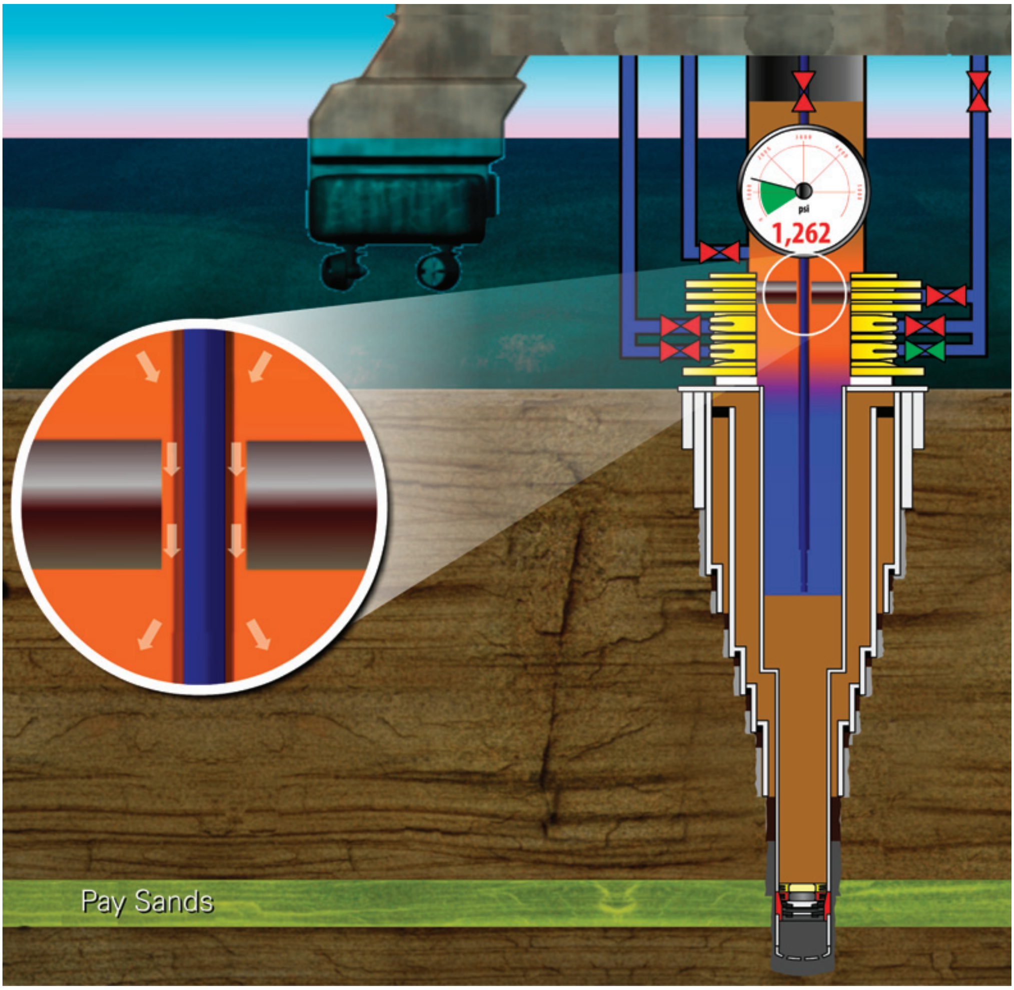
The crew had noticed that the fluid level inside the riser was dropping, suggesting that spacer was leaking down past the annular preventer, out of the riser, and into the well (Figure 4.7). Harrell, who stayed behind in the drill shack as the tour continued, ordered the annular preventer closed more tightly to stop the leak.[77] Harrell then left the rig floor.

With that problem solved, the crew refilled the riser and once again opened up the drill pipe and attempted a second time to bleed the pressure down to 0 psi. This time, they were able to do so. But when they shut the drill pipe in again, the pressure built back up to at least 773 psi. The crew then attempted a third time to bleed off the pressure from the drill pipe, and was again able to get it down to 0 psi. When the crew shut the well back in, however, the pressure increased to 1,400 psi. At this point, the crew had bled the drill-pipe pressure down three times, but each time it had built back up. For a successful negative-pressure test, the pressure must remain at 0 psi when the pipe is closed after the pressure is bled off.

The Transocean crew and BP Well Site Leaders met on the rig floor to discuss the readings. In addition to Kaluza, Vidrine, and Anderson, Dewey Revette (Transocean's on-duty driller) and BP Well Site Leader trainee Lee Lambert were there. According to post-incident statements from both Well Site Leaders, Anderson said that the 1,400 psi pressure on the drill pipe was being caused by a phenomenon called the "bladder effect."[78] According to Lambert, Anderson explained that heavy mud in the riser was exerting pressure on the annular preventer, which in turn transmitted pressure to the drill pipe. Lambert said that he did not recall anyone agreeing or disagreeing with Anderson's explanation.[79]

According to Harrell, after a lengthy discussion, BP Well Site Leader Vidrine then insisted on running a second negative-pressure test, this time monitoring pressure and flow on the kill line rather than the drill pipe. (The kill line is one of three pipes, each approximately 3 inches in diameter, that run from the rig to the BOP to allow the crew to circulate fluids into and out of the well at the sea floor.) The pressure on the kill line during the negative-pressure test should have been identical to the pressure on the drill pipe, as both flow

FIGURE 4.7: Fluids Leak Past Annular Preventer



Spacer fluids (orange) leak past annular preventer.

TrialGraphix

paths went to the same place (and both should have been filled with seawater). Vidrine apparently insisted the negative test be repeated on the kill line because BP had specified that the test would be performed on the kill line in a permit application it submitted earlier to MMS.[80]

For the second test, the crew opened the kill line and bled the pressure down to 0 psi. A small amount of fluid flowed, and then stopped.[81] Rig personnel left the kill line open for 30 minutes but did not observe any flow from it. The test on the kill line thus satisfied the criteria for a successful negative pressure test—no flow or pressure buildup for a sustained period of time. But the pressure on the drill pipe remained at 1,400 psi throughout. The Well Site Leaders and crew never appear to have reconciled the two different pressure readings.[82] The "bladder effect" may have been proposed as an explanation for the anomaly—but based on available information, the 1,400 psi reading on the drill pipe could *only* have been caused by a leak into the well. Nevertheless, at 8 p.m., BP Well Site Leaders, in consultation with the crew, made a key error and mistakenly concluded the second negative test procedure had confirmed the well's integrity. They declared the test a success and moved on to the next step in temporary abandonment.

Displacing Mud from the Riser—and Mounting Signs of a Kick

At 8:02 p.m., the crew opened the annular preventer and began displacing mud and spacer from the riser. Halliburton cementer Chris Haire went to the drill shack to check on the status of the upcoming surface cement plug job. Revette and Anderson told him the negative-pressure test had been successful and that Haire should prepare to set the surface cement plug.[83]

Revette sat down in his driller's chair to monitor the well for kicks—any unplanned influxes of gas or fluids—and other anomalies. As gaseous hydrocarbons in a kick rise up the wellbore, they expand with ever-increasing speed—a barrel of natural gas at Macondo could expand over a hundredfold as it traveled the 5,000 feet between the wellhead and the rig above.[84] And as the gas expands, it pushes mud upward faster and faster, reducing the pressure on the gas and increasing the speed of the kick—making it imperative that rig crews recognize and respond to a kick as early as possible.

The individuals responsible for detecting kicks on a rig include the driller, assistant drillers, and the mudlogger.[85] Dewey Revette was the driller on duty at the time; the two assistant drillers on duty were Donald Clark and Stephen Curtis. Joseph Keith of Sperry Sun was the mudlogger.

These individuals look for kicks by monitoring real-time data displays in the driller's shack, mudlogger's shack, and elsewhere on the rig. They watch two primary parameters. The first, and most reliable when available, is the volume of mud in the active pits. The volume of mud sent from the active pits into the well should equal the volume of mud returning to the active pits from the well. An increase in volume is a powerful indicator that something is flowing into the well.

Second, under normal circumstances, the volume and rate of flow of fluids coming from the well should equal the volume and rate of flow of fluid pumped into the well. If flow out of the well is greater than flow into the well, it is a strong indicator that a kick may be under way.

Active Pit System

Rigs contain multiple mud pits. The Deepwater Horizon had 20 in all. Various fluids can be stored in these pits, including drilling mud. The *active pit system* is a subset of the mud pits that the driller selects for monitoring purposes.

In addition to these two primary parameters, the crew can perform visual "flow checks." There were a number of cameras and stations on the *Deepwater Horizon* where the driller, mudlogger, and others could observe whether fluids were flowing from the well. When the pumps are shut off and mud is no longer being sent into the well, flow out of the well should stop. Visual flow checks are a reliable way to monitor for kicks when pumps are off and are often used to confirm other kick indicators.

Finally, the driller and mudlogger also monitor drill-pipe pressure, but it is a more ambiguous kick indicator than the other parameters because there can be many reasons for a change in drill pressure. If drill-pipe pressure *decreases* while the pump rate remains constant, that may indicate that hydrocarbons have entered the wellbore and are moving up the well past the sides of the drill pipe. The lighter-weight hydrocarbons exert less downward pressure, meaning the pumps do not need to work as hard to push fluids into the well. If drill-pipe pressure *increases* while the pump rate remains constant, that may indicate that heavier mud is being pushed up from below (perhaps by hydrocarbons) and displacing lighter fluids in the well adjacent to the drill pipe. Unexplained changes in drill-pipe pressure may not always indicate a kick, but when observed should be investigated. The crew should shut down the pumps and monitor the well to confirm it is static; if they are unable to do so, they should shut in the well until the source of the readings can be determined.

The *Deepwater Horizon* had two separate systems for collecting and displaying real-time data. The "Hitec" system, owned by Transocean, was the source on which the *Deepwater Horizon*'s drilling crew typically relied for monitoring the well. The "Sperry Sun" system—installed and operated by a Halliburton subsidiary at BP's request—sent data back to shore in real time, allowing BP personnel to access and monitor this data from anywhere with an Internet connection.* Individuals on the rig could monitor data from the Sperry Sun system as well.

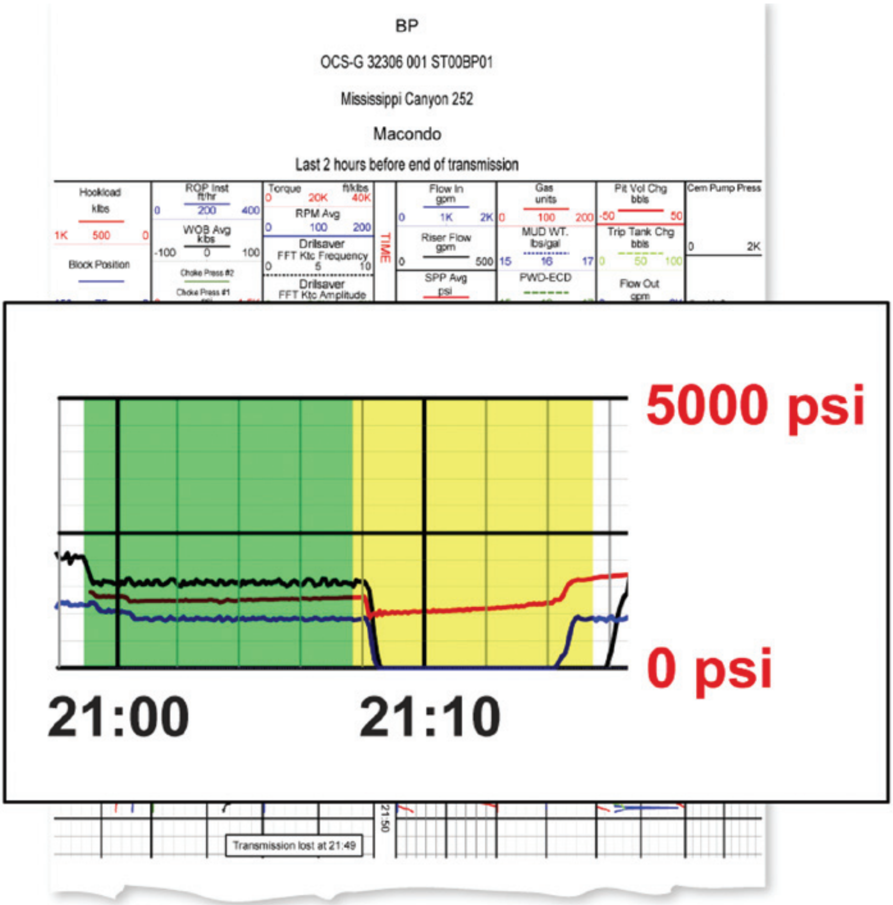
Once the crew began displacing the riser with seawater at 8:02 p.m., they confronted the challenge of dealing with all of the returning mud. The driller repeatedly rerouted the mud returns from one pit to another in order to accommodate the incoming volume.[86] During that time, the crew also sent mud from other locations into the active pit system.[87] It is not clear whether the driller, assistant drillers, or mudlogger could adequately monitor active pit volume (or flow-in versus flow-out) during that time given all the activity.

Nevertheless, things appear to have been relatively uneventful until 9:00 p.m. Drill-pipe pressure was slowly but steadily decreasing over that time as lighter seawater displaced heavy drilling mud in the riser, lowering the pressure in the well and making it progressively easier to push seawater down into the well through the drill pipe.[88]

At approximately 9:01 p.m., however, drill-pipe pressure (shown by the red line in Figure 4.8) began slowly *increasing*, despite the fact that the pump rate remained constant.[89] Over the next seven minutes, it crept slowly upward from 1,250 to 1,350 psi.[90] While the

* It is difficult, if not impossible, to know precisely what the driller, assistant drillers, and mudloggers were doing and what data they were looking at between 8:00 p.m. and the first explosion at 9:49 p.m. Both the Hitec and Sperry Sun displays can be customized, and each operator typically has his own preferred set-up. Moreover, the full Hitec data set sank with the rig, leaving only the Sperry Sun subset of the data behind. Because the Sperry Sun data are all that is now available, the Commission focuses upon that data while recognizing that it is at best an approximation of what the driller, mudlogger, and others on the rig may have been looking at in the hours and minutes leading up to the blowout.

FIGURE 4.8: Increasing Drill-Pipe Pressure



Sperry Sun drill-pipe pressure data (in red).

magnitude of the increase may have appeared only as a subtle trend on the Sperry Sun display, the change in direction from decreasing to increasing was not. [91]

Had someone noticed it, he would have had to explain to himself how the drill-pipe pressure could be increasing while the pump rate was not. One possible reason might have been that hydrocarbons were flowing into the well and pushing heavy drilling mud up past the drill pipe.

The crew may have been distracted by other matters. At about that time, the last of the mud in the riser was arriving at the rig.[92] After that point, the next returning fluid would be the 400-plus barrels of spacer the crew had pumped into the well during the negative-pressure test. BP planned to dump that spacer overboard, but, according to regulations, would first have to run a test to make sure that it had removed all of the oil-based mud from the riser.[93]

At 9:08 p.m., the crew shut down the pumps to perform this "sheen test."[94] They closed a valve on the flow line that had been carrying fluids from the well to the pit system.[95] Mud engineer Greg Meche sampled the fluid and had it tested. Well Site Leader Vidrine waited for confirmation that there was no oily "sheen" on the returning spacer.[96] And mudlogger Joseph Keith performed a visual flow check to ensure the well was not flowing while the pumps were off. According to Keith, there was no flow.[97]

The pumps were shut down for 6 minutes, from 9:08 p.m. to 9:14 p.m. Meche took a sample of the returning fluid from the shaker house* and went to the mud lab to run the test.[98] He then returned to the shaker house, weighed the sample, and spoke with another of the mud engineers about the results.[99] When Vidrine learned the results, he signed off on the test and the crew turned the pumps back on.[100]

What nobody appears to have noticed during those six minutes (perhaps as a result of all of the activity) was that drill-pipe pressure was increasing again. With the pumps off, the drill-pipe pressure (red line in yellow box in Figure 4.8) should have stayed constant or gone down. Instead, it went up by approximately 250 psi.[101] This increase in pressure was clear in the Sperry Sun data, and likely would have been clearer on the Hitec display. Had someone noticed it, he would have recognized this as a significant anomaly that warranted further investigation before turning the pumps back on. But by 9:14 p.m., the crew turned the pumps back on, obscuring the signal. Drill-pipe pressure increased, but so did the pump rate.[102]

Four minutes later, a pressure-relief valve on one of the pumps blew.[103] Revette organized a group of crewmembers to go to the pump room to fix the valve. The group included derrickhand Wyatt Kemp, floorhands Shane Roshto and Adam Weise, and possibly one of the assistant drillers.[104] These men were still attending to the repair at the time of the first explosion.[105]

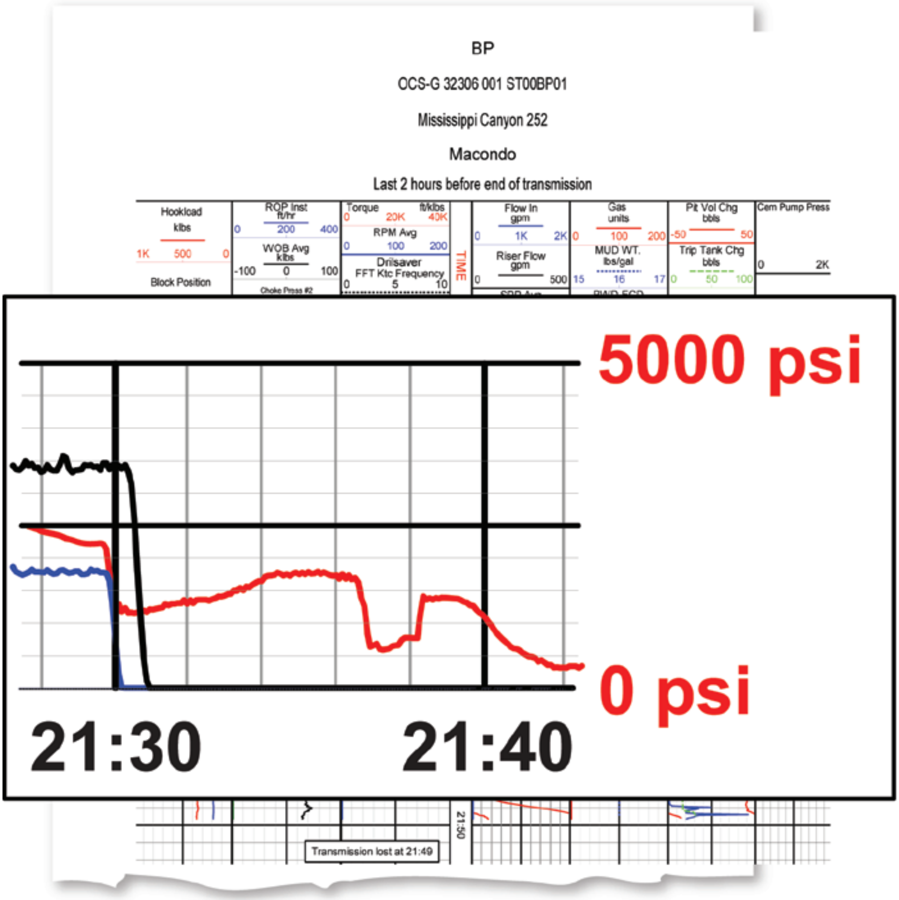
At about 9:20 p.m., senior toolpusher Randy Ezell called the rig floor and asked Jason Anderson about the negative-pressure test. Anderson responded that, "It went good." Ezell then asked about the displacement. Anderson reassured Ezell, "It's going fine. . . . I've got this."[106]

Shortly before 9:30 p.m., Revette noticed an odd and unexpected pressure difference between the drill pipe and the kill line. At roughly 9:30 p.m., the crew shut off the pumps to investigate.[107] At about that time, Chief Mate David Young arrived at the rig floor to discuss the upcoming cement plug job with Revette and Anderson.[108] Young witnessed Revette and Anderson having a calm discussion about a "differential pressure."[109] Anderson informed Young that the cement plug would be delayed.[110]

The drill-pipe pressure initially decreased after the pumps were turned off, but then increased by 550 psi over a 5.5 minute period.[111] (Figure 4.9) Meanwhile, the pressure on the kill line remained significantly lower. At approximately 9:36 p.m., Revette ordered

* The "shaker house" is a room or small separate structure on the rig for "shale shakers"—sieves and shakers that remove cuttings from the mud as it comes out of the well.

FIGURE 4.9: Fluctuating Drill-Pipe Pressure



Sperry Sun drill-pipe pressure data (in red).

floorhand Caleb Holloway to bleed off the drill-pipe pressure, in an apparent attempt to eliminate the difference.[112] The drill-pipe pressure initially dropped off as expected, but immediately began climbing again.[113] Young and Anderson left the rig floor.[114] Despite the mounting evidence of a kick, however, neither Revette nor Anderson performed a visual flow check or shut in the well.

At 9:39 p.m., drill-pipe pressure shifted direction and started decreasing.[115] In retrospect, this was a very bad sign. It likely meant that lighter-weight hydrocarbons were now pushing heavy drilling mud out of the way up the casing past the drill pipe.

Diversion and Explosion

Sometime between 9:40 and 9:43 p.m., drilling mud began spewing from the rotary onto the rig floor. This appears to have been the first moment Revette or others realized that a kick had occurred. At about that time, Anderson and assistant driller Stephen Curtis returned to the rig floor.[116]

The men took immediate action. First, they routed the flow coming from the riser through the diverter system, deciding to send it into the mud-gas separator rather than overboard into the sea (which was another option).[117] Second, they closed one of the annular preventers on the BOP to shut in the well.[118] At roughly 9:45 p.m., assistant driller Curtis called senior toolpusher Ezell to tell him that the well was blowing out, that mud was going into the crown on top of the derrick, and that Anderson was shutting the well in.[119]

Their efforts were futile. By the time the rig crew acted, gas was already above the BOP, rocketing up the riser, and expanding rapidly. At the Commission's November 8, 2010, hearing, a representative from Transocean likened it to "a 550-ton freight train hitting the rig floor," followed by what he described as "a jet engine's worth of gas coming out of the rotary."[120] The flow from the well quickly overwhelmed the mud-gas separator system. Ignition and explosion were all but inevitable. The first explosion occurred at approximately 9:49 p.m. On the drilling floor, the Macondo disaster claimed its first victims.

The Well is Not Sealed by the Blowout Preventer

The BOP is designed to contain pressure within the wellbore and halt an uncontrolled flow of hydrocarbons to the rig. The *Deepwater Horizon*'s BOP did not succeed in containing the Macondo well.

Diverter System

The *diverter system* provides two alternate paths for gas or gas-bearing mud returning to the rig from the well. The first path is through the mud-gas separator ("MGS"). The MGS consists of a series of pipes, valves, and a tank configured to remove gas entrained in relatively small amounts of mud. The gas is then vented from an outlet valve located high on the derrick. The MGS cannot accommodate substantial rates of mud flow. The second path is overboard. The diverter system has two 14-inch pipes, one starboard and one portside, through which flow can be sent overboard on the downwind side of the rig.

Witness accounts indicate that the rig crew activated one of the annular preventers around 9:41 p.m., and pressure readings suggest they activated a variable bore ram (which closes around the drill pipe) around 9:46 p.m.[121] Flow rates at this point may have been too high for either the annular preventer or a variable bore ram to seal the well. (Earlier kick detection would have improved the odds of success.)

After the first explosion, crewmembers on the bridge attempted to engage the rig's emergency disconnect system (EDS). The EDS should have closed the blind shear ram, severed the drill pipe, sealed the well, and disconnected the rig from the BOP.[122] But none of that happened. Amid confusion on the bridge, and initial hesitancy from Captain Kuchta, subsea supervisor Chris Pleasant rushed to the main control panel and pushed the EDS button.[123] Although the panel indicators lit up, the rig never disconnected.[124] It is possible that the first explosion had already damaged the cables to the BOP, preventing the disconnect sequence from starting.

Even so, the BOP's automatic mode function (the "deadman" system) should have triggered the blind shear ram after the power, communication, and hydraulics connections between the rig and the BOP were cut. But the deadman failed too. Although it is too early to tell at this point, this failure may have been due to poor maintenance. Post-incident testing of the two redundant "pods" that control the deadman revealed low battery charges in one pod and defective solenoid valves in the other. If those problems existed at the time of the blowout, they would have prevented the deadman system from working.[125*]

The Immediate Causes of the Macondo Well Blowout

As this narrative suggests, the Macondo blowout was the product of several individual missteps and oversights by BP, Halliburton, and Transocean, which government regulators lacked the authority, the necessary resources, and the technical expertise to prevent. We may never know the precise extent to which each of these missteps and oversights in fact caused the accident to occur. Certainly we will never know what motivated the final decisions of those on the rig who died that night. What we nonetheless do know is considerable and significant: (1) each of the mistakes made on the rig and onshore by industry and government increased the risk of a well blowout; (2) the cumulative risk that resulted from these decisions and actions was both unreasonably large and avoidable; and (3) the risk of a catastrophic blowout was ultimately realized on April 20 and several of the mistakes were contributing causes of the blowout.

The immediate cause of the Macondo blowout was a failure to contain hydrocarbon pressures in the well. Three things could have contained those pressures: the cement at the bottom of the well, the mud in the well and in the riser, and the blowout preventer. But mistakes and failures to appreciate risk compromised each of those potential barriers, steadily depriving the rig crew of safeguards until the blowout was inevitable and, at the very end, uncontrollable.

Cementing

Long string casing vs. liner. BP's decision to employ a long string was not unprecedented. Long strings are used with some frequency by other operators in the Gulf of Mexico, although not very often at wells like Macondo—a deepwater well in an unfamiliar geology requiring a finesse cement job.[126] It is not clear whether the decision to use a long string well design contributed directly to the blowout.[127] But it did increase the difficulty of obtaining a reliable primary cement job in several respects,[128] and primary cement failure was a direct cause of the blowout. The long string decision should have led BP and Halliburton to be on heightened alert for any signs of primary cement failure.

Number of centralizers. The evidence to date does not unequivocally establish whether the failure to use 15 additional centralizers was a direct cause of the blowout. But the process

[*] The Commission has not yet determined whether the BOP failed to operate as designed or whether any of the factors discussed contributed to such a failure. The Commission believes it is inappropriate to speculate about answers to those questions at this time. Test records of critical emergency backup systems have not yet been made available. More importantly, a government-sponsored forensic analysis of the BOP is still under way; when completed, that should shed light on why the BOP failed to shut in the Macondo well.

by which BP arrived at the decision to use only six centralizers at Macondo illuminates the flaws in BP's management and design procedures, as well as poor communication between BP and Halliburton.

For example, it does not appear that BP's team tried to determine before April 15 whether additional centralizers would be needed. Had BP examined the issue earlier, it might have been able to secure additional centralizers of the design it favored. Nor does it appear that BP based its decision on a full examination of all potential risks involved. Instead, the decision appears to have been driven by an aversion to one particular risk: that slip-on centralizers would hang up on other equipment.

BP did not inform Halliburton of the number of centralizers it eventually used, let alone request new modeling to predict the impact of using only six centralizers.[129] Halliburton happened to find out that BP had run only six centralizers when one of its cement engineers overheard a discussion on the rig.[130]

Capping off the communication failures, BP now contends that the 15 additional centralizers the BP team flew to the rig may, in fact, have been the ones they wanted. BP's investigation report states that BP's Macondo team "erroneously believed" they had been sent the wrong centralizers.[131] To this day, BP witnesses provide conflicting accounts as to what type of centralizers were actually sent to the rig.

BP's overall approach to the centralizer decision is perhaps best summed up in an e-mail from BP engineer Brett Cocales sent to Brian Morel on April 16. Cocales expressed disagreement with Morel's opinion that more centralizers were unnecessary because the hole was straight, but then concluded the e-mail by saying

> *But, who cares, it's done, end of story, [we] will probably be fine and we'll get a good cement job. I would rather have to squeeze [remediate the cement job] than get stuck above the WH [wellhead]. So Guide is right on the risk/reward equation.*[132]

Float-valve conversion and circulating pressure. Whether the float valves converted, let alone whether "unconverted" float valves contributed to the eventual blowout, has not yet been, and may never be, established with certainty. But, what is certain is that BP's team again failed to take time to consider whether and to what extent the anomalous pressure readings may have indicated other problems or increased the risk of the upcoming cement job.

BP's team appears not to have seriously examined *why* it had to apply over four times the 750 psi design pressure to convert the float valves. More importantly, the team assumed that the sharp drop from 3,142 psi meant the float valves had in fact converted. That was not at all certain. The auto-fill tube was designed to convert in response to *flow-induced* pressure. Without the required rate of flow, an increase in *static* pressure, no matter how great, will not dislodge the tube.

While BP's Macondo team focused on the peak pressure reading of 3,142 psi and the fact that circulation was reestablished, it does not appear the team ever considered whether sufficient mud flow rate had been achieved to convert the float valves. They should have considered this issue. Because of ECD concerns, BP's engineers had specified a very low circulating pump rate—lower than the flow rate necessary to convert the float valves. BP does not appear to have accounted for this fact.

Cement evaluation log decision. The BP team erred by focusing on full returns as the sole criterion for deciding whether to run a cement evaluation log. Receiving full returns was a good indication that cement or other fluids had not been lost to the weakened formation. But full returns provided, at best, limited or no information about: (1) the precise location where the cement had ended up; (2) whether channeling had occurred; (3) whether the cement had been contaminated;[133] or (4) whether the foam cement had remained stable. Although other indicators—such as on-time arrival of the cement plugs and observation of expected lift pressure—were reassuring, they too provided limited information. Other cement evaluation tools could have provided more direct information about cementing success.

Cement evaluation logs plainly have their limitations, particularly at Macondo. But while many companies do not run cement evaluation logs until the completion phase, BP should have run one here—or sought other equivalent indications of cement quality in light of the many issues surrounding and leading up to the cement job. BP's own report agrees.[134]

Foam cement testing. As explained in an October letter written by the Commission's Chief Counsel, independent cement testing conducted by Chevron strongly suggests the foam cement slurry used at Macondo was unstable.[135] As it turned out, Chevron's tests were consistent with several of Halliburton's own internal test results, some of which appear never to have been reported to BP.

Halliburton's two February tests both indicated that the foam cement slurry would be unstable, which should have prompted the company to reconsider its slurry design.[136] It is irrelevant that the February tests were performed on a slightly different slurry than was actually pumped at Macondo or that assumptions about down-hole temperatures and pressures in February had changed by April 19. Under the circumstances, Halliburton should have examined why the February foam cement slurry was unstable, and should have highlighted the problematic test results for BP.

The two April foam stability tests further illuminate problems with Halliburton's cement design process. Like the two February tests, the first April test indicated the slurry was unstable.* This should have prompted Halliburton to review the Macondo slurry design *immediately*, especially given how little time remained before the cement was to be pumped. There is no indication that Halliburton *ever* conducted such a review or alerted BP to the results. It appears that Halliburton personnel responded instead by modifying the

* Halliburton contends that its lab personnel performed this test improperly, but has not yet produced adequate evidence to support this assertion.

test conditions—specifically, the pre-testing conditioning time—and thereby achieving an arguably successful test result.

Halliburton has to date provided nothing to suggest that its personnel selected the final conditioning time based on any sort of disciplined technical analysis of the Macondo well conditions.[137] Moreover, Halliburton has not yet provided the Commission with evidence to support its view that cement should be "conditioned" for an extended time before stability testing. Given the apparent importance of this view, it should have been supported by careful pre-incident technical analysis and actual physical testing. At present, it appears only to be an unconfirmed hypothesis.

Even more serious, Halliburton documents strongly suggest that the final foam stability test results indicating a stable slurry may not even have been available before Halliburton pumped the primary cement job at Macondo.[138] If true, Halliburton pumped foam cement into the well at Macondo at a time when all available test data showed the cement would be, in fact, unstable.

Risk evaluation of Macondo cementing decisions and procedures. BP's fundamental mistake was its failure—notwithstanding the inherent uncertainty of cementing and the many specific risk factors surrounding the cement job at Macondo—to exercise special caution (and, accordingly, to direct its contractors to be especially vigilant) before relying on the primary cement as a barrier to hydrocarbon flow.

Those decisions and risk factors included, among other things:

- Difficult drilling conditions, including serious lost returns in the cementing zone;
- Difficulty converting float equipment and low circulating pressure after purported conversion;
- No bottoms up circulation;
- Less than recommended number of centralizers;
- Low rate of cement flow; and
- Low cement volume.

Based on evidence currently available, there is nothing to suggest that BP's engineering team conducted a formal, disciplined analysis of the combined impact of these risk factors on the prospects for a successful cement job. There is nothing to suggest that BP communicated a need for elevated vigilance after the job. And there is nothing to indicate that Halliburton highlighted to BP or others the relative difficulty of BP's cementing plan before, during, or after the job, or that it recommended any post-cementing measures to confirm that the primary cement had in fact isolated the high-pressure hydrocarbons in the pay zone.

Negative-Pressure Test

Even when there is no reason for concern about a cement job, a negative-pressure test is "very important."[139] By sending Schlumberger's cement evaluation team back to shore, BP chose to rely entirely on the negative-pressure test to directly evaluate the integrity of the primary cement at Macondo.

It is now undisputed that the negative-pressure test at Macondo was conducted and interpreted improperly. For instance, BP used a spacer that had not been used by anyone at BP or on the rig before, that was not fully tested, and that may have clogged the kill line.[140] The pressure data were not ambiguous. Rather, they showed repeatedly that formation fluids, in this case hydrocarbons, were flowing into the well. The failure to properly conduct and interpret the negative-pressure test was a major contributing factor to the blowout.

Given the risk factors surrounding the primary cement job and other prior unusual events (such as difficulty converting the float valves), the BP Well Site Leaders and, to the extent they were aware of the issues, the Transocean crew should have been particularly sensitive to anomalous pressure readings and ready to accept that the primary cement job could have failed.[141] It appears instead they started from the assumption that the well could not be flowing, and kept running tests and coming up with various explanations until they had convinced themselves their assumption was correct.[142]

The Commission has identified a number of potential factors that may have contributed to the failure to properly conduct and interpret the negative pressure test that night:

- First, there was no standard procedure for running or interpreting the test in either MMS regulations or written industry protocols. Indeed, the regulations and standards did not require BP to run a negative-pressure test at all.

- Second, BP and Transocean had no internal procedures for running or interpreting negative-pressure tests, and had not formally trained their personnel in how to do so.

- Third, the BP Macondo team did not provide the Well Site Leaders or rig crew with specific procedures for performing the negative-pressure test at Macondo.

- Fourth, BP did not have in place (or did not enforce) any policy that would have required personnel to call back to shore for a second opinion about confusing data.

- Finally, due to poor communication, it does not appear that the men performing and interpreting the test had a full appreciation of the context in which they were performing it. Such an appreciation might have increased their willingness to believe the well was flowing. Context aside, however, individuals conducting and interpreting the negative-pressure test should always do so with an expectation that the well might lack integrity.

Temporary Abandonment Procedures

Another factor that may have contributed to the blowout was BP's temporary abandonment procedure.

First, it was not necessary or advisable for BP to replace 3,300 feet of mud below the mud line with seawater. By replacing that much heavy drilling mud with much lighter seawater, BP placed more stress on the cement job at the bottom of the well than necessary. BP's stated reason for doing so was its preference for setting cement plugs in seawater rather than mud.[143] While industry experts have acknowledged that setting cement plugs in seawater can avoid mud contamination and that it is not unusual for operators to set cement plugs in seawater,[144] BP has provided no evidence that it or another operator has ever set a surface cement plug so deep in seawater (particularly without additional barriers). The risks BP created by its decision to displace 3,300 feet of mud with seawater outweighed its concerns about cement setting better in seawater than in mud. As BP has admitted, cement plugs *can* be set in mud.[145] BP also could have set one or more non-cement bridge plugs (which work equally well in mud or seawater).[146] No evidence has yet been produced that the BP team ever formally evaluated these options or the relative risks created by removing 3,300 feet of mud.

It was not necessary to set the cement plug 3,300 feet below the mudline. The BP Macondo team chose to do so in order to set the lockdown sleeve last in the temporary abandonment sequence to minimize the chances of damage to the sleeve. Setting the lockdown sleeve would require 100,000 pounds of force. The BP Macondo team sought to generate that force by hanging 3,000 feet of drill pipe below the sleeve—hence the desire to set the cement plug 3,000 feet below the mud line. BP's desire to set the lockdown sleeve last did not justify the risks its decision created. BP could have used other proven means to protect the lockdown sleeve if set earlier in the process. It also did not need 3,000 feet of space to generate 100,000 pounds of force.[147] Merrick Kelley, the individual at BP in charge of lockdown sleeves in the Gulf of Mexico, told Commission staff that he had recommended setting the plug roughly 1,300 feet below the mud line (using heavier drill pipe), rather than 3,300 feet down. That would have significantly increased the margin of safety for the well.[148]

The most troubling aspect of BP's temporary abandonment procedure was BP's decision to displace mud from the riser before setting the surface cement plug or other barrier in the production casing.[149] During displacement of the riser, the BOP would be open, leaving the cement at the bottom of the well (in the annulus and shoe track) as the *only* physical barrier to flow up the production casing between the pay zone and the rig.[150] Relying so heavily on primary cement integrity put a significant premium on the negative-pressure test and well monitoring during displacement, both of which are subject to human error.

BP's decision under these circumstances to displace mud from the riser before setting another barrier unnecessarily and substantially increased the risk of a blowout. BP could have set the surface cement plug, or a mechanical plug, before displacing the riser.[151] BP could have replaced the mud in the wellbore with heavier mud sufficient to overbalance the well.[152] It is not apparent why BP chose not to do any of these things.

Kick Detection

The drilling crew and other individuals on the rig also missed critical signs that a kick was occurring. The crew could have prevented the blowout—or at least significantly reduced its impact—if they had reacted in a timely and appropriate manner. What is not now clear is precisely why the crew missed these signals.

The Sperry Sun data available to the crew from between 8:00 p.m. and 9:49 p.m. reveal a number of different signals that if observed, should at least have prompted the driller to investigate further, for instance, by conducting a visual flow check, and then shutting in the well if there were indications of flow. For instance, the increasing drill-pipe pressure after the pumps were shut down for the sheen test at 9:08 p.m. was a clear signal that something was happening in the well. Similarly, at roughly 9:30 p.m., the driller and toolpusher recognized an anomalous pressure difference between the drill pipe and kill line.[153] Both of these signals should have prompted action—especially the latter: it was clearly recognized by the crew and echoed the odd pressure readings observed during the negative-pressure test. The crew should have done a flow check and shut in the well immediately upon confirmation of flow.

Why did the crew miss or misinterpret these signals? One possible reason is that they had done a number of things that confounded their ability to interpret signals from the well. For instance, after 9:08 p.m., the crew began sending fluids returning from the well overboard, bypassing the active pit system and the flow-out meter (at least the Sperry Sun flow-out meter). Only the mudlogger performed a visual flow check.[154]

It was neither necessary nor advisable—particularly where the cement at the bottom (in the annulus and shoe track) was the only barrier between the rig and pay zone—to bypass the active system and flow-out meter or to perform potentially confounding simultaneous operations during displacement of the riser. For instance, the crew could have routed the seawater through the active pit system before sending it into the well.

In the future, the instrumentation and displays used for well monitoring must be improved. There is no apparent reason why more sophisticated, automated alarms and algorithms cannot be built into the display system to alert the driller and mudlogger when anomalies arise. These individuals sit for 12 hours at a time in front of these displays. In light of the potential consequences, it is no longer acceptable to rely on a system that requires the right person to be looking at the right data at the right time, and then to understand its significance in spite of simultaneous activities and other monitoring responsibilities.

Diversion and Blowout Preventer Activation

The crew should have diverted the flow overboard when mud started spewing from the rig floor. While that ultimately may not have prevented an explosion, diverting overboard would have reduced the risk of ignition of the rising gas. Considering the circumstances, the crew also should have activated the blind shear ram to close in the well. Diverting the flow overboard and/or activating the blind shear ram may not have prevented the explosion, but likely could have given the crew more time and perhaps limited the impact of the explosion.

There are a few possible explanations for why the crew did neither:

- First, they may not have recognized the severity of the situation, though that seems unlikely given the amount of mud that spewed from the rig floor.

- Second, they did not have much time to act. The explosion occurred roughly six to eight minutes after mud first emerged onto the rig floor.

- Finally, and perhaps most significantly, the rig crew had not been trained adequately how to respond to such an emergency situation. In the future, well-control training should include simulations and drills for such emergencies—including the momentous decision to engage the blind shear rams or trigger the EDS.

The Root Causes: Failures in Industry and Government

Overarching Management Failures by Industry

Whatever irreducible uncertainty may persist regarding the precise contribution to the blowout of each of several potentially immediate causes, no such uncertainty exists about the blowout's root causes. The blowout was not the product of a series of aberrational decisions made by rogue industry or government officials that could not have been anticipated or expected to occur again. Rather, the root causes are systemic and, absent significant reform in both industry practices and government policies, might well recur. The missteps were rooted in systemic failures by industry management (extending beyond BP to contractors that serve many in the industry), and also by failures of government to provide effective regulatory oversight of offshore drilling.

The most significant failure at Macondo—and the clear root cause of the blowout—was a failure of industry management. Most, if not all, of the failures at Macondo can be traced back to underlying failures of management and communication. Better management of decisionmaking processes within BP and other companies, better communication within and between BP and its contractors, and effective training of key engineering and rig personnel would have prevented the Macondo incident. BP and other operators must have effective systems in place for integrating the various corporate cultures, internal procedures, and decisionmaking protocols of the many different contractors involved in drilling a deepwater well.

BP's management process did not adequately identify or address risks created by late changes to well design and procedures. BP did not have adequate controls in place to ensure that key decisions in the months leading up to the blowout were safe or sound from an engineering perspective. While initial well design decisions undergo a serious peer-review process[155] and changes to well design are subsequently subject to a management of change (MOC) process,[156] changes to drilling procedures in the weeks and days before implementation are typically *not* subject to any such peer-review or MOC process. At Macondo, such decisions appear to have been made by the BP Macondo team in *ad hoc* fashion without any formal risk analysis or internal expert review.[157] This appears to have been a key causal factor of the blowout.

A few obvious examples, such as the last-minute confusion regarding whether to run six or 21 centralizers, have already been highlighted. Another clear example is provided by the temporary abandonment procedure used at Macondo. As discussed earlier, that procedure changed dramatically and repeatedly during the week leading up to the blowout. As of April 12, the plan was to set the cement plug in seawater less than 1,000 feet below the mud line after setting the lockdown sleeve. Two days later, Morel sent an e-mail in which the procedure was to set the cement plug in mud before displacing the riser with seawater. By April 20, the plan had morphed into the one set forth in the "Ops Note": the crew would remove 3,300 feet of mud from below the mud line and set the cement plug after the riser had been displaced.

There is no readily discernible reason why these temporary abandonment procedures could not have been more thoroughly and rigorously vetted earlier in the design process.[158] It does not appear that the changes to the temporary abandonment procedures went through any sort of formal review at all.

Halliburton and BP's management processes did not ensure that cement was adequately tested. Halliburton had insufficient controls in place to ensure that laboratory testing was performed in a timely fashion or that test results were vetted rigorously in-house or with the client. In fact, it appears that Halliburton did not even have testing results in its possession showing the Macondo slurry was stable until *after* the job had been pumped. It is difficult to imagine a clearer failure of management or communication.

The story of the foam stability tests may illuminate management problems within BP as well. By early April, BP team members had recognized the importance of timely cement testing.[159] And by mid-April, BP's team had identified concerns regarding the timeliness of Halliburton's testing process.[160] But despite their recognition that final changes to the cement design (made to accommodate their concerns about lost returns) might increase the risks of foam instability,[161] BP personnel do not appear to have insisted that Halliburton complete its foam stability tests—let alone report the results to BP for review—before ordering primary cementing to begin.

BP, Transocean, and Halliburton failed to communicate adequately. Information appears to have been excessively compartmentalized at Macondo as a result of poor communication. BP did not share important information with its contractors, or sometimes internally even with members of its own team. Contractors did not share important information with BP or each other. As a result, individuals often found themselves making critical decisions without a full appreciation for the context in which they were being made (or even without recognition that the decisions *were* critical).

For example, many BP and Halliburton employees were aware of the difficulty of the primary cement job. But those issues were for the most part *not* communicated to the rig crew that conducted the negative-pressure test and monitored the well. It appears that

BP did not even communicate many of those issues to its own personnel on the rig—in particular to Bob Kaluza, who was on his first hitch as a Well Site Leader on the *Deepwater Horizon*. Similarly, it appears at this time that the BP Well Site Leaders did not consult anyone on shore about the anomalous data observed during the negative-pressure test.[162] Had they done so, the Macondo blowout may not have happened.

Transocean failed to adequately communicate lessons from an earlier near-miss to its crew. Transocean failed to adequately communicate to its crew lessons learned from an eerily similar near-miss on one of its rigs in the North Sea four months prior to the Macondo blowout. On December 23, 2009, gas entered the riser on that rig while the crew was displacing a well with seawater during a completion operation. As at Macondo, the rig's crew had already run a negative-pressure test on the lone physical barrier between the pay zone and the rig, and had declared the test a success.[163] The tested barrier nevertheless failed during displacement, resulting in an influx of hydrocarbons. Mud spewed onto the rig floor—but fortunately the crew was able to shut in the well before a blowout occurred.[164] Nearly one metric ton of oil-based mud ended up in the ocean. The incident cost Transocean 11.2 days of additional work and more than 5 million British pounds in expenses.[165]

Transocean subsequently created an internal PowerPoint presentation warning that "[t]ested barriers can fail" and that "risk perception of barrier failure was blinkered by the positive inflow test [negative test]."[166] The presentation noted that "[f]luid displacements for inflow test [negative test] and well clean up operations are not adequately covered in our well control manual or adequately cover displacements in under balanced operations."[167] It concluded with a slide titled "Are we ready?" and "WHAT IF?" containing the bullet points: "[h]igh vigilance when reduced to one barrier underbalanced," "[r]ecognise when going underbalanced—heightened vigilance," and "[h]ighlight what the kick indicators are when not drilling."[168]

Transocean eventually sent out an "operations advisory" to some of its fleet (in the North Sea) on April 14, 2010, reiterating many of the lessons learned and warnings from the presentation. It set out "mandatory" actions to take, acknowledging a "Lack of Well Control preparedness during completion phase," requiring that "[s]tandard well control practices must be maintained through the life span of the well" and stating that "[w]ell programs must specify operations where a single mechanical barrier . . . is in effect and a warning must be included to raise awareness. . . ."[169]

The language in this "advisory" is less pointed and vivid than the language in the earlier PowerPoint. Moreover, according to Transocean, neither the PowerPoint nor this advisory ever made it to the *Deepwater Horizon* crew.[170]

Transocean has suggested that the North Sea incident and advisory were irrelevant to what happened in the Gulf of Mexico. The December incident in the North Sea occurred during the completion phase and involved failure of a different tested barrier. Those are largely

FIGURE 4.10: Examples of Decisions That Increased Risk At Macondo While Potentially Saving Time

Decision	Was There A Less Risky Alternative Available?	Less Time Than Alternative?	Decision-maker
Not Waiting for More Centralizers of Preferred Design	Yes	Saved Time	BP on Shore
Not Waiting for Foam Stability Test Results and/or Redesigning Slurry	Yes	Saved Time	Halliburton (and Perhaps BP) on Shore
Not Running Cement Evaluation Log	Yes	Saved Time	BP on Shore
Using Spacer Made from Combined Lost Circulation Materials to Avoid Disposal Issues	Yes	Saved Time	BP on Shore
Displacing Mud from Riser Before Setting Surface Cement Plug	Yes	Unclear	BP on Shore
Setting Surface Cement Plug 3,000 Feet Below Mud Line in Seawater	Yes	Unclear	BP on Shore (Approved by MMS)
Not Installing Additional Physical Barriers During Temporary Abandonment Procedure	Yes	Saved Time	BP on Shore
Not Performing Further Well Integrity Diagnostics in Light of Troubling and Unexplained Negative Pressure Test Results	Yes	Saved Time	BP (and Perhaps Transocean) on Rig
Bypassing Pits and Conducting Other Simultaneous Operations During Displacement	Yes	Saved Time	Transocean (and Perhaps BP) on Rig

cosmetic differences. The basic facts of both incidents are the same. Had the rig crew been adequately informed of the prior event and trained on its lessons, events at Macondo may have unfolded very differently.[171]

Decisionmaking processes at Macondo did not adequately ensure that personnel fully considered the risks created by time- and money-saving decisions. Whether purposeful or not, many of the decisions that BP, Halliburton, and Transocean made that increased the risk of the Macondo blowout clearly saved those companies significant time (and money).*

There is nothing inherently wrong with choosing a less-costly or less-time-consuming alternative—as long as it is proven to be equally safe. The problem is that, at least in regard to BP's Macondo team, there appears to have been no formal system for ensuring that alternative procedures were in fact equally safe. None of BP's (or the other companies') decisions in Figure 4.10 appear to have been subject to a comprehensive and systematic risk-analysis, peer-review, or management of change process. The evidence now available does not show that the BP team members (or other companies' personnel) responsible for these decisions conducted *any* sort of formal analysis to assess the relative riskiness of available alternatives.

* The Commission cannot say whether any person at BP or another company at Macondo consciously chose a riskier alternative because it would cost the company less money.

Corporations understandably encourage cost-saving and efficiency. But given the dangers of deepwater drilling, companies involved must have in place strict policies requiring rigorous analysis and proof that less-costly alternatives are in fact equally safe. If BP had any such policies in place, it does not appear that its Macondo team adhered to them. Unless companies create and enforce such policies, there is simply too great a risk that financial pressures will systematically bias decisionmaking in favor of time- and cost-savings. It is also critical (as described in greater length in Chapter 8) that companies implement and maintain a pervasive top-down safety culture (such as the ones described by the ExxonMobil and Shell CEOs at the Commission's hearing on November 9, 2010) that reward employees and contractors who take action when there is a safety concern even though such action costs the company time and money.[172]

Of course, some decisions will have shorter timelines than others, and a full-blown peer-reviewed risk analysis is not always practicable. But even where decisions need to be made in relatively short order, there must be systems in place to ensure that some sort of formal risk analysis takes place when procedures are changed, and that the analysis considers the impact of the decision in the context of all system risks. If it turns out there is insufficient time to perform such an analysis, only proven alternatives should be considered.

Regulatory Failures

Government also failed to provide the oversight necessary to prevent these lapses in judgment and management by private industry. As discussed in Chapter 3, MMS regulations were inadequate to address the risks of deepwater drilling. Many critical aspects of drilling operations were left to industry to decide without agency review. For instance, there was no requirement, let alone protocol, for a negative-pressure test, the misreading of which was a major contributor to the Macondo blowout. Nor were there detailed requirements related to the testing of the cement essential for well stability.

Responsibilities for these shortfalls are best not assigned to MMS alone. The root cause can be better found by considering how, as described in Chapter 3, efforts to expand regulatory oversight, tighten safety requirements, and provide funding to equip regulators with the resources, personnel, and training needed to be effective were either overtly resisted or not supported by industry, members of Congress, and several administrations. As a result, neither the regulations nor the regulators were asking the tough questions or requiring the demonstration of preparedness that could have avoided the Macondo disaster.

But even if MMS had the resources and political support needed to promulgate the kinds of regulations necessary to reduce risk, it would still have lacked personnel with the kinds of expertise and training needed to enforce those regulations effectively. The significance of inadequate training is underscored by MMS's approval of BP's request to set its temporary abandonment plug 3,300 feet below the mud line. At least in this instance, there was a MMS regulation that potentially applied. MMS regulations state that cement plugs for temporary abandonment should normally be installed "no more than 1,000 feet below the mud line," but also allow the agency to approve "alternate requirements for subsea wells case-by-case."[173] Crucially, alternate procedures "must provide a level of safety and environmental protection that equals or surpasses current MMS requirements."[174]

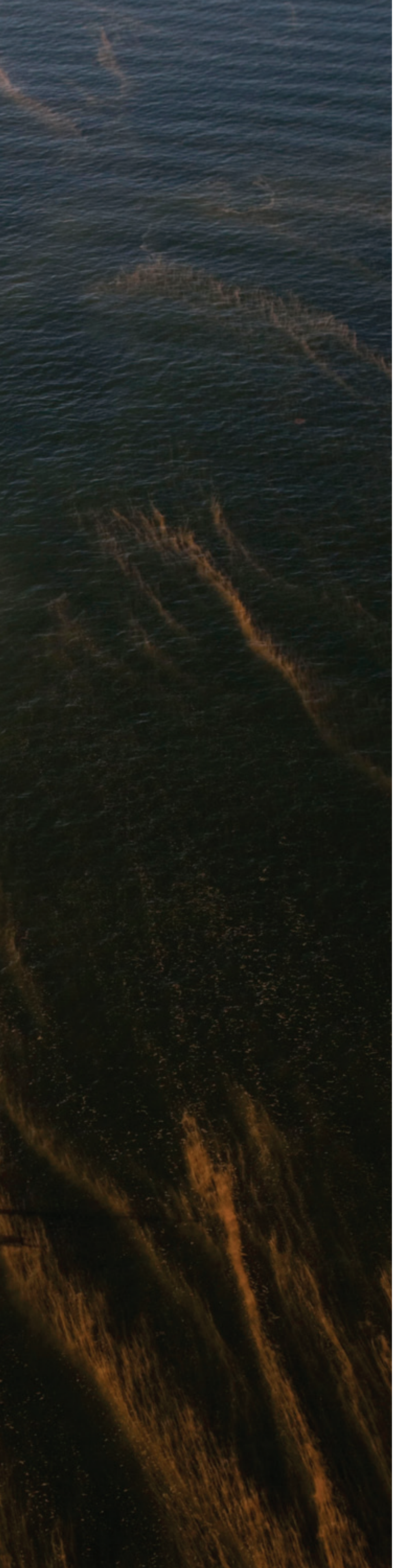
BP asked for permission to set its unusually deep cement plug in an April 16 permit application to MMS.[175] BP stated that it needed to set the plug deep in the well to minimize potential damage to the lockdown sleeve, and said it would increase the length of the cement plug to compensate for the added depth. An MMS official approved the request in less than 90 minutes.[176] The official did so because, after speaking with BP, he was persuaded that 3,000 feet was needed to accommodate setting the lockdown sleeve, which he thought was important to do. It is not clear what, if any, steps the official took to determine whether BP's proposed procedure would "provide a level of safety . . . that equal[ed] or surpass[ed]" a procedure in which the plug would have been set much higher up in the well.

MMS's cursory review of the temporary abandonment procedure mirrors BP's apparent lack of controls governing certain key engineering decisions. Like BP, MMS focused its engineering review on the initial well design, and paid far less attention to key decisions regarding procedures during the drilling of the well. Also like BP, MMS did not assess the full set of risks presented by the temporary abandonment procedure. The limited scope of the regulations is partly to blame. But MMS did not supplement the regulations with the training or the processes that would have provided its permitting official with the guidance and knowledge to make an adequate determination of the procedure's safety.

* * * *

Deepwater drilling provides the nation with essential supplies of oil and gas. At the same time, it is an inherently risky business given the enormous pressures and geologic uncertainties present in the formations where oil and gas are found—thousands of feet below the ocean floor. Notwithstanding those inherent risks, the accident of April 20 was avoidable. It resulted from clear mistakes made in the first instance by BP, Halliburton, and Transocean, and by government officials who, relying too much on industry's assertions of the safety of their operations, failed to create and apply a program of regulatory oversight that would have properly minimized the risks of deepwater drilling. It is now clear that both industry and government need to reassess and change business practices to minimize the risks of such drilling.

The tragic results of that accident included the immediate deaths of 11 men who worked on the rig, and serious injury to many others on the rig at the time of the explosion. During the next few hours, days, weeks, and ultimately months, BP and the federal government struggled with their next great challenge: containing the spill and coordinating a massive response effort to mitigate the threatened harm to the Gulf of Mexico and to the Gulf coast. They faced the largest offshore oil spill in the nation's history—and the first from a subsea well located a mile beneath the ocean's surface.



Chapter Five
"You're in it now, up to your neck!"

Response and Containment

No single story dominated newspaper headlines on April 21 and 22. America's most-read papers led with articles about the progress of financial reform legislation; the Supreme Court's 8–1 ruling in a case about video depictions of animal cruelty and the First Amendment; the death of civil rights leader Dorothy Height; and the Food and Drug Administration's plans to target sodium content in packaged foods.[1] Editors appear to have viewed these as slow news days. The *New York Times*, for example, ran a front-page story on April 22 about how travelers in Europe were coping with flight cancellations caused by volcanic ash, titled "Routine Flights Become Overland Odysseys, Minus Clean Socks."[2]

A reader who flipped 12 more pages into the *Times* would have encountered a less lighthearted headline: "11 Remain Missing After Oil Rig Explodes Off Louisiana."[3] *USA Today* and the *Wall Street Journal* covered the *Deepwater Horizon* explosion on their front pages on April 22.[4] The articles described the tragic accident and ensuing search-and-rescue operation—*USA Today* said it "could be one of the worst offshore drilling accidents in U.S. history"[5]—but did not discuss the potential for environmental calamity. As the *Los Angeles Times* put it, "Coast Guard experts worked to assess any environmental cleanup that may be necessary. . .

Shrimp boats skim oil off the coast of Louisiana in mid-May. At its peak, the response to the spill involved over 45,000 people and thousands of watercraft, including private "vessels of opportunity" put to work by BP. The well was finally capped on July 15—87 days after the explosion.

< *Tyrone Turner/Photo courtesy of National Geographic*

[b]ut the main focus was on the missing workers."[6] Other dimensions of the disaster would emerge in the days that followed.

The Early Response (April 20–28)

On the night of April 20, as the *Deepwater Horizon* burned and the rig's survivors huddled on the *Bankston*, the response began. Coast Guard helicopters from the Marine Safety Unit in Morgan City, Louisiana searched for missing crew members. The first Coast Guard cutter to join the search was the *Pompano*, with others to follow. An offshore supply vessel found two burned life rafts. Coast Guard responders knew that approximately 700,000 gallons of diesel fuel were on the rig and could spill into the Gulf. By 10:00 the next morning, planes involved in the search for survivors reported a variably-colored sheen, two miles long by half a mile wide, on the water.

The Captain of the Marine Safety Unit, Joseph Paradis, directed these preliminary efforts. He became the first Federal On-Scene Coordinator under what is known as the National Contingency Plan, a set of federal regulations prescribing the government's response to spills and threatened spills of oil and other hazardous materials.* Under the Plan, when a spill occurs in coastal waters, the Coast Guard has the authority to respond.[7]

As the search and rescue continued on April 21, the oily sheen grew, more Coast Guard personnel and resources became involved, and Rear Admiral Mary Landry took over as Federal On-Scene Coordinator. The commander of Coast Guard District 8 (which includes, among other regions, the Gulf coast from Texas to the Florida panhandle), she would remain Federal On-Scene Coordinator until June 1. While the firefighting efforts continued, she told reporters, "We are only seeing minor sheening on the water. . . . We do not see a major spill emanating from this incident."[8] At this point, Admiral Landry's concern was the fuel oil that could spill from the rig, though she cautioned, "We don't know what's going on subsurface."[9]

As Coast Guard vessels continued the search and rescue operation, private offshore supply vessels sprayed water on the fire. Transocean hired Smit Salvage Americas, a salvage company, to try to save the rig. There was confusion about whether Transocean, the Coast Guard, the salvage company, or anyone at all was directing the firefighting operations.† Captain James Hanzalik, Chief of Incident Response in District 8, would later say that the Coast Guard, which was focused on the search and rescue and then on the spreading oil, "monitored what was going on, but [was] not directing any firefighting resources."[10] By the morning of April 21, the rig was listing. At 11:53 that evening, it shifted and leaned even more.

At 10:22 a.m. on April 22, the rig sank, taking with it the diesel fuel still on board. By that time, the Coast Guard had established an Incident Command Post in a BP facility in Houma, Louisiana. BP had formed a command post in its corporate headquarters in

* Created in 1968, the National Contingency Plan has been amended and expanded in the years since. The Oil Pollution Act of 1990 substantially expanded the Plan in response to the *Exxon Valdez* spill.

† The Coast Guard/Bureau of Ocean Energy Management, Regulation, and Enforcement *Deepwater Horizon* Joint Investigation Team, which plans to issue a report in March 2011, is examining the firefighting efforts.

Houston, Texas shortly after the explosion, and the Coast Guard established an Incident Command Post there as well.

These Incident Command Posts, along with one in Mobile, Alabama, and others established later, would become the centers of response operations, with their activities directed by the Federal On-Scene Coordinator as part of the government's Unified Command. The latter is a command structure, created and implemented by the National Contingency Plan, which integrates the "responsible party" (here, BP) with federal and state officials "to achieve an effective and efficient response."[11] The Coast Guard established a Unified Area Command—headquarters for the regional spill response—on April 23 in Robert, Louisiana, later moving it to New Orleans. It eventually included representatives from the federal government, Louisiana, Alabama, Mississippi, Florida, and BP.

Other federal agencies—including the National Oceanic and Atmospheric Administration (NOAA) and Minerals Management Service (MMS)*—immediately sent emergency responders to the Unified Area Command and Incident Command Posts. A host of senior officials, including Secretary of the Interior Ken Salazar and Secretary of Homeland Security Janet Napolitano, briefed the President on their departments' efforts on the afternoon of April 22.[12] Members of the National Response Team, drawn from the 16 federal agencies responsible for coordinating emergency preparedness and response to oil- and hazardous-substance-pollution incidents,[13] began conducting daily telephone meetings.

Even before the rig sank, BP and Transocean directed their attention to the 53-foot-tall blowout preventer (BOP) stack sitting atop the Macondo well. At about 6:00 p.m. on April 21, BP and Transocean began using remotely operated vehicles to try to close the BOP and stop the flow of oil and gas fueling the fire.

These early operations primarily attempted to activate the BOP's blind shear ram and seal off the well. During the attempts, MMS officials were embedded, as observers, in the operations centers at Transocean and BP headquarters in Houston. Because of the emergency, on-scene personnel from BP, Transocean, and Cameron (the company that manufactured the BOP) made decisions without the need for government approvals. Beginning on April 21 and continuing throughout the effort to control the well, Secretary Salazar received daily updates through conference calls with BP's technical teams.

The initial news was encouraging. On April 23, Admiral Landry told the press that, according to surveillance by remotely operated vehicles, the BOP, although "[i]t is not a guarantee," appeared to have done its job, sealing off the flow of oil and preventing any leak.[14] The good news did not last. The Coast Guard suspended its search for the 11 missing workers later that day. And, when Admiral Landry spoke, remotely operated vehicles had not yet surveyed the entire length of the broken riser pipe—previously

* On June 18, 2010, Secretary of the Interior Ken Salazar ordered that the Minerals Management Service be officially renamed the Bureau of Ocean Energy Management, Regulation, and Enforcement. For consistency, throughout this chapter, we refer to the agency as the Minerals Management Service (MMS), its name at the time of the April 20 blowout.

Oil spews unchecked from the *Deepwater Horizon*'s severed riser in this video frame taken May 26. When the rig sank, the riser broke off, settling on the sea floor.

© BP p.l.c

connecting the well to the now-sunk *Deepwater Horizon*—that still jutted out of the top of the BOP. By mid-afternoon on April 23, the vehicles had discovered that oil was leaking from the end of the riser, where it had broken off from the *Deepwater Horizon* when the rig sank. By the next morning, the vehicles had also discovered a second leak from a kink in the riser, located above the BOP. On April 24, Unified Command announced that the riser was leaking oil at a rate of 1,000 barrels per day.[15] This number appears to have come from BP, although how it was calculated remains unclear.[16]

As BP realized that the early efforts to stop the flow of oil had failed, it considered ways to control the well other than by triggering the BOP. A primary option was to drill a relief well to intersect the Macondo well at its source and enable a drilling rig to pump in cement to stop the flow of oil. While it could take more than three months to drill, a relief well was the only source-control option mentioned by name in BP's Initial Exploration Plan.[17] Industry and government experts characterized a relief well as the only likely and accepted solution to a subsea blowout.[18] BP had begun looking for available drilling rigs on the morning of April 21; it secured two, and began drilling a primary relief well on May 2 and a back-up well insisted upon by Secretary Salazar on May 17.[19]

Responders, meanwhile, shifted their focus to the release of large amounts of oil. Although the National Contingency Plan requires the Coast Guard to supervise an oil-spill response in coastal waters, it does not envision that the Coast Guard will provide all, or even most, of the response equipment. That role is filled by private oil-spill removal organizations, which contract with the oil companies that are required to demonstrate response capacity. BP's main oil-spill removal organization in the Gulf is the Marine Spill Response Corporation, a nonprofit created by industry after the *Exxon Valdez* disaster to respond to oil spills. The Marine Spill Response Corporation dispatched four skimmers within hours of the explosion.[20] BP's oil-spill response plan for the Gulf of Mexico claimed that response vessels provided by the Marine Spill Response Corporation and other private oil-spill removal organizations could recover nearly 500,000 barrels of oil per day.[21]

Despite these claims, the oil-spill removal organizations were quickly outmatched. While production technology had made great advances since *Exxon Valdez* (see Chapter 2), spill-response technology had not. The Oil Pollution Act of 1990, by requiring double hulls in oil tankers, had effectively reduced tanker spills.[22] But it did not provide incentives for industry or guaranteed funding for federal agencies to conduct research on oil-spill response. Though incremental improvements in skimming and boom had been realized in the intervening 21 years, the technologies used in response to the *Deepwater Horizon* and *Exxon Valdez* oil spills were largely the same.[23]

If BP's response capacity was underwhelming, some aspects of its response plan were embarrassing. In the plan, BP had named Peter Lutz as a wildlife expert on whom it would rely; he had died several years before BP submitted its plan. BP listed seals and walruses as two species of concern in case of an oil spill in the Gulf; these species never see Gulf waters. And a link in the plan that purported to go to the Marine Spill Response Corporation website actually led to a Japanese entertainment site.[24] (Congressional investigation revealed that the response plans submitted to MMS by ExxonMobil, Chevron, ConocoPhillips, and Shell were almost identical to BP's—they too suggested impressive but unrealistic response capacity and three included the embarrassing reference to walruses.[25] See Chapter 3 for more discussion of these plans.)

By April 25, responders had started to realize that the estimated spill volume of 1,000 barrels per day might be inaccurate. Dispersants applied to break up the surface slick were not having the anticipated effect. Either the dispersants were inexplicably not working, or the amount of oil was greater than previously suspected. Between April 26 and April 28, BP personnel within Unified Command reportedly said that they thought 1,000 to 6,000 barrels were leaking each day.[26]

To alert government leadership that the spill could be larger than 1,000 barrels per day, a NOAA scientist created a one-page report on April 26 estimating the flow rate at roughly 5,000 barrels per day. He based this estimate on other responders' visual observations of the speed with which oil was leaking from the end of the riser, as well as the size and color of the oil slick on the Gulf's surface.[27] Both methodologies, the scientist recognized, were highly imprecise: he relied on rough guesses, for example, of the velocity of the oil as it left the riser and the thickness of the surface slick. He told a NOAA colleague in Unified Command that the flow could be 5,000 to 10,000 barrels per day.[28] At a press conference on April 28, Admiral Landry stated, "NOAA experts believe the output could be *as much as* 5,000 barrels" (emphasis added).[29]

Although it represented a five-fold increase over the then-current figure, 5,000 barrels per day was a back-of-the-envelope estimate, and Unified Command did not explain how NOAA calculated it. Nevertheless, for the next four weeks, it remained the official government estimate of the spill size.

The Response Ramps Up (April 29–May 1)

At the peak of the response, more than 45,000 people participated.[30] In addition to deploying active-duty members to the Gulf, the Coast Guard called up reservists. Some 1,100 Louisiana National Guard troops served under the direction of Unified Command.[31] The Environmental Protection Agency (EPA), NOAA, and other federal agencies shifted hundreds of responders to the region.

Consistent with the Unified Command framework, BP played a major role from the outset. Most Coast Guard responders had a BP counterpart. For instance, Doug Suttles, BP's Chief

In a joint press briefing, BP Chief Operating Officer of Exploration and Production Doug Suttles takes the podium alongside Federal On-Scene Coordinator and Coast Guard Rear Admiral Mary Landry. The Coast Guard considered BP a co-combatant in the effort to battle the oil.

U.S. Coast Guard photo/Petty Officer 3rd Class Cory J. Mendenhall

Operating Officer of Exploration and Production, was the counterpart to the Federal On-Scene Coordinator. BP employees were scattered through the command structure, in roles ranging from waste management to environmental assessment. Sometimes, a BP employee supervised Coast Guard or other federal responders.

The preference under the National Contingency Plan is for the Federal On-Scene Coordinator to supervise response activities while the responsible party conducts—and funds—them. When a spill "results in a substantial threat to public health or welfare of the United States," the Plan requires the Federal On-Scene Coordinator to direct all response efforts.[32] The Coast Guard also has the option to "federalize" the spill—conducting and funding all aspects of the response through the Oil Spill Liability Trust Fund, and later seeking reimbursement from the responsible party.[33] But in most spills, especially when the responsible party has deep pockets and is willing to carry out response activities, federalizing is not preferred. Coast Guard leaders, shaped by their experience implementing the National Contingency Plan through a unified command system, viewed the responsible party as a co-combatant in the fight against the oil. From their perspective, BP took its role as responsible party seriously and had an open checkbook for response costs.* That did not mean BP was happy to pay. Tony Hayward, the Chief Executive Officer of BP, reportedly asked board members, "What the hell did we do to deserve this?"[34]

Though willing to fund and carry out the response, BP had no available, tested technique to stop a deepwater blowout other than the lengthy process of drilling a relief well. Forty years earlier, the government had recognized the need for subsea containment technology. In 1969, following the Santa Barbara Channel spill, the Nixon administration had issued a report recommending, in part, that "[u]nderwater methods to collect oil from subsea leaks should be developed."[35] For deepwater wells, however, such development had never occurred. Within a week of the explosion, BP embarked on what would become a massive effort to generate containment options, either by adapting shallow-water technology to the deepwater environment, or by designing entirely new devices. Different teams at BP's Houston headquarters focused on different ways either to stop the flow of oil or to collect it at the source. Each team had what amounted to a blank check. As one contractor put it, "Whatever you needed, you got it. If you needed something from a machine shop and you couldn't jump in line, you bought the machine shop."[36]

While the Coast Guard oversaw the response at the surface, MMS primarily oversaw source-control operations. BP would draft detailed procedures describing an operation it wished to perform around the wellhead. MMS and Coast Guard officials in Houston participated in the drafting process to help identify and mitigate hazards, including risks to worker safety. At Unified Area Command, Lars Herbst, MMS Gulf of Mexico Regional Director, or his deputy, Mike Saucier, would review and approve the procedures, before the Federal On-Scene Coordinator gave the final go-ahead. This hierarchy of approvals remained in place throughout the containment effort.

MMS was the sole government agency charged with understanding deepwater wells and related technology, such as BOPs. But its supervision of the containment effort was limited, in line with its role in overseeing deepwater drilling more generally. Its staff did not attempt to dictate whether BP should perform an operation, determine whether it had a significant likelihood of success, or suggest consideration of other options. This limited role stemmed in part from a lack of resources. At most, MMS had four to five employees in Houston trying to oversee BP's efforts. One employee described his experience as akin to standing in a hurricane.

Interviews of MMS staff members involved in the containment effort also suggest that the agency did not view itself as capable of, or responsible for, providing more substantive oversight. One MMS employee asserted that BP, and industry more broadly, possessed 10

* The day the rig exploded, the emergency reserve available to the Federal On-Scene Coordinator in the Oil Spill Liability Trust Fund and not obligated to other ongoing response actions amounted to $18,600,000. In contrast, by November 11, 2010, BP had paid $580,977,461 to the federal government for response costs. BP's total expenditures on the response also included payments to states and to contractors it hired directly. Paul Guinee, e-mail to Commission staff, November 16, 2010; BP, *Claims and Government Payments Gulf of Mexico Oil Spill Public Report* (November 11, 2010).

times the expertise that MMS could bring to bear on the complex problem of deepwater spill containment. Another pointed out that MMS had trouble attracting the most talented personnel, who are more likely to work in industry where salaries are higher. A third MMS employee stated that he could count on one hand the people from the agency whom he would trust to make key decisions in an effort of this magnitude. Perhaps most revealingly, two different MMS employees separately recalled being asked—one by Secretary Salazar, and the other by Assistant Secretary Tom Strickland—what they would do if the U.S. government took over the containment effort. Both said they would hire BP or another major oil company.

Though the Coast Guard and MMS believed they had to work closely with BP, others in government did not share this view of the relationship with the responsible party. At an April 29 press conference with several senior administration officials, Coast Guard Rear Admiral Sally Brice O'Hara referred to BP as "our partner," prompting Secretary Napolitano to emphasize, "They are not our partner."[37] Secretary Salazar later said on *CNN* that the government would keep its "boot on the neck" of BP.[38]

While struggling to explain its oversight role to the public, the federal government increased its commitment to the spill response. On April 29, a week after the rig sank and a day after the flow-rate estimate rose to 5,000 barrels per day, the Coast Guard designated the disaster a "Spill of National Significance"[39]—the first time the government had used that designation. A Spill of National Significance is one "that due to its severity, size, location, actual or potential impact on the public health and welfare or the environment, or the necessary response effort, is so complex that it requires extraordinary coordination of federal, state, local, and responsible party resources to contain and clean up the discharge."[40] The designation permitted a National Incident Commander to "assume the role of the [Federal On-Scene Coordinator] in communicating with affected parties and the public, and coordinating federal, state, local, and international resources at the national level."[41] Other than the quoted sentence, the National Contingency Plan is silent on the role of the National Incident Commander, who can fill the position, and what tasks he or she will handle. As a result, there is no clear line between the National Incident Commander's responsibilities and those of the Federal On-Scene Coordinator. During the *Deepwater Horizon* spill response, the National Incident Commander coordinated interagency efforts on the wide variety of issues responders faced, and dealt with high-level political and media inquiries, while the Federal On-Scene Coordinator generally retained oversight of day-to-day operations. More than anyone else, the National Incident Commander became the face of the federal response. When President Obama visited the Gulf on May 2, a fisherman asked who would pay his bills while he was out of work; the President responded that the National Incident Commander would take care of it.[42]

On May 1, Secretary Napolitano announced that Admiral Thad Allen, the outgoing Commandant of the Coast Guard and then its only four-star Admiral, would serve as National Incident Commander.[43] Admiral Allen was well known in the Gulf. He had previously overseen the ocean rescue and return to Cuba of Elian Gonzalez in 1999; the Coast Guard's work securing harbors along the Eastern Seaboard after the attacks of September 11, 2001; and the federal response to Hurricanes Katrina and Rita, after the

Surrounded by orange containment boom, National Incident Commander Admiral Thad Allen speaks to the press in Venice, Louisiana. The outgoing Coast Guard Commandant postponed his retirement to assume the post, drawing on his experience leading the federal response to Hurricane Katrina and overseeing oil-spill readiness exercises in the Gulf.

Steven Johnson/Miami Herald/MCT via Getty Images

Bush Administration asked him to replace the stumbling director of the Federal Emergency Management Agency, Michael Brown, as the lead federal official.[44] His leadership during Katrina was widely considered a success. A Baton Rouge *Advocate* editorial published near the end of his time in the Gulf highlighted his local popularity and thanked him for his service.[45] Less celebrated in the media, but no less important for the task facing him as National Incident Commander, was Admiral Allen's role overseeing a 2002 simulation that tested the readiness of the Coast Guard and other agencies to respond to a Spill of National Significance off the coast of Louisiana.[46] As Commandant, Admiral Allen was already participating in the response, and he put off his scheduled retirement when he became National Incident Commander.

As the National Incident Command took shape in early May, BP's efforts to stop the flow of oil continued to focus on actuating the BOP, which BP still believed was the best chance of quickly shutting in the well. These efforts were plagued by engineering and organizational problems. For instance, it took nearly 10 days for a Transocean representative to realize that the stack's plumbing differed from the diagrams on which BP and Transocean were relying, and to inform the engineers attempting to trigger one of the BOP's rams through a hydraulic panel that they had been misdirecting their efforts.[47] (Without properly recording the change, Transocean had reconfigured the BOP; the panel that was supposed to control that ram actually operated a different, "test" ram, which could not stop the flow of oil and gas.[48] BP Vice President Harry Thierens, who was BP's lead on BOP interventions, stated afterward that he was "quite frankly astonished that this could have happened."[49]) While this and other problems delayed BP's efforts, the flow of oil and sand continued to wear down the BOP's parts, making closure more difficult.[50]

BP stopped trying to close the BOP on May 5.[51] By May 7, it had concluded that "[t]he possibility of closing the BOP has now been essentially exhausted."[52] In mid-May, at the suggestion of Secretary of Energy Steven Chu, BP undertook gamma-ray imaging of the BOP, which lacked instrumentation to show the position of its rams.[53] The imaging indicated that, although the blind shear ram had closed at least partially, oil continued to flow past it.

The "Social and Political Nullification" of the National Contingency Plan (April 29–May 1)

The hurricane-stricken Gulf states are all too familiar with emergency response; all are among the top dozen states in number of declared major disasters.[54] State and local officials in the Gulf are accustomed to setting up emergency-response structures pursuant to the Stafford Act, under which the federal government provides funding and assists state and local governments during a major disaster.[55] In contrast, the National Contingency Plan, which governs oil spills, gives the Federal On-Scene Coordinator the power to direct all response actions.[56] Thus, while the Stafford Act envisions a state-directed (though in part federally funded) response, the National Contingency Plan puts federal officials in charge.

State and local officials chafed under federal control of the response. Louisiana Governor Bobby Jindal's advisors reportedly spent days trying to determine whether the Stafford Act or the National Contingency Plan applied.[57] On April 29, Governor Jindal declared a state of emergency in Louisiana, authorizing the director of the Governor's Office of Homeland Security and Emergency Preparedness to undertake any legal activities deemed necessary to respond and to begin coordinating state response efforts.[58] These efforts took place outside of the Unified Command framework. The Governors of Mississippi, Alabama, and Florida followed suit, declaring states of emergency the next day.[59]

At the outset of the spill, the pre-designated State On-Scene Coordinators for Louisiana, Alabama, and Mississippi participated in Unified Command.[60] These individuals were career oil-spill responders: familiar with the National Contingency Plan, experienced in responding to spills, and accustomed to working with the Coast Guard. Some had participated in the 2002 spill exercise run by Admiral Allen. They shared the Coast Guard's view that the responsible party is an important ally, not an adversary, in responding to a spill.

During this spill, however, the Governors and other state political officials participated in the response in unprecedented ways, taking decisions out of the hands of career oil-spill responders. These high-level state officials were much less familiar with spill-response planning. In addition to the National Contingency Plan, each Coast Guard sector is an "Area" with an Area Contingency Plan created by relevant state and federal agencies. When confronted with a contingency plan setting out how the federal and state governments were supposed to run an oil-spill response, one high-level state official told a Coast Guard responder that he never signed it. According to the Coast Guard officer, the state official was not questioning whether his signature appeared on the document, but asserting that he had not substantively reviewed the plan.[61] State and local officials largely rejected the pre-spill plans and began to create their own response structures.

Because the majority of the oil would come ashore in Louisiana, these issues of control mattered most there. Louisiana declined to empower the officials that it sent to work with federal responders within Unified Command, instead requiring most decisions to go through the Governor's office. For example, the Louisiana representative at Unified Area Command could not approve the daily agenda of response activities.[62] Responders worked around this problem, but it complicated operations.

Local officials were even less familiar with oil-spill planning, though they had robust experience with other emergencies. Under Louisiana law, Parish Presidents exercise substantial authority—mirroring that of the Governor—during hurricanes and other natural disasters.[63] The parishes wanted to assert that same control during the spill, and many used money distributed by BP to purchase their own equipment and establish their own operating centers outside of Unified Command. Eventually, the Coast Guard assigned a liaison officer to each Parish President, who attempted to improve relationships with the parishes by providing information and reporting back to Unified Command on local needs.

Local resentment became a media theme and then a self-fulfilling prophesy. Even those who privately thought the federal government was doing the best it could under the circumstances did not say so publicly.[64] Coast Guard responders watched Governor Jindal—and the TV cameras following him—return to what appeared to be the same spot of oiled marsh day after day to complain about the inadequacy of the federal response, even though only a small amount of marsh was then oiled. When the Coast Guard sought to clean up that piece of affected marsh, Governor Jindal refused to confirm its location.[65] Journalists encouraged state and local officials and residents to display their anger at the federal response, and offered coverage when they did. Anderson Cooper reportedly asked a Parish President to bring an angry, unemployed offshore oil worker on his show. When the Parish President could not promise the worker would be "angry," both were disinvited.[66]

As the media coverage grew more frenzied, the pressure increased on federal, state, and local officials to take action and to avoid being seen as in league with BP. What Admiral Allen would later call "the social and political nullification" of the National Contingency Plan, which envisions "unity of effort" between the federal government, state governments, and the responsible party, was well underway.[67]

Spill Impacts and Efforts To Help

Effects on the Gulf economy, environment, and way of life increased as the spill dragged on and oil crept closer to shorelines. Concerns about fisheries took hold immediately. The

Gulf of Mexico is home to crab, shrimp, oyster, and finfish fisheries, all of which were affected by the oil. The Louisiana Department of Wildlife and Fisheries and the Department of Health and Hospitals began closing fisheries and oyster grounds in state waters—three miles or less from shore—on April 30. State fishery closures continued piece by piece, beginning on June 2 in Alabama, June 4 in Mississippi, and June 14 in Florida.[68] NOAA's Office of Response and Restoration began conducting flyovers and modeling the movement of the oil beginning April 23.[69] Responders used these daily trajectory forecasts to anticipate where oil would be over the next 24- and 48-hour periods. Based on the forecasts, as well as sampling in or near affected areas, the federal fishery closures began on May 2. Through an emergency rule, NOAA's National Marine Fisheries Service first closed an area spanning approximately 6,817 square miles, or 3 percent of the Gulf federal fishing zone.[70] On May 7, NOAA increased the closed area to 4.5 percent of that zone.[71] A week later, it extended the closures indefinitely.[72] NOAA continued to close additional areas, and on June 2—at the peak of the closures—it prohibited all fishing in nearly 37 percent of the Gulf zone.[73]

Although unable to fish, many fishermen were not content to lay idle. As contractors and subcontractors set up camp in towns across the Gulf to carry out response activities, residents viewed them with suspicion. People in Lafourche Parish, for example, worried about the out-of-state oil-spill-response contractors who took over their shores bringing crime and taking away spill-related job opportunities.[74] Parish Presidents pushed BP and Unified Command to give clean-up jobs to residents and, in the newly out-of-work fishermen, saw a fleet of experienced captains who were more familiar with the intricate shoreline than any out-of-state oil-spill responders.

The Vessels of Opportunity program was BP's answer, and a way for BP to provide some income to affected residents outside of the formal claims process. Through the program, BP employed private vessels to conduct response efforts such as skimming, booming, and transporting supplies. Vessels of opportunity made between $1,200 and $3,000 per day, depending on the size of the boat. Individual crew members made $200 for an eight-hour day.[75] But the program had delays and problems. BP and the Coast Guard were slow to develop eligibility requirements (such as an operable VHF-FM radio) for boats.[76] Initially, there was not enough work. Later, residents and Parish Presidents complained that BP was not sufficiently targeting out-of-work fishermen at whom the program was ostensibly directed, and that wealthy or non-local boat owners were taking advantage of poor oversight to gain spots in the program. Eventually, BP established a verification process that prioritized boats registered with the state before March 2010 and that accepted only one boat per owner.[77] The group that may have lost out the most on the program was the large population of Vietnamese-American fishermen. Many had arrived in the region as refugees and struggled with the lack of Vietnamese-language training.[78] (Chapter 6 discusses the impacts of the spill on minority fishing communities.)

Angry that BP was deploying non-local boats in his parish waters, Craig Taffaro, President of St. Bernard Parish, started his own program using the commercial fishing fleet based there. He submitted invoices to BP, which it paid. The State of Louisiana also began its own program, as did Plaquemines and Jefferson Parishes.[79] Unified Command struggled to coordinate this floating militia of independent vessels and to give them useful response tasks. Having hundreds of vessels look for oil did not contribute significantly to the response, because aircraft were more effective at spotting oil.[80] Placing boom requires skill and training, and responders differed in their judgments of how much the vessels contributed.

In addition to overseeing the Vessels of Opportunity program, Unified Command needed to ensure that all workers, whether on boats or on shore, were adequately trained and taking safety precautions. The Occupational Safety and Health Administration (OSHA) began working with Unified Command at the end of April; under the National Contingency Plan, all response actions must comply with OSHA's training and safety requirements.[81] OSHA established rules regarding protective equipment and, because the response relied in part on untrained workers, a shortened training course.[82] Residents were eager to take on clean-up jobs, but some worried that, notwithstanding OSHA's involvement, response-related work would affect their health.[83] (Chapter 6 discusses the impacts of response activities on health.)

Health issues for non-workers were thornier. The Centers for Disease Control and Prevention represents the Department of Health and Human Services on the National Response Team and had participated in recent spill training exercises. The Centers for Disease Control, however, had not foreseen that an oil spill could affect the health of the broader population and had not fully considered the role health agencies might play in a spill response.[84] Others in the Department, including the Assistant Secretary for Preparedness and Response, had not either.[85] Consequently, the Department had to consider during the disaster how it would fund spill-related activities, because BP would have to pay only for those deemed response measures by Unified Command. The Department was concerned that neither the Oil Spill Liability Trust Fund nor BP would reimburse it for activities such as long-term health surveillance, and negotiations over what costs qualified for reimbursement took time.[86] At the request of Unified Command, Health and Human Services eventually, in June, sent a Senior Health Policy Advisor to support the National Incident Commander on public health issues.[87]

The spill affected wildlife health as well. On April 30, the *Times-Picayune* reported the recovery of the first oiled bird.[88] From then on, crude-covered animals were a fixture in the media coverage and public perceptions of the disaster. The U.S. Fish and Wildlife Service, NOAA's Fisheries Service, state wildlife agencies, and academic organizations oversaw animal response and rehabilitation efforts.[89] Wildlife responders took recovered animals to one of several treatment centers, washing, monitoring, and then releasing them.[90] According to the Audubon Society, more than 12,000 volunteers signed up to help with these efforts during a single week in early May.[91] Not all offers of assistance were accepted. Some groups that could have provided skilled wildlife responders, such as the National Wildlife Federation, felt discouraged from helping; in their view, there was no effective process for integrating skilled volunteers into the response structure.[92] Would-be volunteers worried that animal mortality was greater than it would have been had more rescuers been out looking for oiled animals.[93] (Chapter 6 discusses impacts on wildlife in detail.)

Free once more, a pair of pelicans test their wings in Aransas National Wildlife Refuge after being de-oiled and nursed back to health. Taking part in the release are veterinarian Sharon Taylor and Refuge manager Dan Alonso. Over a thousand birds affected by the spill were rehabilitated; thousands of others were not so fortunate.

U.S. Coast Guard photo/Petty Officer 3rd Class Robert Brazzell

Along with volunteering for wildlife rescue, members of the general public submitted to BP and the Coast Guard numerous ideas for how to clean up the oil or plug the well. For instance, movie star Kevin Costner argued for the use of his oil-water separator, and BP eventually purchased 32 units.[94] Citizens without Costner's resources had more trouble getting their ideas reviewed. On June 4, the Coast Guard established the Interagency Alternative Technology Assessment Program to receive, acknowledge, and evaluate ideas.[95] The program received about 4,000 submissions.[96] Most of the proposals were not viable or required too much time for development into operational response tools.[*] As ideas came in, the Coast Guard screened them and sent the most promising to the Federal On-Scene Coordinator, who ended up testing about a dozen during the course of the spill. None was implemented on a large scale, but the Coast Guard plans to use some of the proposals in its spill-response research.[97]

Foreign companies and countries also offered assistance in the form of response equipment and vessels. The Coast Guard and National Incident Command accepted some of these offers and rejected others.[98] News reports and politicians alleged that the federal government turned away foreign offers of assistance because of the Jones Act, a law preventing foreign vessels from participating in trade between U.S. ports.[99] While decisionmakers did decline to purchase some foreign equipment for operational reasons—

[*] Although intellectual property concerns prohibit the Coast Guard from disclosing the proposals actually submitted, news outlets reported that individuals suggested ideas like dumping popcorn from airplanes; soaking up the oil with packing peanuts, sawdust, kitty litter, and air conditioning filters; and using liquid nitrogen to freeze the oil. Julie Schmit, "After BP Oil Spill, Thousands of Ideas Poured in for Cleanup," *USA Today,* November 15, 2010; John W. Schoen, "BP's Suggestion Box Is Spilling Over," MSNBC, May 14, 2010.

for example, Dutch vessels that would have taken weeks to outfit and sail to the region, and a Taiwanese super-skimmer that was expensive and highly inefficient in the Gulf—they did not reject foreign ships because of Jones Act restrictions.[100] These restrictions did not even come into play for the vast majority of vessels operating at the wellhead, because the Act does not block foreign vessels from loading and then unloading oil more than three miles off the coast.[101] When the Act did apply, the National Incident Commander appears to have granted waivers and exemptions when requested.[102]

In the end, the response technology that created the most controversy was not a mechanical tool like a skimmer or oil-water separator, but a chemical one.

Initial Dispersant Decisions (April 30–May 10)

Even before they were certain that oil was spilling into the Gulf, responders had readied planes full of dispersants to use in a potential response. Dispersants include surfactants that break down oil into smaller droplets, which are more likely to dissolve into the water column.[103] On April 24, once Unified Command knew a leak existed and coastal impacts were possible, Admiral Landry told reporters: "We have one-third of the world's dispersant resources on standby. . . . Our goal is to fight this oil spill as far away from the coastline as possible."[104] Faced with what one Coast Guard captain called a "tradeoff of bad choices" between spraying chemicals on the water or watching more oil reach the shore,[105] responders would wield dispersants in the battle against oil for the next 12 weeks, using novel methods and unprecedented volumes.

Dispersants do not remove oil from the water altogether. Energy from wind and waves naturally disperses oil, and dispersants accelerate this process by allowing oil to mix with water. Dispersed oil is diluted as it mixes vertically and horizontally in the water column.[106] Using dispersants has several potential benefits. First, less oil will reach shorelines and fragile environments such as marshes.[107] Second, animals and birds that float on or wade through the water surface may encounter less oil.[108] Third, dispersants may accelerate the rate at which oil biodegrades.[109] Finally, responders to an oil spill can use dispersants when bad weather prevents skimming or burning. But dispersants also pose potential threats. Less oil on the surface means more in the water column, spread over a wider area, potentially increasing exposure for marine life. Chemically dispersed oil can be toxic in both the short and long term. Moreover, some studies have found that dispersants do not increase biodegradation rates—or may even inhibit biodegradation.[110]

At the direction of the Federal On-Scene Coordinator, responders first sprayed dispersants on the surface oil slick on April 22.[111] Long before the spill, interagency "Regional Response Teams" had evaluated and preauthorized the use of specific dispersants in the Gulf of Mexico, with limits as to geographic areas where the chemicals could be applied, but not on overall volume or duration of use.[112] The teams included representatives from relevant state governments and from federal agencies with authority over oil spills, including the Coast Guard, EPA, the Department of the Interior, and NOAA. Preauthorization, requiring the concurrence of the Team, allows the Federal On-Scene Coordinator to employ dispersants immediately following a spill.[113] Timing matters, because the chemicals are most effective when oil is fresh, before it has weathered and emulsified.[114] Without preauthorization, responders can still use dispersants during a spill if EPA and state authorities approve.[115] With the permission of the Federal On-Scene Coordinator, BP and its contractors applied 14,654 gallons of the dispersant Corexit on the surface during the week of April 20 to 26.[116]

Under the terms of the preauthorization, Corexit was a permissible dispersant because EPA listed it on the National Contingency Plan Product Schedule. EPA obtains toxicity data from the manufacturer before placing a dispersant on that schedule.[117] Some toxicologists have questioned the reliability and comparability of the testing by manufacturers.[118] Moreover, the required testing is limited to acute (short-term) toxicity studies on one fish species and one shrimp species;[119] it does not consider issues such as persistence in the environment and long-term effects.

Dispersant use increased during the first weeks of the spill. From April 27 to May 3, responders applied 141,358 gallons to the surface. The following week, they applied 168,988 gallons. The Coast Guard and other responders had often deployed dispersants to respond to spills, but never in such volumes; during the *Exxon Valdez* spill, responders sprayed about 5,500 gallons, and that use was controversial.[120]

Faced with high-volume dispersant use, Gulf residents became concerned that the chemicals were just as bad as the spilled oil itself. Some workers reported nausea and headaches after coming into contact with dispersants.[121] However, OSHA found no evidence of unsafe dispersant exposure among responders.[122] Environmental groups pressured Nalco, the company that manufactures Corexit, to disclose its formula. Although it had given the formula to EPA during the pre-listing process, Nalco declined to make the formula public, citing intellectual property concerns.[123] This decision did not reassure the citizens of the Gulf.

As the volume of dispersants sprayed on the surface grew, BP raised the idea of applying dispersants directly at the well, rather than waiting for the oil to reach the surface a mile above.[124] Responders had never before applied dispersants in the deep sea. Within Unified Command, some scientists were cautiously optimistic. They hoped that, in addition to reducing shoreline impacts, subsea application would mean less dispersants used overall, because they would be more effective in the turbulent subsea environment. Responders would later conclude that subsea dispersant application also helped to protect worker health by lowering the concentrations of volatile organic compounds at the surface.[125]

But responders were concerned about the absence of information on the effects of dispersants in the deepwater environment. No federal agency had studied subsea dispersant use and private studies had been extremely limited.[126] BP's Hayward was less than helpful; he told a British newspaper, "The Gulf of Mexico is a very big ocean. The amount of volume of oil and dispersant we are putting into it is tiny in relation to the total water volume."[127] While federal officials did not possess the scientific information they needed to guide their choices, they had to make choices nevertheless.

From April 30 to May 10, scientists within Unified Command worked intensively to create a monitoring protocol for subsea dispersant use that would detect adverse environmental effects and provide criteria for when the use was appropriate. It was unclear whether the preauthorizations by the Regional Response Teams covered subsea dispersant use. EPA believed they did not and wanted to make decisions about such use at a high level within the agency. But it had trouble establishing clear and rapid communication, both internally and outside the agency.[128] This slowed creation and review of the testing protocols, while Coast Guard responders and NOAA scientists chafed at the delay.

On May 10, after several rounds of testing and revision, EPA adopted a testing protocol created by NOAA and BP scientists as its directive regarding subsea dispersant use. The directive, as later amended by EPA, limited subsea application to 15,000 gallons per day and required monitoring and compliance with environmental toxicity guidelines.[129] Administrator Lisa Jackson ultimately gave EPA's approval for subsea dispersant use and would later call it the hardest decision she ever made.[130] Observed toxicity levels never exceeded the guidelines in EPA's directive, and responders continued to apply dispersants at the source until BP capped the well.

Deploying the Containment Dome (May 6–8)

While scientists tried to determine if subsea dispersant use was even possible, BP engineers simultaneously worked to contain and recover oil until they could kill the well. Within days of discovering the leaks from the broken riser on the sea floor, they began to consider use of a large containment dome. The idea was to place the dome, also known as a cofferdam, over the larger of the two leaks, with a pipe at the top channeling oil and gas to the *Discoverer Enterprise*, a ship on the surface. BP already had several cofferdams, which it had used to provide safe working space for divers repairing leaks from shallow-water wells following Hurricanes Katrina and Rita.[131] By May 4, BP had finished modifying for deep-sea use and oil collection a preexisting dome that was 14 feet wide, 24 feet long, and 40 feet tall.[132] Following an MMS inspection of the *Discoverer Enterprise*, BP began to lower the 98-ton dome to the sea floor late in the evening of May 6.[133]

The likelihood of collecting oil with the cofferdam was uncertain. BP's Suttles publicly cautioned that previous successful uses had been in much shallower water.[134] BP recognized that chief among potential problems was the risk that methane gas escaping from the well would come into contact with cold sea water and form slushy hydrates, essentially clogging the cofferdam with hydrocarbon ice.[135] Notwithstanding the uncertainty, BP, in a presentation to the leadership of the Department of the Interior, described the probability of the containment dome's success as "Medium/High."[136] Others in the oil and gas industry were not so optimistic: many experts believed the cofferdam effort was very likely to fail because of hydrates.[137]

The effort did fail, for that reason. Although BP had a plan to deal with hydrates once the cofferdam was in place, it had not planned to mitigate hydrate formation during installation.[138] When crews started to maneuver the cofferdam into position on the evening of May 7, hydrates formed before they could place the dome over the leak, clogging the opening through which oil was to be funneled.[139] According to Richard Lynch, a vice president overseeing the effort, BP never anticipated hydrates developing this early.[140]

Because hydrocarbons are lighter than water, the containment dome became buoyant as it filled with oil and gas while BP tried to lower it. BP engineers told Lynch that they had "lost the cofferdam" as the dome, full of flammable material, floated up toward the ships on the ocean surface. Averting a potential disaster, the engineers were able to regain control of the dome and move it to safety on the sea floor.[141] In the wake of the cofferdam's failure, one high-level government official recalled Andy Inglis, BP's Chief Executive Officer of Exploration and Production, saying with disgust, "If we had tried to make a hydrate collection contraption, we couldn't have done a better job."[142]

Inaccurate estimates of the well's flow also affected the cofferdam effort. According to Suttles, during this time, no one at BP believed the flow was greater than 13,000 to 14,000 barrels per day.[143] The government's then-current estimate of the flow was 5,000 barrels per day. The far larger volume of the actual flow—about 60,000 barrels per day, according to the government's now-current estimate—may be part of the reason hydrates formed more quickly than expected.[144] Moreover, BP had publicly predicted that the cofferdam would remove about 85 percent of the oil spilling into the sea.[145] But the ship it planned to connect to the cofferdam was capable of processing a maximum of 15,000 barrels per day.[146] While BP may have misjudged the probability of success, its decision to deploy the dome instead of another containment device appears to have turned more on timing than on perceived effectiveness: the dome was largely off-the-shelf and therefore ready to use in early May, before other equipment.[147]

With the failure of the cofferdam highlighting the shortage of viable options to contain and control the well, somewhat outlandish suggestions filled the void. In mid-May, a Russian newspaper suggested detonating a nuclear weapon deep within the well to stop the flow of oil, as the former Soviet Union had done on a number of occasions.[148] BP moved on: a little over a week after giving up on the cofferdam, on May 16, it was able to deploy a new collection device. Named the Riser Insertion Tube Tool, the device was a tube, four inches in diameter, that fit into the end of the riser and carried oil and gas up to the *Discoverer Enterprise*. This tool, BP's first effective means of containment, collected approximately 22,000 barrels of oil over its nine days of use.

Flow-Rate Estimates Creep Up (May 27)

After Unified Command announced its best estimate of the flow rate as 5,000 barrels per day on April 28, a number of independent scientists began to register their disagreement. BP had contacted scientists at the Woods Hole Oceanographic Institution on May 1 about undertaking diagnostic work on the BOP and measuring the flow using a remotely operated vehicle with sonar and acoustic sensors. But BP cancelled the Woods Hole project on May 6 to instead deploy the containment dome.[149] Based on satellite imagery of the surface slick, other non-government scientists arrived at estimates in late April and early May ranging from 5,000 to 26,500 barrels of oil per day.[150] Using the appearance of oil on the surface to assess flow from a source 5,000 feet below is inherently unreliable, but the outside scientists had no other data. That changed on May 12, when BP released a 30-second video of oil and gas streaming from the end of the broken riser. Within 24 hours, independent scientists had seized on this information and published three new estimates of the combined flow of oil and gas that ranged from 20,000 to 100,000 barrels per day.[151] On May 18, BP released another video, this time of the leak at the kink. Combining estimated flow from the two sources, a non-government scientist, Steve Wereley, testified before Congress that approximately 50,000 barrels of oil per day were flowing into the Gulf.[152]

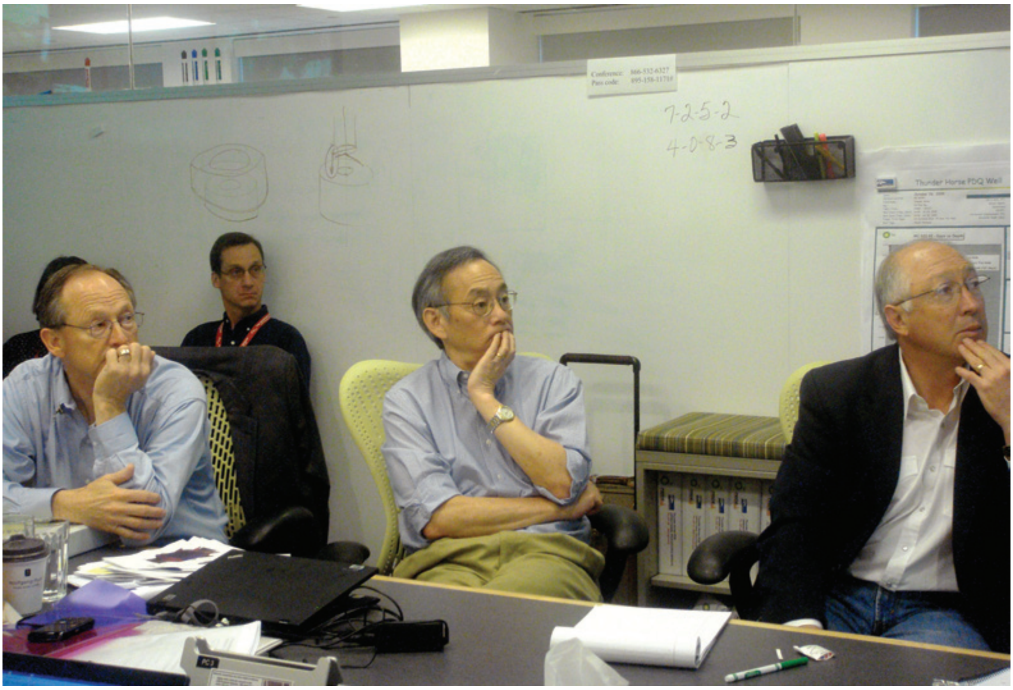
BP dismissed these new estimates, with spokesman Bill Salvin stating, "We've said all along that there's no way to estimate the flow coming out of the pipe accurately."[153] The government disagrees with Salvin's claim: according to Marcia McNutt, Director of the U.S. Geological Survey, if a similar blowout occurs in the future, the government will be able to quickly and reliably estimate the flow rate using the very oceanographic techniques that Woods Hole was prepared to use on May 6.[154*] At the time, the government responded to the independent estimates by devoting greater resources to the question of flow rate. On May 19, the National Incident Command created an interagency Flow Rate Technical Group and charged it with generating a preliminary flow rate as soon as possible and, within two months, a final estimate based on peer-reviewed methodologies. On May 23, at Secretary Salazar's recommendation, the National Incident Command appointed McNutt the leader.

The Group consisted of both government and non-government scientists, and included subgroups using different methodologies. It published its first estimate on May 27, stating: "The only range of flow rates that is consistent with all 3 of the methods considered by the [the Group] is 12,000 to 19,000 barrels per day. Higher flow rates [of up to 25,000 barrels per day] are consistent with the data considered by [one subgroup]."[155] The Group released little additional information about its calculations. A few days later, it issued a two-page report stating that the 12,000 to 25,000 barrel range represented the "lower bound" of one subgroup's estimates, and that this subgroup had chosen not to release its "upper bound" estimates, deeming them speculative because of "unknown unknowns."[156]

Responders uniformly contended that they were responding to the oil as it appeared on the water's surface, and that the problems with quantifying the flow from the source did not affect their ability to respond. In response to a congressional inquiry later in the summer about dispersant use, however, Admiral Allen indicated that early dispersant decisions were based on the 5,000 barrels per day figure, and that the higher estimate from the Flow Rate Technical Group "spurred responders to consider reassessing the strategy for the use of dispersants as well as other oil recovery methods."[157]

Later studies would conclude that 12,000 to 25,000 barrels a day was still a significant underestimate of the amount of oil streaming into the Gulf.

* At the behest of the Coast Guard, Woods Hole used its sonar and acoustic technology on May 31 to gather data that later yielded a flow-rate estimate of 58,000 barrels per day. On June 21, Woods Hole, again with the support of the Coast Guard, collected source samples, which initially demonstrated that 43.7 percent of the total flow was oil, while the remainder was gas. (Woods Hole has since revised this figure to 42.8 percent.)



Top government officials work on source control out of BP's Houston headquarters. At center is Secretary of Energy Steven Chu, flanked by Secretary of the Interior Ken Salazar (right) and Director of Sandia National Laboratories Tom Hunter.

Unified Area Command, Deepwater Horizon Response

The Top Kill and Junk Shot (May 26–28)

Throughout May, the federal government increased its presence in Houston, the hub of the well-control effort. In early May, scientists and engineers from three Department of Energy national laboratories began to work on-site with BP on containment. On May 7, Secretary Salazar asked McNutt, who had traveled to the Gulf with him on May 4, to remain in Houston. Finally, on May 10, President Obama directed Secretary Chu to form a team of government officials and scientists to work with BP on source control.[158] On May 11, Secretary Chu called several prominent scientists and asked them to join him the next morning for a meeting in Houston.[159]

The May 12 meeting signified the beginning of an oversight role for Secretary Chu and his team of science advisors. Secretary Chu is a Nobel Prize-winning physicist who had previously directed the Lawrence Berkeley National Laboratory, where he had led an effort to expand research into synthetic biofuels.[160] Though well known for his wide-ranging intelligence, Secretary Chu was not an oil and gas or drilling expert. During the following weeks, he immersed himself in the finer points of petroleum engineering and became intimately involved in decisionmaking with respect to containment of the well.

Although they were highly respected within their fields of study, the members of the advisory team had limited experience with well control and varying levels of experience with petroleum engineering generally. Secretary Chu assumed—correctly—that BP had already hired a host of containment experts, and he wanted advisors known for creative thinking. His principal deputy on the team, Tom Hunter, was about to retire from his position as Director of Sandia National Laboratories. Along with McNutt, Hunter served as a link between the on-site government scientists and engineers and the rest of Secretary Chu's science advisors, who were for the most part based elsewhere. Another team member, Richard Garwin, helped design the world's first hydrogen bomb and had worked to extinguish oil fires in Kuwait following the first Gulf War. Alexander Slocum, an MIT professor who holds about 70 patents, had done some previous work on drilling design. George Cooper had been the head of the Petroleum Engineering Program at the University of California, Berkeley.

The role of both the national laboratories scientists and Secretary Chu's advisors took time to evolve from helping BP diagnose the situation—for instance, using gamma-ray imaging to show the position of the BOP's rams—to substantively overseeing BP's decisions on containment. In part, this was because the Secretary of Energy, his team of advisors, and the national laboratories personnel lacked a formal role within Unified Command. Their supervision was informally grafted onto the command framework.

In addition, the national laboratories team did not immediately integrate itself into the existing source-control structure, led by MMS and the Coast Guard. While MMS, the Coast Guard, and McNutt worked out of offices on the third floor of BP's Houston headquarters, the national laboratories team sat on the eighteenth floor.[161] One MMS staff member who was in Houston from late April through early July said that he never interacted with the national laboratories team: they never reached out to him, and he had no idea what they were working on. Perhaps because the lines of authority were unclear, BP's sharing of data with the government science teams was uneven at first. BP gave information when asked, but not proactively, so government officials had to know what data they needed and ask for it specifically.[162] Finally, both the national laboratories team and the science advisors had to educate themselves on the situation, and on deepwater petroleum engineering, before they knew enough to challenge BP and participate in high-level decisionmaking.[163]

With more substantive government oversight on the way but not yet in place, BP moved toward its first attempt to kill the well completely, via procedures called the "top kill" and "junk shot." Those names were fodder for late night comics: Jay Leno suggested that the top kill "sound[ed] like some bad Steven Seagal movie from the '80s."[164] In fact, both procedures are standard industry techniques for stopping the flow from a blown-out well (though they had never been used in deepwater[165]). A top kill—also known as a momentum or dynamic kill—involves pumping heavy drilling mud into the top of the well through the BOP's choke and kill lines, at rates and pressures high enough to force escaping oil back down the well and into the reservoir. A junk shot complements a top kill. It involves pumping material (including pieces of tire rubber and golf balls) into the bottom of a BOP through the choke and kill lines. That material ideally gets caught on obstructions within the BOP and impedes the flow of oil and gas. By slowing or stopping the flow, a successful junk shot makes it easier to execute a top kill.

BP's top-kill team began work in the immediate aftermath of the initial efforts to trigger the BOP.[166] In planning the operation, both BP and federal engineers modeled different scenarios based on different rates at which oil might be flowing from the well. National laboratories engineers used the then-current flow-rate estimate of 5,000 barrels per day.[167] Paul Tooms, BP's Vice President of Engineering, recalled that given the planned pumping rates, the top kill was unlikely to succeed with flow rates greater than 15,000 barrels of oil per day.[168] A senior administration official similarly recalled being told by a BP engineer that the top kill would not work if the flow rate exceeded 13,000 barrels per day.[169]

With the approval of the Federal On-Scene Coordinator, the top kill began on the afternoon of May 26. Secretary Chu and some members of his science team were in the command center in Houston.[170] During three separate attempts over three consecutive days, BP pumped mud at rates exceeding 100,000 barrels per day and fired numerous shots of junk into the BOP.[171] During each effort, pressures within the well initially dropped, but then flattened, indicating that the top kill had stopped making progress.[172] After the third unsuccessful attempt, BP and the government agreed to discontinue the strategy.[173]

As with the cofferdam, BP struggled with public communications surrounding the top kill. At the time, both industry and government officials were highly uncertain about the operation's probability of success. One MMS employee estimated that probability as less than 50 percent, while a BP contractor said that he only gave the top kill a "tiny" chance to succeed.[174] But BP's Hayward told reporters, "We rate the probability of success between 60 and 70 percent."[175] After the top kill failed, that prediction may have lessened public confidence in BP's management of the effort to control the well.

The Federal Role Increases (Late May)

By late May, the competence and effectiveness of the federal response was under assault. Polls showed that 60 percent of adults thought the government was doing a poor job of handling the spill.[176] News articles chronicled local anger that BP appeared in charge of clean-up efforts.[177] The government's estimate of the flow rate was climbing and, with the failure of the top kill, no end to the spill was in sight.

On May 28, President Obama made his second trip to the region to see response efforts and meet with state and local leaders. Plaquemines Parish President Billy Nungesser would later claim, incorrectly, that he had not been invited to this important meeting.[178] He told the *Plaquemines Gazette* that he had smuggled himself and another Parish President across bays and bayous and through an armada of state boats, gaining access only after threatening to call Anderson Cooper.[179]

The meeting with the President occurred at the Coast Guard station in Grand Isle, Louisiana, and included, among others, Governor Jindal, Florida Governor Charlie Crist, Alabama Governor Bob Riley, Louisiana Senators David Vitter and Mary Landrieu, Louisiana Congressman Charlie Melancon, New Orleans Mayor Mitch Landrieu, Lafourche Parish President Charlotte Randolph, and Parish President Nungesser.[180] President Obama emphasized the seriousness with which the government was treating the spill, announcing at a press conference after the meeting that he would triple the federal manpower and equipment involved in the response.[181] Though Coast Guard responders believed they were already dedicating every available resource to the spill, and did not see across-the-board "tripling" as the best use of resources, they dutifully attempted to triple the personnel engaged and boom deployed. They chronicled their progress in Louisiana in a report titled "Status on Tripling."[182]

Under fire, President Barack Obama meets with dissatisfied state and local officials in Grand Isle, Louisiana on May 28, during his second visit to the Gulf since the spill began. Visible clockwise from the President: Plaquemines Parish President Billy Nungesser, Louisiana Governor Bobby Jindal, New Orleans Mayor Mitch Landrieu, Grand Isle Mayor David Camardelle, and Florida Governor Charlie Crist.

David Grunfeld/The Times-Picayune. Photo © 2010 The Times-Picayune Publishing Co., all rights reserved. Used with permission of The Times-Picayune.

While in Grand Isle, President Obama also received an "earful" about Louisiana's proposal to build massive offshore sand berms as a physical obstacle to oil, which the National Incident Command had declined to approve in its entirety.[183] Parish President Nungesser, seated immediately to the President's left, was the first attendee to speak at the meeting and was adamant about the need for the entire berms project. Governor Jindal echoed him. In line with the federal government's effort to be more responsive to local demands, President Obama turned to Admiral Allen and asked him, in front of the berms' strongest proponents, to figure out a solution.[184]

The "tripling" order and promise to promptly reevaluate the berms project were only two of many actions at the end of May by which the federal government attempted to demonstrate its focus on the *Deepwater Horizon* disaster and commitment to the communities in the Gulf. The President signed the Executive Order creating this Commission on May 21.[185] On May 27, he announced a moratorium on offshore deepwater drilling and held a press conference about the administration response.[186] The same day, Elizabeth Birnbaum, the head of MMS, resigned—"on her own terms and on her own volition," according to Secretary Salazar.[187] Most symbolically, the federal government stopped holding joint press conferences with BP. From June 1 on, Admiral Allen gave his own daily press briefing.[188] But local officials continued to attack the adequacy of the federal response and to assert that that BP was running the response effort.

The Battles over Boom and Berms (May to June)

While the response had many dimensions, local communities fixated on the deployment of boom to prevent oil from washing ashore. Although not the most effective response tool, boom is a measurable, physical object that visibly stops oil. Residents could not see source-control efforts on the ocean floor or skimming far out in the Gulf, but they could see boats laying ribbons of bright orange or yellow floating boom to protect their shorelines. According to one Terrebonne Parish resident, boom was eye candy—seeing it gave him a sense of satisfaction (even if it did not do much).[189]

The Moratorium

On May 27, after a 30-day interagency examination of deepwater drilling operations, Secretary Salazar directed MMS to issue a six-month moratorium on all drilling at a water depth of more than 500 feet in the Gulf of Mexico and the Pacific Ocean. Department officials justified the moratorium as providing time for this Commission to do its work and for MMS to undertake needed safety reforms. The moratorium took effect on May 30 and halted work on 33 offshore deepwater rigs in the Gulf.

The oil and gas industry, local communities, and elected officials from the region immediately criticized the action. Senator Landrieu testified before this Commission in July that the moratorium was "unnecessary, ill-conceived and has actually created a second economic disaster for the Gulf Coast that has the potential to become greater than the first." On July 30, BP established a $100 million charitable fund to assist rig workers experiencing economic hardship because of the moratorium.

The federal government concluded that the moratorium's impact would be less severe. On September 16, a federal interagency report stated that the moratorium "may temporarily result in up to 8,000 to 12,000 fewer jobs in the Gulf Coast," with these losses attributed mostly to small businesses. Louisiana elected officials criticized the report's methodology and the decision to conduct this analysis after, instead of before, the moratorium began.

A group of companies that provide support services for deepwater drilling vessels challenged the moratorium in federal district court in Louisiana. On June 22, the court ruled that the moratorium violated the Administrative Procedure Act and enjoined its continued enforcement. The federal government asked the Fifth Circuit Court of Appeals to stay the district court's ruling, but the Fifth Circuit denied that request on July 8. The Department of the Interior then issued a revised moratorium on July 12, which limited drilling based on the equipment a rig used rather than the depth of the wellhead. Neither the first nor the second moratorium provided a company with the option of avoiding the bar on drilling by proving the safety of its rig operations to the government. A second group of offshore support companies challenged the revised moratorium. Before the district court could rule on this new lawsuit, the Department lifted the moratorium on October 12, seven weeks ahead of its scheduled November 30 expiration.

On September 30, a few weeks before lifting the moratorium, the Department promulgated new regulations on topics such as well casing and cementing, blowout preventers, safety certification, emergency response, and worker training. Compliance with the new rules is a prerequisite for both shallow and deepwater drilling permits. Some companies called these new requirements a "de facto moratorium" because of the time needed to meet them and for the Department to verify compliance.

A vessel places containment boom in Louisiana's Barataria Bay. Hundreds of miles of boom were deployed along the Gulf coast, but politicians clamored for more of the highly visible barriers.

U.S. Coast Guard photo/Petty Officer 3rd Class Ann Marie Gorden

Boom became a symbol of federal responsiveness to local communities. NOAA scientists worked through the night, every night, to prepare oil trajectory forecasts for federal responders to review as they began their days.[190] Responders used those forecasts to plan their actions, including where to place boom. Federal responders thought that officials and residents complaining about lack of boom did not understand their strategy for deployment; officials and residents thought that federal responders were inattentive to local needs.[191] The National Incident Command was not deaf to these complaints and gave an unofficial order to "keep the parishes happy."[192] Coast Guard responders distributed many miles of boom according to political, rather than operational, imperatives. They felt hamstrung by the outrage that resulted when a parish or state felt slighted by allocation decisions, so they placed boom wherever they could.[193]

Every Governor wanted more boom. When the oiling risk was highest in Louisiana, the Coast Guard directed boom there. Governor Riley of Alabama contended that this decision left his state's shoreline in danger.[194] At a press conference in mid-May, Governor Jindal said that the containment boom provided to Louisiana by the Coast Guard and BP was inadequate, while local officials behind him held up pictures of oil-coated pelicans.[195] Florida Department of Environmental Protection Secretary Mike Sole told reporters, "A lot of the decisions about Florida are being made in Mobile." He said he had warned the Federal On-Scene Coordinator, "Florida is important. We have 770 miles of shoreline to protect. I'm concerned that we're not getting enough focus on Florida."[196]

The competition for boom occurred at the parish and town levels as well. St. Bernard Parish had its own contractor bring in boom; it then sought to make the Coast Guard purchase and deploy that boom locally.[197] Some parishes reportedly ordered boom directly from suppliers and told them to "send the bill to BP."[198] Lafourche Parish kept demanding more boom—until it realized that certain skimmers were more effective and began demanding those skimmers instead.[199] Unified Command struggled to track how much boom was deployed and where.

Initially, responders made booming decisions based on their knowledge of the region's geography, the location of environmentally sensitive areas, and NOAA's oil trajectory forecasts. The oil-spill planning documents did not lay out a specific booming map, because the coastal ecosystem, particularly in the marshes, frequently changes. Unified Command eventually brought the Parish Presidents together to review boom plans that each parish had created. Some were infeasible—for instance, requesting that boom be placed in tidal passes where currents would drive oil under the boom or else damage it. In addition to worrying about useless or unnecessary boom, responders were concerned that storms could blow it into delicate marsh habitat. They deployed boom based on local pressures only to pull it away during bad weather.[200]

Once parishes had boom, they did not want to let it go. On July 22, Parish President Nungesser threatened to blow out the tires of trucks carrying away boom as the Coast Guard prepared for Tropical Storm Bonnie. Though he claimed that he was joking, the FBI called to reprimand him.[201] Other Parish Presidents issued orders prohibiting the removal of response equipment from their parishes and threatened Coast Guard responders with arrest.[202] Officials asked responders to measure "feet of boom deployed"—a statistic that was time-consuming to generate and had little value in assessing response efforts.[203] All of these problems distracted responders from their focus on cleaning up the spill.

The boom wars never reached a resolution. Responders knew that in deploying boom they were often responding to the politics of the spill rather than the spill itself. And the miles of boom along the coastline still did not prevent oil from washing up on the shore.

The boom wars were relatively civil, however, compared to the struggle among the State of Louisiana, the Army Corps of Engineers, the National Incident Command, and, ultimately, the White House over berms. Reinforcing barrier islands had long been a component of Louisiana's and Plaquemines Parish's coastal restoration plans.[204] But by early May, Governor Jindal and Parish President Nungesser had seized on an idea (originally proposed by Deltares, a Dutch independent research institute, together with Van Oord, a Dutch dredging and marine contractor) to construct massive, linear sand berms along Louisiana's barrier islands for spill response, to guard the coastline from oil.[205] The berms project presented an opportunity for Louisiana to take the lead on a large-scale response measure—with BP footing the bill. Moreover, after the spill ended, the berms' purpose could "pivot" from response to coastal restoration.[206]

On May 11, Louisiana's Office of Coastal Protection and Restoration applied to the Corps for an emergency permit to construct berms to "enhanc[e] the capability of the islands to

Voices from the Gulf
"If I was a mom, what would I do?"

Michelle Rolls-Thomas/Associated Press

Sheryl Lindsay, Orange Beach Weddings, Orange Beach AL

When Sheryl Lindsay picked up the April 21 Mobile *Press-Register* and read the headline, "At least 11 workers sought after gulf rig explosion," she recalled, "My heart went out to the workers on that rig, the victims and their families. I couldn't believe what had happened." The newspaper reported that six of the *Deepwater Horizon* survivors had been flown to a Mobile, Alabama, trauma unit.

For six years, Lindsay had been president of Orange Beach Weddings, which coordinated and arranged "The Wedding of Your Dreams" on Alabama's Gulf Coast near the Florida line. Her offices on Perdido Boulevard overlooked the pristine white sand beaches of Orange Beach, Alabama—one of her firm's specialties was elegant beach ceremonies and festivities. Her busy season was starting, with 73 weddings booked for 2010. She worked with numerous contractors, from wedding planners and caterers to ministers and photographers. She knew that BP's Macondo well was now spewing oil; "But I never thought it would affect us here."

On April 30, the day after the U.S. Coast Guard declared the Macondo blowout a "spill of national significance," Lindsay was in her office when the phone rang. It was her first cancellation. "When the bride called to cancel, she said it was because of the spill. She didn't want her guests coming down to find oil on the beaches. She didn't want to come if they couldn't swim or eat the seafood. That's when I knew."

In the wake of the oil spill, "Every time the phone rang, all we got was another cancellation—or someone asking how bad it was down here. I became a counselor for these brides. Orange Beach is a popular spot for destination weddings, and many of my brides come from out of state. But if girls' weddings were still a few months out, they still had time to change plans and move the wedding somewhere else. A lot of girls asked me what they should do—they were worried about the smell, whether the guests could swim and the quality of the seafood." She continued, "This was their big day. It was tough. And you think, 'If I was a mom, what would I do?'"

"What's funny," Lindsay said, "is we only had about three bad weeks where oil was washing on shore and BP was staging clean-up on the beach. That was in June. The rest of the summer the beaches were pretty much clean but folks still didn't come down." As the spill gushed on, Lindsay began to realize she had no idea what the next year would look like, but it didn't look good. She did not think she could afford to renew her office lease. In 2009, she had taken out a small business loan from the local bank for $55,000 to expand her firm, but now she began to fear she could not meet those payments as her business diminished.

reduce the inland movement of oil from the BP Deepwater Horizon Oil Spill."[207] Colonel Alvin Lee, two months shy of the end of his three-year tour as the Commander of the Corps for the District of New Orleans, cancelled a long-scheduled vacation, and the Corps immediately sought comments on the proposal from relevant federal and state agencies.[208]

The patience of Louisiana officials quickly wore thin. On May 17, Governor Jindal's office summoned Colonel Lee to the New Orleans airport for a meeting that included three Parish Presidents, the Chairman of the Office of Coastal Protection and Restoration, the Adjutant General for Louisiana, and the Governor himself. The group's message to Colonel Lee was clear: approve the berms project, and do it quickly.[209] The entire Louisiana congressional delegation wrote Colonel Lee on May 20, to "implore [him] to immediately approve the emergency authorization request" for the Louisiana berms.[210] In a May 21 letter to President Obama, Senator Vitter asked the President to stop the "tragic bureaucratic stranglehold" and to "make this happen now."[211]

The Corps reviewed agency comments, conducted its own evaluation of the project, and engaged in dialogue with state officials. On May 27—just 16 days after it had received Louisiana's application—the Corps approved the issuance of an emergency permit for a significantly scaled-back berms project: six "reaches" totaling 39.5 miles in length.[212] During the review process, commenting agencies expressed skepticism that the berms could be constructed in time to be effective for spill response and concern that partially completed berms would do more environmental harm than good.[213] The Corps' job, however, was to analyze the "feasibility and environmental impacts" of the berms. The National Incident Commander had the task of determining whether the berms would be "effective. . . in combating the oil spill."[214] That determination was necessary to make BP pay for the project as a response measure.

The same day the Corps approved the six reaches, Admiral Allen authorized one of the six as a prototype oil-spill response mechanism.[215] Earlier in May, an interagency task force had advised the National Incident Command that the project would not be an effective spill-response measure, in part because the berms could not be constructed in time to fight the spill.[216] But public and political pressure had been unyielding. In an attempt to balance both sets of concerns, on May 22, Admiral Allen e-mailed an idea to his deputy: "What are the chances we could pick a couple of no brainer projects and call them prototypes to give us some trade space on the larger issue and give that to Jindal this weekend?"[217] Five days later, the National Incident Command announced its approval of one prototype berm, to cost $16 million.[218] The accompanying press release promised that additional berms could be constructed if the approved section proved effective. Building even one prototype segment would take months, however, and the segment would then need to be analyzed. Any further construction therefore would not begin until the fall.

But because of the meeting in Grand Isle on May 28, where Parish President Nungesser and Governor Jindal urged President Obama to approve the entire project, the National Incident Command would change course. At the meeting, the President turned to Admiral Allen and, in front of the assembled Governors and other leaders, asked him to assemble a group of experts to examine the merits of Louisiana's proposal as a spill-response measure.

Admiral Allen replied that this might take some time. It was the Friday afternoon before Memorial Day weekend. But the President pushed, asking, "Can you do it next week?" Admiral Allen, put on the spot, pledged to do his best.[219]

After the meeting, Governor Jindal immediately announced that the President had "agreed that work on the first segment must begin immediately" and that the federal government would decide "within two to three days" whether the additional five segments should proceed.[220] Parish President Nungesser told a similar story to Anderson Cooper on *CNN* that evening, saying "The President committed by early next week, we will have an answer and I believe that he's going to task BP."[221]

On June 1, Admiral Allen convened a summit in New Orleans "which included members of academia [one from Louisiana State University and a second from the University of New Orleans], federal trustees, fish and wildlife service and NOAA," as well as Governor Jindal and Parish President Nungesser. Although some experts at the summit expressed concern about causing harm to the environment, the discussion focused on the berms' potential to protect marshlands.[222] The politics of the project remained close at hand: Parish President Nungesser walked out, calling the meeting a "Dog and Pony Show,"[223] only to return in time to speak at the end. Governor Jindal continued to express his frustration and pressed for approval of all six reaches covered by the Corps permit.[224] In the face of the spill and in front of the Louisiana politicians, no one directly opposed the berms, and a "preponderance of opinion" at the summit suggested the berms would be an effective response measure.[225]

That evening, following the summit, Admiral Allen and BP's Hayward had dinner together in New Orleans to discuss the berms.[226] The following afternoon, Admiral Allen gave the go-ahead to all six reaches approved by the Corps, to be funded by BP.[227] BP estimated the cost to be $360 million, double the entire amount it had spent as of early June in "helping the region respond to the oil spill."[228] The Corps pegged the cost at $424 million.[229]

Louisiana awarded contracts for the project to Shaw Group, a Baton Rouge-based engineering, construction, and environmental services firm, and C.F. Bean LLC, a dredging contractor based in Plaquemines Parish.[230] Shaw estimated that five of the six berm reaches would be completed by November 1, and that the sixth would be completed by the end of November.[231] The National Incident Command estimated that the construction time for all six reaches would be six to nine months.[232] Even if those estimates had been correct, the project would have been nowhere close to complete by the time the government expected BP to kill the Macondo well with a relief well. As it happened, all of the estimates were far too rosy. Only a fraction of the planned reaches would be finished before the spill ended, and very little oil would be captured.

From Containment to Collection (Late May to Early July)

Following the unsuccessful top kill, BP teams in Houston met through the night of May 28 to assess the operation.[233] Some meetings occurred behind closed doors, without government participation. At one point, Herbst of MMS and Admiral Kevin Cook, who had been dispatched by Admiral Allen to be his representative in Houston, entered a meeting and stated that they had a right to be present. Apparently, government officials had not previously insisted on joining these types of meetings, and BP personnel were surprised by the interruption.[234] The failure of the top kill marked a turning point for the government science teams, with the government significantly increasing its oversight of the containment effort.

The next morning, BP presented its analysis of why the top kill failed to stop the flow of oil. The analysis focused on the well's 16-inch casing, the outermost barrier between the well and the surrounding rock for more than 1,000 vertical feet. That casing was purposely fabricated with three sets of weak points, called rupture disks. During the well's production phase, the hot oil coursing through the production casing, which is inside the 16-inch casing, would lead to a buildup of pressure in the well. If the pressure buildup was too high, it could cause the collapse of one of the two casings. The disks were designed to rupture and relieve this potential buildup of pressure before a casing collapsed.

The disks could rupture in two ways. If pressure between the 16-inch casing and the production casing were too high, the rupture disks would *burst outward* before the production casing collapsed. If pressure outside the 16-inch casing were too high, the rupture disks would *collapse inward* before the casing itself collapsed.[235] Once ruptured, the disks would create small holes in the 16-inch casing, bleeding built-up pressure off into the rock. According to BP's top-kill analysis, pressures created by the initial blowout could have caused the rupture disks to collapse inward, compromising the well's integrity.[236] BP believed that the mud it had pumped down the well during the top kill could have gone out into the rock through the rupture disks, instead of staying within the well and pushing oil back down into the reservoir as intended.[237]

Collapse of the rupture disks was only one of BP's possible explanations for the unsuccessful top kill.[238] But the company presented it to the government as the most likely scenario.[239] Although the government science teams did not fully accept BP's analysis of what happened to the mud, they agreed that the rupture disks could have collapsed during the blowout, and that the integrity of the well had to be considered in future containment efforts.[240] In retrospect, government officials have suggested that the top kill likely failed because the rate at which oil was flowing from the well was many times greater than the then-current 5,000 barrels-per-day estimate. Because BP did not pump mud into the well at a rate high enough to counter the actual flow, oil and gas from the well pushed mud back up the BOP and out of the riser.[241]

BP had previously said that, if the top kill failed, its next step might be to install a second BOP on top of the existing one to shut in the well.[242] But now, the company engineers viewed the possibility that the rupture disks had collapsed as a reason to discard capping the well as an option.[243] If BP shut the well in, oil and gas could flow out the rupture disks and into the rock surrounding the well in a "broach" or "underground blowout." From there, the hydrocarbons could rise through the layers of rock and flow into the ocean from many points on the sea floor. This would make containment nearly impossible, at least until the completion of a relief well. Thus, in the aftermath of the top kill, BP and the government focused on trying to collect the oil, with the relief wells still providing the most likely avenue for killing the well altogether.[244]

Transocean's huge drill ship the *Discoverer Enterprise*, its derrick towering 400 feet above the sea, and Helix's *Q4000* (foreground) sit over the gushing wellhead. Together the vessels were able to recover up to 25,000 barrels of oil per day.

Julie Dermansky ©2010

BP had a team ready to proceed with new collection tools almost immediately.[245] On May 29, the company and the government announced that BP would attempt to cut off the portion of the riser still attached to the top of the BOP and install a collection device—the "top hat"—which would then be connected via a new riser to the *Discoverer Enterprise* above.[246] BP began installing the device on June 1, and had the top hat in place and functioning by 11:30 p.m. on June 3. Having learned from its cofferdam experience, BP injected methanol to prevent formation of hydrates. By June 8, the *Discoverer Enterprise* was collecting nearly 15,000 barrels of oil per day.

BP also developed a system to bring oil and gas to the surface through the choke line on the BOP. BP outfitted the *Q4000*, a vessel involved in the top-kill effort, with collection equipment, including an oil and gas burner imported from France. After it became operational on June 16, the *Q4000* system was able to process and burn up to 10,000 barrels of oil per day.*

On occasion, BP was overly optimistic about the percentage of the oil it could remove or collect. On June 1, Suttles said that he expected the top hat, when connected to the *Discoverer Enterprise*, to be able to collect the "vast majority" of the oil.[247] Within days, it became apparent that the top hat and *Discoverer Enterprise* were inadequate. On June 6, Hayward told the *BBC* that, with the *Q4000* in place, "we would very much hope to be containing the vast majority of the oil."[248] But when the *Q4000* came online in mid-June, the two vessels' joint capacity of 25,000 barrels per day was still insufficient.

* Over the course of June and early July, BP worked on further expanding its containment system, which it asserted would eventually be able to collect up to 90,000 barrels of oil per day. BP never used the complete system, based around two freestanding risers connected to the choke and kill lines on the BOP, because it succeeded in capping the well on July 15.

It is unclear whether BP could have increased its collection capacity more rapidly than it did. BP's Lynch said that the speed at which the company brought capacity online was limited solely by the availability of dynamically positioned production vessels.* One senior Coast Guard official challenged BP's definition of availability: he suggested that BP did not consider options such as procuring ships on charter with other companies until the government pushed it to do so. Obtaining another production vessel might have enabled BP to collect oil through the BOP's kill line at a rate comparable to that of the *Q4000*.[249]

Continued Conflict about Dispersant Use (May 10–July 14)

Because of the insufficient collection capacity, oil continued to flow into the Gulf. Though the subsea use of dispersants proved helpful in preventing huge surface slicks, it did not initially have the predicted effect of reducing the total volume of dispersants applied. At a May 24 press conference, EPA Administrator Jackson announced that the government was instructing BP to "take immediate steps to significantly scale back the overall use of dispersants" and expressed EPA's belief that "we can reduce the amount of dispersant applied by as much as half, and I think probably 75 percent, maybe more."[250] A Coast Guard–EPA letter and joint directive issued two days later instructed BP to "eliminate the surface application of dispersants," except in "rare cases when there may have to be an exemption."[251]

Despite this directive, surface use of dispersants continued. When surveillance aircraft spotted oil and no other method of cleaning it up was available in the area, BP would ask for an exemption from the Federal On-Scene Coordinator, who would then seek EPA's approval. The Coast Guard could not unilaterally allow the exemption; EPA had the final vote.

EPA expressed frustration that BP sought regular exemptions, and it repeatedly asked for more robust explanations of why BP could not use mechanical recovery methods, such as skimming and burning, instead of dispersants.[252] Coast Guard responders, who viewed dispersants as a powerful tool to protect the coastline, wondered why EPA wanted to cast aside the advance planning that went into the preauthorization of surface dispersant use.[253]

These different perspectives on dispersants led to conflicts between EPA and the Coast Guard. For example, on June 7, BP requested permission to spray dispersants on several large slicks. Despite Federal-On Scene Coordinator Rear Admiral James Watson's statement that he had "determined aerial dispersant the best and only way to mitigate the pending landfall effect of the oil spotted," EPA would not approve the exemption.[254] The Coast Guard captain leading the majority of front-line operations was furious. "It would be a travesty," he wrote, "if the oil hits the beach because we did not use the tools available to fight this offshore. This responsibility needs to be placed squarely in EPA's court if it does hit the shoreline."[255] Later that day, without having received responses to its requests for additional data, EPA threatened to issue a directive "to stop the use of all dispersants."[256]

* Dynamically positioned vessels have computer-controlled systems that maintain the vessel's exact position and direction, despite external factors such as wind, waves, and current.

The working relationship between the agencies improved over time, with more complete justifications for dispersant use included in the daily requests for exemptions.[257] But disagreements came to a boil again in mid-July. By this point, EPA had finally installed a senior official, Assistant Administrator for Solid Waste and Emergency Response Mathy Stanislaus, on the ground at Unified Area Command.[258] On July 13, BP's head of dispersant operations made a request to apply 10,000 gallons to slicks.[259] The request ultimately went to Stanislaus, who denied it, noting that skimming in particular had been extremely effective over the past few days.[260] The Federal On-Scene Coordinator (by this time Rear Admiral Paul Zukunft) replied that he could not "take the dispersant tool out of my kit when" oil threatened to hit environmentally sensitive areas in Louisiana. "We spent over a month cleaning Barataria Bay with over 1500 people and 600 vessels," he added, "and still incurred significant wildlife kills while exposing these clean-up crews to extreme heat conditions. That is the trade-off option where dispersants come into play. . . ."[261] The back-and-forth continued, with BP ultimately prohibited from using dispersants on July 14.[262] The capping of the well the next day tabled the conflict.

Months later, Admiral Allen and Administrator Jackson would say that they had cooperated closely, nearly attained the goal of a 75 percent reduction in dispersant use, and were satisfied with the use of dispersants to mitigate the spill.[263]

The Well Is Finally Capped (Late June to July 15—and Beyond)

Meanwhile, in Houston, the government continued to develop a more effective structure for oversight of well control. The basic elements of the structure were in place by mid-May, and the roles of the different government teams were better defined by mid-June. MMS and the Coast Guard continued to focus on identifying hazards in BP's technical procedures; personnel from the national laboratories and the U.S. Geological Survey provided information and analyses to the science advisors and BP; and the science advisors conducted their own independent analyses and helped inform the government's ultimate decisionmakers, including Secretary Chu, Secretary Salazar, McNutt, Hunter, Carol Browner (Director of the White House Office of Energy and Climate Change Policy), and Admiral Allen.[264]

Following the failure of the top kill, BP began presenting its source-control plans for review by these government teams. The science advisors would question BP's assumptions, forcing it to evaluate worst-case scenarios and explain how it was mitigating risks.[265] The government saw its pushback as essential because BP would not, on its own, consider the full range of possibilities.[266] According to one senior government official, before the increased supervision, BP "hoped for the best, planned for the best, expected the best."[267] BP often found the supervision frustrating. Tooms, BP's Vice President of Engineering, believed that the government science advisors unnecessarily slowed the containment effort, arguing that scientists consider risk differently than engineers and that BP had expertise in managing risk.[268] BP, however, was not in the best position to tout that expertise: its well had just blown out.

In mid- to late June, the government teams also began to seek more frequent input from other oil companies, primarily through large conference calls of 30 or more people.

Although BP had previously turned to others in industry for advice, it had generally asked discrete questions about aspects of source control. The government teams, by contrast, asked other companies to comment on BP's overall plans and to help force BP to consider contingencies. BP, which believed its competitors suffered from a conflict of interest, did not appreciate the increased industry involvement. After one meeting in which BP's competitors aggressively challenged its plans, BP refused to meet with them again, forcing the government teams to schedule separate meetings.[269]

The conference calls were somewhat disorganized, with no agenda and participants sometimes not knowing who was speaking. One industry participant recalled an instance when he was chagrined to learn he had been talking to Secretary Chu without realizing it.[270] A senior government official noted that some colleagues viewed BP's conflict-of-interest concerns as valid and took the competitors' advice "with a grain of salt."[271] But government personnel generally found the industry participation helpful.

The science advisors' oversight increased substantially during June. On June 18, Secretary Chu sent an e-mail to the advisory team as well as some national laboratories scientists, describing their expanded role. The e-mail cited a scene from the classic World War II movie *The Guns of Navarone*, and quoted the character played by Gregory Peck: "[Y]our bystanding days are over! You're in it now, up to your neck! They told me that you're a genius with explosives. Start proving it!" Recognizing that there were "[p]robably no shaped charges to be used on this mission," Secretary Chu wrote that "the rest rings true." He enclosed a directive that Admiral Watson, the Federal On-Scene Coordinator, would issue the next day, formally requiring BP to submit any "pending decision" on containment to the government "for review."[272]

The role of the science advisors and the on-site scientists increased just as the source-control effort approached a critical phase. By late June, BP was well on its way toward deploying a "capping stack," which, once installed on top of the BOP, would enable BP to shut in the well. The capping stack was essentially a smaller version of a BOP, similarly designed to stop the flow of oil and gas. BP had internally discussed installing a tight-sealing cap within a week of the blowout.[273] Following the top kill, however, BP and the government had shelved the idea of shutting in the well, in part because of concerns that the rupture disks in the well's 16-inch casing had collapsed, potentially allowing oil to flow out of the well into the rock. The government and BP had to take these concerns into account when planning for use of the capping stack.

Secretary Chu and Hunter briefed the President on the capping stack in late June or early July, and he approved its use. The government appears to have delayed installation for a few days, however, to continue analyzing the significant risks of shutting in the well.[274] One critical analysis involved the geology surrounding the Macondo well. The government's scientific Well Integrity Team concluded that it would take a total of approximately 100,000 barrels of oil flowing through the rupture disks into the surrounding rock for oil to create paths through the rock to the sea floor. The Team further concluded that such paths were likely to close or "heal" *if* BP and the government detected oil flow into the rock and reopened the capping stack with sufficient speed. To spot any

Voices from the Gulf

"This unnatural, unnatural catastrophe. . . ."

The Louisiana Seafood Marketing and Promotion Board

Al & Sal Sunseri, P&J Oyster Company, New Orleans, LA

Al and Sal Sunseri are co-owners of P&J Oyster Company, their family's 134-year-old business in the French Quarter of New Orleans. P&J processes and sells some 60,000 Louisiana oysters to the city's best restaurants and local oyster bars on a typical day. When Al first heard about the *Deepwater Horizon* rig accident, he recalled thinking, "'What a terrible thing for those people.'" He added, "I didn't think more about it because the Coast Guard and everyone said it would be limited."

Al's routine remained unchanged in the days after the *Deepwater Horizon* blowout and fire: early mornings bustling with deliveries, the din of his skilled shuckers pounding and prying open oysters, preparing orders. Then, on Saturday, April 24, the Sunseris and the rest of America heard that oil was leaking from the rig's broken riser. With each passing day, the news only got worse.

P&J oysters are an institution in New Orleans, a celebrated brand proudly listed on local menus as a promise of taste and quality. P&J specializes in Louisiana oysters; most of their suppliers farm in the Barataria Basin, west of the Mississippi River. P&J had survived floods, the Great Depression, and even Hurricane Katrina. But now, the Sunseri family and the staff were all at the mercy of a runaway oil spill, with no end in sight.

Throughout May, the Macondo well gushed on unchecked, and by early June, the government had closed Louisiana oyster beds. The Sunseris had taken over from their father 25 years earlier. Now, for the first time, they had to lay off 11 skilled shuckers. "These ladies here, those guys—I grew up with them," Al said. "We were in our twenties when we started." Longtime employee Wayne Gordon, 42, had been shucking at P&J since he was 18: "Twenty-four years. I cannot imagine not being here." As the shuckers worked their way through what was to be the final pile of succulent Louisiana shellfish, the owner of a nearby restaurant appeared with a breakfast buffet of scrambled eggs, fried ham, grits, and biscuits. "After a funeral, we bring food," said the restaurateur, a longtime customer.

Al's son Blake, 24, has spent the past three years learning the business, intent on becoming the sixth family generation to run it. "This is a real devastating event for me," he said. "This is my home, it feels like I don't really have a say in what's going on around me." He could have been speaking for millions of his fellow Americans, all along the Gulf of Mexico coast, who suddenly found themselves and their worlds facing ruin from what his uncle, Sal, called "this unnatural, unnatural catastrophe."

problem quickly enough to avoid lasting damage, the Team recommended monitoring shut-in pressure at the BOP as well as visual, seismic, sonar, and acoustic data.[275] Because shutting the capping stack would increase the pressure inside the well, the government was also concerned about bursting either the rupture disks (if they had not already collapsed) or another weak point in the casings. One industry executive recalled discussing this issue on a conference call with the science advisors; he expressed his view that allowing the pressure to climb above the level recorded during the top kill would be traveling into uncharted territory, with uncertain risks.

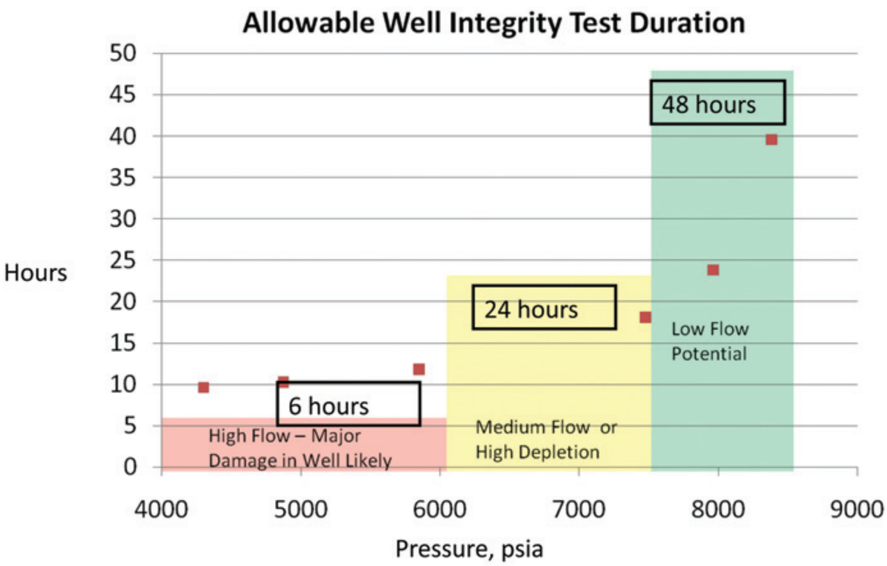
On July 9, as analysis of these risks continued, Admiral Allen authorized BP to install the capping stack, but not to close it.[276] The extremely complicated operation began the next day. After removing the top hat from the top of the riser, remotely operated vehicles had to unbolt the stub of riser connected to the top of the *Deepwater Horizon* BOP stack, remove this stub, look for any pieces of drill pipe sticking up through the top of the BOP stack, slide the capping stack into place, and bolt it to the BOP stack. The process went smoothly, and BP finished installing the capping stack without incident by July 12. Suttles described this installation as the best operation of the entire source-control effort.[277]

BP next prepared to temporarily close the capping stack in a planned "well integrity test," to determine whether the well had been compromised and oil could flow into the rock formation. In a July 12 letter, Admiral Allen formally authorized the test to begin.[278] But it did not. About two hours before the test was supposed to start, the government teams met with BP and industry representatives, including from Exxon (in person) and Shell (by phone). Secretary Chu and Admiral Allen were both present in person. BP faced significant criticism of the wisdom of attempting the test, with Exxon and Shell raising concerns associated with shutting in the well that had yet to be considered by BP or the government.[279] In the most extreme scenario, one industry expert suggested that an underground blowout could cause the sands around the wellhead to liquefy and the entire BOP to disappear into the sea floor.[280] Because Secretary Chu and the science advisors believed that these risks required further study, Admiral Allen delayed the test to allow for 24 hours of additional analysis.[281]

Overnight, the government science teams reached out to industry and academia for help. By 10:00 the next morning, experts had reassured the government that catching a leak early enough would prevent catastrophic consequences.[282] With the government teams satisfied, Admiral Allen reauthorized the well integrity test. The test was to last from 6 to 48 hours, and BP had to monitor pressure, sonar, acoustic, and visual data continuously, as recommended by the Well Integrity Team.[283] Secretary Chu required BP to dedicate two remotely operated vehicles to visually monitor for leaks at the wellhead.

Although the Well Integrity Team had calculated that it would take a leak of approximately 100,000 barrels for oil and gas to reach the sea floor, the government was prepared to permit a leak of only 20,000 barrels before requiring the capping stack to be reopened.[284] Using an estimate for the expected pressure at shut-in derived from BP's modeling of the reservoir, the Team developed guidelines for the length of the test.[285] If the pressure at shut-in was less than 6,000 pounds per square inch, major well damage was likely—BP would

FIGURE 5.1: Protocol for Well Integrity Test



▪ Duration (in hours) calculated by National Labs flow analysts using estimated flow rates at varying BOP (PT-B) pressures and maximum allowable flow into formation of 20,000 bbls.

have to terminate the test within six hours and reopen the well. If the shut-in pressure was greater than 7,500 pounds per square inch, the risk of a leak was low, and the test could proceed for the full 48 hours. Finally, if the shut-in pressure was between 6,000 and 7,500 pounds per square inch, the risk of a leak was uncertain—either there was a medium-sized leak or the reservoir was highly depleted. Under this scenario, the test could proceed for 24 hours. (See Figure 5.1.) If the pressure was too high, there was also the risk of causing a new rupture.

After a 24-hour delay to repair a minor leak, BP shut the stack and began the well integrity test at about 2:25 p.m. on July 15.[286] For the first time in 87 days, no oil flowed into the Gulf of Mexico. Initial wellhead pressure readings were just over 6,600 pounds per square inch—in an uncertain middle range that one senior administration official termed "purgatory"—and rising slowly.[287] Later that afternoon, the science advisors, including McNutt and Hunter, met with Secretaries Salazar and Chu to determine whether to keep the well shut in. Based on the early pressure data, the group appears to have been firmly in favor of reopening the well. Garwin, who had opposed even undertaking the well integrity test, voiced the strongest opinion, arguing BP ought to stop the test immediately and wondering whether it was already too late. No one at the meeting appears to have argued in favor of keeping the well closed.[288]

Following the science team meeting, Admirals Allen and Cook, Browner, Secretaries Chu and Salazar, and McNutt had a series of conversations to determine how to proceed. Keeping the capping stack shut could cause an underground blowout and, in the worst case, loss of a significant portion of the 110-million-barrel reservoir into the Gulf.[289] This risk had to be balanced against the benefit of stopping the spill, a continuing environmental disaster. The government decisionmakers recognized that the public wanted the well plugged and the flow of oil into the Gulf stopped, but the risk of causing greater harm was real.

Admiral Cook made the argument that eventually prevailed. He reminded the others that, before the test began, BP and the government had considered the possibility of pressure measurements like those being observed. Both had agreed that, in such a case, the test should last 24 hours, with consultation between the parties before reopening the well.[290] The government leaders decided that they should follow this protocol: the stack would stay closed overnight.

This additional time proved critical. Using a single cell-phone photograph of the plot of initial pressure readings, Paul Hsieh, a U.S. Geological Survey scientist then in Menlo Park, California, worked overnight to develop an explanation of the results of the test, including the lower-than-expected shut-in pressure. Pre-test expectations had been based on an incomplete understanding of the reservoir's geometry and on pressure readings from a single gauge at the bottom of the BOP, which was only accurate to plus or minus 400 pounds per square inch and functioning sporadically. At the government's behest, BP had equipped the capping stack with pressure gauges.[291] Following the shut-in of the well, those gauges provided accurate pressure data for the first time. Using that data along with a flow-rate estimate of 55,000 barrels per day and BP's estimate that the reservoir contained 110 million barrels of oil, Hsieh was able to generate a model that predicted the observed shut-in pressure without having to assume a significant oil and gas leak into the rock formation.[292]

The next morning, the government principals and the science advisors—who had been convinced that reopening the stack was necessary—hosted a meeting. Both BP and Hsieh made presentations explaining the observed pressures at shut-in, with BP arguing that the well should remain capped.[293] Participants had different recollections as to whether Hsieh's or BP's presentation carried more weight. But the outcome of the meeting was clear: the stack would stay shut, with the government reevaluating that decision every six hours.

While it went unrealized at the time, a critical point had passed. As intense monitoring of the area around the wellhead continued over the next several days, Hsieh's model continued to predict the behavior of the well, and a leak into the formation became progressively less likely.[294] Although the well integrity test had originally been scheduled to last a maximum of 48 hours, Admiral Allen began to extend it in 24-hour increments beginning on July 17. At his July 24 press briefing, he stated what was by then plain: "our confidence [in the capping stack] is increasing and we have better integrity in the well than we may have guessed."[295]

Meanwhile, on July 19, BP publicly raised the possibility of killing the well before completing a relief well, through a procedure called a "static kill."[296] Like the top kill, the static kill involved pumping heavy drilling mud into the well in an effort to push oil and gas back into the reservoir. But because the oil and gas were already static, the pumping rates required for the static kill to succeed were far lower than for the top kill.

The primary concern with the static kill was the pressure it would put on the well. On July 28, BP received an unsolicited letter from Pat Campbell, a Vice President at Superior Energy Services, which owned BP contractor Wild Well Control, recommending in no uncertain terms that the static kill not proceed. Campbell, who had worked with legendary well-control expert Red Adair, reiterated a point already raised by others in the industry: that the only pressure the well could withstand for certain was the current shut-in pressure (approximately 6,920 pounds per square inch at the time he wrote).[297]

Despite these issues, after some delays caused by weather and work on the first relief well, the government approved the plan for the static kill on August 2.[298] A mud injection test began on August 3, and pressure at the wellhead increased only slightly before beginning to drop.[299] Based on the positive results of the test, BP began slowly pumping more drilling mud into the well later that same day. By 11:00 p.m., the static kill had succeeded.[300] The following evening, Admiral Allen authorized BP to follow the mud with cement.[301] BP finished cementing the next day. On August 8, Admiral Allen reported that the cement had been pressure-tested and was holding.[302]

The Fate of the Oil (August 4)

On August 4, the same day it announced the static kill's success, the federal government released a 5-page report titled *BP Deepwater Horizon Oil Budget: What Happened to the Oil?*, as well as a 10-page supporting document titled *Deepwater Horizon MC252 Gulf Incident Oil Budget*.[303] The "Oil Budget" provided the government's first public estimate of the total volume of oil discharged during the spill—roughly 4.9 million barrels. The government arrived at this number using its current flow-rate estimate, which ranges from 62,200 barrels per day on April 22 to 52,700 barrels per day on July 14, just before the capping stack stopped the flow.[304] * The Oil Budget also described the efficacy of different response methods.

The Oil Budget was originally an operational tool, intended as a guide for responders, not as the basis for a scientific report on what happened to the oil. Nonetheless, in late July, the White House decided to publicly release the Oil Budget and asked NOAA to take the lead on drafting a short report to introduce the tool.[305] The Budget cleared the interagency review process in time for its August 4 release.†

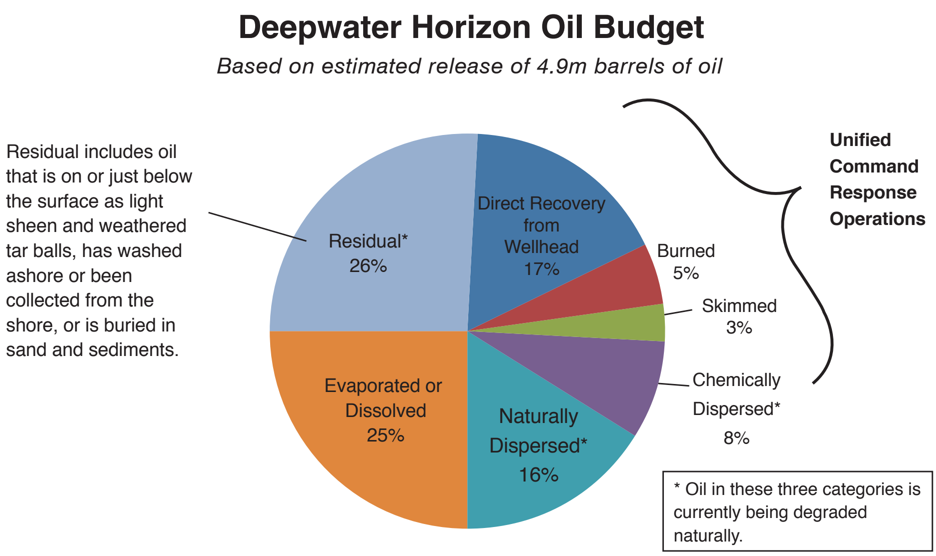
The White House's Browner appeared on six morning newscasts on August 4 to discuss both the successful static kill and the Oil Budget report. On *NBC*, *MSNBC*, and *ABC*, she told viewers that, according to the report, "the vast majority," or approximately three-quarters, of the oil "is gone" or "appears to be gone."‡ The Budget, however, did not

* The government's estimate, which is current as this report goes to press, has an uncertainty factor of ±10 percent. It is the Commission's understanding that the government's Flow Rate Technical Group will issue a final report in January 2011. In a peer-reviewed paper published in *Science Express* on September 23, 2010, Timothy Crone and Maya Tolstoy of Columbia University's Lamont-Doherty Earth Observatory estimated that the total release was roughly 5.2 million barrels—slightly higher than the government's estimate. While BP has not released its own flow-rate figures, it has suggested that the government's estimate of the total amount of oil released from the Macondo well is 20 to 50 percent too high.

† During the review process, EPA expressed concerns about the pie chart's potential to obscure the uncertainty of the government's estimates. Lisa Jackson, e-mail to Jane Lubchenco, July 31, 2010. For example, EPA recommended that NOAA combine chemically and naturally dispersed oil into a single category because there was not enough information to accurately distinguish between the two mechanisms. Bob Perciasepe, e-mail to Jane Lubchenco and others, July 31, 2010; Bob Perciasepe, e-mail to Stephen Hammond and others, August 1, 2010. NOAA disagreed. Administrator Jane Lubchenco asserted that combining the two categories would not decrease any uncertainty and that "'[c]hemically dispersed' is part of the federal response and 'naturally dispersed' is not, and there is interest in being able to sum up the federal response efforts." Jane Lubchenco, e-mail to Bob Perciasepe and others, August 1, 2010.

‡ On the other three shows, Browner similarly stated that "what the scientists are telling us is that the vast majority of the oil has been cleaned, it's been captured, it's been skimmed, it's been burned, mother nature has done its part" (*Fox News*); "our scientists are telling us that the vast majority of the oil has been contained, it's been burned, it's been cleaned" (*CBS*); and "our scientists and external scientists believe that the vast majority of the oil has now been contained, it's been skimmed, mother nature has done its part, it's been evaporated" (*CNN*).

FIGURE 5.2: August 4 Oil Budget



show that most of the oil was gone. The three-quarters of the oil not in the "remaining" category included "dissolved" and "dispersed" oil that was potentially biodegrading, but not necessarily gone. By 9:00 a.m., NOAA Administrator Jane Lubchenco e-mailed Browner's deputy and other officials to express her concern "that the oil budget is being portrayed as saying that 75% of the oil is gone": "It's not accurate to say that 75% of the oil is gone. 50% of it is gone—either evaporated or burned, skimmed or recovered from the wellhead." Lubchenco asked the officials to "help make sure" the error was corrected.[306*] She had made the same point to the White House before the Budget rollout; a July 30 e-mail to Browner's deputy had emphasized that Lubchenco opposed grouping dispersed oil with recovered oil because the former was "still out there or [was] being degraded."[307]

At a press briefing that afternoon, Browner said that the report had "been subjected to a scientific protocol, which means you peer review, peer review, and peer review." Earlier in the same briefing, Lubchenco had said "[t]he report was produced by scientific experts from a number of different agencies, federal agencies, with peer review of the calculations that went into this by both other federal and non-federal scientists."[308] The Budget, however, was not "peer-reviewed" as the scientific community uses that term. Many of the outside scientists listed as reviewers had not even seen the final report.

The rollout of the Oil Budget drew immediate criticism, with scientists pointing out that Browner's optimism about the percentage of the oil that was gone was unsupported, especially because of the uncertain rate of biodegradation.[309] Moreover, after a summer of ever-increasing official estimates of the spill's size, the public was dubious of the government's conclusions. As a *Times-Picayune* editorial noted, "From the start of the

[*] The U.S. Geological Survey, which had also been involved in developing the Oil Budget tool and editing the report, expressed similar misgivings about the portrayal of the report. At 11:00 a.m., U.S. Geological Survey scientist Mark Sogge told a colleague, "We need to keep in mind, and make it clear to others, that this is NOT a [U.S. Geological Survey] product." Mark Sogge, e-mail to Stephen Hammond, August 4, 2010.

disaster. . . the government has badly underestimated the amount of oil spewing from the runaway well. That poor track record makes people understandably skeptical of [the Oil Budget] report."[310] Lubchenco has since acknowledged that she was "in error" when claiming that the Oil Budget had been peer-reviewed.[311] NOAA has emphasized that the report's "purpose was to describe the short-term fate of the oil and to guide immediate efforts to respond to the emergency" rather than to "provide information about the impact of the oil" or "indicate where the oil is now."[312]

NOAA supplied these explanations on November 23, when it released a new version of the Oil Budget: *Oil Budget Calculator Technical Documentation*, a peer-reviewed report of over 200 pages that gave the formulas used and updated the percentages in the original budget.[313] The new version's biggest change was its estimate of the amount of oil chemically dispersed, which doubled from 8 percent to 16 percent. Of this additional 8 percent, 3 percent came from the "naturally dispersed" category, 2 percent from the "evaporated or dissolved" category, and 3 percent from the "residual" category. (These changes brought the total amount of "residual" oil down from 26 to 23 percent.)

As a tool for responders, the Oil Budget indicated that response and containment operations collected, eliminated, or dispersed about 41 percent of the oil, with containment ("direct recovery from wellhead") the most effective method, and chemical dispersants breaking down a substantial fraction. Response technology (skimming or burning) removed—as opposed to dispersed—only 8 percent of the oil. Dispersion of the oil before it reached the surface limited the amount that responders could skim, burn, or disperse at the surface. Nevertheless, responders considered burning an important success: it had never before been attempted on this scale, and burning techniques advanced during the spill.[314] Skimming was less of a success: despite the participation of hundreds of ships and thousands of people, it collected only 3 percent of the oil.

The least effective response technology was the berms, which the Oil Budget documents do not even mention. By the time BP capped the well on July 15—day 44 of the berm construction project—Louisiana's contractor estimated that 10 percent of one reach—6 percent of the total project—had been completed.[315] In late May, Governor Jindal had asserted that "[w]e could have built 10 miles of sand [berms] already if [the Corps] would have approved our permit when we originally requested it."[316] In fact, it took five months to build roughly 10 miles of berms, at a cost of about $220 million.[317] Estimates of how much oil the berms collected vary, but none is much more than 1,000 total barrels.[318] On November 1, Governor Jindal announced plans to convert the berms into part of a long-term coastal restoration project, which BP would continue to fund. In his recently released book, the Governor maintained that the berms were "one of the most effective protection measures" against oil reaching the Louisiana coast.[319]

The End of the Well, but Not the End of the Response

In mid-September, the first relief well—which BP had begun drilling in early May—finally intercepted the Macondo well, allowing BP to pump in cement and permanently seal the reservoir. On September 19, 152 days after the blowout, Admiral Allen announced: "the Macondo 252 well is effectively dead."[320]

But fears about health and safety did not die with the well. Some Gulf residents continued to believe that BP had used dispersants onshore, nearshore, at night, and without government approval, and that it had continued using them after it capped the well. The Commission has not seen credible evidence supporting these claims. NOAA reopened one-third of the area closed to fishing on July 22 and continued to reopen additional sections based on a testing and sampling protocol developed and implemented with the Food and Drug Administration.[321] But some scientists questioned the protocol, while some fishermen were hesitant to give up income from the Vessels of Opportunity program and return to their regular jobs in the midst of public concern about Gulf seafood.[322] (Chapter 6 discusses seafood safety.)

Residents also had to cope with the miles of used boom and other debris. Despite the typical spill-responder uniform of rubber gloves and protective coveralls, BP planned to send the thousands of tons of oily debris generated over the summer to ordinary municipal landfills.[323] Wastes from oil exploration and production are classified as non-hazardous by law and do not require specialized disposal.[324] Although the federal government generally does not supervise the disposal of non-hazardous waste, on June 29, the Coast Guard and EPA issued a directive requiring BP to test its waste for hazardous elements, publicize the results, and consult with the communities where the waste was to be stored.[325] In addition, EPA announced it would conduct its own twice-monthly testing of the debris and would post the results online.[326] BP was initially slow to release its testing data. After receiving a sternly-worded letter from Federal On-Scene Coordinator Admiral Zukunft on July 24, however, it started regularly posting the results on its website.[327] EPA began sampling the waste and posting the test data as well, after some criticism and delay.[328] As of November 17, EPA's tests had not shown any of the waste to be hazardous.[329]

As BP and EPA implemented the waste directives, environmental justice activists argued that BP was dumping the debris disproportionately in poor and non-white communities.[330] Residents of Harrison County, Mississippi fiercely opposed the disposal of oiled waste in their Pecan Grove landfill, and BP agreed not to use it.[331] Environmental justice advocate and scholar Robert Bullard contended that the racial makeup of Harrison County was a factor, and EPA objected to BP's decision.[332] The Federal On-Scene Coordinator instructed BP to follow the approved waste plan, noting that "[a]llowing one community to reject acceptance of waste. . . may complicate remaining waste disposal efforts." BP began to use the site for waste staging, though not for disposal.[333]

With the well sealed, the number of responders in the Gulf decreased. The National Incident Command officially stood down on October 1.[334] Admiral Allen turned over the remaining tasks to Federal On-Scene Coordinator Admiral Zukunft and finally retired. BP started to shut down some of its programs, and Coast Guard responders started to head to their next posts. The spill and the emergency response had ended. Figuring out the extent of the damage, and how to repair it, had begun.

Voices from the Gulf

"I don't know what to do with myself."

Susan Poag/The Times-Picayune. Photo © 2010 The Times-Picayune Publishing Co., all rights reserved. Used with permission of The Times-Picayune.

Dean Blanchard, Dean Blanchard Seafood Inc., Grand Isle, LA

Dean Blanchard runs Louisiana's biggest shrimp business, on Grand Isle—a Mississippi River Delta barrier island 50 miles south of New Orleans, fully exposed to the Gulf of Mexico. During the warm months of a typical shrimp season, Blanchard Seafood and its extensive network of bayside wharves are a frenetic cacophony of languages and accents—Spanish, Vietnamese, a smattering of Cajun French, and the various Deep South dialects—as more than a thousand fishermen offload the catch from their shrimping vessels. The shrimp are sorted by size and dispatched into the world.

During 30 years in business, Blanchard had become one of the nation's principal suppliers—and a multi-millionaire. In season, he bought as much as 500,000 pounds of shrimp daily from more than a thousand fishermen. The cold 2009-2010 winter had raised high hopes: "Every 10 years, when you get a cold winter, you get a really good shrimp crop," he explained. "We were licking our chops."

But with the Macondo well gushing more than 50,000 barrels of oil a day, and no end in sight, the brown shrimp season had been canceled just as it was about to start. By mid-May, tar balls and oil had started washing up onto Grand Isle's wetlands and beaches. By mid-June, Blanchard figured, "I've lost $15 million of sales in the last 50 days. That would have been $1 million in my pocket." The usually busy docks were quiet, the only activity the occasional coming and going of boats and crews working for BP cleaning and containing the oil."I don't know what to do with myself," Blanchard explained. "I built all this over the last 30 years, and now for what?" "We've got 1,400 vessels that go and catch shrimp, come to our facility." Now, he continued, "basically we've lost all our customers because we can't supply them."

For decades, oil and seafood had mixed comfortably in Louisiana's coastal culture. Each year Morgan City hosted the annual Shrimp and Petroleum Festival, a rollicking celebration of the state's two high-profile economic mainstays. Oil has long provided the region's best-paying jobs, and the revenue to finance everything from state roads to free school books. The maritime world of seafood has deeper cultural roots, and provides a living and a way of life along the gulf coast, one of the nation's most productive fishing waters. Many families had members in both worlds. Indeed, Blanchard's own grandfather had made a fortune servicing the offshore oil industry.

But now those two worlds had collided—and everything seemed at risk.

Chapter Six

"The worst environmental disaster America has ever faced."

Oiling a Rich Environment: Impacts and Assessment

When President Barack Obama addressed the nation from the Oval Office on June 15—nearly two months after the Macondo well began gushing crude oil and one month before engineers subdued it—he said:

> Already, this oil spill is the worst environmental disaster America has ever faced. And unlike an earthquake or a hurricane, it's not a single event that does its damage in a matter of minutes or days. The millions of gallons of oil that have spilled into the Gulf of Mexico are more like an epidemic, one that we will be fighting for months and even years.[1]

The *Deepwater Horizon* blowout produced the largest accidental marine oil spill in U.S. history,[2] an acute human and environmental tragedy. Worse still, as discussed in Chapter 7, it occurred in the midst of environmental disasters related to land-based pollution and massive destruction of coastal wetlands—chronic crises that proceed insidiously and will require not months but decades of national effort to address and repair.

A lone beachgoer encounters bands of oil along Alabama's Orange Beach. Though wind and currents helped keep most of the spilled oil offshore, all told some 650 miles of Gulf Coast habitat were oiled to one degree or another—Louisiana was hardest hit—impacting ecosystems, the economy, and human health.

< Tyrone Turner/Photo courtesy of National Geographic

Laws guide resolution of damages from the spill itself. There is a suite of policies and programs aimed at improving discrete environmental issues within the Gulf and along its coast. The law also provides compensation for direct economic impacts. This chapter analyzes these immediate impacts, not only on the natural environment but also on the economy and on human health in the affected region. Unfortunately, the human-health effects are the least-recognized fallout from the spill, and those least-well addressed in existing law and policies.

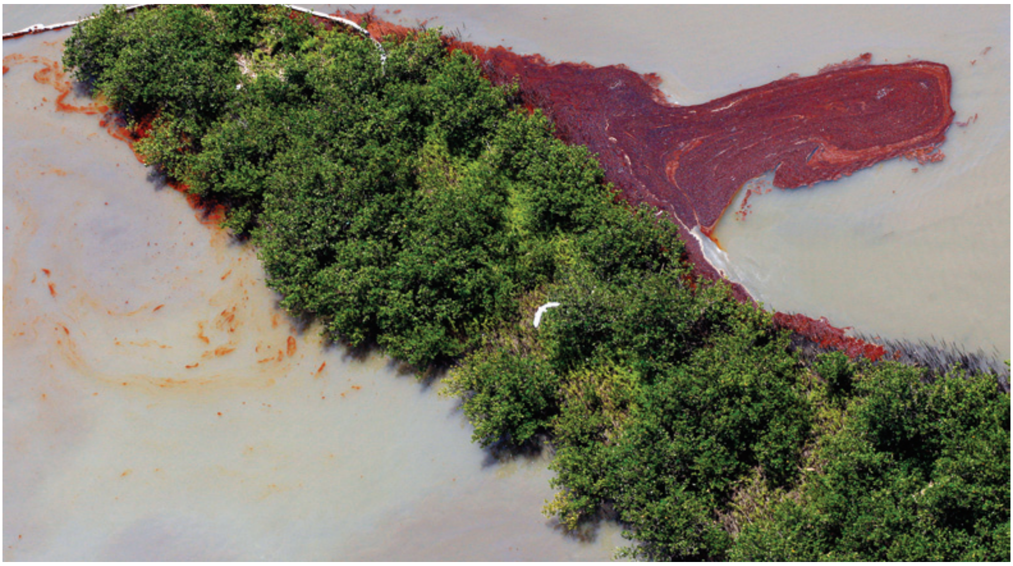
The Impact on Nature

The *Deepwater Horizon* oil spill immediately threatened a rich, productive marine ecosystem. To mitigate both direct and indirect adverse environmental impacts, BP and the federal government took proactive measures in response to the unprecedented magnitude of the spill.[3] Unfortunately, comprehensive data on conditions before the spill—the natural "status quo ante" from the shoreline to the deepwater Gulf—were generally lacking.[4] Even now, information on the nature of the damage associated with the released oil is being realized in bits and pieces: reports of visibly oiled and dead wildlife, polluted marshes, and lifeless deepwater corals. Moreover, scientific knowledge of deepwater marine communities is limited, and it is there that a significant volume of oil was dispersed from the wellhead, naturally and chemically, into small droplets.[5] Scientists simply do not yet know how to predict the ecological consequences and effects on key species that might result from oil exposure in the water column, both far below and near the surface.[6]

Much more oil might have made landfall, but currents and winds kept most of the oil offshore, and a large circulating eddy kept oil from riding the Loop Current toward the Florida Keys.[7] Oil-eating microbes probably broke down a substantial volume of the spilled crude, and the warm temperatures aided degradation and evaporation[8]—favorable conditions not present in colder offshore energy regions.[9] (Oil-degrading microbes are still active in cold water, but less so than in warmer water.) However widespread (and in many cases severe) the natural resource damages are, those observed so far have fallen short of some of the worst expectations and reported conjectures during the early stages of the spill.[10] So much remains unknown that will only become clearer after long-term monitoring of the marine ecosystem. Government scientists (funded by the responsible party) are undertaking a massive effort to assess the damages to the public's natural resources. Additionally, despite significant delays in funding and lack of timely access to the response zone, independent scientific research of coastal and marine impacts is proceeding as well.

A rich marine ecosystem. Particularly along the Louisiana coast, the Gulf of Mexico is no stranger to oil spills.[11] But unlike past insults, this one spewed from the depths of the ocean, the bathypelagic zone (3,300–13,000 feet deep). Despite the cold, constant darkness and high pressure (over 150 atmospheres), scientists know that the region has abundant and diverse marine life. There are cold-water corals, fish, and worms that produce light like fireflies to compensate for the perpetual night. Bacteria, mussels, and tubeworms have adapted to life in an environment where oil, natural gas, and methane seep from cracks in the seafloor. Endangered sperm whales dive to this depth and beyond to feed on giant squid and other prey.[12]

Elmer's Island in Grand Isle, La.



A dark tongue of oil invaded sensitive wetlands last May near Grand Isle, Louisiana, despite the presence of booms deployed to stop it. In a hopeful development over the summer, scientists found new plant growth in similarly oiled marshes, indicating that oil had not penetrated into root systems.

Patrick Semansky/Associated Press

Higher up the water column, light and temperature gradually increase and the ascending sperm whales—and Macondo well oil—encounter sharks, hundreds of fish species, shrimp, jellyfish, sea turtles, and dolphins. As the sperm whales surface for air at the bright and balmy Gulf surface, they pass through multitudes of plankton, floating seaweed beds, and schools of fish. Some of these fish species spend their early lives in the coastal waters and estuaries; others travel along annual migration routes from the Atlantic Ocean to the Gulf. The floating seaweed beds (sargassum), fish larvae, and plankton drift with the surface currents and are driven by the wind—as is the oil rising from below. The critical sargassum habitats lure sea turtles, tuna, dolphins, and numerous game fish to feed on the snails, shrimp, crabs, and juvenile species that seek shelter and food in the seaweed.[13]

Overhead are multitudes of seabirds—among them brown pelicans, northern gannets, and laughing gulls—that in turn feed in the ocean and coastal estuaries.[14] Dozens of bird species fly the Mississippi migration route each year, a major attraction for bird watchers, who flock to coastal Louisiana and Texas to catch a glimpse of migrating and resident shorebirds and nesting seabirds. Some of these birds feed on estuarine shrimp, fish, and crabs; others depend on shellfish and other small organisms that populate the expansive mudflats. Larger wading birds stalk their prey in the shallow water of mangroves, marshes, and other habitats that shelter fish and frogs. Raptors, including ospreys, bald eagles, and peregrine falcons, also pluck their prey from any of these environments and carry it to their perches.

As the unprecedented volume of oil gushing from the Macondo blowout reached the surface, it had the potential to affect all of these marine and coastal organisms and to wash into the salt marshes, mudflats, mangroves, and sandy beaches—each in its way an

Oiled Sargassum

Wildlife biologist Mark Dodd surveys a raft of oil-soaked sargassum, also known as gulfweed. The floating beds are home to snails, shrimp, crabs, and other small creatures that—oiled or not—are ingested by turtles, dolphins, tuna, and game fish.

Blair Witherington/FWC

essential habitat at one or more stages of many species' lifecycles.[15] And these marine and coastal species are so interdependent that a significant effect on any one has the potential to disturb several existing populations in this complex food web.[16]

Encountering oil. Organisms are exposed to oil through ingestion, filtration, inhalation, absorption, and fouling.[17] Predators may ingest oil while eating other oiled organisms or mistaking oil globules for food. Filter feeders—including some fish, oysters, shrimp, krill, jellyfish, corals, sponges, and whale sharks—will ingest minute oil particles suspended in the water column. Surface-breathing mammals and reptiles surrounded by an oil slick may inhale oily water or its fumes. Birds are highly vulnerable to having their feathers oiled, reducing their ability to properly regulate body temperature.[18] Moderate to heavy external oiling of animals can inhibit their ability to walk, fly, swim, and eat. Similarly, oiling of plants can impede their ability to transpire and conduct photosynthesis, and oiling of coastal sediments can smother the plants they anchor and the many organisms that live below.

Americans watched as the oil eventually came to rest along intermittent stretches of the Gulf coast. Before it arrived, scientists rushed to collect crucial baseline data on coastal and water-column conditions. Some of the oil propelled up from the wellhead was dispersed by natural and chemical means (as described in Chapter 5), creating a deep-ocean plume of oil droplets and dissolved hydrocarbons.[19] A portion of the oil that rose to the surface was also naturally and chemically dispersed in the shallow water column.[20]

The oil that made landfall was fairly "weathered," consisting of emulsions of crude oil and depleted of its more volatile components. More than 650 miles of Gulf coastal habitats—

salt marsh, mudflat, mangroves, and sand beaches—were oiled; more than 130 miles have been designated as moderately to heavily oiled. Louisiana's fragile delta habitats bore the brunt of the damage, with approximately 20 additional miles of Mississippi, Alabama, and Florida shorelines moderately to heavily oiled.[21] Light oiling and tar balls extended east to Panama City, Florida. Except for occasional tarballs, *Deepwater Horizon* oil never reached Texas or the tourism centers along the southwest Florida coast.[22]

Assessing the mixture of oil and life at the water's edge. The most biologically productive area along a sandy beach occurs where seaweed and other organic materials wash up just above the high tide line in the "wrack zone." Here, shorebirds forage for insects and other small organisms. As oil moves onto a beach with the rising tide, it is deposited in the wrack zone. Removing oiled wrack is the most prudent means of removing the oil—but doing so removes the living community, too. As the response to the spill proceeded, the Audubon Society evaluated wrack density along shorelines; it found that the wrack density on beaches east of the Mississippi River, where cleanup activities occurred, was "nearly absent," indicating "diminished habitat quality."[23]

Few beachgoers realize that millions of microscopic organisms live in the Gulf's soggy sands between high and low tide. By comparing samples taken before and after beaches were oiled, Holly Bik of the University of New Hampshire's Hubbard Center for Genome Studies, together with scientists at Auburn University and the University of Texas, hopes to determine the impact on this understudied community of sediment-dwelling microfauna.[24]

Tidal mudflats, generally devoid of vegetation and exposed at low tide, are more sensitive to pollutants than beaches.[25] The Louisiana delta and the estuarine bays of Mississippi and Alabama have large expanses of tidal mudflats, which support dense populations of burrowing species (vulnerable to smothering), foraging birds, crabs, and other organisms.[26] As oil settles on the flats, crabs and other burrowing animals help mix the oil into the sediment layer (an ecological process called bioturbation), extending the potential damage below the surface.[27]

Salt marsh and mangroves are both highly productive and sensitive habitats. Marsh grasses tolerate surface coating by weathered oil fairly well, but they will die if oil penetrates the saturated sediments and is absorbed by the root system.[28] When that happens, the plants' root systems degrade, making the marsh much more susceptible to erosion and threatening the habitat on which a wide variety of animals depend. People and equipment deployed in response to the spill can themselves damage the marsh; for example, summer storms pushed boom (used to corral waterborne oil) deep into the marshes, from which it could only be removed by intrusive methods that caused additional harm to the marsh topography.[29] Scientists working in oiled marshes observed new plant growth during the summer of 2010—a positive sign that oil had not penetrated into the rich, organic soils and inhibited root systems.[30] Professor Eugene Turner of Louisiana State University's Coastal Ecology Institute plans to study the effects of oil on the local salt marshes for at least the next year. His preliminary observations, through the fall of 2010, indicate some stress resulting in loss of marsh along its edge, but the estimated loss "pales in comparison" to the annual loss associated with dredging and flood protection (described in Chapter 7).[31]

The marine impacts. When water temperatures warm in the late spring, female oysters release millions of eggs into the water column. The timing of the Macondo oil spill may have been detrimental to oyster reproduction and the spawning of many other species.[32] Submerged oil floating in the nearshore water column poses potential threats to diverse shellfish and fish species. Although the impacts are not yet known, the presence of oil in the nearshore environment has been documented. Oil that reached the Gulf's estuarine waters forced closures of and likely damaged substantial tracts of Louisiana oyster beds.[33] Oyster mortality observed in the highly productive areas of Barataria Bay and Breton Sound, estuaries that flank the lower Mississippi River, appear to be due, in large part, to the flood of fresh water introduced through river diversions in what many believe was a futile attempt to keep oil from entering the estuarine areas.[34]

Beyond their commercial import, oysters are a keystone species—an organism that exerts a shaping, disproportionate influence on its habitat and community.[35] A single adult oyster can filter more than one gallon of water per hour, effectively removing impurities—including oil—from the water column.[36] Oyster reefs established on an estuary's muddy bottom can increase the surface area fifty-fold, creating intricate habitats for crabs, small fish, and other animals, which in turn sustain larger species.[37]

Harriet Perry, Director of the Center for Fisheries Research and Development at the University of Southern Mississippi, and scientists at Tulane University are studying the potential effects of oil on larvae of blue crabs, another keystone species. The slick from the Macondo oil spill ultimately covered about 40 percent of the offshore area used by larvae of the northern Gulf's estuarine-dependent species.[38] The Gulf coast's blue crab population had already declined considerably during the past 8 to 10 years as a result of a regional drought.[39] Perry and other scientists raced to take samples before the oil arrived and then after, hoping to be able to separate the oil-related impacts on wildlife from climate-related changes.[40]

Many large fish species are dependent on the health of the estuarine and marine habitats and resources. The National Oceanic and Atmospheric Administration (NOAA) noted that species with "essential fish habitat"[41] near the oil spill include scalloped hammerhead, shortfin mako, silky, whale, bigeye thresher, longfin mako, and oceanic whitetip sharks; and swordfish, white marlin, blue marlin, yellowfin tuna, bluefin tuna, longbill spearfish, and sailfish. Other important Gulf fish include red snapper, gag grouper, gray triggerfish, red drum, vermilion snapper, greater amberjack, black drum, cobia and dolphin (mahi-mahi); coastal migratory open-water species, such as king and Spanish mackerel; and open-water sharks.[42]

Oil in the water column affects fish and other marine organisms through dermal contact, filtration, or ingestion. How much oil they accumulate depends on its concentration in food, water, and sediments they encounter, time and exposure, and the characteristics of each species—particularly the extent of their fatty tissue. Although oil is not very soluble

Voices from the Gulf

"I have to make house payments and boat payments."

Claire Luby

Ve Van Nguyen,

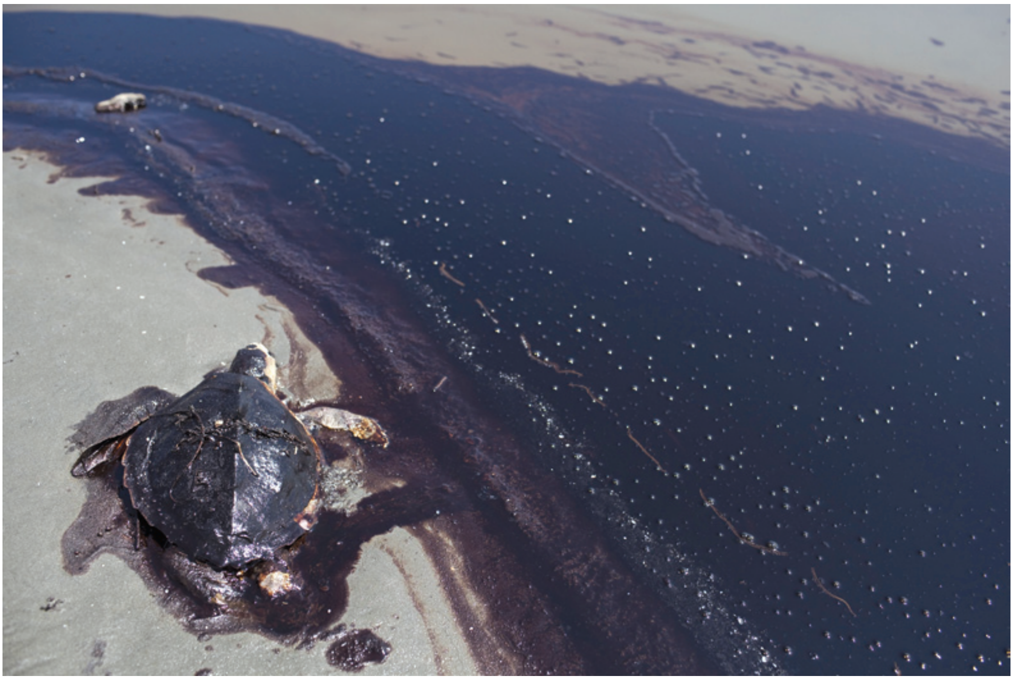
Oysterman, Buras, LA

Ve Van Nguyen was an oystermen working for one of the suppliers to P&J Oyster Company. A Vietnamese refugee who fled his homeland with his wife and young family in a boat in 1978, Van Nguyen had made it to the United States. He eventually settled in Buras, located in Plaquemines Parish in 1983, joining a large Vietnamese and Cambodian community that found limited English skills no impediment to earning a living fishing and shrimping. He had been a fisherman in Vietnam, and as he explained in his native language, "I grew up near the sea and I'm used to eating seafood. I wanted to live where there's lots of seafood." He and his wife had both worked on the water, and in recent years they had purchased two specially outfitted oystering boats, in addition to two other boats used for gill fishing. They had loans to repay. In 2009, when they had $80,000 in income from harvesting oysters, that was not a problem. Their four children were grown, with one still at home.

When Van Nguyen heard on television about the oil spill, he recalls, "I felt that I was going crazy and was really worried that I can't work anymore. I was afraid that the oil would spread and people can't eat what we catch so I wouldn't be able to work. So I was going through a mental crisis." Louisiana has about 25,000 Vietnamese Americans.

All through May, the Macondo well gushed oil as the government was closing Louisiana oyster beds. Ve Van Nguyen and his wife both found interim work using their boats to install booms against the spreading oil slicks, as part of BP's clean up. But he made nowhere near as much money as he would have harvesting oysters. Like so many others around the Gulf, he said, "I worry about myself and my wife. I don't know how we can make it." He had received some BP payments, but wondered how long those would go on? "I have to make house payments and boat payments." At age 60, he was no longer young, but certainly expected to continue oystering. But now, if BP does not compensate him for an amount similar to the lost income, "I can't do anything except for applying for welfare and food stamps." He had had his four boats towed back to his house. The future? "Everyone is worried and scared about that. They are scared of poisoning so we have to rely on the government to take care of it. I don't know what will happen."

Turtle in East Grande Terre Island, LA



Sad testament to the spill, a sea turtle lies dead beside the black tide that took its life along East Grand Terre Island in Louisiana. As of November 2010, the carcasses of more than 600 of the endangered reptiles had been collected. Countless others undoubtedly perished.

Benjamin Lowy/Edit by Getty Images

in water, oil and lipids do mix very well, so high concentrations of petroleum can be found in the fat-rich tissues of the liver, brain, kidneys, and ovaries. Muscle generally has the lowest lipid concentrations, but fish with fatty flesh can accumulate more oil than leaner species.[43] Oil constituents can be transferred through the food chain: heavier hydrocarbons can be passed from water to phytoplankton and then to zooplankton, or from sediments to polychaete worms and eventually to fish.[44] Because animals that are several steps up the food chain, like small fish, have the capability to metabolize hydrocarbons fairly rapidly, their predators will actually not accumulate much from eating them. Accordingly, bioaccumulation of toxic oil components does occur in fish, but biomagnification, with increasingly higher concentrations in animals at each level, does not occur.[45]

It would be impossible to sample and assess each of the thousands of marine fish and other species inhabiting the open-ocean water column. But scientists monitoring the spill along the shorelines and aboard research vessels have sampled plankton, shellfish, fish, water, sediment, and other environmental media to better understand the potential impacts on all terrestrial and marine organisms.[46] Tens of thousands of samples have been collected. They will likely analyze the samples to determine concentrations of oil and dispersants, and combine that information with existing data on species populations and distributions to model the potential impact of contamination in the water column on different species. In addition, large fish—like bluefin tuna and whale sharks (the world's largest fish)—mammals, and turtles are being tagged with tracking devices so scientists can follow their movements in the hope of learning how they have been affected by the spill.[47] By overlaying maps of the extent of the oil spill, derived from satellite images from the European Space Agency, with simulations of bluefin tuna spawning grounds and models of larval development, the Ocean Foundation estimated that the spill could have affected 20 percent of the 2010 season's population of bluefin tuna larvae, further placing at risk an already severely overfished species.[48]

Birds, mammals, turtles. Oiled birds are often the most visually disturbing and widely disseminated images associated with a major oil spill—as in the landmark Santa Barbara accident of 1969.[49] Through November 1, 2010, wildlife responders had collected 8,183 birds, 1,144 sea turtles, and 109 marine mammals affected by the spill—alive or dead, visibly oiled or not.[50] Given the effects of hiding, scavenging, sinking, decomposition, and the sheer size of the search area, many more specimens were not intercepted.[51] Therefore, scientists will assess the estimated total damage by applying a multiplier to the final observed number of casualties, and will likely issue separate estimates of sub-lethal effects and the impact of the spill on future populations.

In September 28 testimony before the Commission, Jane Lyder, Deputy Assistant Secretary of the Department of the Interior for Fish and Wildlife and Parks, said that "With more than 60 percent of the data verified, the three most affected [bird] species appear to be Brown Pelicans, Northern Gannets, and Laughing Gulls." She added that "The fall migration is underway. Songbirds and shorebirds began their migration to the Gulf coast in July. Waterfowl began arriving in late August and early September. We know there are significant impacts to marsh and coastal wetland habitats along sections of the Louisiana coast, particularly near Grand Isle, Louisiana. We are continuing to monitor what the full impact will be to migratory birds and other wildlife."[52]

The potential impact on marine mammals and sea turtles is harder to assess. Tim Ragen, Executive Director of the federal Marine Mammal Commission, testifying before a House of Representatives subcommittee on June 10, 2010, could only conclude, "Unfortunately, the scientific foundation for evaluating the potential effects of the *Deepwater Horizon* spill on many marine mammals inhabiting the Gulf is weak."[53]

According to NOAA, "Of the 28 species of marine mammals known to live in the Gulf of Mexico, all are protected, and six (sperm, sei, fin, blue, humpback and North Atlantic right whales) are listed as endangered under the Endangered Species Act." Also of note, "At least four species of threatened/endangered sea turtles (Kemp's ridley, green, leatherback, and loggerhead) are residents of the northern Gulf of Mexico and are represented by all life stages. A fifth species, the hawksbill turtle, can be found in the southern Gulf. The only nesting beaches in the world for Kemp's ridley turtles are in the western Gulf of Mexico."[54] As of November 1, the Unified Area Command reported that nine marine mammals had been collected alive (and three were released).[55] One hundred mammals were collected dead, though only four of those were visibly oiled. Most of the marine mammal mortalities were bottlenose dolphins.[56] Also among the dead was one juvenile sperm whale; it was found floating more than 70 miles from the source of the spill, reportedly unoiled.[57] More than 600 dead sea turtles were collected.[58]

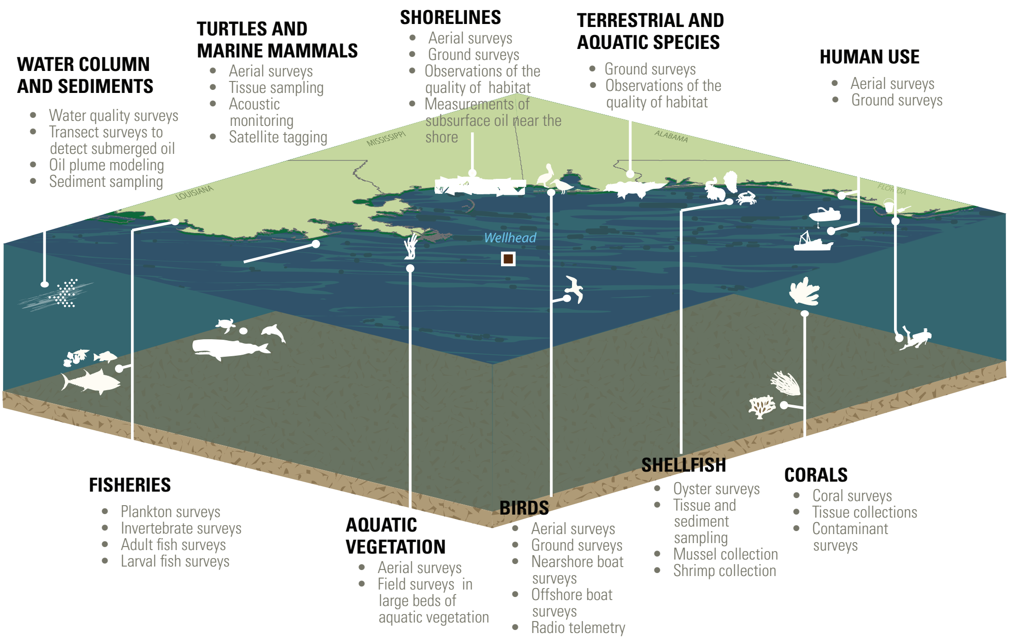
Deepwater plumes of dispersed oil. The highly visible damage to wildlife aside, public and scientific concern about the *Deepwater Horizon* spill—at unprecedented water depths—has for some time focused on the impacts of an invisible subsurface "plume," or more accurately "clouds" of minute oil droplets moving slowly over the seabed. As of November 2010, three independent, peer-reviewed studies[59] confirmed the presence of a deepwater plume of highly dispersed oil droplets and dissolved gases at between 3,200 and 4,200 feet deep and extending for many miles, primarily to the southwest of the wellhead.

How will such substances affect the deepwater environment? One concern centered on decomposition and the resulting depletion of the oxygen supply on which aquatic species depend. Bacterial decomposition begins quickly for the light hydrocarbon gases, propane and ethane, but more slowly for the heavier hydrocarbons typically present in a liquid form and for the predominant gas, methane. The blooms of bacteria stimulated by lighter hydrocarbons prime the populations for degradation of other hydrocarbons. The degradation rates are sufficient to reduce the dissolved oxygen concentrations in the plume, but not to harmfully low levels associated with dead zones, where aquatic species cannot survive.[60] Subsequent mixing with adjacent, uncontaminated waters by slow-flowing currents appears to have been sufficient to prevent any further depletion of dissolved oxygen in the aging plumes.[61] These findings do not rule out potential impacts of deepwater oil and dispersant concentrations on individual species.[62] Chemical analyses of water samples taken from the established deepwater plume in May 2010 suggest that hydrocarbon concentrations were high enough at the time to cause acute toxicity to exposed organisms,[63] although concentrations declined over several miles from the well as the plume mixed with the surrounding water.

Federal scientists have estimated that about 15 percent of the oil escaping the wellhead was physically dispersed by the fluid turbulence around the flow of oil and gas. The deepwater plume would have formed even if chemical dispersants had not been injected at the wellhead. But the addition of 18,379 barrels of dispersants to the discharging oil and gas stream may have increased the volume of oil in the deepwater plumes to a degree comparable to that from physical dispersion alone.[64] As of late 2010, there have been unconfirmed reports of oil deposited on the seafloor in the vicinity of the Macondo well.[65] If confirmed by chemical analyses, this would not be particularly surprising because oil droplets can become entrained in denser particulate matter, including the flocks of organic matter (referred to by scientists as "marine snow") that characterize open-ocean waters, and settle on the ocean floor. There have also been recent reports of dead or dying deepwater corals living on rock outcrops that could have been impinged by the deep plumes.[66]

Because the *Deepwater Horizon* spill was unprecedented in size, location, and duration,[67] deepwater ecosystems were exposed to large volumes of oil for an extended period. It will take further investigation and more time to assess the impacts on these ecosystems, their extent and duration. Unfortunately, except for studies that have focused on rare and specialized communities associated with rocky outcrops or seeps, scientific understanding of the deepwater Gulf ecosystem has not advanced with the industrial development of deepwater drilling and production.[68]

Figure 6.1: Assessment Categories for Natural Resource Damage Assessment



This figure represents the various natural resource categories being assessed as part of the Deepwater Horizon Natural Resource Damage Assessment. Such an assessment, which always follows an oil spill, is used to make the public whole for ecological damages caused by a spill. This graphic illustrates the three-dimensional challenges that an assessment of a deep sea blowout presents.

NOAA (adapted)

Natural Resource Damage Assessment

The federal Oil Pollution Act (OPA or the Act) creates a process for assessing the damages caused by an oil spill and then the expenditure of monies collected to address those damages. To that end, the Act formally designates "natural resource trustees," who are responsible for assessing the "natural resources damages" of the spill.[69] (Figure 6.1) The trustees accordingly prepare a "natural resource damage assessment" that seeks to quantify oil-spill damages to: (1) public natural resources; (2) the services they provide (e.g., oysters provide water filtration); and (3) the public's lost use of those resources.[70] For the Macondo spill, NOAA and the Department of the Interior are leading the effort as trustees on behalf of the federal government.[71] The Department of Defense will also participate on behalf of affected military property along the Gulf coast.[72] The federal representatives will be joined by natural resource trustees from the five Gulf States.[73]

Identifying and quantifying damages, particularly where complex ecosystems are involved, present enormous challenges. Developing sound sampling protocols that cover adequate time scales, teasing out the effects of other environmental disturbances, and scaling the damages to the appropriate restoration projects often takes considerable time. A typical damage assessment can take years. Two sets of determinations—one concerning the baseline conditions against which damages to each species or habitat will be assessed and another concerning the quantification of those damages—are particularly difficult and consequential in terms of the overall results.

The goal of a natural resource damage assessment is "to make the environment and public whole for injuries to natural resources and services resulting from [an oil spill]."[74] The injury is quantified by reference to baseline conditions: "the condition of the natural resources and services that would have existed had the incident not occurred."[75] But making this determination is often inherently difficult and highly contentious. Without well-established baseline conditions, there can be inaccurate quantification of damages or required restoration. Given that the ecological baseline can vary seasonally, annually, and over much longer time scales, it can be difficult to pinpoint the exact condition of an ecosystem prior to a spill. Because long-term historical data are often nonexistent or discontinuous, natural resource trustees are likely to be disadvantaged by a lack of sufficient information to fully characterize the condition of relevant ecosystems prior to the incident in question.[76]

As OPA regulations indicate, "baseline" for purposes of damage assessment is generally considered to be the condition of the resource just prior to the spill.[77] The precise application of this definition has particular importance in the Gulf of Mexico context, where many coastal habitats have been substantially degraded over decades—even centuries—under the pressure of ever-expanding industrial, commercial, and residential development. The natural resource damage assessment regulations, as generally applied, require that BP and other potentially responsible parties restore Gulf resources to their functioning level as of April 19, 2010—by which point the Gulf ecosystem in April 2010 was already weakened.[78] In this context, effective long-term restoration will require the stabilization and eventual reversal of a number of long-standing, damaging trends.

The effort to thoroughly address the ecological impacts of this historic pollution event is unprecedented in scale. Thousands of samples have been collected from dozens of research cruises. Hundreds of miles of coastline have been observed and sampled.[79] Marine mammals and turtles are being observed aerially and monitored by satellite or radio tracking devices.[80] The assessment of natural resources damages is the largest and most complex that the government has ever undertaken to assess oil spill impacts.

Supporting independent scientific research. Apart from these governmental efforts, independent scientists have also sought to study the spill's impacts. But funding for academic and other scientists in the days and weeks immediately after the spill was limited.[81] As a result, the nation lost a fleeting opportunity to maximize scientific understanding of how oil spills—particularly in the deep ocean—adversely affect individual organisms and the marine ecosystem. Such research depends on sampling, measurements, and investigations that can be accomplished only during and right after the spill.
The National Science Foundation tried to fill the gap by funding studies under its Grants for Rapid Response Research (RAPID) Program, aimed at better understanding potential impacts to coastal and marine habitats and resources.[82] Through September 2010, the Foundation funded 167 *Deepwater Horizon* research projects totaling $19.4 million.[83] The Foundation became practically the sole provider of emergency funding for independent

scientists as the disaster unfolded. Nevertheless, the Program was not a panacea—because individual RAPID grants cannot exceed $200,000 per year, many scientists were left to seek additional funding to pay for the necessary, costly chemical analyses of their environmental samples.

In May, BP committed to provide $500 million for independent research on ecosystem assessment, impacts, and recovery efforts. Unfortunately, for multiple procedural and political reasons, by late November 2010 BP had only allocated a small portion of that money.[84] BP has since announced that it intends to work through the Gulf of Mexico Alliance, an organization led by the five Gulf coast governors, to implement this research program.[85] Here too, meaningful scientific inquiry will need to include long-term monitoring of the impacts of the spill on the Gulf's marine and coastal ecosystems.

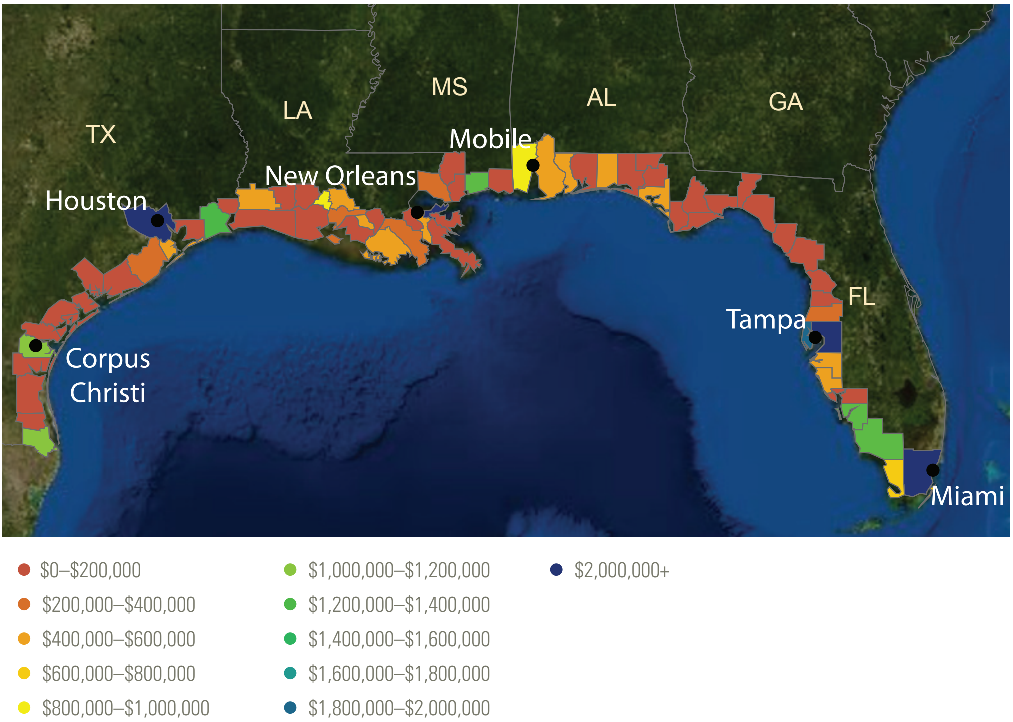
With numerous studies under way through both the government's damage-assessment process and independent scientific research, the published literature regarding environmental impacts from the Macondo blowout can be expected to grow substantially. Major research commitments, totaling hundreds of millions of dollars, have already been made.[86]

Economic Impacts

The *Deepwater Horizon* oil spill put at risk two enormous economic engines that rely on it. Tourism and fishing, the industries affected as collateral damage, were highly sensitive to both direct ecosystem harm and, indirectly, public perceptions and fears of tainted seafood and soiled beaches. For this reason, whatever uncertainty may exist about the immediate and long-term adverse environmental impacts of the oil spill, no such uncertainty exists in terms of the significant adverse economic effects—especially from loss of confidence in commercial fishing.[87] The Gulf coast's economy depends heavily on commercial fisheries, tourism, and energy production[88]—each directly and immediately affected by the oil gushing from the Macondo well. Federal and state closures of commercial fisheries—a precautionary public-health measure—at once suspended much of the fishing and processing industry;[89] public concern nationwide that seafood was not safe to eat further compounded the economic impact along the Gulf.[90] Similarly, public perception that otherwise clean beaches were, or would become, oiled or that air quality during peak vacation season was impaired led to declines in hotel bookings, restaurant seatings, and a wide array of coastal activities.[91] Claims for losses have been submitted by real-estate agents and developers,[92] fishing charters,[93] and even an Alabama dentist who alleged a loss of summer customers.[94] And the Gulf oil and gas industry, its workers, and the regional economy were affected as the federal government imposed a moratorium (described in Chapter 5) on deepwater drilling intended to prevent another disastrous spill while the causes and consequences of the blowout were evaluated.[95]

That BP agreed to place in escrow a $20 billion fund to help address financial losses, at President Obama's urging, indicates the magnitude of the economic impact from the loss of control of this one deepwater well.[96] In its first eight weeks of operation, as of November 23, the independently administered Gulf Coast Claims Facility had paid out more than $2 billion to approximately 127,000 claimants.[97] By comparison, during its two-year

Figure 6.2: Annual Tourism & Fishing Revenue: Economic Activity by County



Source: 2007 U.S. Economic Census
Note: Tourism includes: sporting goods stores, scenic/sightseeing transport (water), fishing clubs/guides, hunting/fishing reserves, camps, boat rentals, hotels, casinos, and nature parks. Fishing inlcudes: finfish, shellfish, other seafood, canning, frozen seafood, seafood markets and wholesalers.

lifespan, the September 11th Victim Compensation Fund awarded just over $7 billion to 5,560 individual claimants.[98]

It is currently not clear, however, the extent to which the enormous indirect economic impacts associated with loss of consumer confidence and injuries to the Gulf coast "brand" will ultimately be deemed compensable and that resulting uncertainty has generated intense debate among diverse government entities, local communities, interest groups, and BP. The federal Oil Pollution Act, for instance, does expressly recognize the appropriateness of compensation for "loss of profits or impairment of earning capacity resulting from property loss or natural resource injury."[99] But there is no easy legal answer to the question of how closely linked those lost profits or earnings must be to the spill before they should be deemed compensable. The search for such a rational endpoint for liability has already stymied the Gulf Coast Claims Facility in its processing of claims.[100] The absence of clear and fair procedures for systematically evaluating such claims deserves focused attention as the lessons from the *Deepwater Horizon* oil spill are learned.

The major industries in the "hardest working basin." Florida State University oceanographer Ian McDonald has called the Gulf of Mexico "the hardest working of our ocean basins."[101] The southern coast of the United States produces more than one-third of the nation's domestic seafood supply,[102] including most of the shrimp, crawfish, blue crabs, and oysters.[103] It produces one-third of all domestic oil,[104] and claims four of the top seven trading ports by tonnage.[105] The northern Gulf also provides diverse fish nursery and feeding grounds in the form of expansive marshes, mangrove stands, swamp forests, and seagrass beds, and boasts some of best beaches and waters in the United States for recreation and tourism.[106] Coastal tourism and commercial fisheries generate more than $40 billion of economic activity annually in the five Gulf States.[107] (Figure 6.2)

In 2008, according to NOAA, Gulf commercial fishermen harvested 1.27 billion pounds of finfish and shellfish that earned $659 million in total landings revenue.[108] Other contributors to the total Gulf fishing economy are seafood processors, warehouses, distributors, and wholesalers. Gulf fishermen land 73 percent of the nation's shrimp—half from Louisiana waters. Louisiana accounts for 67 percent of the nation's oyster production and 26 percent of the blue crab production.[109]

As described in Chapter 5, NOAA and state fisheries agencies responded to the *Deepwater Horizon* spill by closing huge portions of the Gulf to commercial and recreational fishing. At the most extensive point, 88,522 square miles of the Gulf of Mexico were closed to fishing[110]—one-third of the U.S. portion of the Gulf of Mexico, an area larger than the six New England states. In mid-June, NOAA and the Food and Drug Administration (FDA) released a protocol for reopening fisheries that would apply consistently to state and federal waters while striking a balance between keeping tainted seafood from market and unnecessarily crippling the seafood industry.[111] What ensued was likely the most rigorous seafood-testing campaign in U.S. history.

By late September, when nearly 32,000 square miles of the Gulf were still closed to fishing,[112] government officials made strong statements about the safety of seafood caught in reopened areas. "The shrimp, fish, and crabs are perfectly safe to eat," claimed Bob Dickey, Director of Seafood Science and Technology at the FDA.[113] Bill Walker, Executive Director of the Mississippi Department of Marine Resources, pronounced that "based on credible scientific data collected using federally-approved sampling and analytical techniques, Mississippi seafood has been safe and healthy to eat throughout the entirety of this event."[114] NOAA Administrator Jane Lubchenco stated, "I have confidence in our protocols and have enjoyed Gulf seafood each trip I've made to the region."[115]

But despite these assurances, some citizens continue to doubt the safety of Gulf seafood. "Everybody's credibility has been damaged by all this," said Ian MacDonald. He continued, "[The] many changes of course that NOAA took. The great concern about [the Environmental Protection Agency] and the licensing of dispersant use. The fact of the way it was handled has undermined public confidence."[116] Florida journalist Travis Pillow asked, "If people couldn't believe [the government's] estimates of how much oil was gushing into the Gulf, how could they believe their reassurance that beaches were clean or seafood was safe?"[117]

Constant media coverage about the spill also plainly shaped citizens' perception of the risks to public health. According to Timothy Fitzgerald, Senior Policy Analyst for the

Vendor Sign at Taste of Chicago

Perception is reality for the Gulf seafood industry. The economic calamity that descended when commercial fisheries were closed as a health-safety precaution should have been alleviated when they reopened, but the public still wasn't buying. Fact: After a rigorous testing campaign, most commercial species appear untainted.

Albert Ettinger

Environmental Defense Fund's Ocean Program, "Most people have very little connection to, or understanding of, the fish they buy,"[118] increasing their reliance on mass media to inform their decisions.[119] Scott Dekle, general manager of the VersaCold Atlas seafood warehouse, noted that news of the spill "got plastered all over the local and national media day after day after day. No one sees Anderson Cooper now standing outside Southern Seafood saying, 'This is great.'"[120] As a result, the public has come to associate Gulf seafood with oil. In August, Jonah Berger, a marketing professor at the University of Pennsylvania's Wharton School, said of Gulf seafood, "[R]ight now, the only association is a negative one, and so it's going to be much harder for that association to disappear."[121]

Most commercial Gulf seafood species seem to have emerged from the oil spill without any clear evidence of taint or contamination.[122] The real impact here is the reputational damage to Gulf seafood as a safe brand. Continued government testing, improvements in public outreach, and a coordinated marketing campaign may be needed to expedite its recovery. After several requests over several months, BP relented in early November and agreed to give Louisiana $48 million and Florida $20 million for seafood testing and marketing.[123] As of early December, BP is considering a similar request from Alabama.[124]

Voices from the Gulf

"We were called liars when we said we didn't have oil on the beaches"

Joe Mayer

Patricia Denny, Destin, FL

On May 2, 1985, Patricia Denny took a job as a secretary in a brand new real estate company in Destin, Florida, a small Emerald Coast family beach town proud of its white beaches and green waters. She married, had two girls, and worked hard at Holiday Isle Properties, rising to General Manager, where she managed 177 vacation rentals. In 2009, her longtime boss retired and Denny became the owner. "I was beyond excited. My dream was coming true—all the late hours, 7-day work weeks. Something I felt so passionate about was finally happening."

In her 24 years as a property manager, Denny has weathered some tough years: "I truly never thought things could be worse than 2004-5. Not only did the real estate market come to an abrupt halt, we had hurricane after hurricane. . . . But we rebounded on our own—no hand-outs, no help from government or our insurance company."

In late April 2010, when Denny saw the news on TV about the *Deepwater Horizon* explosion, "I remember thinking, 'How awful,' but the news reported that BP was going to stop the oil from spewing and all would be well. . . . Then NOAA predicted a shift in the weather and that impact from the oil was imminent. I was devastated. I couldn't sleep, I couldn't eat. It was the worst time of my life. Everything was at risk—my home, my income, my children's education, my three employees who are like a family to me."

In early May, to show that their pristine beaches were still sugary white, "We started filming daily and sometimes twice daily a video for YouTube called Shore Shots. It involved one of my employees standing in front of the camera and showing the Gulf of Mexico and the lack of oil despite being told otherwise. . . . It was not always well received. We were called liars when we said we didn't have oil on the beaches and told we were poisoning people with Corexit for our own greedy gain. It was definitely tough.

"By July the oil was here. No way I could prevent it from coming on – revenue dropped significantly. By August it was awful. No one, I mean no one, believed that we weren't covered in oil similar to the *Exxon Valdez*."

Denny's older daughter was a junior and biology major at the University of Alabama in Birmingham. As the cancellations rolled in, the young woman withdrew from college in July for what would have been her senior year. She moved home to help her mother run the company." It breaks my heart to see her do this," says Denny. "I am hoping she can go back sometime in the future but at this time I don't know when that is."*

*In early December 2010, Denny received compensation for her losses from the Gulf Coast Claims Facility, administered by Kenneth Feinberg and funded by BP.

Public Health Precautions

A sign of the times is posted at a public beach in Alabama. Long viewed strictly as environmental disasters, major oil spills can be hazardous to human health, beyond direct fatalities or injuries. Many Gulf Coast residents have complained of respiratory problems and headaches, and depressive illness has skyrocketed.

Rocky Kistner/NRDC

Coastal tourism. The Gulf coast generates an estimated $19.7 billion of tourism activity annually.[125] Florida accounts for more than 50 percent of the total[126] and, accordingly, attributes enormous actual and potential losses in tourism-related revenue to the oil spill. Quantifying such losses and the value of reputational damage may be even more difficult than assigning a value to the indirect losses suffered by the Louisiana fishing industry. Furthermore, responsibility for compensating those who may have suffered the indirect financial losses poses challenges of law, administration, and equity.

Floridians expressed frustrations with the news coverage of the oil spill—not all of it accurate. As described by Keith Overton, Chairman of the Florida Restaurant and Lodging Association and Chief Operating Officer of the TradeWinds Island Resorts in St. Pete Beach, in testimony before the Commission in July 2010, "These losses have occurred in our area, in the Tampa Bay area, without a single drop of oil ever reaching our beach and that is true for most of Florida. Pensacola has had some oil but the rest of the Panhandle is in pretty good shape right now. But you wouldn't know that if you looked at the national news media or you read the newspaper each day."[127] With dismay, he described a newscast that showed footage of President Obama walking along an unoiled Pensacola beach in mid-June, but with superimposed oil dripping down the screen behind him.

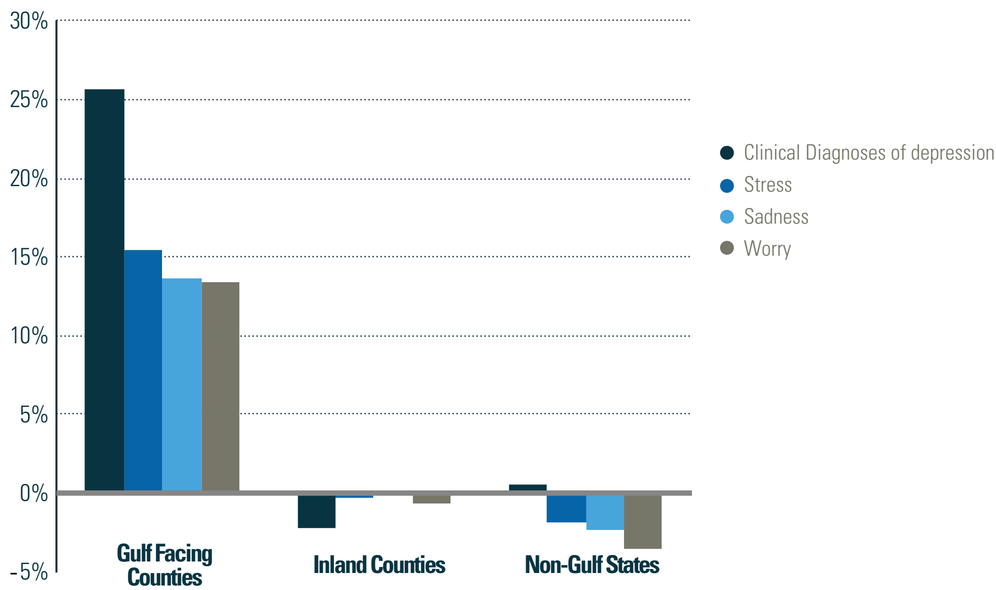
Just as the potential extent of the spill's impact was coming into focus, Michael Hecht, President of Greater New Orleans, Inc., a regional economic alliance in southeast Louisiana, testified in July that "going forward . . . this perception, this brand issue, is incredibly important."[128] A Louisiana-commissioned national poll conducted in early August 2010 found that 29 percent of respondents who were planning to visit the state said they were actively canceling or postponing their visits because of the oil spill.[129] Overton noted that the downturn in hotel reservations through June 2010 in unoiled Pinellas County had cost roughly $70 million and could total in the billions for the Florida Panhandle.

Human Health

Because oil spills have historically been viewed as environmental disasters, affecting nature, the Oil Pollution Act of 1990 and related policies offer fewer tools for addressing the human dimensions of such accidents. But in the case of the Macondo blowout—of unprecedented size, affecting a broad area, and the entire regional economy—assessment of impacts must also include the effects on human health, mental and physical. The *Deepwater Horizon* crew of course bore the immediate, devastating effects of the rig's destruction: 11 deaths, 17 injuries, and the unquestioned trauma of losing colleagues; the terror of the explosions and fires, the harrowing rescue, and the sense of involvement in the wider damages that ensued; and the rigors of the investigations and recovery efforts since.

But the tangible human health effects are more widespread. It was certainly a cruel, added misfortune that the Macondo spill bore down most heavily on southern Louisiana, less than five years after Hurricane Katrina ravaged the Louisiana and Mississippi coast, ruined much of New Orleans, killed hundreds, drove some of the population away permanently (including essential medical professionals), devastated the local economy, and shocked the nation with images of disorder and suffering. An unfortunate lesson of the oil spill is

Figure 6.3: Recent Changes in Emotional Well Being Along the Gulf Coast



This figure depicts the recent changes in emotional well-being along the Gulf coast, as indicated in the Gallup Survey conducted April 21 to August 6, 2010.

Gaullup-Heathways Well-Being Index Change Since April 20th 2010

that the nation was not well prepared for the possibility of widespread, adverse effects on human health and mental well-being, especially among a particularly vulnerable citizenry. Gulf communities have long-time residents with strong roots to the region. Of coastal Louisiana residents surveyed after the spill, 60 percent of respondents reported living in their communities their entire lives and another 21 percent had lived there at least 20 years.[130] This context of regional and cultural ties to their communities exacerbates the worry and stress caused by the oil spill. Nearly 60 percent of respondents reported feeling worried almost constantly during the week prior to being surveyed because of the spill.[131] Louisiana shrimper Donald Johnfroe, Jr., said, "Everything I'm making now is going to pay off debt from this summer. I'm behind on my child-support payments, house payments. I need money."[132] Residents are worried about the economy, their way of life, and the stability of their communities. All of these factors play a role in affecting their health.

During the Commission's first public hearing in New Orleans on July 12–13, representatives of community groups focused on the psychological impacts. "Our people are used to tragedies and pulling themselves up from their bootstraps . . . but no one is saved from depression and fear," said Sharon Gauthe, Executive Director of Bayou Interfaith Shared Community Organizing. Grace Scire, Gulf coast Regional Director for Boat People SOS, told the Commission about her experiences working with the Vietnamese, Laotian, and Cambodian communities in the Gulf: "People are so dejected—it's not even the word for that—they're still recovering from Katrina."[133] Both speakers emphasized the need for additional community mental health services.

Industry and government responders did not adequately anticipate or address the magnitude of potential health impacts. Meanwhile, many citizens were coping with physical ailments (e.g., respiratory problems, headaches) and stress. Though health agencies eventually issued personal protective equipment guidelines for response workers and created a registry of these newly trained personnel, they missed the crucial window for screening their baseline physical health before the workers were directly exposed to oil products.[134]

Although many of the behavioral and psychological effects of the oil spill remain unknown, a Gallup survey of nearly 2,600 residents revealed that medical diagnoses of depressive illness had increased by 25 percent since the rig explosion.[135] The "well-being index" included in the Gallup study showed that coastal residents reported being stressed, worried, and sad more often than their inland counterparts (Figure 6.3).

There is also an indication that domestic violence increased. Between April and June 2010, the Administration for Children and Families observed a spike in calls to the National Domestic Violence Hotline from Gulf coast states, most notably in Louisiana.[136] Such broad community impacts suggest the need to monitor and respond to longer-term effects as warranted, and to pay special attention to especially vulnerable populations along the Gulf coast, including children, minority fishing communities, and Indian tribes.

Children and families. Children are particularly vulnerable to disruption in social, familial, and community stability as a result of disaster. A study conducted after Katrina found that children exposed to the hurricane were five times more likely to suffer from serious emotional disturbances than they were before the hurricane.[137] Although the direct impacts of the oil spill of course cannot be compared to the utter devastation wrought on entire communities by Katrina, some studies have already begun to document the spill's impact on children and families. A telephone survey of more than 900 coastal Louisiana adults two months after the spill began indicated that 46 percent felt they were unable to take care of their families as well as they would like.[138] In another survey of more than 1,200 adults living within 10 miles of the coast, parents from Louisiana and Mississippi reported that more than one-third of their children were suffering mental or physical health effects as a result of the oil spill. The most significant health impact was reported among families earning less than $25,000 annually.[139]

Exactly what proportion of health symptoms is attributable to the oil spill? Meaningful measurement is difficult at best. The preliminary findings of one academic study reported an "exposure differential" between exposed and non-exposed subjects.[140] Adults and children who were directly exposed to oil were, on average, twice as likely to report new physical or mental health issues as those who were not.[141]

Minority fishing communities. Another sensitive community is the 40,000 Southeast Asian immigrants who live along the Gulf coast (primarily Vietnamese, but also Laotians and Cambodians, many of them refugees from the decades-long wars in that region), one-fifth of who are fishermen.[142] Most of these families suffered direct, grievous harm from the 2005 hurricanes[143] and now face the spill-related loss of their livelihoods for an uncertain duration. Many of the fishermen speak little or no English, making their access to the Gulf Coast Claims Facility especially challenging[144] and posing difficulties in finding work outside the fishing industry. As the Commission heard in July, the cultural stigma associated with mental health problems in some of these communities complicates efforts to help those in need.[145]

Tribal communities. According to Brenda Robichaux, former principal Chief of the United Houma Nation, tribal communities on the coast are paying "the ultimate price" for both the mismanagement of the Mississippi River Delta over the past half-century (see discussion in Chapter 7) as well as the development of the offshore oil industry.[146] Both activities have contributed to the loss of wetlands and the destruction of barrier islands, which play crucial roles in protecting the tribes from major storms. Just as they began to recover from four hurricanes in three years, many members of Gulf coastal tribal communities for whom fishing is a lifestyle and a livelihood, suffered directly from the oil spill and face a difficult future.

Long-term health effects. The long-term health impacts of oil spills remain largely uncertain, but research conducted in the wake of other disasters provides some insight. A survey conducted one year after *Exxon Valdez* found that cleanup workers classified as being subjected to "high exposure" were 3.6 times as likely to have a generalized anxiety disorder and 2.9 times as likely to have post-traumatic stress disorder as members of an unexposed group.[147] Alaska Natives were particularly prone to effects of chemical exposure and, for cultural reasons, less likely to seek mental health services.[148] Unlike natural disasters, where mental health consequences generally dissipate relatively quickly, technological disasters are known to have chronic impacts on affected individuals and communities—a problem that is worsened as issues of fault and compensation are negotiated or litigated over an extended period.[149] Important symptoms include depression, substance abuse, domestic violence, psychological disorders, and disruption of family structures.[150] Evidence of these effects, as noted, has already appeared in the Gulf coast communities most directly influenced by the oil spill.[151]

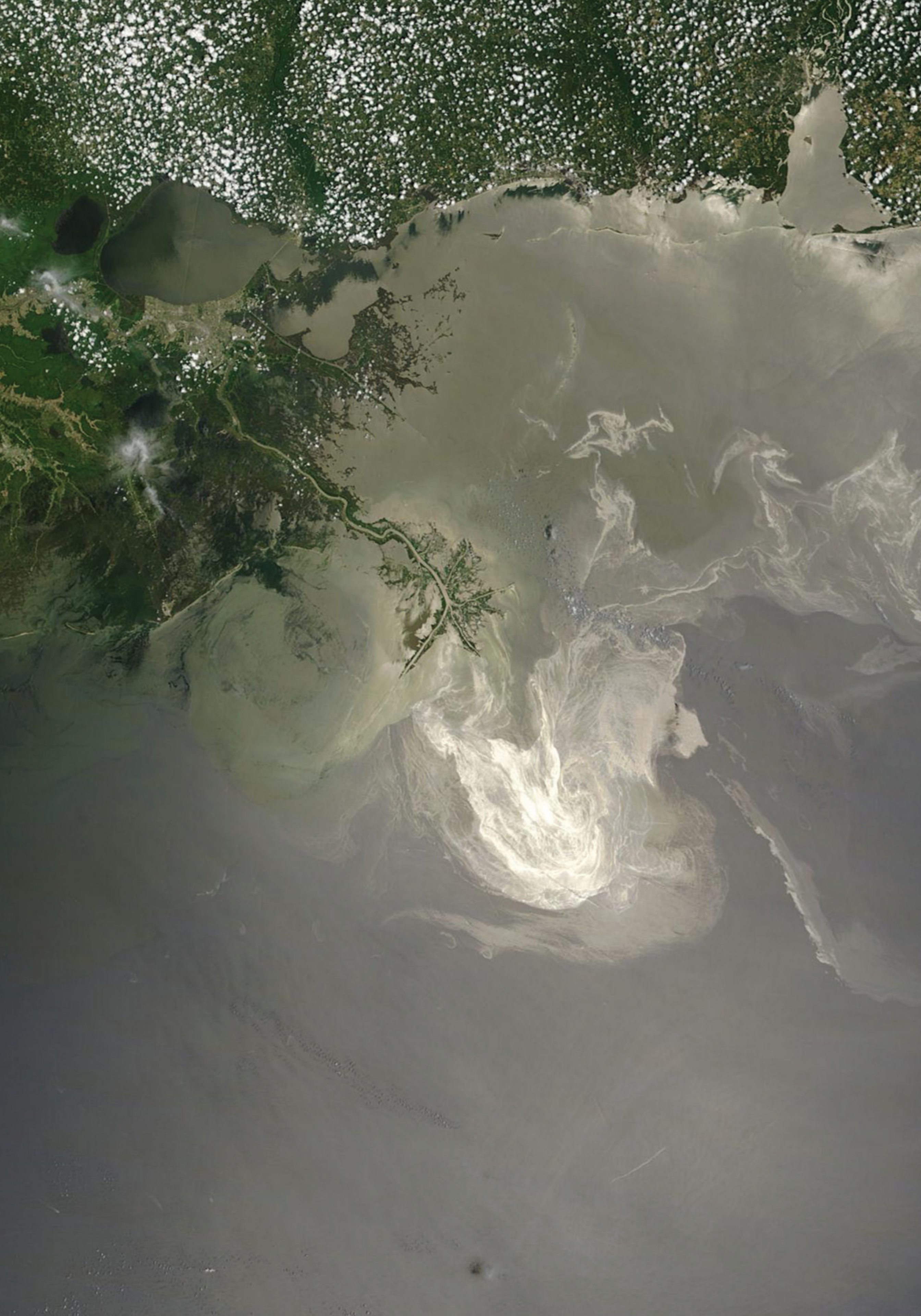
To date, the Gulf Coast Compensation Fund has maintained that it will not pay damages for mental illness caused by the spill. According to its administrator, Kenneth Feinberg: "If you start compensating purely mental anguish without a physical injury—anxiety, stress—we'll be getting millions of claims from people watching television. You have to draw the line somewhere."[152] The affected Gulf coast states' health departments (excluding Texas) received $42 million for mental health from BP, and the Substance Abuse and Mental Health Administration received $10 million.[153]

Because no biological specimens were taken at the outset of the response, the study of future health effects will be constrained by a lack of baseline data. No biological samples were taken from cleanup workers before or immediately after their exposure to oil. More generally, given the unreliability of surveillance in the days and weeks after the spill, the quality of any baseline data for studies on long-term health effects was compromised. For future emergency response efforts, the government should have enhanced authority to ensure adequate baseline data and surveillance measures.[154] In the meantime, at a minimum, long-term monitoring of *Deepwater Horizon* responders' health and of community health in the most affected coastal areas is warranted and scientifically important.

However, the focus on long-term research cannot overshadow the need to provide immediate medical assistance to affected communities, which have suffered from limited access to healthcare services.[155] In the years following Hurricane Katrina, many of the damaged healthcare facilities were not rebuilt or replaced, including the major provider of indigent care, Louisiana State University Charity Hospital.[156] This left coastal communities vulnerable and lacking adequate access to care.[157] The greatest damage to Louisiana's health-services infrastructure was in Region One (Orleans, Jefferson, St. Bernard, and Plaquemines Parishes).[158] A year after the storm, New Orleans had been federally designated as a health professional shortage area (HPSA) for primary care, mental healthcare, and dental care. By 2008, 86 percent of Louisiana's parishes were HPSA-designated, with Medicaid and uninsured residents hardest hit.[159] Resources including federal Primary Care Access Stabilization Grants were made available to the state[160] and by August 2010, five years after Katrina, substantial progress had been made in restoring healthcare resources through a redesigned primary-care safety net.[161]

* * * *

Assessing the environmental, economic, and human health damages from the *Deepwater Horizon* oil spill is, of course, only the threshold challenge. The even larger challenge now facing the Gulf is how to achieve its restoration, notwithstanding years of failed efforts to recover from past destruction.



Chapter Seven

“People have plan fatigue . . . they’ve been planned to death”

Recovery and Restoration

Whatever the final tally of shorelines oiled, fishing days lost, and waterfowl killed, the *Deepwater Horizon* oil spill touched virtually every aspect of life on the Gulf of Mexico coast— and far beyond. Tens of thousands of residents draw fish and seafood from the Gulf’s waters, which supply much of the nation. Many thousands more produce oil and gas from its buried stores. Gulf coast ports handle enormous volumes of grain and freight leaving American farms and factories and goods arriving from abroad. Vacationers come from across the country and around the globe to sun and swim on Gulf coast beaches.

But even before the highly visible damages caused by the spill became clear, many of those crucial Gulf resources faced long-term threats. Indeed, the Louisiana coast—that essential borderland and nursery to the nation’s richest fisheries—has hit a dark trifecta. First, more than 2,300 square miles[1] of coastal wetlands (an area larger than the State of Delaware) have been lost to the Gulf since the United States raised the massive levees along the lower Mississippi River after the devastating Great Flood of 1927. Exceptionally powerful hurricanes, always a threat to the region, struck the coast in

Satellite-eye views of the Gulf a month after the Macondo blowout reveal the extent of the spill. Oil appears lighter or darker in the photograph depending on the relative angles of sun and camera.

< NASA/GSFC, MODIS Rapid Response

FIGURE 7.1: Maximum Extent of Oil

Surface Oiling Surveys: May 17 - July 25
Shoreline Oiling: Most severe oiling observed through November

Map courtesy of National Geographic (surface oil) and modified by Commission staff, NOAA/Coast Guard SCAT map (shoreline oiling)

2005 (Katrina and Rita) and 2008 (Gustav and Ike), causing even more wetland loss and erosion. Second, low-oxygen bottom waters were in the process of forming a massive "dead zone" extending up to 7,700 square miles during the summer of 2010. Referred to as hypoxia, this phenomenon has intensified and expanded since the early 1970s[2] as a result of nutrient pollution, mainly from Midwestern agriculture. And finally, the *Deepwater Horizon* disaster made matters worse: 11 rig workers killed in the explosion and 17 injured;[3] many thousands of people out of work; birds and sea animals killed and significant habitats damaged or destroyed.

These three protracted tragedies—coastal land loss, hypoxia, and the oiling itself—set up the central question for recovery from the spill: can or should such a major pollution event steer political energy, human resources, and funding into solutions for a continuing, systemic tragedy? The spill itself is a regional issue, but the slow-motion decimation of the Gulf of Mexico's coastal and marine environment—created by federal and state policies, and exacerbated by energy infrastructure and pollution—is an unmet national challenge.

Beyond these acute effects, the wider American public might not understand (and certainly has not given high priority to addressing) the root problems affecting the interrelated Mississippi River–Gulf of Mexico system that extends into the nation's heartland. Absent a comprehensive approach and national commitment to the Gulf coastal ecosystems, there are insufficient authorities and inadequate funds available to address the costly and progressive environmental losses now underway. In the aftermath of the *Deepwater Horizon* spill, state and federal authorities have moved to link spill recovery to more comprehensive reforms that were already in progress.[4]

A comprehensive response to the oil spill (and preparedness for the future) requires a national vision for restoring the waters, land, and their ecosystems to health. "Restoration" is the term of art for attempting to bring natural resources back after a spill. It also describes the recovery of large ecosystems by addressing the longstanding environmental problems that have caused their deterioration. The goal of any such effort is not necessarily to rebuild wetlands and barrier islands so that the coast looks like it did 100 years ago, but rather to reintroduce elements of the natural system so that the Mississippi River Delta—the epicenter of the threatened coastal region—can begin to heal itself.[5]

To that end, conversations about repairing the Gulf coast and marine ecosystems increasingly aim at restoring the region's natural "resilience."[6] Prior to the spill, Gulf states and federal authorities were already in various stages of restoring parts of the Gulf. Numerous ecosystem challenges now face the regions of the Gulf coast affected by the *Deepwater Horizon* spill. Barrier islands and shorelines are eroding from Florida to Texas. Essential habitats in coastal bays and estuaries have been lost to or degraded by pollution, energy or other development, changes in freshwater inflows, and overfishing.[7]

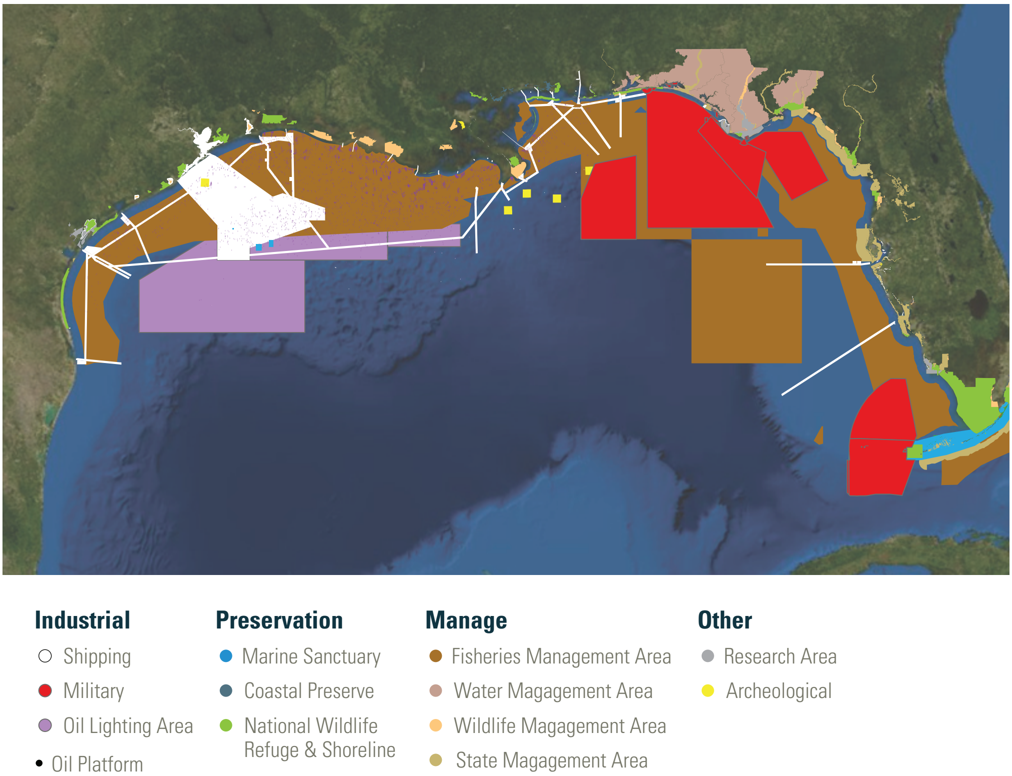
The largest and most formidable challenges, however, are to bring balance and efficiency to the Gulf's shared marine resources, and to address the rapid and continuous loss of wetlands, barrier islands, and shorelines comprising the Mississippi Delta and associated Chenier Plain of southwestern Louisiana. While many areas along the Gulf Coast require such restoration, the Mississippi Delta and the Gulf itself requires special attention.

Advancing Restoration Options for Offshore Ecosystems and Resources

Beyond restoration of Delta and other coastal ecosystems, a broader restoration effort—guided by new research and an understanding of what long-term damages may be resulting from the spill—seeks to improve the environmental quality of the marine habitat. These issues link a complex web of problems (including the annual appearance of the low-oxygen dead zone in waters of the Louisiana-Texas continental shelf) with the continued efforts to conserve the biodiversity and resources of offshore ecosystems.

Implementing the Gulf Hypoxia Action Plan. Hypoxia kills or excludes most marine animals over vast areas of the continental shelf. Scientific investigations have shown that such extensive and severe hypoxia is a recent phenomenon, fueled by the increased loads of nutrients carried down the Mississippi and Atchafalaya rivers, largely as a result of fertilizers used to support intense agriculture within the river basin.[8] Phytoplankton bloom thanks to the nutrients, and the process of their decay depletes oxygen over thousands of

FIGURE 7.2: Coastal Marine Users



NOAA

square miles of seabed. These hypoxic seafloor habitats could become prime candidates for restoration efforts in the aftermath of the *Deepwater Horizon* disaster.

A plan of action produced in 2001 and updated in 2008 by the Mississippi River Gulf of Mexico Watershed Nutrient Task Force[*] outlines how to proceed.[9] The Action Plan aims to reduce the average extent of the hypoxic zone to less than 5,000 square kilometers (1,930 square miles), or about one-fourth the area affected in 2010, by reducing the discharges of nitrogen and phosphorus into the Gulf. The original target date for achieving this goal was 2015, but implementation has languished. As part of a comprehensive restoration program, regulations that limit discharges under the Clean Water Act could be more rigorously applied, and federally-authorized conservation programs could be better targeted to achieve greater results. Hypoxia abatement should also be integrated with coastal ecosystem restoration in order to optimize nutrient removal by river diversions and to reduce the risks of injecting greater nutrient loads into the waters of the continental shelf.

Marine spatial planning. The U.S. part of the Gulf of Mexico is already as compartmentalized as any water body in the world. The Department of the Interior divides

[*] The Task Force consists of state and natural resources agencies and federal agencies, including NOAA, EPA, the Departments of Agriculture and of the Interior, and the Army Corps of Engineers.

the northern Gulf into a grid for administrative purposes. Oil and gas companies lease individual blocks within this grid for exploration and production.[10] Other entities manage the Gulf to maximize their own benefit—for fishing, tourism, or conservation.

All this activity also makes the Gulf a crowded space administratively, with coordination insufficient to resolve potential conflicts among oil and gas development, fishing, navigation, and military operations. The *Deepwater Horizon* disaster occurred at a time when U.S. policy toward its waters was under significant revision. The National Oceans Council, created by Executive Order in July 2010,[11] is authorized to set and manage executive-branch marine policy and to implement recommendations of a task force appointed by President Obama in 2009.[12]

Among the most significant initiatives are steps that would reorganize—or in some cases organize—how Americans benefit from resources in federal waters. Scientists and policy advocates use the phrase "coastal and marine spatial planning" to describe a suite of technologies, best practices, and inter-industry networking to optimize the use of resources for all.[13] In the Gulf of Mexico, where the oil and gas industry has a very large presence, marine spatial planning can help lead to better oversight, and in the event of an accident, better communication among all users. Massachusetts and Rhode Island recently formalized this approach to their state waters.[14] Norway has implemented planning in its crowded northern waters, an area which includes oil and gas infrastructure.[15]

More a management or governance strategy than a discrete program, marine spatial planning is evolutionary in nature. The Department of the Interior is already charged to manage energy resources on the outer continental shelf in a way that is, among other requirements, "consistent with the need . . . to balance orderly resource development with protection of the human, marine, and coastal environments."[16] Proponents expect federal and statewide marine spatial planning to bring together agencies, jurisdictions, and communities to share information and best practices—and in so doing, better balance the many interests on and beneath the water.[17]

Marine protected areas. Within the context of coastal and marine spatial planning, there are opportunities for protection and restoration of resources harmed not only by the present oil spill, but also by oil and gas development generally and other commercial activities. Marine protected areas have been effective as a means to conserve marine biodiversity and enhance the resilience of fish stocks in the face of harvest pressures.[18] Strategically selected and designated marine protected areas could be an effective way to restore offshore ecosystems within the framework of a comprehensive restoration program. Modern management tools can go a long way toward making Gulf fisheries more robust by preventing overfishing. The *Deepwater Horizon* disaster delayed the start of a new National Oceanic and Atmospheric Administration (NOAA) fisheries management policy. On November 4, 2010, the "NOAA Catch Share Policy" went into effect. The policy divides the total allowable catch in a fishery into shares held by individuals and various entities. The holders of the catch shares must cease fishing once they have reached their limit. This is one step toward protecting the health of commercial and recreational fisheries.

FIGURE 7.3: Coastal Vulnerability Index

USGS National Assessment of Coastal Vulnerability to Future Sea-Level Rise –Open File Report 00-179

Toward a Functioning Delta

The Delta difference. The land at the mouth of the Mississippi River differs from that of neighboring regions: the underlying rock is hundreds of feet below the surface,[19] buried by mud deposited over many millennia. River-borne sediment has, literally, created the land—a coastal habitat of remarkable biological productivity, and a buffer that protects the densely settled land upriver from the full force of battering waves. But the sea constantly carries that coastal land away.

The Mississippi River, extending some 2,300 miles upstream to Minnesota, runs through the heart of the third largest watershed in the world (after the Amazon and the Congo). Water enters its basin from 31 states. Water from the northern reaches of the basin can take a month to reach the Gulf. About two weeks after the historic rains that flooded Nashville and killed at least 31 people across the southeast in May 2010, the water flowed past New Orleans; when it entered the Gulf, that freshwater swell may have helped keep oil-covered offshore waters away from marshes in the spill's early days.[20]

As the Mississippi meanders south, it picks up silt, sand, and organic materials. Under largely natural conditions (before the 1930s), the river cast this sediment across the wetland plain before draining into the Gulf. The accumulating material attracts the microbes and marsh grasses that undergird the coastal ecosystem. During the 7,000 to 8,000 years since the end of the last ice age, the Mississippi has shaped and reshaped its delta—even, on occasion, carving wholly new routes to the Gulf.

Voices from the Gulf

“Louisiana is paying a grave price for what the rest of the country is enjoying.”

Dennis Woltering

Brenda Dardar Robichaux,

Former Chief of the United Houma Nation, Raceland, LA

Brenda Dardar Robichaux could not help noticing as the local coastline, ditched for oil-related navigation and pipeline corridors, progressively disappeared all through Terrebonne, Lafourche, Jefferson, St. Mary, St. Bernard and Plaquemines parishes. As Principal Chief (from 1997 until 2010) of the 17,000-member United Houma Nation, whose people lived in and made their livelihoods from the coastal lands of southeastern Louisiana, she said, “We have seen small canals turn into large bayous; we have watched hundreds of acres of wetlands wash away; we have seen freshwater bayous turn into saltwater.” And her people have become exposed to severe risks: “Hurricanes Gustav and Ike destroyed our community on Isle de Jean Charles because we no longer have the barrier islands protecting us. Today Isle de Jean Charles is just a sliver of what it once was. The length of the island is still several miles, but the width is maybe an acre. When I was little there were fields that we [the Houma People] raised cattle and horses on. We had gardens and the kids played baseball. Now there is no such thing. The backyards are water.”

Former Chief Robichaux initially saw some possible good coming from the spill: serious attention being paid to coastal restoration. “The spill certainly adds another level of awareness to the problem—like Katrina did—but we need major change now, and not just little projects. When the oil spill happened, I was hopeful that all the attention it was bringing might finally wake people up. I was optimistic. I was thinking if we’re ever going to get vision for coastal restoration off the ground, now is the time. But I don’t see that happening.”

For centuries, the United Houma Nation’s culture and economy have been entwined with the bounty of the gulf. “Our people follow the seasons,” Robichaux explained. “In the summer we catch shrimp, crabs, and garfish. In the winter we harvest oysters and trap nutria, muskrat, and otters…Houma fishermen are intimately familiar with the lakes and bayous of our region. They know the stories of how these places got their names. They know how the tides flow and the winds blow… All of these traditions are in danger of disappearing.”

Like all Americans, she knew well the nation’s dependence on oil: “Louisiana is paying a grave price for what the rest of the country is enjoying, whether it’s seafood or what oil and gas provide. But our tribal citizens are paying the ultimate price, because we live along the coast of southeast Louisiana. We as a nation, not only people in Louisiana, not just people on the coast, but the nation, need to evaluate our dependency on oil and gas. We need to re-evaluate our entire lifestyle. It’s not just a Gulf Coast issue.”

Beginning late in the nineteenth century, the Atchafalaya River in southern Louisiana captured an increasing share of Mississippi waters, greatly reducing flow into the lower part of the Mississippi.[21] Were nature left to itself, the flow would have diverted over time primarily to the Atchafalaya, which provides a much shorter route to the Gulf. This change would have been catastrophic to communities and industry along the lower river, leaving the port of New Orleans on a silted-in bayou without a freshwater supply. To forestall that switch in river channels, the U.S. Army Corps of Engineers built the Old River Control Structures: a series of dams, completed in 1963, that ensure 70 percent of Mississippi waters flow past New Orleans and 30 percent reach the Gulf through the Atchafalaya. All other distributaries of the great river have been closed.[22]

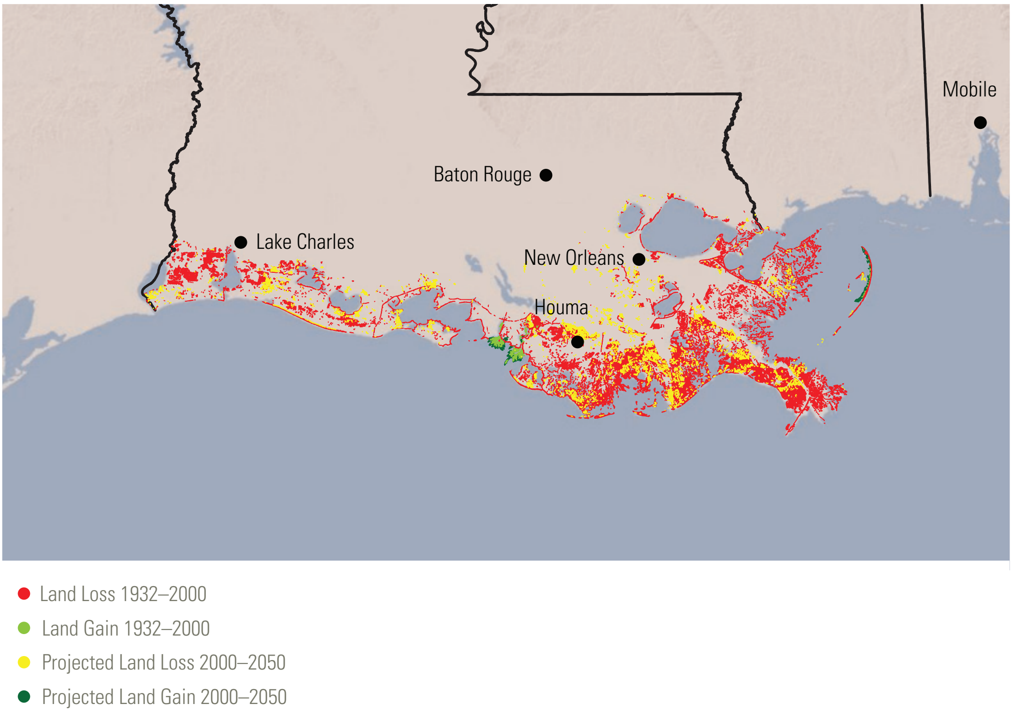
Managing the river for human ends—to improve navigation and control flooding with artificial levees—accelerates the natural deterioration of coastal wetlands and landforms. Flooding is the process that feeds this landscape, causing the accretion of sediments through which nature constructed the Delta. Under human control, the river now carries that sediment out into the Gulf, where it is deposited beyond the reach of natural deltaic processes, breaking the Delta's means for self-preservation. Managing the flow down the Atchafalaya was only the most recent intervention that has disrupted the natural mechanisms at work in the Delta. Addressing the central issue of the Delta's functioning lies at the core of strategies for long-term restoration.

The sediment problem. The re-engineering of the Mississippi River system—resulting in the "sediment starvation" of the Delta—began even before the Great Flood of 1927, when 145 levees failed, at least 246 people died, and floodwaters throughout the river basin caused the modern equivalent of $2 billion to $5 billion in damage.[23] It accelerated after that flood, when the Flood Control Act of 1928 authorized an epic levee-building program.[24] The Mississippi River and Tributaries Project engaged the Corps in building levees to contain floods, constructing strategic floodways, improving the river channels for shipping and floodwater carrying capacity, and reconstructing tributary basins for flood control. The Corps now manages the resulting protective system, with 2,203 miles of levees.[25]

As flooding decreased, and improved river traffic and long-distance shipping allowed local communities to grow, the closure of the Mississippi's crevasses, flood plains, and distributaries had the unforeseen consequence of endangering the very communities that enjoyed those benefits. In written remarks to the Commission, Senator Mary Landrieu decried the "strangulation" of nature: "For more than a century, the federal government has mismanaged critical water-resource projects, placing delicate ecosystems like the Mississippi River Delta at extreme risk of complete and utter collapse."[26] The loss of protective wetlands, like a catastrophic oil spill, is a manmade disaster.

In effect, the system built by the Corps is causing southern Louisiana to disappear (even though the Corps has, during the past 20 years, begun taking steps to offset these unforeseen consequences).[27] The annual sediment load reaching the Delta has decreased from 400 million metric tons before 1900 to 145 million metric tons in recent years. And very little of that reaches wetlands.[28]

FIGURE 7.4: Louisiana Coastal Erosion



USGS Open File Report 2009-11-0408

Rising waters. Even as the altered river delivers less sediment to replenish the Delta, the relative sea level is rising in southern Louisiana—the net result of land subsidence and actual sea level rise.[29] Subsidence is a critical problem in the Gulf region, which naturally sinks 1 to 5 millimeters per year. In some places near the outer Delta, subsidence is nearly 10 millimeters per year, largely from manmade impacts.[30] It is particularly intense in the Delta, where the Gulf has swallowed more than 2,300 square miles of coastal wetlands since the early part of the twentieth century.[31] Explanations for the phenomenon vary. One is that sediment rich in organic material behaves like a sponge: squeeze out the water and it shrinks.[32] Another relates to deep tectonic faulting.[33] A third correlates hydrocarbon extraction with subsidence-driven wetland loss.[34] Whatever the reason, the channeling of river sediment into the Gulf is interrupting natural land generation, and the region cannot keep pace with relative sea level rise.

Navigation and channeling the wetlands. Relative sea level rise endangers marsh grasses and other swamp trees as they become subject to inundation by the salty Gulf. At the same time, the growing oil and gas industry dredged 10,000 miles of canals through Louisiana's wetlands in order to move in drilling barges or lay pipelines, leaving arrow-straight channels through what had been a convoluted maze.[35] Dredged sediment lines the canal: artificial banks change water flow and prevent flooding, so sediment mobilized by tidal flows cannot replenish the land. Water forms pools behind the banks, submerging marsh. And the channels admit saltwater flow into brackish and freshwater environments, jeopardizing the overall ecosystem. Researchers have reached no solid consensus on how much wetland loss to attribute to the canals' direct and indirect effects, although some scientists attribute 35 percent to the canals' indirect effects.[36] In 2009, a Minerals Management Service study concluded, "The construction of outer continental shelf-related pipelines through coastal ecosystems can cause locally intense habitat changes, thereby contributing to the loss of critically important land and wetland areas" through their conversion to open water, or from freshwater marsh into saltwater marsh.[37]

Congress and the Corps put the most well known of the navigation canals out of business in 2008. The Corps in 1968 finished the Mississippi River Gulf Outlet—affectionately, or derisively, called "Mr. Go" (MRGO)—a straight shot from the Gulf to the Port of New Orleans. This canal's story is emblematic of the larger problem of wetland canals' environmental impacts. The 66-mile outlet shortened and simplified ships' approach to the port. Heralded as a boon to economic development, the project never proved transformative—except environmentally. Construction destroyed the existing ecosystems and excavated more than 270 million cubic yards of material—slightly more than was removed to build the Panama Canal.[38] The project converted about 3,350 acres of fresh or intermediate marsh and 8,000 acres of cypress swamps into brackish marsh. Nearly 20,000 acres of brackish marsh and swamp became saline marsh. More than 5,000 acres of marsh next to the channel had disappeared by 1996.[39] Maintenance costs increased significantly over the years, including costs related to hurricanes—even as shipping through the canal declined. The Corps estimated that the canal would require $22.1 million per year in dredging, or about $12,657 per ship every day. By the late 1990s, multiple stakeholders had pressed the Corps to close the canal.[40]

That was before Katrina. As the hurricane approached Louisiana's eastern coast, its storm surge pushed into the shipping channel, breaching levees, thereby contributing to the flooding of New Orleans.[41] Congress de-authorized the Mississippi River Gulf Outlet canal in 2008 and a contractor sealed off its southern entrance with rock fill in 2009.[42] Congress has undertaken no similar effort to address the ongoing harm caused by vast network of canals and infrastructure built into the wetlands—incursions that have hastened by decades the demise of the already sediment-starved Delta.

Planning without end. By the early 1950s, Gulf coast researchers had become aware of gaps in understanding how coasts naturally worked. In 1952, Louisiana State University created a Coastal Studies Institute. Scientists there and elsewhere sought to explain the relationship between floods breaching natural levees and the health of marshland and barrier islands fed by the sediment.[43]

The U.S. Fish and Wildlife Service in 1959 sent the Corps a memorandum suggesting that the declining health of oyster reefs caused by increasing salinity might be addressed by diverting fresh water from the Mississippi into discrete areas.[44] The first diversion, at Caernarvon, was authorized in 1965, and two years later Congress instructed the Corps to develop a strategy "in the interest of hurricane protection, prevention of saltwater intrusion, preservation of fish and wildlife, [and] prevention of erosion."[45] A 1973 report to the Corps suggested diversions to deliver sediment and lower salinity.[46] A 1979 study examined the economic impacts of wetland loss, with guidelines that "center on avoiding the disruption of wetland hydrology," and found that land loss was greater than previously measured.[47] Eight years later, a new group called the Coalition to Restore Coastal Louisiana suggested the same strategy: fix the hydrology.[48] In the 20 years since, a few small-scale programs and many reports have directed the state and federal governments to fix the hydrology. None approach the necessary scale for meaningful restoration[49], although they have provided smaller successes and helpful organizational models.

Simulations predict that, at the current rate of land loss, much of southern Louisiana will disappear by 2100. The region will transition from marshy lowlands to a fully aquatic system because of erosion and submergence,[50] leaving New Orleans an expensive island fortress.

Among efforts to identify and begin to address the problem are these highlights:

- Louisiana Act 6. In 1989, the Louisiana legislature passed Act 6, establishing a wetlands authority and an executive office to prioritize and manage a restoration strategy and projects.

- The Coastal Wetlands, Planning, Protection and Restoration Act. The following year, Congress enacted the so-called Breaux Act, named for its sponsor, Louisiana Senator John Breaux. It authorizes civil works aimed at marsh regeneration, shoreline protection, barrier-island reconstruction, hydrologic engineering, and the use of dredged material for restoration purposes. The Act has a dedicated funding source, the Sport Fish Restoration and Boating Trust Fund, which receives taxes on gasoline for motorboats and other small engines, and on sport-fishing equipment.[51] The taxes have yielded between nearly $30 million and $80 million per year.[52] Programs under the Act, which involve collaboration among Louisiana and five federal agencies including the Corps, have been credited with protecting 110,000 acres of wetlands.[53]

  In 1998, more ambitiously, the Breaux Act agencies agreed to the recommendations of Coast 2050, an 18-month feasibility study for coastal restoration. The report was based upon original research and 65 public meetings, and was supported by 20 coastal parishes. The report's recommendations were aimed at allowing healthy flows of sediment into the Mississippi, preserving salinity levels and land critical to sensitive habitats, and diverting sediment-rich fresh water to replenish starving marsh.[54]

  In 2004, the Corps produced its Louisiana Coastal Area Comprehensive Coastwide Ecosystem Restoration report, a package of projects meant to meet the coastal challenges. This led to creation of the Louisiana Coastal Area Ecosystem Restoration Program under the 2007 Water Resources Development Act. After the Office of Management and Budget opposed the high price tag of a more comprehensive proposal—about $14 billion—the Corps slimmed its initial implementation down to 15 projects that would together cost more than $2 billion.[55]

Katrina's aftermath. Weeks after Hurricane Katrina ravaged much of coastal Louisiana and Mississippi, the Louisiana legislature established a Coastal Protection and Restoration Authority that combined responses to wetland loss and hurricane risk—related goals separated in state bureaucracy. In September 2006, Louisianans approved a constitutional amendment that explicitly ties state revenues from oil and gas activities in federal waters to storm protection and rebuilding wetlands.[56]

The relative priority of the two goals is not yet certain. Although one rule of thumb for the Louisiana coast holds that each 2.7 square miles of marshland reduces a hurricane's storm surge by one foot,[57] the relationship has not been easy to precisely quantify. In the meantime, construction for storm protection is tangible and has been readily funded. The Corps has been able to fast-track building new levees to protect New Orleans from the projected "100-year storm"; the project should be completed in 2011—just five years after it began. By contrast, direct instructions and guaranteed funding have mostly eluded restoration efforts. The state has engaged the Corps to design and build two new, large levee systems, but their effects on southern Louisiana communities and wetland survival are still being studied.[58] Traditional flood protection usually involves "hard-engineering," essentially levee-building. Part of the promise of the state's newly organized approach is in protective "soft-engineering," or regenerating wetlands and barrier islands for the dual purposes of ecosystem restoration and storm protection.

Congress also asked the Corps to develop comprehensive statewide hurricane-protection options after Hurricanes Katrina and Rita. The Department of Defense Appropriation Act of 2006 directed the Corps to design a suite of improvements to the Louisiana and Mississippi coasts, including improvements for "hurricane and storm damage reduction, prevention of saltwater intrusion, preservation of fish and wildlife, prevention of erosion, and other related water resource purposes at full Federal expense."[59] A September 2009 Chief of Engineers' report suggested 12 projects for Mississippi, costing more than $1 billion, that would help restore barrier islands, beaches, sensitive habitats, and coastal ecosystems. Congress has appropriated $439 million to implement Mississippi's program so far.[60] The Corps has also drafted a counterpart Louisiana Coastal Protection and Restoration Final Technical Report,[61] but the future of the Louisiana program is uncertain, as the report includes a wide range of options rather than a specific plan.

Other sources of funding for sustained restoration efforts include the State of Louisiana's Coastal Protection and Restoration Fund, about $25 million a year from state mineral income plus budget surpluses in 2007–2009;[62] the federal Coastal Impact Assistance Program, which authorizes $250 million split among six states in each fiscal year from 2007–2010 to fund natural resources recovery, conservation, and protective measures;[63] and the federal Gulf of Mexico Energy Security Act, in which participating Gulf states (all but Florida) share 37.5 percent of federal offshore revenue from new lease areas for use in coastal protection, including onshore infrastructure projects that mitigate the impacts of outer continental shelf energy activities.[64]

Voices from the Gulf

"An entire culture being washed away by crude oil and chemicals"


Claire Luby

Clarence R. Duplessis, Commercial Fisherman, Davant, LA

When Clarence R. Duplessis was born in 1945 in the small Gulf Coast fishing community of Davant, just north of Pointe-a-la-Hache, he became the seventh generation of his family to live in Plaquemines Parish, Louisiana. After high school, Duplessis, joined the U.S. Marine Corps, served a tour of duty in Vietnam, and met his wife, Bonnie, who served in the Navy.

Upon their return to Louisiana, Mr. Duplessis found work at the Kaiser Aluminum plant in Chalmette, La. In 1989, when the plant shut, he says, "I had a young family to feed, clothe, and educate. This. . . was a problem with a solution. I was still young and had experience with shrimping and oystering. I had salt water in my veins at birth. I went fishing and my children paid their college tuition by working as deckhands.

"In 2005, Hurricane Katrina hit us with a crippling blow. Wow! A major problem!. . . My wife and I lost everything we owned in Hurricane Katrina. . . Even then, though the entire region was wiped out and the insurance companies packed their bags and left us, there was still a solution…The fishing communities and people of South Louisiana are some of the hardest working, defiant yet kindest people on God's earth. After the storm we faced the difficult task of rebuilding, but that was the solution.

"Now, five years later we are facing the *Deepwater Horizon* oil spill. This is the worst of our problems because we have no answers, no solutions, only questions. As we watch our livelihood and even an entire culture being washed away by crude oil and chemicals that no one knows the long term effects of, we ask: [W]ill we have the mortgage payment next month? . . . How long will this last? Will I be able to go oystering next year or ever again? How long will it take the fisheries to recover?. . . Will BP do what is right or will they pack their bags and leave us like the insurance companies did? What can I do to survive?...I have a thousand questions and no answers. Now, I hope you can understand why this problem is the worst of my life!"

Toward coordinated strategies and action. In the fall of 2009, President Obama directed the Council on Environmental Quality and the Office of Management and Budget to co-chair a Louisiana-Mississippi Gulf Coast Ecosystem Restoration Working Group, made up of federal agency and state representatives.[65] Six months later—about six weeks before the *Deepwater Horizon* exploded—the group presented a "road map" for federal-state collaboration and set out 2010–2011 deadlines for advancing policymaking.[66] The President's fiscal year 2011 budget requested $19 million for construction, sediment use, and river diversions and $16.6 million for studies of eventual restoration projects.

After the spill, the President in June commissioned Secretary of the Navy and former Governor of Mississippi Ray Mabus to study Gulf coast recovery and propose ways to address chronic Gulf marine and coastal issues. The resulting "Mabus report," published on September 28, 2010, analyzed ecosystem restoration, human health, economic recovery, and the nonprofit sector.[67] A week later, the President issued Executive Order 13554, creating a Gulf Coast Ecosystem Restoration Task Force comprised of federal agency and state representatives to "coordinate intergovernmental responsibilities, planning, and exchange of information so as to better implement Gulf Coast ecosystem restoration and to facilitate appropriate accountability and support throughout the restoration process."[68]

In the course of his work, Secretary Mabus repeatedly referred to the rising public impatience with plans unaccompanied by action. As he put it in June, "I also understand that people have plan fatigue, that they've been planned to death."[69] In the meantime, at current erosion rates, an area of the Delta the size of a football field is consumed by Gulf waters every hour.[70]

Identifying options for funding and governance. The twentieth-century re-engineering of the Mississippi River basin, and subsequent piecemeal efforts to restore its nourishing flows of water and sediment, teach important lessons about any future, comprehensive approach to coastal management. Many of the re-engineering projects have provided only incremental gains.[71] Discrete restoration projects, moreover, are unable to reverse the loss of Delta land and habitats in the aggregate. The many layers of federal, state, and local authorities—some overlapping and conflicting—make it difficult as a practical matter to devise, implement, and make mid-course corrections to a strategy for restoration. And secure, sustained sources of funding on the scale required to do the necessary work are not now in place.[72] The contrast with the reconstruction of the protective hurricane levees around New Orleans from 2006 through 2011 could not be clearer.

Estimates of the cost of Gulf restoration, including but not limited to the Mississippi Delta, vary widely, but according to testimony before the Commission, full restoration of the Gulf will require $15 billion to $20 billion: a minimum of $500 million annually for 30 years.[73] Current funding sources do not approach those figures. Beginning in 2017, Phase II of the Gulf of Mexico Energy Security Act,[74] which governs sharing of oil-related revenues, will begin to bring large amounts of money to the Gulf States. Much of this could be directed to restoration.

The *Deepwater Horizon* disaster provides a significant opportunity to begin funding restoration sooner. It will generate monies that can be directed to jumpstart key Gulf restoration projects. And it can provide the basis for launching a long-needed federal-state entity capable of managing the restoration effort over the longer term, guided by a clear set of principles.

In the aftermath of the spill, the responsible party (or parties) will be liable for damages in the amount necessary for "restoring, rehabilitating, replacing, or acquiring the equivalent of" natural resources harmed by the spill.[75] The responsible party will also pay fines if found in violation of federal laws. The maximum civil penalties under the Clean Water Act could range from $4.5 billion to $21 billion, depending upon findings of negligence and the calculation of barrels discharged. The Act provides for a civil penalty for unpermitted discharges of up to $37,500 per day of violation or up to $1,100 per barrel of oil discharged. In the case of an operator's gross negligence or willful misconduct, the penalty becomes not less than $140,000 and not more than $4,300 per barrel of oil discharged.[76] Criminal fines could be large, as well.[77] A negligent violation of the Clean Water Act's criminal provision is subject to a fine of between $2,500 and $25,000 per day of violation for a first violation and up to $50,000 per day for subsequent violations.[78] For knowing violations of the Act, criminal fines range between $5,000 and $50,000 per day of violation for a first conviction, and up to $100,000 per day for subsequent violations.[79] Civil and criminal fines are both deposited in the Oil Spill Liability Trust Fund, established after the *Exxon Valdez* spill to help pay for cleanup and certain damages after a spill, but use of that Fund is restricted.[80]

The Mabus report, as well as regional members of Congress and Governors from the Gulf, have proposed directing a significant amount of the penalty funds to long-term ecosystem restoration in the Gulf (and in the case of the Mabus report, to economic and health recovery as well). Secretary Mabus recommended that the President urge Congress to pass legislation to dedicate some of the penalties for those purposes.

Legislative proposals to establish a coordinating and decisionmaking council, as recommended in Secretary Mabus's report,[81] call for a state-federal governing entity that has authority to prioritize restoration projects based on a comprehensive strategic plan. Although the details of early proposals varied, most recognized the need for a single, Gulf-wide decisionmaking authority and a strong leadership commitment to fund only those projects that conform to an agreed-upon vision for long-term restoration.

Planning and program design for any comprehensive Gulf restoration effort will have to be based on sound science. In different circumstances, the *Exxon Valdez* Trustee Council Science Panel reviewed all proposed projects both for technical merit and for consistency with the overall restoration goals (as set forth in the Restoration Plan) and annual work plans.[82] This effort, although encompassing projects of a different nature and scope than those in the Gulf, enabled effective scientific communication with the Trustee Council.[83]

A successful Gulf-wide scientific process would likewise be structured to allow meaningful and timely input by scientists into the decisionmaking process. Ideally, it would provide a science program with the resources to evaluate individual projects for consistency with a comprehensive plan; to research long-term restoration issues; and to develop and apply performance measures and indicators of long-term restoration that allow decisionmakers to adjust the plan based on new science or changed circumstances. Particularly with respect to long-term research issues, the diverse resources and expertise of the federal government should be brought to bear.

Finally, no authority will succeed without the confidence and support of the citizens of the region. Leaders of restoration efforts emphasize the importance of gaining the support of those most directly affected by restoration projects. Local citizen support is important for several reasons: it can reduce delay of projects due to litigation or other opposition; it contributes to political support for overall goals and funding, in the short and long terms; and it contributes to overall trust in government, which results in support for local projects.[84] Any structure should therefore include a citizens' advisory council to provide formal advice and a direct line to citizens' concerns.

Putting Restoration on the Agenda

Speaking to the nation in June 2010 from the Oval Office, President Obama clearly linked spill recovery and long-term stewardship: "The oil spill represents just the latest blow to a place that's already suffered multiple economic disasters and decades of environmental degradation that has led to disappearing wetlands and habitats. And the region still hasn't recovered from Hurricanes Katrina and Rita. That's why we must make a commitment to the Gulf Coast that goes beyond responding to the crisis of the moment."[85] In mid-July, Louisiana Governor Bobby Jindal announced his "Agenda for Revitalizing Coastal Louisiana," which extols Louisianans' resilience both in general and in recovering from the 2005 and 2008 storms: "There is not a doubt in my mind that we will recover and restore our coast and our wetlands to not only be Sportsman's Paradise again, but to be an even more plentiful source of abundant natural resources than ever before."[86]

"Restoration" itself has several specified meanings. NOAA defines post-spill restoration under the Oil Pollution Act as "the goal of a natural resource damage assessment, which involves rehabilitating, replacing, or acquiring the equivalent of injured natural resources and the services they provided."[87] In some cases after an oil spill, natural resource trustees—such as the involved state and federal agencies—and the party responsible for the spill can alter the charge. For example, the concept of "enhancement" that emerged after *Exxon Valdez* gave trustees additional latitude in restoring Prince William Sound and its ecological region.[88] This addition enabled planners to strive for improvements, rather than returning to a baseline.

Nature has no baseline: natural systems change and evolve continuously. "Restoration" therefore should have another, broader meaning. In the Gulf, it must encompass reversing the progressive erosion of coastal land and habitats that buffer human communities from storms and sustain the area's biological productivity. In this context, restoration does not imply returning landforms to a particular map, but rather making the river, Delta, and Gulf coastal and marine systems more resilient. The economies of the Gulf—fisheries, energy, and tourism—are as rooted in the environment as any in the developed world. Restoration, or restored resilience, represents an effort to sustain these diverse, interdependent activities and the environment on which they depend for future generations.