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IN THE UNITED STATES DISTRICT COURT FOR
THE EASTERN DISTRICT OF LOUISIANA

In re: Oil Spill by the Oil Rig Deepwater Horizon
in the Gulf of Mexico on April 20, 2010 (MDL No. 2179)

Before the Honorable Judge Carl J. Barbier

EXPERT REPORT OF DR. JOHN L. WILSON

BP Internal Well Flow Rate Estimates in April and May 2010

May 1, 2013

Submitted by Transocean Offshore Deepwater Drilling, Inc.

John L Wilson

John L. Wilson, Ph.D.

CONFIDENTIAL

TABLE OF CONTENTS

I. EXPERIENCE AND QUALIFICATIONS

I am an engineer specializing in fluid flow and related transport processes, with special attention to flow in porous media and the science of hydrogeology. I have a BCE from the Georgia Institute of Technology (1968) and MS (1970), CE (1974), and PhD (1974) engineering degrees from the Massachusetts Institute of Technology (MIT).

I am currently Professor of Hydrology in (and former Chairman of) the Department of Earth and Environmental Science at the New Mexico Institute of Mining and Technology (Tech) in Socorro, New Mexico. I have been at Tech for over 25 years; for the first 12 years I led Tech's seven-faculty-member Hydrology Program. Prior to that I was on MIT's faculty in the School of Engineering.

I am also former Chair of the Board of Directors of the Consortium of Universities for the Advancement of Hydrologic Science, Inc., a consortium of over 100 research universities. I am past President of the 7,000-member Hydrology Section of the American Geophysical Union (AGU), a former member of AGU's Board of Directors, and a Fellow of AGU and of the Geological Society of America (GSA). I hold the Hydrologic Sciences Award from AGU and the Meinzer Award from GSA, their highest honor in the field of hydrogeology. I am a former Darcy Lecturer for the National Ground Water Association.

I have over 40 years of experience, much of it related to the flow of fluids and transport of solutes (see attached CV). Twenty years ago a substantial portion of my work was focused on petroleum reservoir simulation and the effects of reservoir heterogeneity on oil recovery; at that time I was active in the Society of Petroleum Engineers. My current supported research activities include National Science Foundation-supported studies of the interaction between streams and aquifers, fractured-rock hydrogeology, and karst hydrogeology (with additional support from the Environmental Protection Agency and U.S. Geological Survey).

I am compensated at the hourly rate of $400 for document review, research, and report preparation, and at the hourly rate of $600 for testimony, depositions, and related activity.

Over the past four years I have testified as an expert witness, either in deposition or at trial, in the following cases:

> United States District Court, Southern District of New York, In re. Methyl Tertiary Butyl Ether (MTBE) Products Liability Litigation, MDL No. 1358 (SAS), City of Fresno, Plaintiff, v. Chevron U.S.A. Inc., et al., Defendants, Case No.: 04 Civ. 04973 (SAS), 2012
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> United States District Court, Southern District of New York, In re. Methyl Tertiary Butyl Ether (MTBE) Products Liability Litigation, MDL No. 1358 (SAS), Orange County Water District, Plaintiff, v. Unocal Corp., et al., Defendants, Case No. 04 Civ. 4968, 2012.
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> Superior Court of the State of California, in and for the County of Merced, Case No. 148451, City of Merced, Plaintiff, v. Chevron U.S.A., Inc., et al., Defendants, 2011 and 2012.

Superior Court of the State of California, in and for the County of Los Angeles, Santa Clara Case No. 1-05-CV-049053, Antelope Valley Groundwater Cases, Lead Case: Los Angeles County Waterworks District No. 40 v. Diamond Farming Co., Case No. BC 325 201, 2011.

United States District Court, Southern District of New York, In re. Methyl Tertiary Butyl Ether (MTBE) Products Liability Litigation, MDL No. 1358 (SAS), Crescenta Valley Water District, Plaintiff, v. Mobil Corporation, et al., Defendants, Case No. 07 Civ. 9453 (SAS), 2011.

Superior Court of the State of California, in and for the County of San Bernardino, Case No. SCVSS 120627, City of Redlands, Plaintiff, v. Shell Oil Company, et al., Defendants, 2010.

United States District Court, Eastern District of California, Case No. 1:07-cv-00388-OWW-DLB, Abarca, Raul Valencia, et al., Plaintiffs, v. Merck & Co., Inc., et al., Defendants, 2010.

Superior Court of the State of California, in and for the County of Sonoma, Carla M. Clark, et al., Plaintiff(s), v. Union Pacific Railroad Company, et al., Defendant(s), No. 227896, 2009.

II. SCOPE OF WORK

I have been retained by Transocean for the purpose of providing expert testimony regarding the BP oil spill MDL 2179. Specifically, this report addresses the flow rate and other modeling performed by BP in April and May 2010 and its relation to the top kill operation.

My opinions, expressed in this report, are based on a reasonable degree of scientific certainty and are supported, whenever possible, by the evidence and testimony reviewed to date. I reserve the right to supplement my opinions in the event that additional evidence or testimony warrants such supplementation.

III. SUMMARY OF OPINIONS

A. Immediately after the blowout of the Macondo MC 252-1 well, BP began conducting well flow rate modeling to inform its source control efforts, including the top kill operation.

Immediately following the Macondo blowout, BP mobilized its vast resources to perform modeling to understand the Macondo well's fluid and pressure behavior, including flow rates. Simon Bishop, BP's 30(b)(6) corporate representative on flow rates, acknowledged that BP ran these models "to assess the robustness of a number of operations associated with source control."[1] Well flow rates were particularly important with respect to the top kill effort. Tony Hayward, BP's CEO at the time, testified that "[t]here were certainly

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[1] Deposition of Simon Bishop, September 27, 2012, 95:7-9.

[flow] estimates to try and estimate under what circumstances the top kill could work and on what circumstances it would not."[2]

B. <u>In the weeks following the blowout BP's computer models suggested higher well flow rates than those BP reported to the government, the press and the public.</u>

In the six weeks that followed the blowout, engineers at BP and their contractors, including Halliburton, used computer-based mathematical models to understand what had happened to the well and to assist in the design of source control measures to bring the well under control. The models developed and applied by these engineers, and shared with BP management, typically demonstrated well flow rates of tens of thousands of barrels oil per day (BOPD).

Despite the lack of communication between different BP workgroups, the range of modeled well flow rates were similar. A significant majority of modeled flow rates were much greater than the rates expressed by BP management to the government, the press and the public, such as the flow rate of 5,000 BOPD mentioned in their May 10, 2010 letter to Admiral Landry of the U.S. Coast Guard, their May 24, 2010 letter to Congress, and during a series of televised interviews in April and May.

BP represented the flow rate of 5,000 BOPD as the "most likely model"[3] despite BP engineers internally expressing concern over BP's reliance on the 5,000 BOPD rate because it "has little if no origin" and "would appear to err on the low side."[4]

C. <u>BP knew or should have known from its modeling efforts that the top kill was very likely to fail because the well flow rate exceeded a 15,000 BOPD threshold rate.</u>

One of BP's considered source control measures was the top kill, which included a dynamic (momentum) kill in which mud was pumped into the well through the BOP in an attempt to arrest the flow of oil and gas.

BP ran models of the dynamic kill during the month of May in support of the kill design. The models demonstrated that well flow rates of 15,000 BOPD or more would doom the kill attempt. This threshold rate was communicated to BP management and discussed in a meeting on or about May 17, 2010. "Modeling indicates that a dynamic kill cannot be successfully executed if the oil flow rate is 15000 STBpd."[5]

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[2] Deposition of Tony Hayward, June 6, 2011, 264:20-265:2.

[3] Email from Doug Suttles to Mary Landry et al., "Re: MC 252 Response -- United States Coast Guard Request for Proprietary Information Regarding Potential Productive Capacity of the Macondo Well," May 10, 2010, Deposition Exhibit 9255.

[4] Email from Tim Lockett to Trevor Hill, May 17, 2010, Deposition Exhibit 9254.

[5] Summary Points from the Kill the Well on Paper Discussion, May 18, 2010, Deposition Exhibit 8553.

This 15,000 BOPD threshold rate was well below a significant majority of flow rates modeled by BP engineers and contractors. It was also well below the minimum well flow rate calculated by Halliburton (30,000 BOPD) based on temperature measurements at the BOP, and used to design the cement job that was part of the top kill.

In short, BP knew or should have known that the flow rate from the well was higher than a 15,000 BOPD threshold at or above which the top kill was likely to fail. Proceeding with the top kill under these conditions delayed other source control measures that may have had a greater likelihood of success.

D. After the top kill failed, BP was informed that the failure was most likely due to the flow rate.

As predicted by BP's modeling, the top kill failed. During the top kill operations a BP engineer reported to BP management that the kill was failing because the flow rate was higher than 15,000 BOPD: "Too much flowrate - over 15000 and too large an orifice."[6]

Post-top kill analysis by BP and its contractors further confirmed that the top kill failed due to a flow rate higher than 15,000 BOPD.

IV. BACKGROUND

On April 20, 2010 a catastrophic blowout and fire occurred during abandonment operations of BP exploration well Macondo MC 252-1 in the Gulf of Mexico. The Deepwater Horizon rig sank to the bottom two days later. A riser connected the drilling rig to the wellhead and BOP (Blow-Out Preventer) through the LMRP (Lower Marine Riser Package) on the seafloor. After the blowout the riser separated from the rig and came to rest on the seafloor still connected to the LMRP. Shortly after, cameras mounted on Remotely Operated Vehicles (ROVs) observed oil and gas from the well pouring out of the broken end of the riser and through intermediate gaps closer to the LMRP. One of the larger discharge points was just above the LMRP where the riser had kinked as it fell.

Immediately after the accident, BP engineers and their contractors rallied to understand what had happened to the well and to assist in the design of remedial measures to bring the well under control. This report reviews the efforts of BP's modelers, those engineers who used computer-based mathematical models to simulate the petroleum reservoir that had been tapped by MC 252-1, the relationship between the well and the reservoir, and the fluid flow in the well, BOP, LMRP and riser. It examines those efforts from late April and through the end of May 2010.

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[6] Text message from Kurt Mix to Jon Sprague, May 27, 2010, Deposition Exhibit 9160.

V. OPINIONS

A. Immediately after the blowout of the Macondo MC 252-1 well, BP began conducting well flow rate modeling to inform its source control efforts, including the top kill operation.

The purpose of BP's flowrate and other modeling was "to assess the robustness of a number of operations associated with source control."[7] BP mobilized its teams of engineers and contractors from around the world to work on this modeling and other aspects of well control. As Tony Hayward, BP's CEO at the time, stated: "At the peak, there were almost a thousand engineers and scientists, operating in that [crisis] center." [8]

Well flow rates were vital to BP's source control efforts, including the top kill effort. BP's top executives have acknowledged that fact. Tony Hayward testified that "[t]here were certainly [flow] estimates to try and estimate under what circumstances the top kill could work and on what circumstances it would not."[9] Richard Lynch, BP's Vice President of Drilling and Completions, testified that "[t]hey had to form a view of the flow rates in order to design the dynamic kill involved in the top kill."[10] Doug Suttles, at the time BP's Area Commander on the Unified Area Command, also testified, "I'm sure there is…some relationship between the flow rate out of the well and the rates required to do dynamic kill."[11] James Dupree, at the time BP's most senior official in the Gulf of Mexico Strategic Performance Unit (GOM SPU) and a leader of the response effort, stated: "Flow rate was a component of the calculations of the top kill. I mean, it was – it was modeled in the top kill calculations."[12] Charles Holt acted as BP's leader of the Well Capping Team in May 2010 before he transitioned to leader for the operations component of the top kill in late May. Holt stated outright that "flow rate does impact top kill."[13] BP's own May 18, 2010 "Kill the Well on Paper" summary stressed the importance of flow rate to the top kill: "Knowledge of the flow rate is needed to form a view of the probability of success…". [14]

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[7] Deposition of Simon Bishop, September 27, 2011, 95:7-9.

[8] Deposition of Tony Hayward, June 8, 2011, 859:25-860:11.

[9] Deposition of Tony Hayward, June 6, 2011, 264:20-265:2.

[10] Deposition of Richard Lynch, May 20, 2011, 542:19-543:11.

[11] Deposition of Douglas Suttles, May 19, 2011, 486:23-487:9.

[12] Deposition of James Dupree, June 17, 2011, 371:16-19.

[13] Deposition of Charles Holt, November 28, 2012, 247:25-248:4.

[14] Summary Points from the Kill the Well on Paper Discussion, May 18, 2010, Deposition Exhibit 8553.

B. In the weeks following the blowout BP's computer models suggested higher well flow rates than those BP reported to the government, the press and the public.

1. BP Engineers Had Sufficient Tools and Information to Model Flow Rates from the Macondo Well

BP engineers and their contractors doing the modeling appear to have had access to almost unlimited resources, except for the urgency of time. They employed conventional petroleum reservoir and well modeling software packages, each with its unique assumptions, capabilities, data needs, and outputs, and with which they were largely well acquainted. The well packages had names like PipeSim, PROSPER, OLGA, and WELLCAT. OLGA was the most sophisticated of the well packages. MBAL, a simple "material balance" petroleum reservoir model, was often used in conjunction with PROSPER.

BP engineers and their contractors had access to proprietary data regarding the reservoir and the engineered infrastructure of MC-252. Proprietary and other information about the reservoir and its fluids was available from measurements taken during the drilling and logging of the Macondo well, and from analogs in other nearby Gulf wells. Seismic surveys provided additional information about the reservoir thickness and extent. Of course, BP and its contractors had designed and constructed the well, so the design and the as-built architecture of the well casing, BOP, LMRP, and riser were known to BP. As a consequence the BP engineers knew or had high-quality estimates of the reservoir, fluid properties, and the engineered infrastructure.

Nevertheless BP engineers and their contractors were challenged by some uncertainty, mostly created by the accident. During abandonment procedures, and just before the accident, there was an attempt to cement the well to seal it from the reservoir. Without knowing more about the accident, the degree to which this seal was disrupted was unknown. Consequently the strength of the connection between the well and the reservoir became a focus of the modeling. While the wellbore architecture was documented, the accident could have damaged that architecture. Depending on that damage there were several possible fluid flow paths up the well from the reservoir, but which path the fluids were taking was unclear. The blowout itself demonstrated that the BOP had failed to close, but the nature of the failure and the resulting obstruction to flow (or "choke") in the BOP was also unclear. Finally, fluids entering the riser from the LMRP were discharging at several points along the riser, including near the kink located just above the LMRP; engineers also believed the kink itself was likely to be a choke.

BP engineers and its contractors were organized into informal, ad hoc workgroups, with ties to established BP organization charts. But within BP, the workgroups had shifting membership and there was a lack of communication between workgroups.[15] While horizontal lines of communication were limited, communications of their findings upward to management were exhaustive, although often informal (e.g., meetings, email, and PowerPoint presentations).[16]

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[15] Deposition of Michael Mason, January 25, 2013, 367:22-368:1, 369:4-16, 369:18-25.

[16] For example, reservoir engineers from the Gulf of Mexico Exploration group sent their results via email to Vice President of Exploration David Rainey. (Email from Walt Bozeman to David (footnote continued)

From my review, it appears that at least four different workgroups within BP performed modeling related to the flow rate from the Macondo well: reservoir engineers from BP's Gulf of Mexico Exploration group; BP drilling engineer Kurt Mix and contractors Bill Burch (Wild Well Control) and Ole Rygg (Add Energy); production engineers from BP's EPT Base Management Group led by Mike Mason; and "flow assurance" engineers led by BP engineer Trevor Hill. The work of these groups will be described in more detail below.

The BP engineers used PipeSim, MBAL, and PROSPER software. Shortly after the accident, the BP workgroup led by drilling engineer Kurt Mix arranged to purchase a license for OLGA-ABC (ABC=Advanced Blowout Control), a more capable well software package specifically programmed to model difficult multiphase (water, oil and gas) flow situations, an important consideration in this application.[17] Another BP contractor, Add Energy, also used OLGA. Add Energy had previously developed its own OLGA enhancements for modeling, among other things, dynamic kill operations, whereby mud is pumped into a blowout to arrest the flow of reservoir fluids to the wellhead. In the Macondo kill attempt, kill mud was simultaneously pumped into the well through the BOP's choke and kill lines, which were two direct connections from the surface into the bottom of the BOP. Add Energy's enhanced version of OLGA was called OLGA-Well Kill, and it allowed for two flow paths to be modeled in parallel.

Halliburton, which had been contracted to design and pump the mud and cement to follow the dynamic kill, used its own well package, WELLCAT, to model the well flow, pressures and temperatures. The latter was needed to properly design the cement mix and model the curing process. Initially BP also asked Halliburton to model the dynamic kill itself, before giving that job to Add Energy.[18]

Typical model outputs for these software packages are fluid pressures and flow rates at various locations between the reservoir and the sea floor. Typical inputs vary with the package and can include reservoir and fluid properties, reservoir extent, thickness and/or productivity index (a measure of the amount of flow into the well for a given pressure reduction in the well at the depth of the reservoir), well and reservoir connectivity (represented by a so-called "skin factor" in most models), well/BOP/LMRP/riser architecture, and obstructions to flow or chokes in the BOP and riser.

Rainey, et al., "RE: WCD – Updated," April 21, 2010, Deposition Exhibit 3372.) BP engineer Michael Mason summarized his group's results in powerpoint presentations and emailed them to Jasper Peijs, an executive assistant, who apparently passed them on to BP CEO of Exploration and Production Andy Inglis. (Email from Michael Mason to Cindy Yeilding, et al., "FW: Meeting Presentation May 11 2010 (3).ppt," May 11, 2010, Deposition Exhibit 9156 ["All, Jasper's feedback after reviewing with Andy Inglis is very positive."].)

[17] Email from William Burch to Christopher J. Murphy, et al., "042110 – Notes from BP Reservoir/Geology Group (WWCI 2010-116)," April 22, 2010, Deposition Exhibit 3907.

[18] Deposition of Richard Vargo, August 22, 2012, 282:20-284:9; *see also* Email from Jae Song to Gary Godwin, et al., "Top Kill Modeling Support Update," May 23, 2010, Deposition Exhibit 5792.

The simplest software packages take a well flow rate as input and model the resulting pressures. For example, a simple material-balance reservoir model like MBAL – sister software to PROSPER – was used by BP to model reservoir pressure depletion due to the flowing well, and provide a forecast of potential well production over time.[19] More sophisticated packages, such as PipeSim, PROSPER, OLGA, and WELLCAT, take pressures as boundary conditions and model well flow and pressures between the boundaries. In these latter applications, the pressure boundaries were selected for the desired application and based on available pressure data or estimates. The most elaborate model might go all the way from the reservoir to the ocean, but the more typical application examined only a portion of the system, say along the well from the reservoir to the wellhead (once pressure readings were available for a pressure gauge located at the bottom of the BOP), or from the wellhead to the seafloor through the BOP and riser. The difference between the higher and lower pressure bounds used in the model is referred to as the model "pressure differential" or more frequently, the "pressure drop." Well software was used by itself, sometimes with a simple representation of the reservoir, or run together with a reservoir package. PROSPER for the well and MBAL for the reservoir were often run together.

BP engineers and their contractors had estimates and/or measurements for the pressure at the sea floor where the fluids discharged to the ocean from the riser. They had also measured a bottom-hole reservoir pressure of 11,850 psi while drilling the Macondo well.[20] As of at least May 8, a wellhead pressure measurement of approximately 3800 psi was available to the BP engineers from a PT-B pressure gauge at the base of the BOP.[21] Though BP has since stated this measurement was unreliable, it was the best available pressure measurement at the time and was relied upon by the modeling workgroups. These three pressure data points (seafloor, wellhead, and reservoir) were used by BP to model the potential flow rate from the Macondo well.

An example of this is included as Fig. 1 below. On May 9, 2010, Add Energy's Ole Rygg emailed BP's Kurt Mix a chart of "Blowout Rates" with a table of OLGA-Well Kill flow rate outputs for the Macondo well.[22] These outputs were based on the differential pressure between the reservoir and either the BOP or the sea floor. The downstream boundary pressure in Rygg's model relied on a pressure reading of 3800 psi from the BOP's PT-B gauge to represent the backpressure exerted by whatever obstructions or chokes existed in the BOP and/or riser. He also provided comparison flow rates for a downstream boundary pressure of 2244 psi, representing a direct discharge to the sea floor without a choke in the BOP/riser (this is the pressure exerted by the weight of the approximately 5,000 ft. of sea water, the water column, above the point of discharge). The resulting well flow rates range from 37,000 to 87,000 BOPD.

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[19] Email from Kelly McAughan to Jay Thorseth, et al., "RE: Flow rate and production profile," April 22, 2010, Deposition Exhibit 9539.

[20] Macondo Holistic System Analysis Report for MC-252, May 22, 2010, Deposition Exhibit 11170 at internal pg. 7 ("The reservoir pressure has been measured as ~11,850 psi at 17,991 ft. TVD when the well was logged.").

[21] MC-252 Pressure Trends, June 7, 2010 (from metadata), Deposition Exhibit 9315.

[22] Email from Ole Rygg to Kurt Mix, "[B]lowout Rates," May 9, 2010, Deposition Exhibit 9266

Flow Path	Seabed	Back Pressure psi	Oil rate bopd	Gas rate mmscfd
Annulus	Unrestricted to seabed	2244	43000	120
Annulus	Current restrictions/measured	3800	37000	110
Casing	Unrestricted to seabed	2244	63000	180
Casing	Current restrictions/measured	3800	55000	160
Both	Unrestricted to seabed	2244	87000	250
Both	Current restrictions/measured	3800	74000	210

Fig. 1 from Ex. 9266.

In this model the simulated well flow rate was an output, the result of the applied pressure boundary conditions, and known or estimated parameters for the reservoir, fluid, and engineered infrastructure in the well and the BOP/riser. Rygg testified these flow rates were stock tank barrels per day.[23]

2. BP Modeled Flow Rates for the Macondo Well to Assess the Well and to Evaluate Source Control Efforts.

BP's models often had two phases. In the first phase, a diagnostic phase, modelers would employ a "scenario approach" to try to understand the state of the well. For each scenario a set of parameters was assumed, for example, for a shallow choke in the BOP/riser, the flow path in the well, and/or the conditions where the reservoir and well meet. Multiple scenarios allowed the engineers to explore how different conditions would influence the flow rate, pressures and other system states like temperature. An example of this approach is shown by the results presented above in Fig. 1.

Some scenario options were discrete, in which a quantifiable number of options were possible.[24] For example three possible flow paths up the well were often considered. One of these was through the casing, the second was through the annulus surrounding the casing, and the third was a combination of these, as in Fig. 1. Additional flow path scenarios were created by also considering the configuration of the drill string and other well features. The presence or, alternatively, the absence of a shallow choke at the BOP and riser were two other contrasting discrete scenarios, again as illustrated in Fig. 1.

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[23] Deposition of Ole Rygg, October 3, 2012, 310:17-31:2. Stock tank barrels refer to the amount of oil at standard (surface) pressure and temperature. All well flow rates in this report refer to stock tank barrels of oil per day, unless specified otherwise.

[24] An example of a discrete event is flipping a coin; only a certain number of outcomes are possible for any given flip.

On the other hand most scenario options were continuous, but with a range of possible values.[25] For example a shallow choke was often represented by a so-called "orifice size." This refers to the equivalent measurement of a plate set across the diameter of the pipe, but allowing flow through a circular hole or orifice at its center. The orifice diameter can take on a value between zero (complete obstruction by the plate; the orifice is closed) and the diameter of the pipe (no obstruction). Some modeling packets of the shallow choke scenarios included more than a half-dozen orifice sizes. A second example is the "skin" measurement, which is a numerical value that describes the connectivity between the well and reservoir.[26] In the case of the Macondo well, BP engineers suggested skin values between 0 and 50 (a skin of 0 represents no obstruction). Instead of simulating all possible values of skin in this range, they typically selected one to as many as three (e.g., 10, 20, 50).

Other parameters with continuous values within a certain range were the reservoir thickness, permeability, and productivity index. The *Deepwater Horizon* drilled approximately 88 feet into the reservoir, but it was uncertain how much of the reservoir was in communication with the well after the blowout. To test this issue smaller thicknesses were sometimes considered, typically 44 feet and 12 or 10 feet. Reservoir permeability was sometimes varied as well, typically from the expected value of 300 mD (millidarcys) to a smaller value like 170 mD.[27] Productivity index (PI), a measurement of flow rate over pressure drop at the reservoir sand face, was also adjusted using test values. A high PI means a reservoir can produce relatively more hydrocarbons. The day after the blowout, BP's reservoir engineers calculated a PI of 50 for the Macondo well, meaning the well could produce 50 barrels per day per psi (flow rate over the pressure drop between the reservoir and the bottomhole pressure at the well).[28] By contrast, in mid-May, other BP engineers were applying a PI (bbl/day/psi) of only 1, 2, 4, or 5 in order to achieve very small model flow rates, in essence treating the PI as a model calibration parameter in order to "match" a prescribed target flow rate.[29]

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[25] An example of a continuous event is the amount of time it takes to commute to the office in the morning; this number varies given any number of factors such as the weather, how much traffic there is, and whether there is construction on the roads.

[26] A conventional way to imagine skin is as an air conditioning filter around the base of the well. If there is zero skin, the filter is "clean" and hydrocarbons pass without obstruction into the wellbore. If the filter is "dirty," perhaps because the rock face has been damaged by drilling, or sand or silt has become entrapped in the porous rock by flow, hydrocarbons cannot move into the wellbore as quickly and the well is said to have a higher "skin". In this case, the skin represented whatever flow path existed between the reservoir and the well (through the failed cement job, for example).

[27] Permeability measures the ability of fluid to flow through rock or other porous media. It is represented by a unit of measure called the "millidarcy" (mD). An example of modeling that varies these continuous values is summarized in a slidepack from Mike Mason's group in Deposition Exhibit 9156, which will be described further below.

[28] Email from Walt Bozeman to Kurt Mix, et al., April 21, 2010, Deposition Exhibit 9480 ("We are calculating a PI of 50 bbl/psi.")

[29] Deposition of Adam Ballard, October 16, 2012, 128:3-9; Email from Tim Lockett to Trevor Hill, May 13, 2010, Deposition Exhibit 9448.

By varying parameters, modelers could easily create several dozen individual simulated scenarios within a packet of model scenarios (Fig. 1 illustrates a packet of six scenarios). As just noted, modelers could also vary the parameters in order to simulate a particular target flow rate. Typically this involved decreasing the orifice size in the BOP/riser, creating a more restrictive flow path in the well, or simulating restricted conditions where the reservoir and well meet (increasing the skin, decreasing reservoir thickness, decreasing permeability, or decreasing productivity index).

In the second phase of modeling, models were applied to answer questions associated with the design of "source control" measures – remedial measures to bring the well under control.[30]

For example, the well flow rate was critical to the design of the dynamic kill, in which mud was pumped into the well to arrest and then reverse the flow. The kill mud weight and pumping rate were important design parameters. If the kill mud weight and/or mud pumping rate were too low to arrest the flow of oil and gas coming up the well, then the kill mud would simply be blown out the BOP, LMRP and riser to the ocean, rather than moving down hole and arresting the upward flow of oil and gas from the well.

The well flow rate was also critical to the static kill, at the end of which cement would be injected to replace the kill mud and permanently kill the well. The proper design of the cement mix and curing depended on the temperature profile to which it would be exposed. Greater well flow causes higher temperatures. Model runs addressing these and other design issues were performed by BP engineers and its contractors, and by Halliburton engineers who were contracted by BP to pump kill mud for dynamic and static kills, and design and pump cement to complete the static kill.

For some applications, BP prescribed specific flow rates for modelers to use as targets. For example, on April 30, 2010, BP contracted with Stress Engineering to perform modeling of a hydrocarbon plume (technically, a jet) coming out of the top of the BOP that would be created by removing the riser and the LMRP.[31] Stress was asked to determine the upward forces that would be exerted by the flow when lowering a new BOP on top of the damaged one.[32] BP originally requested Stress to run the model with a 5,000 BOPD flow rate, followed by some "sensitivities on flow" at 10, 20, 40, 80, and 160 thousand BOPD. When told the runs would take 10-12 hours apiece and that they should start with the "best estimate," BP responded that Stress should run

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[30] Deposition of Simon Bishop, September 27, 2012, 95:2-9 ("Q. Okay. The only purpose for this modeling was to potentially inform operations associated with source control? A. This modeling was done in -- to assess the robustness of a number of operations associated with source control.").

[31] See, for example, SES Report – Cases 1 & 2 – Flow Analysis Horizon BOP – 5-1-2010.ppt, May 3, 2010, Deposition Exhibit 10091.

[32] This is not a well model or reservoir model; this is a conservation of momentum model contrasting fluid flow versus the weight of the BOP using computational fluid dynamics (CFD). It is referenced here to show how BP would sometimes prescribe target flow rates for its contractors' use.

the model at 70,000 BOPD, and then at 35,000 and 17,500 BOPD.[33] BP also labeled these prescribed "best estimate" flow rates as "confidential information."

One BP engineer in BP's Base Management Group, Tony Liao, gave a BP-internal presentation on July 12, 2010 about how his group (the Mike Mason group) approached various challenges in modeling the Macondo well during the response effort, including April and May. A slide from this presentation is Fig. 2 below. As shown in a bullet on this slide, one objective of his group's modeling was to "estimate[] ranges of oil [flow] rates based on possible range of reservoir parameters."[34] Some of those parameters are illustrated in the table in the lower right hand corner (88' and 44' of reservoir exposed, 300 and 170 mD permeability, various skin values, and various possible flow paths). As discussed further below, this group's estimated ranges of well flow rates were then used in the second phase of modeling to assess source control efforts.

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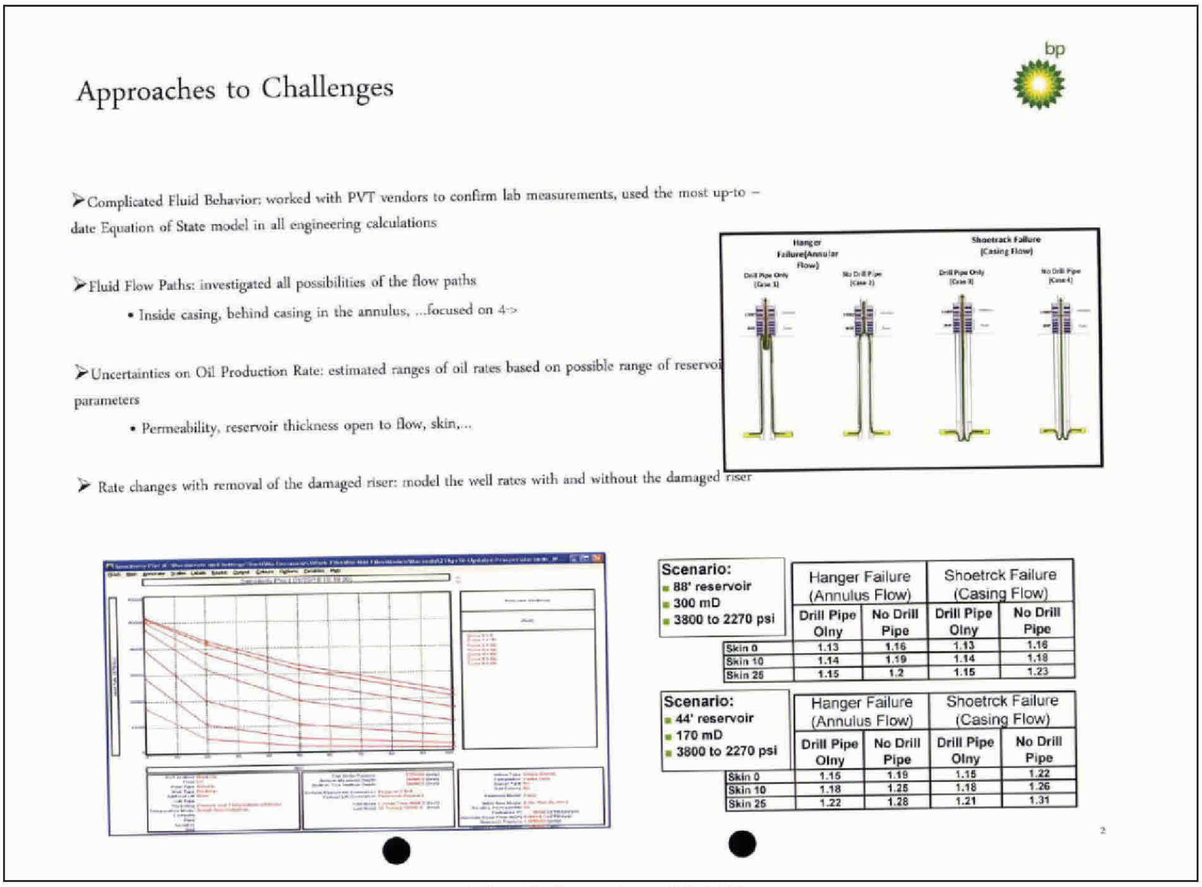
[33] Email from Richard Simpson to Chris Matice et al., "Flow rate for first modeling run: BP Macondo Modeling Parameters." April 30, 2010, Deposition Exhibit 9629 and Deposition Exhibit 9672.

[34] Deposition of Tony Liao, January 11, 2013, 391:16-21 ("Q. One objective of your group's modeling was to estimate ranges of oil rates based on possible range [sic] of reservoir parameters and fluid flow paths? A. Correct. And assumed fluid -- fluid flow paths, correct."). See also Email from Tony Liao to Mike Mason, June 12, 2010, "Overview of Macondo Well Modeling, 12 July 2010.PPT," Deposition Exhibit 11159.



Approaches to Challenges

- Complicated Fluid Behavior: worked with PVT vendors to confirm lab measurements, used the most up-to – date Equation of State model in all engineering calculations
- Fluid Flow Paths: investigated all possibilities of the flow paths
  - Inside casing, behind casing in the annulus, ...focused on 4->
- Uncertainties on Oil Production Rate: estimated ranges of oil rates based on possible range of reservoi parameters
  - Permeability, reservoir thickness open to flow, skin,...
- Rate changes with removal of the damaged riser: model the well rates with and without the damaged riser

Scenario:
- 88' reservoir
- 300 mD
- 3800 to 2270 psi

	Hanger Failure (Annulus Flow)		Shoetrck Failure (Casing Flow)	
	Drill Pipe Olny	**No Drill Pipe**	**Drill Pipe Olny**	**No Drill Pipe**
Skin 0	1.13	1.16	1.13	1.16
Skin 10	1.14	1.19	1.14	1.18
Skin 25	1.15	1.2	1.15	1.23

Scenario:
- 44' reservoir
- 170 mD
- 3800 to 2270 psi

	Hanger Failure (Annulus Flow)		Shoetrck Failure (Casing Flow)	
	Drill Pipe Olny	**No Drill Pipe**	**Drill Pipe Olny**	**No Drill Pipe**
Skin 0	1.15	1.19	1.15	1.22
Skin 10	1.18	1.25	1.18	1.26
Skin 25	1.22	1.28	1.21	1.31

Fig. 2 from Ex. 11159.

3. Review of Representative BP's Flow Rate Modeling.

I have reviewed the modeling of various workgroups active at BP and its contractors during April and May 2010, and considered relevant deposition testimony. It is my opinion that a significant majority of modeled flow rates were much greater than the rate of 5,000 BOPD expressed by BP management to the government, the press and the public. A timeline of the BP group modeling from April and May that I have reviewed is attached as Appendix A.

Reservoir Modeling

BP began modeling the flow from the Macondo well immediately following the blowout. Throughout the rest of April and early May 2010, reservoir engineers from the Gulf of Mexico Exploration group conducted what they called "worst case discharge" calculations, apparently using PROSPER and MBAL software, in which they input reservoir properties from the Macondo well.[35] True worst-case discharge calculations assume an open hole without casing, no restrictions at the wellhead (no shallow choke), and perfect communication between the reservoir and wellbore (that is, a skin of 0). The pre-drilling worst-case discharge calculation for the Macondo well was 162,000 BOPD. Though referred to as worst-case discharge or "WCD" plots,

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[35] I have excluded from my analysis modeling performed by this group regarding the relief wells.

the modeling by this group in fact assumes various restrictions at the wellhead. I therefore consider the model results to be flow rates given the specified parameters.

Representative modeling from this group includes:

- On April 21, 2010, BP engineer Walt Bozeman emailed to David Rainey and other BP executives a worst case discharge of 100,000 BOPD "assuming the riser falls." As shown in Fig. 3, the software plotted IPR curves[36] and an outflow curve using the basic knowns about the well: reservoir pressure of 11850 psi, fluid properties, 88' height of reservoir, zero skin, and a sea floor pressure of 2270 psi. The model did not assume any restrictions at the BOP or riser (part of the "open hole" assumption). Bozeman also varied permeability values (100 mD, 400 mD, and 1000 mD), all of which achieved flow rates at higher than 50,000 BOPD. (Fig. 3 is a screenshot of the model output.)

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[36] An IPR curve (green curves in the figure), or "Inflow Performance Curve," is the relationship between the well flow rate and the bottomhole well pressure; it's a measure of the reservoir's ability to produce oil. The outflow curve (red) is a measure of the well's ability to deliver that oil from the reservoir to the seafloor. The flow rate for a given scenario is indicated by where the two curves cross.

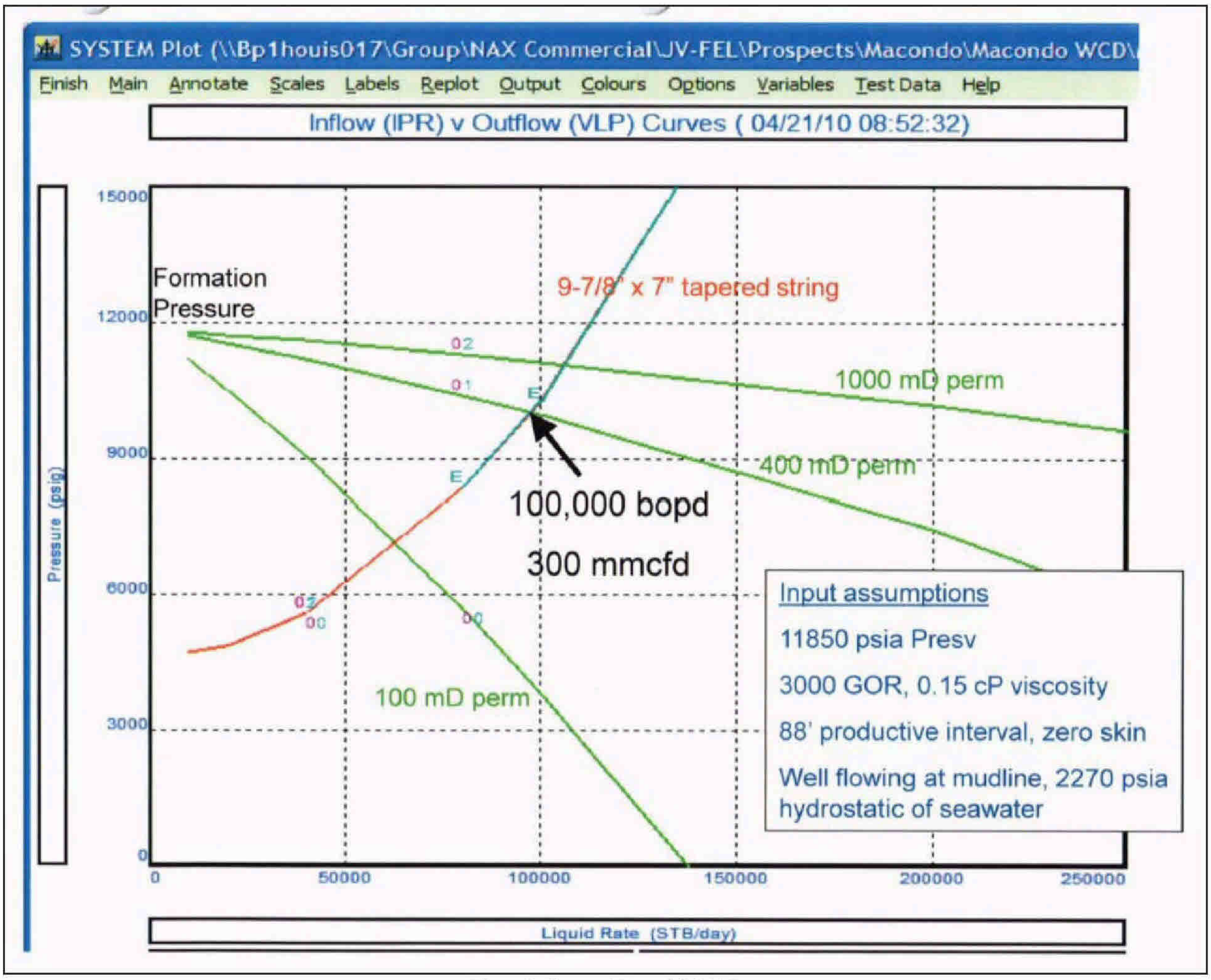

Fig. 3 from Ex. 10855.

- On April 22, 2010, an engineer on Bozeman's team, Kelly McAughan, created a forecast of future well flow rates starting at approximately 100,000 BOPD and decreasing slowly over time as reservoir pressure was depleted until the bubble point is reached.[37]

- On May 5, 2010, Jasper Peijs requested certain "worst case discharge" plots based on various wellhead restrictions from Kelly McAughan, apparently in response to a request from Tony Hayward and Andy Inglis. On May 6 McAughan ran two additional cases and sent Peijs the excel file of the MBAL forecasts so he could "edit freely." These forecasts, shown in Fig. 4, depict how flow rates, starting at prescribed initial values of 5,000 , 10,000, 20,000, 40,000, 55,000, 60,000, 109,000, and the pre-drill WCD of 162,000

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[37] Email from Kelly McAughan to Jay Thorseth et al., "RE: Flow rate and production profile," April 22, 2010, Deposition Exhibit 9539.

BOPD, decrease over time as reservoir pressure is depleted.[38] Various restrictions at the wellhead (shallow chokes or orifices) were assumed to generate the requested lower rates of flow.

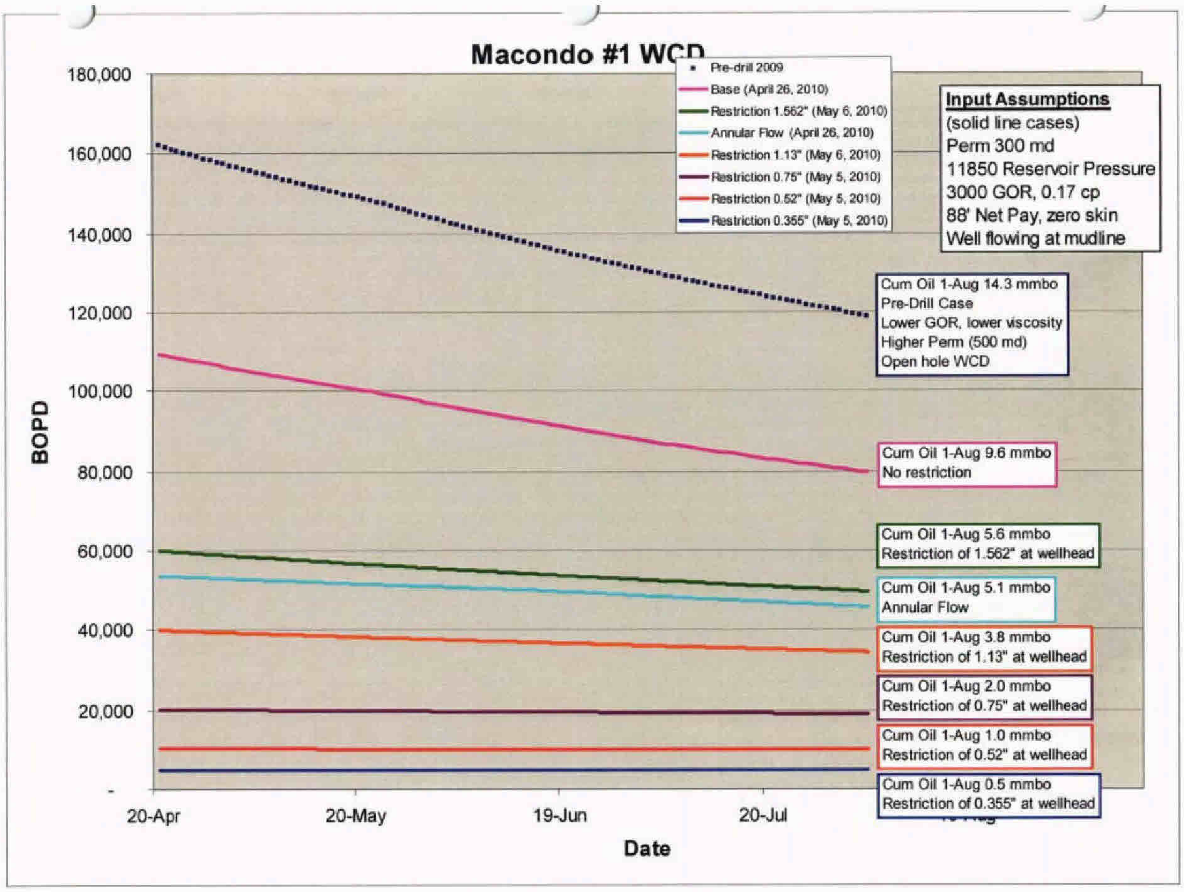

Fig. 4 from Ex. 9330.

As is clear from Fig. 4, the restrictions necessary at the wellhead to generate flow rates of only 5,000 or 10,000 BOPD were quite severe for modeled conditions. The shallow choke required an orifice with a diameter of only 0.355 and 0.52 inches, respectively. Given that the riser was approximately 19 inches in diameter, and its internal pipe was approximately six inches in diameter; even when kinked over, such a small orifice is unlikely.

OLGA-ABC and OLGA-Well Kill Modeling

Another BP workgroup involved in flow modeling was led by BP drilling engineer Kurt Mix and was comprised of BP contractors Bill Burch from Wild Well Control and Ole Rygg from Add Energy. As discussed above, the OLGA software is designed specifically for multiphase flow

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[38] Email from Kelly McAughan to Bryan Ritchie, "WCD Plots Request," May 6, 2010, Deposition Exhibit 9157; Email from Kelly McAughan to Jasper Peijs et al., "RE: WCD Plots," May 6, 2010, Deposition Exhibit 9330.

and had capabilities exceeding ordinary petroleum well modeling software. The modeling performed by this group generally used the PI (bbl/day/psi) of 50 that the BP reservoir group had calculated.

Representative modeling from this group includes:

- On April 29, Burch emailed Mix a power point summarizing OLGA-ABC runs for a number of different cases. Versions of this modeling had been communicated to BP as early as April 22.[39] Cases 1-4 assumed that hydrocarbons were escaping at the surface (i.e. that the rig had not yet sunk). Case 5, assuming a casing flowpath and seafloor exit, yielded a flow rate of 146,000 BOPD. Case 6, assuming a casing flowpath where the drill string had dropped into the well and was obstructing the flow, yielded a flow rate of 77,000 BOPD. Case 7 assumed an annular flow and yielded a flow rate of 69,500 BOPD. Case 8, shown in Fig. 5, assumed an annular flow and varied the diameter (ID) of an orifice which was used to represent the shallow choke caused by the kink in the riser (the kink is illustrated in the diagram). The resulting flow rates for this shallow choke case range from 1,000 BOPD for a small 0.73” orifice to 60,500 BOPD at 12” and above (essentially, no shallow choke).

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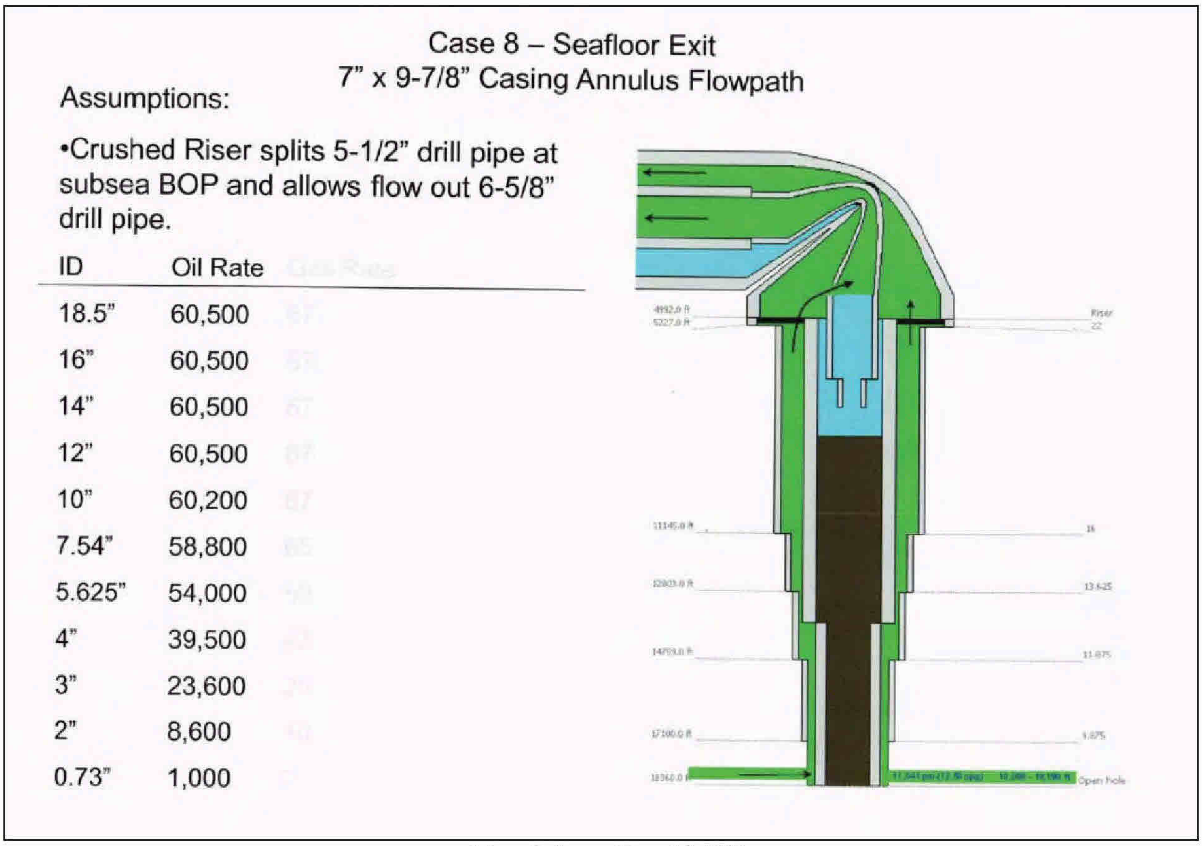
[39] *See, e.g.*, Email from Bill Burch to Chris Murphy, “RE: BP Reservoir/Geology Group Notes,” April 22, 2010, Deposition Exhibit 3907 and 10483; Email from Bill Burch to Kurt Mix, “DOI well control modeling presentation,” April 28, 2010, Deposition Exhibit 8942.



Case 8 – Seafloor Exit
7" x 9-7/8" Casing Annulus Flowpath

Assumptions:

- Crushed Riser splits 5-1/2" drill pipe at subsea BOP and allows flow out 6-5/8" drill pipe.

ID	Oil Rate
18.5"	60,500
16"	60,500
14"	60,500
12"	60,500
10"	60,200
7.54"	58,800
5.625"	54,000
4"	39,500
3"	23,600
2"	8,600
0.73"	1,000

Fig. 5 from Ex. 10489.

- On May 9, Ole Rygg performed "blowout rate" modeling using OLGA-Well Kill and sent the results to Kurt Mix. Those rates are given in Fig. 1, above, and ranged from 37,000 to 87,000 BOPD. That same day, those rates were reported to BP manager Jon Sprague.[40]

Rygg was subsequently asked to use OLGA-Well Kill to model the dynamic kill for the top kill, which is discussed in Section V.C.

Flow Assurance Orifice Modeling

In late April and throughout May 2010, a workgroup of BP flow assurance engineers including at various times Trevor Hill, Tim Lockett, Julian Austin, Farah Saidi, Adam Ballard, and Ian Stillwell conducted modeling for orifice size and well flow rate. This group assumed various downhole restrictions, that is, deep choke conditions at the bottom of the well that would restrict flow – as well as restrictions at the wellhead. For example, rather than use a reservoir PI (bbl/day/psi) of 50, as calculated by the reservoir engineers, this group used smaller PIs of 1, 2,

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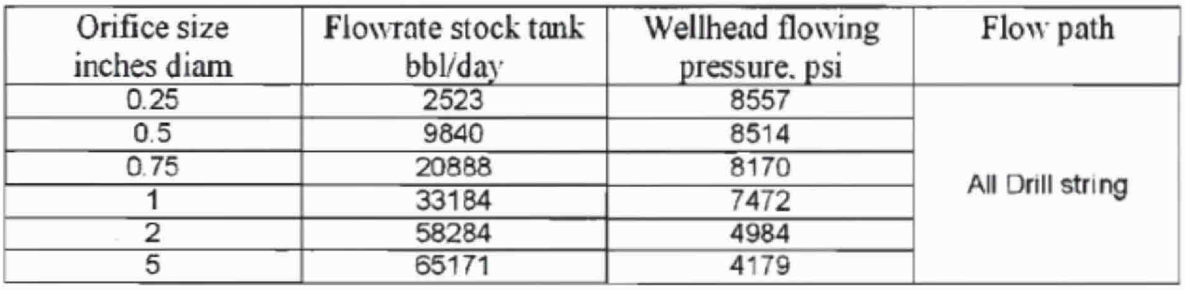
[40] Email from Ole Rygg to Kurt Mix, "[B]lowout Rates," May 9, 2010, Deposition Exhibit 9266; Memorandum from Kurt Mix, Ole Rygg, and Bill Burch, Hydraulic Kill Team, to Jon Sprague, May 9, 2010, Deposition Exhibit 9240.

4, 5, and 10 to represent a deep choke and help obtain lower flow rates. A shallow choke was represented by an orifice.

Representative modeling from this group includes:

- On April 28, 2010, in response to a request from BP executives Andy Inglis and Gordon Birrell, Trevor Hill emailed that his group had "modeled the whole system from reservoir to sea in order to bound the answers on flowrate." He included a memorandum entitled "Modeling of system flow behavior (reservoir to sea)." His model "solves for flowrate and wellhead flowing pressure, given the orifice size" and reservoir pressure of "~12000 psi" (i.e. 11,850 psi, the reservoir pressure) and seawater pressure of "~2250 psi."[41] The results, ranging up to 65,171 BOPD, are found in a table, given in Fig. 6 below. The memorandum also includes a chart comparing well flow rate (leakage rate) to the shallow-choke orifice diameter, assuming deep choke PI values of 1 and 10 (Fig. 7). With the exception of the case where PI (bbl/day/psi) = 1, all the modeled rates exceed 20,000 BOPD when the orifice size is at least one inch in diameter.



Orifice size inches diam	Flowrate stock tank bbl/day	Wellhead flowing pressure, psi	Flow path
0.25	2523	8557	All Drill string
0.5	9840	8514	
0.75	20888	8170	
1	33184	7472	
2	58284	4984	
5	65171	4179	

Fig. 6 from Ex. 5063.

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[41] Email from Trevor Hill to Gordon Birrell, et al., "RE: Action items from 3:00 PM Sunday telecon - flow modeling," April 28, 2010, Deposition Exhibit 5063.

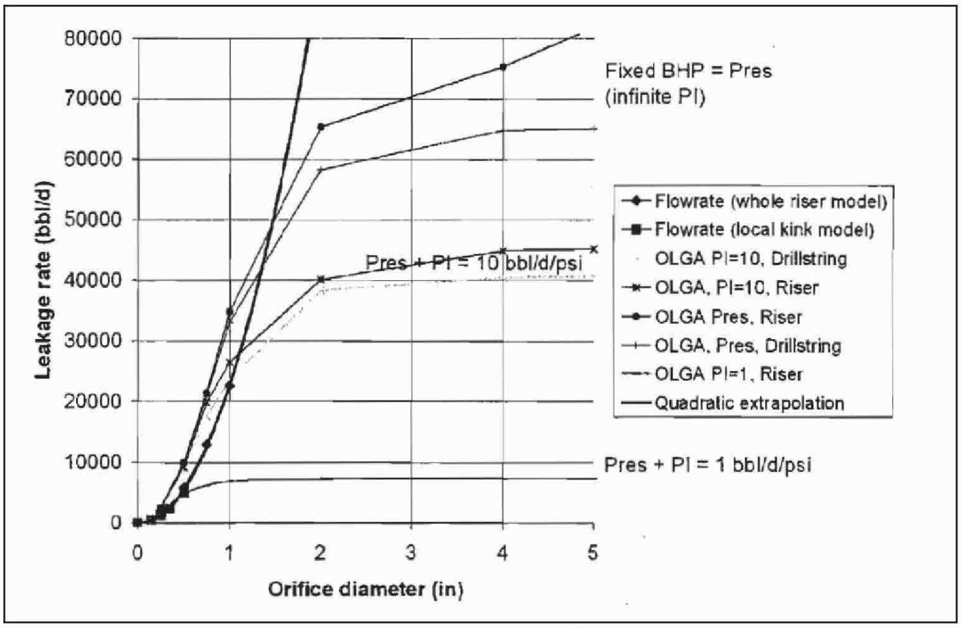
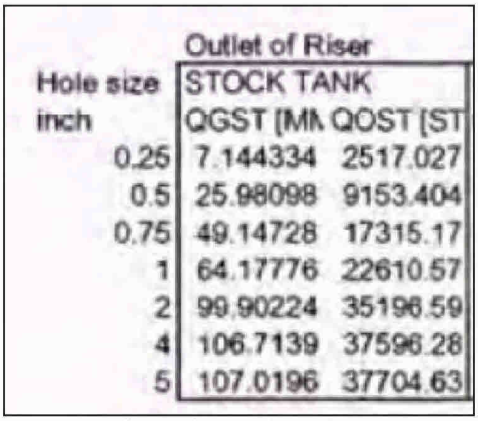


Fig. 7 from Ex. 5063.

- On May 3, 2010, Tim Lockett sent an email to Trevor Hill with the subject line "Best estimate." He stated that he had updated an earlier model "to give a flowrate estimate as a function of pressure at the BOP, temperature at the BOP and D/s [downstream] of the crimp, and velocity of either liquid or mixed phase in the riser…." In other words, by triangulating these three factors, Lockett was suggesting a "best estimate" of flow rate could be obtained. A spreadsheet attached to the email contains graphs and charts of oil flow rates and orifice sizes. Figure 9 below is an excerpt from the spreadsheet showing orifice size on the left, gas flow rate in the center, and stock tank barrels of oil (well flow rate) on the right. The model assumes a PI (bbl/day/psi) of 10. These flow rates are lower than the April 28 values, but still indicate that a one inch diameter hole size is expected to produce flow rates that exceed 20,000 BOPD.

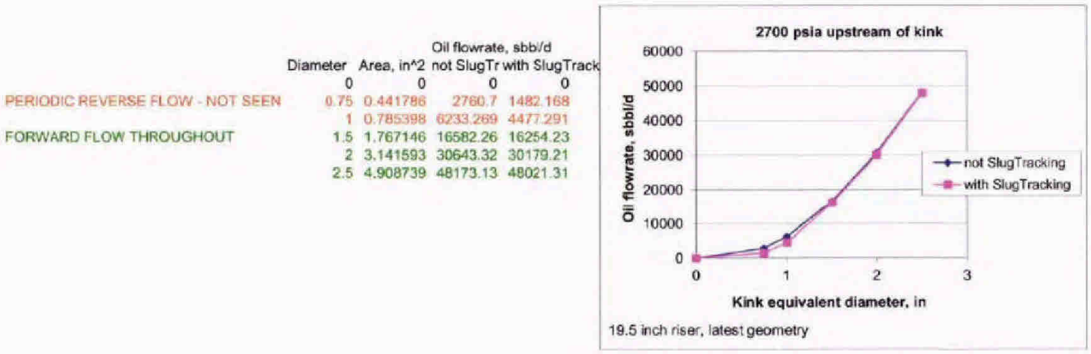


	Outlet of Riser	
Hole size	STOCK TANK	
inch	QGST [M	QOST [ST
0.25	7.144334	2517.027
0.5	25.98098	9153.404
0.75	49.14728	17315.17
1	64.17776	22610.57
2	99.90224	35196.59
4	106.7139	37596.28
5	107.0196	37704.63

Fig. 8 from Ex. 9446.

- On May 13, 2010, Tim Lockett and Ian Stillwell re-ran the model targeting flow rates of approximate values of 5,000, 10,000, 15,000, and 20,000 BOPD. He approximately matched his targets by applying PIs of 1, 2, 4, and 5 (bbls/day/psi), respectively. The resulting equivalent diameter orifice sizes were between 0.59" and 1.15."[42]

- On May 14, 2010, Tim Lockett emailed Trevor Hill about running their model with a new measurement of pressure at the bottom of the BOP of 2700 psi. The resulting flow rates are given in Fig. 9. Interestingly, in this model Lockett has noted that the smallest values of flow rate would involve periodic reverse flow, a condition that he did not observe in the video of the plume coming out of the riser. This modeling therefore indicates that orifice diameters of less than 1 inch, and flow rates of less than 6,233 or 4,477 (depending on modeling slug flow), are not consistent with video observations. For that reason, Lockett indicates these values are not credible.



			Oil flowrate, sbb/d	
	Diameter	Area, in^2	not SlugTr	with SlugTrack
	0	0	0	0
PERIODIC REVERSE FLOW - NOT SEEN	0.75	0.441786	2760.7	1482.168
	1	0.785398	6233.269	4477.291
FORWARD FLOW THROUGHOUT	1.5	1.767146	16582.26	16254.23
	2	3.141593	30643.32	30179.21
	2.5	4.908739	48173.13	48021.31

Fig. 9 from Ex. 10642.

As is clear from these representative models, the flow rate estimates from the flow assurance group ranged between a few thousand to 40,000 or even 60,000 BOPD. By mid-May, moreover, the modelers had indications that the lower values should be discounted.

Production Engineering Modeling

During the month of May, another BP workgroup was active that consisted largely of production engineers from BP's EPT Base Management Team. Led by Mike Mason, this team included Simon Bishop, Chris Cecil, Tony Liao, Yun Wang, Frank Sweeney, Ashish Chitale, and Metin Gokdemir. Farah Saidi, Debbie Kercho, and Kelly McAughan also assisted this workgroup, though they were not part of the BP Base Management Team. These engineers focused on modeling different flow paths as well as varying reservoir and wellhead parameters to get ranges of flow rates and, in particular, apply those ranges to assessments of source control operations.

Representative modeling from this group includes:

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[42] Email between Trevor Hill, Ian Stillwell, and Tim Lockett, "RE: Update of choke information," May 13, 2010, Deposition Exhibit 10641.

- In early May 2010, Mason's team performed extensive scenario modeling resulting a variety of well flow rates. The team varied flow path, skin (between 0 and 50), height of the reservoir (88', 80', and 10'), and chokes at the wellhead (no choke, 1/2" orifice, and 1/4" orifice). Well flow rates ranged at the high end up to 95,336 BOPD (casing and annular flow, a skin of 0, 88' of the reservoir exposed, and no choke) to as low as 1,914 (annular flow only, a skin of 50, 10' of the reservoir exposed, and a 1/4" orifice at the wellhead).[43]

- On May 11, 2010, Mason's team summarized scenario modeling in a power point presentation for Andy Inglis and Jasper Peijs. This modeling explored well flow rates for four different flow paths (see Fig. 10); three possible skin values (0, 10, 25); permeability values of 300 mD and 170 mD; and exposed reservoir thicknesses of 88' and 44'. Rather than impose an orifice size at the wellhead, the team relied on the measured PT-B value of 3800 psi at the bottom of the BOP as a pressure boundary. Scenarios were then repeated with a pressure boundary taken at the seafloor (2270 psi), representing flow without a shallow choke. By comparing the two sets of model runs, with and without the shallow choke, the increase in flow rate for the 2270 psi cases represented the impact of eliminating the shallow choke should the riser be removed from the LMRP. The resulting flow rates were reported in two charts given below as Figs. 12 and 13 (values are in the thousands). The upper part of each figure represents the flow with the shallow choke (i.e., 3800 psi at the bottom of the BOP), and the lower part of each figure represents the flow without the shallow choke, which is relatively higher. Values for the slide labeled "Maximum Reservoir Exposed, High K" (K stands for permeability) ranged from 21,000 BOPD to 96,000 BOPD. Values for the slide labeled "Partial Reservoir Exposed, Low K" ranged from 14,000 BOPD to 65,000 BOPD. [44]

- This May 11 power point presentation also contained a stand-alone slide for "The Case for 5000 BOPD at 3800 psi," given in Fig. 13. This slide indicated that a flow rate of 5000 BOPD, given the measured pressure of 3800 psi at the bottom of the BOP, could only be achieved by inputting parameters more restrictive than those given on the previous slides. In other words, and particularly compared with the previous slides, the case for 5000 BOPD could only be made assuming annular flow, a "low" permeability of 170 mD, a minimal reservoir thickness of 10' or 12' (depending on the presence of drill pipe), and a large skin of 25.

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[43] Email from Mike Mason to Frank Sweeney et al., "LiaoCases(3).xls," May 1, 2010, Deposition Exhibit 11160; Native Spreadsheet, dated (from metadata) May 2, 1010, Deposition Exhibit 11135; Native Spreadsheet, dated (from metadata) May 2-3, 2010, Deposition Exhibit 10185.

[44] Email from Mike Mason to Cindy Yeilding et al., "FW: Meeting Presentation May 11 2010 (3).ppt," May 11, 2010, Deposition Exhibit 9156 ("All, Jasper's feedback after reviewing with Andy Inglis is very positive. He will let us know if anything else is required.").

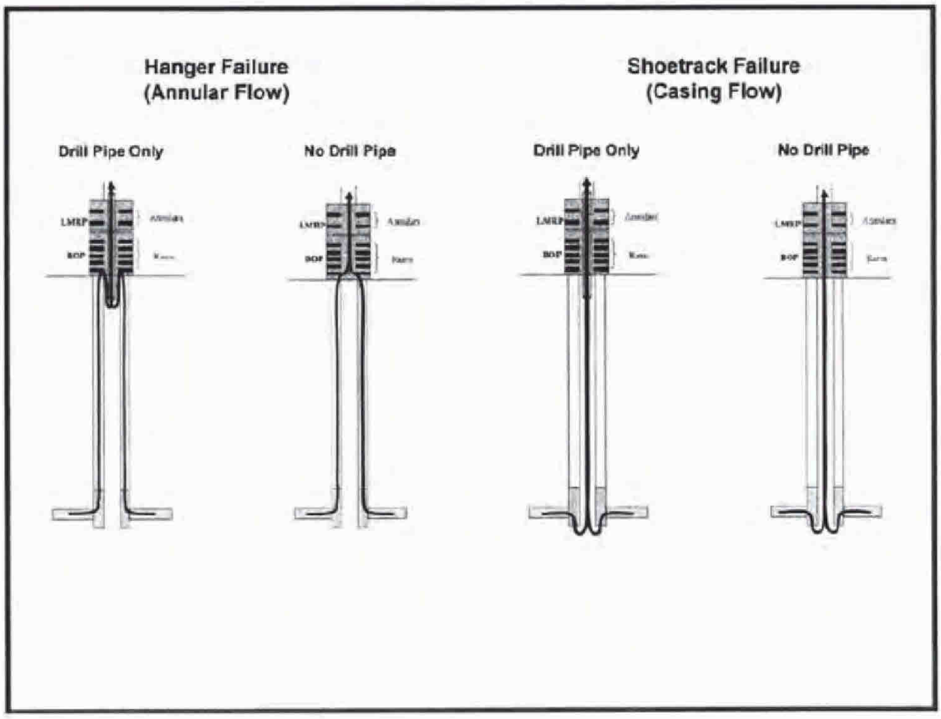
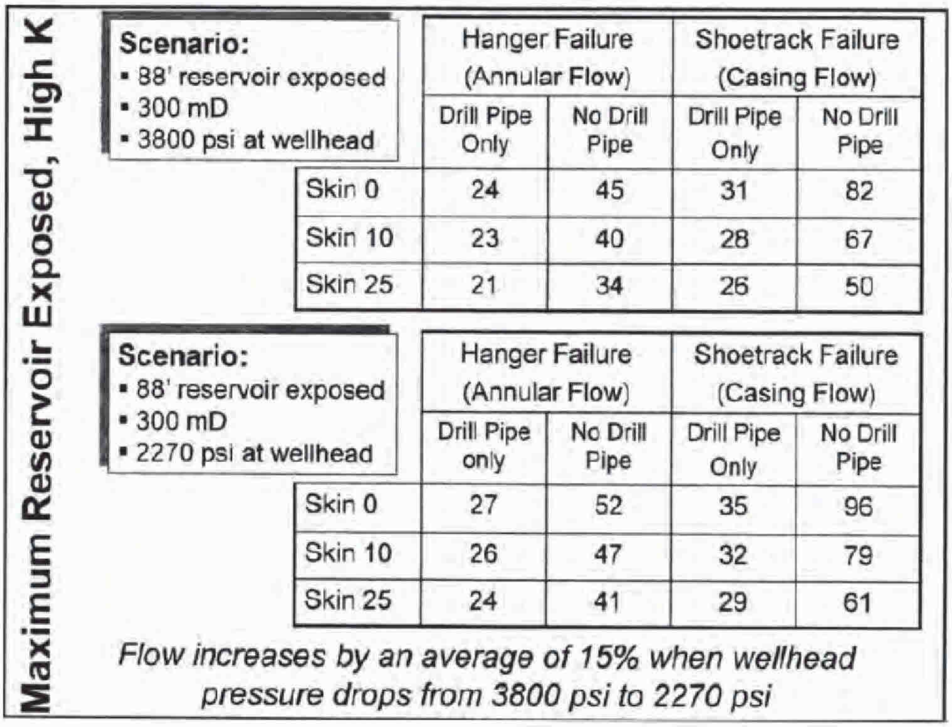


Fig. 10 from Ex. 9156.



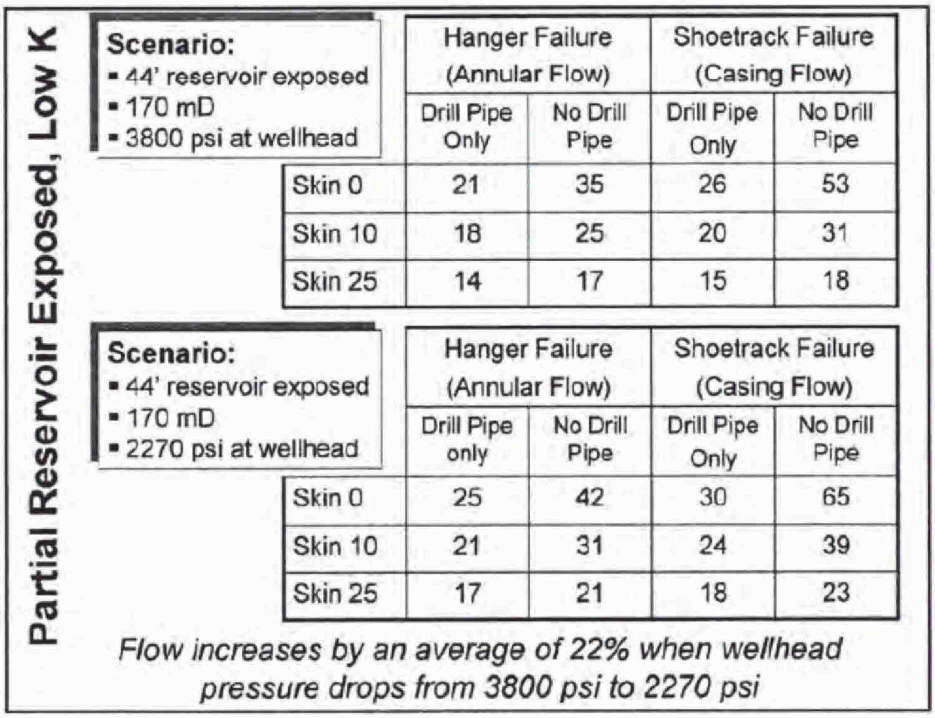
Maximum Reservoir Exposed, High K

Scenario: ▪ 88' reservoir exposed ▪ 300 mD ▪ 3800 psi at wellhead	Hanger Failure (Annular Flow)		Shoetrack Failure (Casing Flow)	
	Drill Pipe Only	No Drill Pipe	Drill Pipe Only	No Drill Pipe
Skin 0	24	45	31	82
Skin 10	23	40	28	67
Skin 25	21	34	26	50

Scenario: ▪ 88' reservoir exposed ▪ 300 mD ▪ 2270 psi at wellhead	Hanger Failure (Annular Flow)		Shoetrack Failure (Casing Flow)	
	Drill Pipe only	No Drill Pipe	Drill Pipe Only	No Drill Pipe
Skin 0	27	52	35	96
Skin 10	26	47	32	79
Skin 25	24	41	29	61

Flow increases by an average of 15% when wellhead pressure drops from 3800 psi to 2270 psi

Fig. 11 from Ex. 9156.



Partial Reservoir Exposed, Low K

Scenario:
- 44' reservoir exposed
- 170 mD
- 3800 psi at wellhead

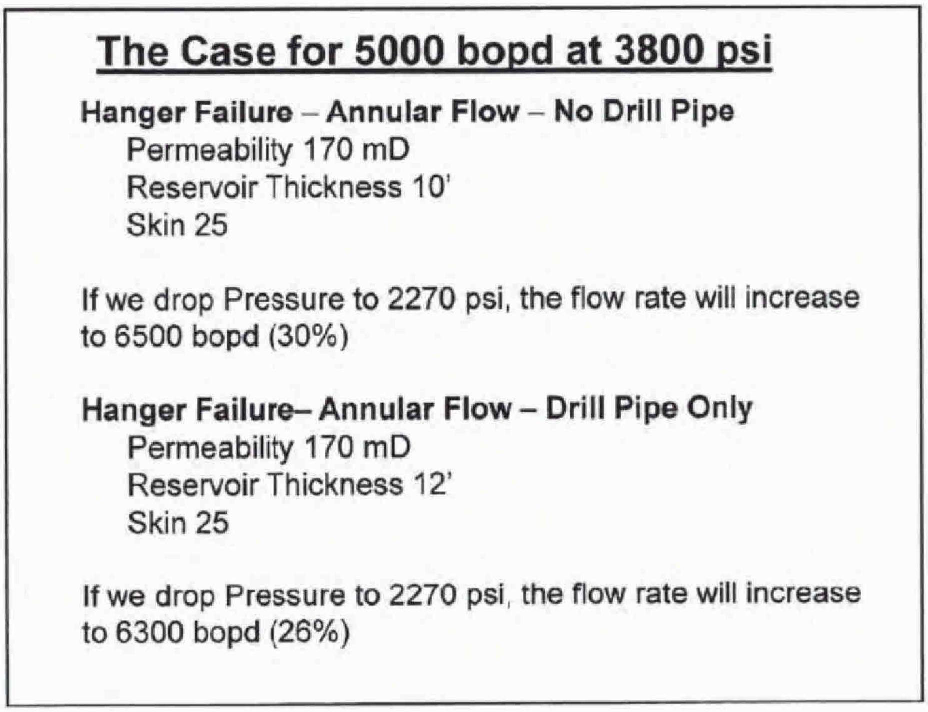
	Hanger Failure (Annular Flow)		Shoetrack Failure (Casing Flow)	
	Drill Pipe Only	No Drill Pipe	Drill Pipe Only	No Drill Pipe
Skin 0	21	35	26	53
Skin 10	18	25	20	31
Skin 25	14	17	15	18

Scenario:
- 44' reservoir exposed
- 170 mD
- 2270 psi at wellhead

	Hanger Failure (Annular Flow)		Shoetrack Failure (Casing Flow)	
	Drill Pipe only	No Drill Pipe	Drill Pipe Only	No Drill Pipe
Skin 0	25	42	30	65
Skin 10	21	31	24	39
Skin 25	17	21	18	23

Flow increases by an average of 22% when wellhead pressure drops from 3800 psi to 2270 psi

Fig. 12 from Ex. 9156.



The Case for 5000 bopd at 3800 psi

Hanger Failure – Annular Flow – No Drill Pipe
Permeability 170 mD
Reservoir Thickness 10'
Skin 25

If we drop Pressure to 2270 psi, the flow rate will increase to 6500 bopd (30%)

Hanger Failure– Annular Flow – Drill Pipe Only
Permeability 170 mD
Reservoir Thickness 12'
Skin 25

If we drop Pressure to 2270 psi, the flow rate will increase to 6300 bopd (26%)

Fig. 13 from Ex. 9156.

- On or about May 15, 2010, the PT-B gauge at the bottom of the BOP registered a decrease in pressure from 3800 psi to 3100 psi. Mason asked Tony Liao to run a MBAL model with a 700 psi reservoir pressure decrease in order to "calculate the rate required to deliver that sort of reservoir depletion." On May 16, 2010, Liao responded that the required flow rate would be 86,600 BOPD.[45] Mason forwarded this email to BP executives Gordon Birrell and James Dupree.[46] Mason also reran model for the "case for 5000 BOPD" using the new pressure boundary condition and emailed it to Jasper Peijs. This model required even more flow restrictions to be assumed.[47]

Halliburton

Although not a workgroup focused on well flow rate estimation, BP contractor Halliburton used their own computer program WELLCAT to model flow rates, pressures, and temperatures in the well in order to design the cement job for the top kill.[48] As Richard Vargo testified, Mike Bednarz of BP had told him to use a 5,000 BOPD flow rate in Halliburton's model.[49] However, Halliburton determined that it could not match the measured BOP temperatures with a flow rate of 5,000 BOPD. To get a match it had to assume a flow rate of at least 30,000 BOPD.[50]

- On May 21, 2010, prior to the top kill operation, Halliburton submitted a report to BP on the cement job.[51] It reported Halliburton's modeled minimum well flow rate of 30,000 BOPD. Richard Vargo of Halliburton not only emailed this report to BP but hand carried

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[45] Email from Tony Liao to Mike Mason, "RE: Macondo SIWHP Build-up Rate Final Report.doc," May 16, 2010, Deposition Exhibit 11140.

[46] Email from Mike Mason to Gordon Birrell and James Dupree, May 16, 2010, Deposition Exhibit 9313.

[47] Email from Mike Mason to Debbie Kercho et al., "5MBD Case Base plotsa (3).PPT," May 16, 2010, Deposition Exhibit 9329. The PT-B gauge continued to register the 700 psi pressure drop until May 19, 2010, at which point the values trended upward again. Though BP now claims that this gauge was unreliable, BP engineers at the time relied on this gauge's measurements. See Deposition Exhibit 9315 for a graph of the pressure readings from PT-B.

[48] Well temperature is a key variable in the design of the cement mixture and in cement curing. Well temperature is largely controlled by the well flow rate. Because of the earth's geothermal gradient, temperature increases with depth as heat is conducted from the earth's interior up to the ocean bottom. A flowing well disrupts the local temperature gradient since the flow carries warm fluid from the reservoir upward toward the cooler seabed. As a consequence the wellhead and BOP become warmer than the surrounding seawater. The larger the flow rate, the warmer the BOP becomes. Halliburton used temperature measurements at the BOP to calibrate their WELLCAT model. If the modeled flow rate was too small then the modeled temperature at the BOP would be less than measured. If the modeled flow rate was too large the modeled temperature at the BOP would be too high.

[49] Deposition of Richard Vargo, August 22, 2012, 133:22-134:2.

[50] Deposition of Richard Vargo, August 22, 2012, 132: 11-25.

[51] Email from Richard Vargo to Erick Cunningham, "Current Cementing Program – Ver 5," May 21, 2010, Deposition Exhibit 8544.

a copy and spoke to BP engineers about the rate.[52] After Halliburton discussed its modeling with BP's Erik Cunningham, Cunningham approved Halliburton's use of a 30,000 BOPD flow rate in its WELLCAT modeling for purposes of the post-top kill cement job. BP did not inform Halliburton that BP had determined that the dynamic kill would not succeed if the flow rate was greater than 15,000 BOPD, as discussed below.[53]

Conclusion

As this overview makes clear, in April and May 2010 BP and its contractors modeled numerous different flow rate estimates for the Macondo well.[54] The flow rates varied given the assumptions; however, certain general conclusions can be drawn from the analysis here. Flow rates modeled using known or estimated pressure values, such as for reservoir pressure (11,850 psi), wellhead pressure below the BOP (measured at 3800 psi as of May 8), and seafloor pressure (~2250 psi); and known or estimated reservoir properties, such as exposed reservoir thickness (88' based on the drilling logs) and a calculated PI (50 bbls/day/psi, as calculated by the Gulf of Mexico reservoir engineering group), were high. Using OLGA-Well Kill, the state-of-the-art blowout modeling software package, these known and estimated parameters yielded maximum flow rates between 37,000 BOPD to 87,000 BOPD, depending on flow path (Fig. 1). Lower flow rates could only be achieved by assuming additional restrictions, such as a shallow choke at the BOP and riser or a deep choke at the reservoir-well connection.

None of the modeling and testimony I have reviewed supports the contention that 5,000 BOPD would be a "most likely" or best estimate of flow. Moreover, 5,000 BOPD did not represent a reasonable estimate of flow to use in planning source control operations. Nor does the modeling indicate that a flow rate of lower than 15,000 BOPD is any more likely than higher flow rates.

4. <u>BP's Internal Flow Rate Estimates Far Exceeded its Representations to the Public, the Press, and Unified Area Command.</u>

BP represented to the United States and to the public that the flow rate was lower than many of its internal flow rate estimates. Adm. Landry of the U.S. Coast Guard and the Federal On Scene Coordinator for the spill testified that she had a "vivid recollection" of a meeting on April 28, 2010 with BP executive Doug Suttles. Suttles told her that a BP employee in Houston had modeled a flow rate estimate ranging from 1,000 and 5,000 BOPD, with the best estimate being

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[52] Deposition of Richard Vargo, August 22, 2012, 134:21-138:20, 262:16-267:7.

[53] Deposition of Richard Vargo, August 22, 2012, 91:8-15.

[54] Adam Ballard, BP's 30(b)(6) witness for flow rate estimates made via modeling using subsea pressure or temperature measurements, inexplicably testified that, other than a calculation he made after the capping stack was installed, no employee or contractor at BP between April 20 and July 15 was involved in "predicting, estimating, characterizing, or measuring" the daily amount of hydrocarbons flowing from the Macondo well. Deposition of Adam Ballard, September 25, 2012, 477:8-23; 488:13-489:9; 490:19-491:13. Given the above overview, this testimony should not be regarded as credible.

2,500 BOPD.[55] Based on this meeting, Adm. Landry announced publicly the flow could be as high as 5,000 BOPD. Suttles stated this same range of 1,000 to 5,000 BOPD was a "reasonable estimate" and BP's "best estimate" the next day (April 29, 2010) on national TV, when he appeared on ABC's "Good Morning America," CBS's "Early Show, and NBC's "Today Show."[56]

Based on my review of BP's internal flow rate modeling from April 21-April 28, 2010, I have seen no indication that a range of 1,000 - 5,000 BOPD, with a best estimate of flow at 2,500 BOPD, was modeled by BP. I have seen no basis on which BP could have reasonably relied on such a range and have represented it as accurate to the United States and to the public.[57]

Moreover, on May 10, 2010, Suttles emailed a letter to Admiral Landry, National Incident Commander Admiral Thad Allen, and the MMS Gulf of Mexico Regional Director Lars Herbst in response to a request to describe the well's "worst case scenario."[58] Suttles twice referred to the "currently estimated rate of 5,000 barrels per day." Suttles' letter also attached a graph that the letter stated "presents the oil flow profile graphically." The graph was labeled "Macondo Reservoir Model" and indicated that 5,000 BOPD was the "Most Likely Model" and 55,000 was the "Worst Case Model." This graph is at Fig. 14.

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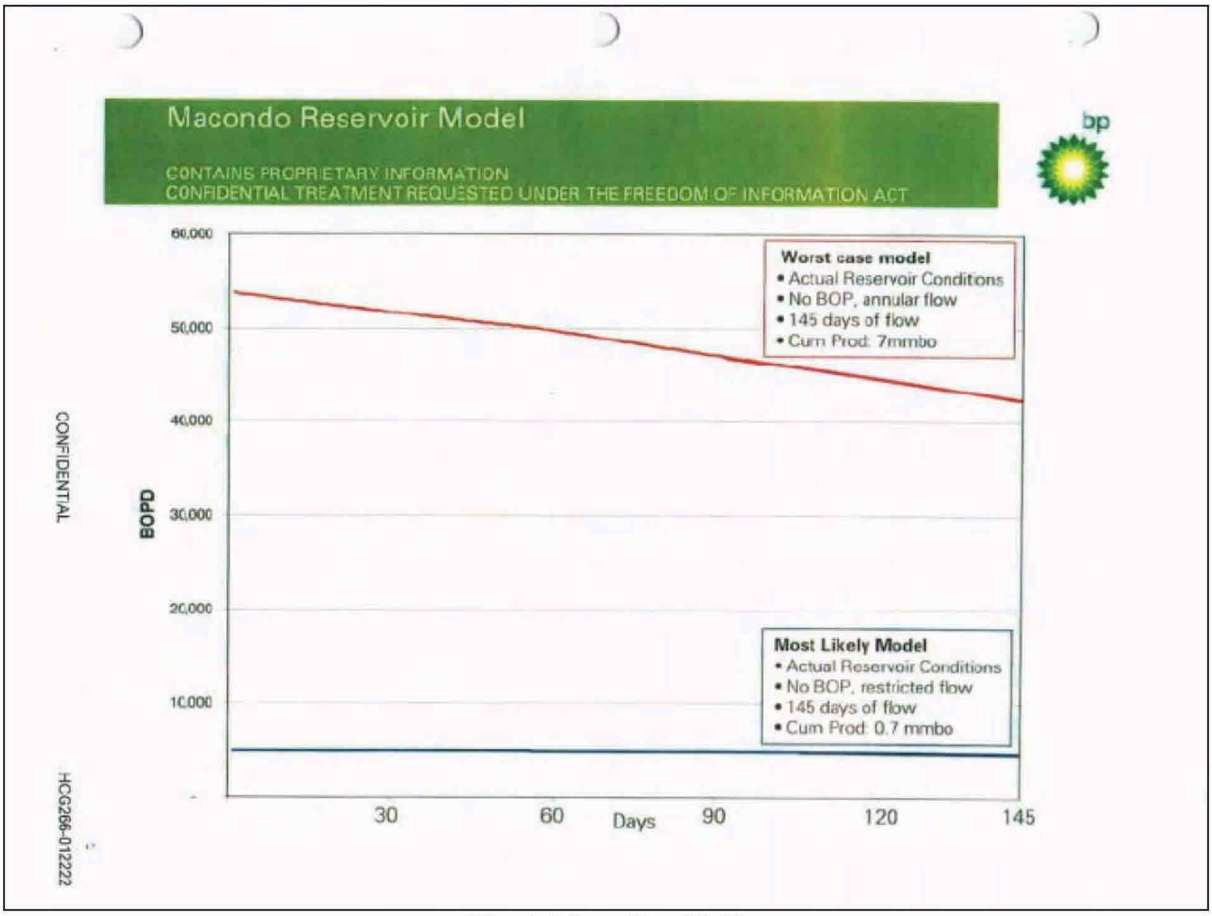
[55] Deposition of Adm. Landry, October 22, 2012, 23:13-19, 24:9-26:6, 188:14-199:5, 299:17-300:2; Deposition of Adm. Landry, October 23, 2012, 565:13-571:3; Deposition Exhibit 9628.

[56] SEC Complaint ¶ 32.A; Ryan Owen, Sarah Netter, and Ned Potter, *Oil Leak in Gulf Worse Than Estimated, BP Takes Some Responsibility*, abcnews.com (April 29, 2010), http://abcnews.go.com/GMA/Eco/oil-spill-gulf-mexico-severe-estimated-bp-confirms/story?id=10506409 ("Suttles told 'Good Morning America' he still believes it to be between 1,000 barrels -- the company's original estimate -- and 5,000."); *BP Exec: We'll Accept Military Help to Stem Leak*, cbsnews.com (April 29, 2010), http://www.cbsnews.com/8301-500202_162-6443358.html; SEC Complaint ¶ 32.C. (quoting Suttles on the "Today Show": "I would say the range is 1,000 to 5,000 barrels a day."); *BP welcomes military help for oil leak*, neworleanscitybuisness.com (April 29, 2010), http://neworleanscitybusiness.com/blog/2010/04/29/bp-welcomes-military-help-for-larger-gulf-oil-leak/ (quoting Suttles on the "Today Show" stating "we can now say it looks like it's more than a thousand. It's a range" and placing the upper end of the range at 5,000 BOPD).

[57] For example, IPR curves generated by Mix and Burch on Apr. 24 ranged from 8,600 to 69,500 BOPD. Deposition Exhibit 10487 at 4. Preliminary orifice modeling by Hill, Saidi, and Austin resulted in ranges of 5000 to 22,000 BOPD based on restrictions of 0.5" - 1" diameter. Deposition Exhibit 9439.

[58] Letter of Doug Suttles to Adm. Landry et al., May 10, 2010, Deposition Exhibit 9155.



Macondo Reservoir Model

CONTAINS PROPRIETARY INFORMATION
CONFIDENTIAL TREATMENT REQUESTED UNDER THE FREEDOM OF INFORMATION ACT

Worst case model
- Actual Reservoir Conditions
- No BOP, annular flow
- 145 days of flow
- Cum Prod: 7mmbo

Most Likely Model
- Actual Reservoir Conditions
- No BOP, restricted flow
- 145 days of flow
- Cum Prod: 0.7 mmbo

Fig. 14 from Ex. 9155.

Based on my review of BP's internal flow modeling up to May 10, 2010 and BP testimony I have seen no scientific basis for representing 5,000 BOPD as the "most likely model." The ranges of BP flow estimates leading up to May 10 are largely well above 5,000 BOPD. As one BP engineer testified, he did not have any way of verifying reservoir parameters in order to determine a "most likely" rate.[59] In addition, numerous BP engineers have testified they did not calculate 5,000 BOPD as the "most likely" rate, including BP's 30(b)(6) witness for flow rate modeling, who testified that no modeling of any kind was performed during this time.[60] The

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[59] Deposition of Tony Liao, January 11, 2013, 403:9-404:7.

[60] Deposition of Adam Ballard, October 17, 2012, 490:19-491:13; Deposition of Tony Liao, January 11, 2013, 403:9-404:20 ("Q. Did you personally ever come to the conclusion, based on your modeling, that 5,000 barrels of oil per day was the most likely flow rate? A. I -- no."); Deposition of Michael Levitan, January 31, 2013, 403:15-21 ("Q. Did any of your work ever suggest that the flow rate was at any point 5,000 barrels of oil per day? A. No."); Deposition of David Barnett, December 14, 2012, 257:7-16 ("Q. And so in -- in late April 2010, you're not aware of any analysis that would suggest that 5,000 barrels per day was the most likely estimate of the flow rate, correct? A. No, I'm not aware of any. Q. And you're not aware, throughout May (footnote continued)

chart attached to Suttles' May 10 letter appears to be a modification of the MBAL modeling performed by Kelly McAughan on May 6 (see Fig. 4 above), which she sent to Jasper Peijs with the message that he can "edit freely."

Once public sources began to question the low flow rate in mid-May 2010, BP continued to stand behind the figure of 5,000 BOPD.[61] Internally, however, BP engineers from several different modeling workgroups expressed concerns that this number was too low, particularly as modeling in preparation for the Top Kill commenced. On May 15, Mike Mason emailed Jasper Peijs and Andy Inglis the email contained in Fig. 16 below, warning that "[w]e should be very cautious standing behind a 5,000 BOPD figure as our modeling shows that this well could be making anything up to ~ 100,000…".[62]

On May 16, Ole Rygg began modeling for the Top Kill effort and, as discussed in more detail below, concluded that a dynamic kill would not be successful if the flow rate exceeded 15,000 BOPD. Referring to the 700 psi pressure decrease measured at the PT-B pressure gauge the day before, he wrote to Trevor Hill that one explanation was restrictions at the wellhead giving way and "less chance of ever being able to do a dynamic top kill."[63] He also wrote, "Be aware we are working on the 5000 BOPD case. That could be too optimistic."

In response to this email, Tim Lockett replied to Trevor Hill, "The apparent reliance in Ole's email on the 5 mbd number [5,000 BOPD], which has little if no origin, is concerning. From all the different ways we have looked at flowrate, 5 mbd would appear to err on the low side."[64]

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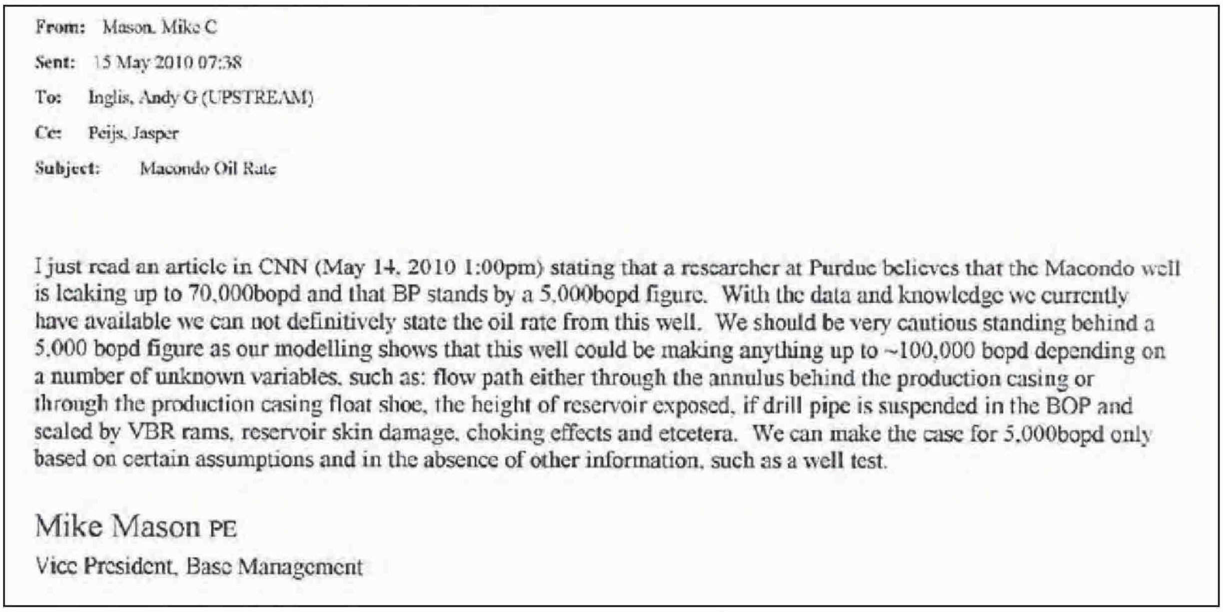
of 2010, of any analysis showing that 5,000 barrels per day was the most likely estimate of the flow rate, correct? A. Correct.").

[61] *See* Interview of Doug Suttles, Good Morning America, May 14, 2010, ("But ourselves and people from NOAA and others believe that something around 5,000, that's actually barrels a day, is the best estimate."); Interview of Doug Suttles, Today Show, May 14, 2010 (stating he did not believe the actual number was "wildly different" from 5,000 BOPD though "it could be a bit above or below."). SEC Complaint ¶ 32.D-E; Jeffrey Kofman, *BP Oil Spill Day 25: How Much Is Really Leaking?*, abcnews. com (May 14, 2010), http://abcnews.go.com/GMA/oil-leak-day-25-oil-spilling-gulf-mexico/story?id=10642498; *BP COO: We'll find who's at fault*, today.com (May, 14, 2010), http://www.today.com/video/today/37147007#37147007.)

[62] Email from Mike Mason to Jasper Peijs and Andy Inglis, "Macondo Oil Rate," May 15, 2010, Deposition Exhibit 3220.

[63] Email from Ole Rygg to Trevor Hill, et al., "RE: Pressure build-up," May 16, 2010, Deposition Exhibit 9250.

[64] Email from Tim Lockett to Trevor Hill, "RE: Pressure build-up," May 17, 2010, Deposition Exhibit 9250.



From: Mason, Mike C
Sent: 15 May 2010 07:38
To: Inglis, Andy G (UPSTREAM)
Cc: Peijs, Jasper
Subject: Macondo Oil Rate

I just read an article in CNN (May 14, 2010 1:00pm) stating that a researcher at Purdue believes that the Macondo well is leaking up to 70,000bopd and that BP stands by a 5,000bopd figure. With the data and knowledge we currently have available we can not definitively state the oil rate from this well. We should be very cautious standing behind a 5,000 bopd figure as our modelling shows that this well could be making anything up to ~100,000 bopd depending on a number of unknown variables, such as: flow path either through the annulus behind the production casing or through the production casing float shoe, the height of reservoir exposed, if drill pipe is suspended in the BOP and sealed by VBR rams, reservoir skin damage, choking effects and etcetera. We can make the case for 5,000bopd only based on certain assumptions and in the absence of other information, such as a well test.

Mike Mason PE
Vice President, Base Management

Fig. 15 from Ex. 3220.

Aside from these concerns, some of BP's engineers and contractors also made visual estimates of flow by viewing ROV footage of the discharge of oil from the riser. Rygg made a visual estimate of flow on May 10, emailing Kurt Mix and Jon Sprague that based on video observation "I do not think it can be ruled out that the flow out at seabed is [o]n the order of 40,000 BOPD."[65] He has testified this figure was in reservoir barrels and only referred to the plume out of the riser, and not the leak at the kink. Converting from reservoir barrels to stock tank at 0.41,[66] this yields 16,400 stock tank BOPD out of the riser alone. Around May 15, Trevor Hill also made a visual estimate of 20-25,000 BOPD using the video, which he later revised downward to 15-20,000 BOPD.[67] These visual estimates, combined with the modeling results to date, should have indicated to BP that the likely flow rate was higher than 5,000 or even 15,000 BOPD. Yet testimony suggests the top kill was ultimately designed for an assumed flow rate of 5,000 BOPD.[68]

On May 17, 2010, Adm. Landry sent a letter to BP's Doug Suttles requesting that Suttles "provide [her] designated representative(s) with full access to all information related to the oil discharge rate as soon as possible."[69] On May 19, 2010, Suttles sent Landry and Adm. Allen an email attaching a document prepared by David Rainey ("Rainey memo"). Suttles' cover email stated: "Attached below is our most recent work on flow rate estimation."[70] The attachment

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[65] Email from Ole Rygg to Kurt Mix et al., "Current flow out the riser," May 10, 2010, Deposition Exhibits 8866 and 10798.
[66] Deposition of Ole Rygg, October 3, 2013, 292:7-296:18
[67] Deposition of Trevor Hill, January 15, 2013, 394:18-395:5; 398:22-399:6; 425:2-18.
[68] Deposition of Charles Holt, November 11, 2012, 160:16-161:4, 179:25-180:11.
[69] Letter from Adm. Landry to Doug Suttles, May 17, 2010, Deposition Exhibit 11193.
[70] Email from Doug Suttles to Adm. Landry et al., "FW: Flow Rate Note?," May 19, 2010, Deposition Exhibit 3218.

stated that based on measurements conducted between April 27 and 30, the "Low end was always around 1,000 barrels a day," "Best guess was between 5,000 and 6,000 barrels per day," and "High end varied from 12,000 to 14,000 barrels per day." It then reported "an updated range of possible flow rates as follows: 2,000 – 6,000 – 13,000 barrels per day." Five days later, on May 24, 2010, BP provided the Rainey memo to Congress. BP has since admitted in its Nov. 15, 2012 guilty plea that this May 24 submission to Congress "withheld information and documents relating to multiple flow-rate estimates prepared by BP engineers that showed flow rates far higher than 5,000 BOPD, including as high as 96,000 BOPD."[71] Based on the BP internal flow rate modeling and analysis that I reviewed above, I agree that the Rainey memo BP provided to Congress on May 24 withheld numerous flow rate estimates prepared by BP engineers that showed flow rates in excess of 5,000 BOPD.

Finally, on May 22, 2010, just before the top kill, BP executive Doug Suttles gave an interview to NPR's "Weekend Edition" during which he was asked by the interviewer "… let's say that it's 30,000 barrels a day that are spilling." Suttles' response was, "We don't think the rate's anywhere near that high."[72] However, just the day before on May 21, Halliburton had submitted its cement report with the flow rate estimated at 30,000 BOPD or above. And as clear from the prior discussion, BP's internal modeling showed a range of flow rates up to and exceeding 30,000 BOPD.

5. BP Concealed Flow Rate Information Both Internally and Externally

BP's apparent effort to conceal flow rates estimates extended to even internal discussions among engineers. For example, Adam Ballard, a BP engineering team lead working on the modeling for the response effort, wrote on May 17, 2010 to another BP flow assurance engineer, Farah Saidi, requesting collection rate information from the Riser Insertion Tube Tool (RITT).[73] Ballard was interested in applying what BP was learning regarding the flow rate to the design of containment projects. Richard Lynch, BP's Vice President of Drilling and Completions, responded to Adam Ballard and Farah Saidi and stated "at this point we are not releasing any information that can be related to rate."[74] Lynch later reiterated BP's stance that "we remain in a position where no flow related information can be released internally or externally."[75]

Furthermore, prior to the top kill, BP instructed employees to refrain from putting flow rates in writing. After Mike Mason emailed Andy Inglis warning that "[w]e should be very cautious standing behind a 5,000 BOPD figure as our modeling shows that this well could be making anything up to ~ 100,000,"[76] Mason received a call from Jasper Peijs, Inglis's executive

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[71] Trial Exhibit 52673.

[72] SEC Complaint, ¶32.I.

[73] Email thread with top email from Mike Brown to Philip Maule, "RE: MC 252 Fluid Composition," May 18, 2010, Deposition Exhibit 9475.

[74] *Id.*

[75] *Id.*

[76] Email from Mike Mason to Jasper Peijs and Andy Inglis, "Macondo Oil Rate," May 15, 2010, Deposition Exhibit 3220.

assistant, requesting an immediate meeting that morning.[77] At the meeting, Peijs told him, "Next time you have an idea or a thought like this E-mail note, we would appreciate it if you would walk over and discuss with us."[78] When asked what Mason thought Peijs was referring to, Mason testified, "Well, I asked him what the problem with -- was with this note a number of times, and he said: 'It's the big number.'" By "the big number," Mason understood Peijs was referring to the 100,000 BOPD reference.[79]

BP also communicated the same message to Farah Saidi. On May 16, 2010, Farah Saidi responded to Trevor Hill's request for collection information from the RITT with "[s]ince the rates are confidential and I was told by Mike Brown not to write anything about it, he advises to call Paul Tooms."[80] She testified at deposition that she was instructed not to forward the rates to anyone.[81] She understood this direction to keep the rates confidential came from BP Vice President Richard Lynch.[82]

There are other examples of BP's apparent policy to conceal flow rate data. On April 22, 2010, a BP Incident Commander, Gary Imm, responded to an email regarding an estimated flow rate of 82,000 BOPD by a BP employee Alistair Johnston with "we already have had difficult discussions with the USCG on the numbers. Please tell Alistair not to communicate to anyone on this."[83] BP met with a representative from Exxon on May 4, 2010 to review BP's modeling assumptions. BP's summary notes from the meeting expressly state that "[a]fter agreeing reasonable assumptions [were] used in our modeling, we intentionally did not perform calculations in his presence."[84] On May 5, 2010, Jasper Peijs emailed Kelly McAughan and Cindy Yielding (a BP Vice President) regarding their worst case discharge plots. Peijs noted: "Both Tony [Hayward] and Andy [Inglis] have seen it … This is exactly what they asked for. This information is sensitive, so please do not forward."[85] On May 6, 2010, Kelly McAughan wrote, "Andy Inglis requested WCD (worst case discharge) plots on various flow rate restrictions. Attached is the file, but like Jasper [Peijs] said please don't pass around."[86] BP's lack of transparency extended to the top kill failures: on May 28, 2010 Paul Tooms, Vice

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[77] Deposition of Mike Mason, January 24, 2013, 319:2-320:20.
[78] *Id.* at 321:2-4.
[79] *Id.* at 321:5-12.
[80] Email from Trevor Hill to Farah Saidi, "RE: Update," May 16, 2010, Deposition Exhibit 9474; see also Deposition of Farah Saidi, January 10, 2013, 130:15-133:22.
[81] Deposition of Farah Saidi, January 11, 2013, 407:2-7.
[82] *Id.* at 408:25-409:6.
[83] Email from Rob Marshall to Gary Imm et al., "RE: Macondo flowing well rate," April 22, 2010, Deposition Exhibit 8656.
[84] Meeting Summary Notes, May 4, 2010, Deposition Exhibit 9306.
[85] Email from Kelly McAughan to Brian Ritchie, "WCD Plots Request," May 6, 2010, Deposition Exhibit 9157.
[86] *Id.*

President of Engineering E&P, wrote that no one is to receive top kill data "outside the circle of trust."[87]

C. BP knew or should have known from its modeling efforts that the top kill was very likely to fail because the well flow rate exceeded a 15,000 BOPD threshold rate.

In May 2010, as part of its source control efforts, BP considered performing a "top kill" to regain hydrostatic control of the well. BP planned the top kill to include a "dynamic" (or "momentum") kill in which mud would be pumped into the well through the BOP's kill and choke lines.[88] To be successful, the dynamic kill would have to overcome the well's flow rate.

In early to mid-May, BP's consultants at Add Energy led by Ole Rygg ran models of the dynamic kill in support of the top kill design, using the OLGA-Well Kill software. Eventually, they adjusted the model parameters to meet a series of target flow rates prescribed by BP.[89] For each flow rate scenario they then modeled the injection of mud through the choke and kill lines at the bottom of the BOP and the efficacy of the dynamic kill.

Add Energy's models demonstrated that for well flow rates at 15,000 BOPD or higher, the dynamic kill would fail. Specifically, the injected mud would not overcome the well flow rate and simply be carried upward through the BOP and be discharged to the ocean. Add Energy communicated the 15,000 BOPD failure threshold to BP in a May 16, 2010 email from Ole Rygg to BP's Kurt Mix: "Looks like with 15000 bopd, you can not [sic] kill it with 50 bpm."[90]

On or about May 17, BP management, staff, contractors, and some U.S. government scientists met to review the top kill operation.[91] Meeting attendees included Ole Rygg, Kurt Mix and BP engineering manager Jon Sprague. A May 18 "Kill the Well on Paper" memo summarizes the meeting discussion.[92] Two of the five summary bullet points in the memo emphasize the 15,000 BOPD well flow rate threshold and the importance of an accurate flow rate estimate for a successful kill:

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[87] Email from Paul Tooms to Rupen Doshi, et al., "RE BJ and Halli Data," May 27, 2010, Deposition Exhibit 9164.

[88] A related part of the top kill operation was a "junk shot" in which, alternating with the mud, solid bridging material would be periodically pumped into the bottom of the BOP to help plug it above the injection point.

[89] See email from Ole Rygg to Bill Kirton, et al., May 20, 2010, Deposition Exhibit 9269 (modeling at 5,000, 10,000, and 15,000 bopd).

[90] Email from Ole Rygg to Kurt Mix, "Top Kill – 5000 and 15000 bopd," May 16, 2010, Deposition Exhibit 8537. The 50 bpm in this quote is a reference to the mud pump rate, a technology limitation of the kill, in barrels per minute (bpm).

[91] Summary Points from Kill the Well on Paper Discussion, May 18, 2010, Deposition Exhibit 8553.

[92] *Id.*

- "Modeling indicates that a dynamic kill cannot be successfully executed if the oil flow rate is 15000 STBpd."
- "Knowledge of the flow rate is needed to form a view of the probability of success, as is knowledge of the position of flow restrictions."[93]

As clearly set forth in this memo, BP management knew or should have known that the well flow rate was important to the success of the dynamic kill, and that if the flow rate was 15,000 BOPD or more, the dynamic kill would fail.

As set forth in Section V.B above, the 15,000 BOPD threshold was below a significant majority of well flow rates modeled by BP engineers and contractors. More specifically, by mid-May when the "Kill the Well on Paper" meeting occurred and memo was circulated, a substantial number of BP's model results suggested flow rates higher than 15,000 BOPD. Therefore, BP knew or should have known that its models were predicting a well flow rate that was likely to be greater than the 15,000 BOPD dynamic kill failure threshold.

The 15,000 BOPD failure threshold was also well below the minimum well flow rate of 30,000 BOPD calculated by Halliburton.[94] Nevertheless, BP did not inform Halliburton of the 15,000 BOPD flow rate threshold. Had Halliburton known of this threshold, Halliburton's Richard Vargo testified that the inherent risks of the kill, both to equipment and staff, would not have been worth taking.[95]

In short, BP knew or should have known that the flow rate from the well was higher than a 15,000 BOPD threshold above which the dynamic kill was likely to fail. Proceeding with the top kill under these conditions delayed other source control measures that may have had a greater likelihood of success.

D. After the top kill failed, BP was informed that the failure was most likely due to the flow rate.

BP conducted the top kill operation from May 26 to May 28, 2010. It failed to kill the well.[96]

As predicted by BP's pre-top kill modeling , the dynamic kill failed due to the well flow rate. In fact, on May 27 during the top kill operations, BP engineer Kurt Mix sent BP engineering manager Jon Sprague the following text message:

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[93] Note that the term "bubble point" in the first bullet refers to the fluid pressure at which gas begins to come out of solution and form a separate fluid phase; it is an issue if there is a deep choke -e.g., small skin- at the reservoir level.

[94] Deposition of Richard Vargo, August 22, 2012, 131:23-132:25.

[95] Deposition of Richard Vargo, August 22, 2012, 94:15-95:4 and 99:9-13.

[96] Email from David Barnett to Mark Mazzella et al., "Top Kill Summary," May 31, 2010, Deposition Exhibit 10632.

> "Too much flow rate--over 15000 and too large an orifice. Pumped over 12800 bbl of mud today plus 5 separate bridging pills. Tired…Going home and getting ready for round three tomorrow."[97]

Video from ROVs stationed alongside the riser confirmed what BP's models had earlier predicted. Instead of going down the well the mud was blown out of the BOP stack and riser to the sea.[98] On May 29, 2010, Fred Ng with BP consultant Wild Well Control, emailed to colleagues at his company:

> "It is quite apparent from the video that most if not all the mud pumped in these operations went out the DWH riser and no[t] down the hole. In spite of increasing pump rate, junk shot, cubes and balls etc., there was little change in the mud plume exiting the riser."[99]

Additional post-top kill analysis by BP and its consultants/contractors further confirmed that the top kill failed due to the flow rate.[100]

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[97] Text Message from Kurt Mix to Jon Sprague, May 27, 2010, Deposition Exhibit 9160.

[98] Email from David Barnett to Mark Mazzella et al., "Top Kill Summary," May 31, 2010, Deposition Exhibit 10632.

[99] Email from Christopher Murphy to Fred Ng, et al., "RE: Burst disc calculations," May 30, 2010, Deposition Exhibit 10534.

[100] Deposition of Richard Vargo, August 22, 2012, 132:24-133:21, 106:17-21; Email from Christopher Murphy to Fred Ng, et al., "RE: Burst disc calculations," May 30, 2010, Deposition Exhibit 10534; Email from David Barnett to Mark Mazzella et al., "Top Kill Summary," May 31, 2010, Deposition Exhibit 10632.

Appendix A

Timeline of BP Flow Rate Modeling Documents: April and May 2010

APRIL 21:

- Exhibits 3063, 3372 & 5239: Email from Walt Bozeman to David Rainey, et al., "RE: WCD – Updated."
  - Bozeman writes, "We have updated the earlier WCD calculation with new subsurface parameters from the Macondo team and modeled a flow rate at the sea floor (assuming riser falls) in Prosper …. All the Res in GoMX participated in this evaluation along with numerous members of the Macondo team. We calculate 100,000 BOPD and 300 MMCFPD based on these parameters."
- Exhibit 9480: Email from Walt Bozeman to Kurt Mix and Robert Bodek, "Macondo Info."
  - "We are calculating a PI of 50 bbl/psi."
  - Attached slides "Inflow (IPR) v. Outflow Curves (VLP)" show a flowrate of 100,000 bopd with input assumptions of 11,850 psia, 3000 GOR, and 88' productive interval, zero skin.

APRIL 22:

- Exhibits 5241 & 9539: Email from Kelly McAughan to Jay Thorseth, et al., "Re: Flowrate and production profile."
  - "Attached are the forecasts plus cumulative production and raw numbers for the base case."
  - Attachment begins with date April 21, 2010 and has columns for Reservoir Pressure (psi), Base Oil (bopd), Base Gas (mmcf), Cum Oil (mbo), Cum Gas Prod (bcf). The Base Oil column begins at 97,585 bopd for April 21, 2010 and runs through December 2010 (decreasing).
- Exhibit 8656: Email from Rob Marshall to Gary Imm, et al., "Re: Macondo flowing well rate."
  - "…Alistair Johnston altered his Macondo well model to approximate open hole flowing conditions, and calculated a rate of 82,000 barrels per day…"
  - Gary Imm's reply: "…we already have had difficult discussions with the USCG on the numbers. Please tell Alistair not to communicate to anyone on this."
- Exhibit 3907 & 10483: Email from William Burch to Christopher J. Murphy, et al., "042110 – Notes from BP Reservoir/Geology Group (WWCI 2010-116)."
  - "Reservoir Engineer slapped together a quick number this morning to give to management of 162,000 bpd and then this afternoon revised those numbers to 92,500

bpd. The revised numbers are based on the modeling aspects of a similar sand package as Nakika and *assumes a 10,000 psi frictional pressure loss from surface to TD."*

  - "If the well is flowing from inside the casing and exiting the riser, OLGA-ABC shows 138,000 bpd to the surface."
  - "If the well is flowing from inside the casing and around the DP still stu[ck] inside the DP and exiting the riser, OLGA-ABC shows 110,000 bpd to the surface."
  - "If the well is flowing from inside the casing and the DP has been dropped and hung in the top of the 7" casing and exiting the riser, OLGA-ABC shows 93,000 bpd to the surface."
  - "If the well is flowing behind the 7"x9-7/8" casing thru the 16" liner top and over the exposed 22" into and out of the riser, OLGA-ABC shows 64,000 bpd to the surface."

- Exhibit 10484: Email from John Shaughnessy to William Burch, "Re: OLGA-ABC Simulation Run Snapshot (WWCI 2010-116)."
  - Contains a snapshot of screenshots from OLGA-ABC modeling that shows an oil flowrate for the worst-case scenario of flow up the 7"x9-7/8" casing and exiting at the seafloor with no drillpipe in the hole. The screenshot appears to show well flow of approximately 140,000 BOPD.
  - John Shaughnessy replies, "That number is going to be high focus in the morning."

APRIL 23:

- Exhibit 10486: Email from William Burch to Kurt Mix, "Emailing: Macondo_Seafloor_Blowout_DP.dml."
  - Sends model file described as "Simulation runs to support on going operations. Original Mud at time of incident is seawater in the riser and sobm in the hole. The equivalent pressure at td is 11937 psi at 18360' tvd equals 12.5 ppg. Data Gathered from Tiger Team Pore Pressure version 7 dated 3/16/2010. Adjusted reservoir pressure to 10255 psi by reducing the original reservoir pressure by a 0.3 psi/ft light oil gradient. This run has added a 2245 psi back pressure to account for seawater column."

APRIL 24:

- Exhibit 10487: Email from William Burch to Kurt Mix, "IPR Curve vs. OLGA FBHP Numbers."
  - Attached is "IPR Curves.xlsx" showing flowrates at points for 69,500; 52,000; 41,000; 24,000; and 8,600 bopd apparently for different riser flow conditions (equivalent pipe diameters).

APRIL 25:

- Exhibit 9438 (earliest email): Email from Adam Ballard to Julian Austin, "Preliminary Results for Orifice Size."

- Summarizes Pipesim modeling in which Ballard concludes, “Orifice Size expected to flow ~1000 bbl/d through two orifice restrictions is 0.15 to 0.2 inches.”
- Results are forwarded to BP’s Trevor Hill on April 26.

APRIL 26:

- Exhibit 9274: Email from Jonathan Bellow to Martin Albertin, et al., “FW: Rate and Pressure profiles.”
  - Attached is “Forecast from MBAL 4-26 V2.xls.”
  - Jonathan Bellow writes, “This is a depletion estimate in pressure space to go along with the rates slides I sent last week.”
  - Attachment includes, "High Rate Case" and "Low Rate Case" with different PVT and fluid properties. The MBAL prediction has the liquid rate beginning at approximately 110,000 bopd, decreasing to approximately 55,000 bopd over time.

APRIL 27:

- Exhibits 1626 & 2416: Email from Jason Caldwell to Doug Suttles, et al., “Notes from 4/27 Morning Interface Meeting.”
  - Attached are meeting notes.
  - “Send Doug a summary of flowrate calculations based on well head pressure vs. orifice size.”
- Exhibit 10180: Email from Trevor Hill to Julian Austin, et al., “Flowrate vs orifice.”
  - “Calcs so far with drill pipe in well, and whole riser cross-section downstream of BOP kink give Orifice diameter 0.5 inch 5800 bbl/day, 0.75 inch 12900 bbl/day, 1 inch 22600 bbl/day. … I will ask Farah to repeat the calcs but with drill pipe downstream of BOP kink.”
- Exhibit 9439: Email from Julian Austin to Farah Saidi and Trevor Hill, et al., “RE: Horizon pipesim model.”
  - Farah Saidi responds to Trevor Hill’s request: “For 10 mbd and flow thru drill pipe of 5.625 inch ID, the orifice size of 0.59” is what I calculated.”
- Exhibit 9445: Email from Tim Lockett to Farah Saidi, “Horizon pipesim model.”
  - At orifice size restrictions of size equivalent to .5, .75 and 1 inch diameter. “We get flowrates of 5000 to 22000 bbl/d” using Pipesim.
  - Includes screenshots of the modeling runs.

APRIL 28:

- Exhibit 5063 & 9331: Trevor Hill email to Gordon Birrell, et al., “RE: Action Items from 3:00 PM Sunday telecon - flow modeling.”

    - Attached is "Modeling of system flow behaviour rev 1.doc." Estimates are between 2,523 to 65,171 bopd depending on orifice size and flowing wellhead pressure.

- Exhibit 8942: Email from William Burch to Kurt Mix, et al., "FW: 042910 – Dept. of Interior Well Control Modeling Presentation."
    - Attached is a PowerPoint by Kurt Mix and Wild Well Control's William Burch with well control simulation results for eight cases, resulting in flow rate estimates: 138,300, 110,000, 93,000, 64,000, 146,000, 77,000, 69,500 bpd.
    - The eighth case analyzes casing annulus flow path and split DP at BOP, depending on orifice size: .73"=1,000 bpd; 2"=8,600 bpd; 3"= 23,600; 4"= 42,100 bpd; 5.625"= 51,800 bpd.

- Exhibit 10488: Email from Kurt Mix to William Burch, "Macondo-2_Well-Control-Modeling.ppt."
    - Attached is PowerPoint, "Well Control Simulation Results - April 22, 2010 Seafloor Exit @ 4,992 ft Water Depth" showing oil rates ranging up to 146,000 bopd.

APRIL 29:

- Exhibit 10489: Email from William Burch to Kurt Mix, "Revised Numbers for Choked Cases."
    - Attachment has 8 cases of different flow paths ranging up to 146,000 bopd. "Case 8" has flowrates at IDs of 0.73" to 18.5" diameters, 1,000 - 60,500 bopd, respectively.

APRIL 30:

- Exhibits 9629 & 9672: Email from Richard Simpson to Chris Matice, William Burch, James Wellings and Charles Holt, et al., "Flow rate for first modeling run: BP Macondo Plume Modeling Parameters."
    - Chris Matice writes that they will start modeling with a 5,000 bpd flowrate. Burch responds that "some sensitivities on flow" should also be done at rates of "10,000, 20,000, 40,000, 80,000, 160,000 bbls if this is easy. If there is significant computational time in each run, let's discuss the best way to capture the most value for the least number of runs."
    - After Matice notes that each run will take 10-12 hours and that they should "start with the best estimate", Simpson responds: "NOTE: Confidential Information. For the first run, use 70,000 bpd. For the second run, use 35,000 bpd. Third run, 17,500 bpd."

- Exhibit 9328: Email from Tony Liao to Bruce Friesen, "FW: Follow up: tubing id for sub pump option → Re: Offer of OLGA modeling assistance."
    - "It would be great if you can have a conversation with Farah to offer her the rationale for NOT to MAXIMIZE rate from this well (riser). It is understandable as she wouldn't know this." This is in response to an email from Farah Saidi dated April 29,

2010 regarding her Pipesim simulation and input assumptions totaling a liquid rate of 15,437 stb/d.

MAY 1:

- Exhibit 11160: Email from Mike Mason to Frank Sweeney, et al., "LiaoCases (3).xls."
    - The LiaoCases include a chart of FWHT and Oil Rate and 9 cases (Situation 1-3 with Cases 1-3) showing rates up to 95,336.
- Exhibit 11135: Native Document spreadsheet, encompassing modeling rates similar to Ex. 11160.
- Exhibit 10091: Report from Stress Engineering Services Inc. to BP Exploration, "CFD Analysis – Cases 1 & 2."
    - CFD Analysis for Horizon BOP stack top flow performed by Stress Engineering team, Anup Paul, Harbi Pordal and Christopher Matice.
    - "Conclusions: The center line of the plume shifts 26 feet downstream at 600 feet above seabed in current direction of 70,000 BPD oil flow. The center line of plume shifts 40 feet downstream at 600 at in the current direction at 35,000 BPD oil flow."

MAY 2:

- Exhibit 10185: Flowrate calculations apparently performed by Farah Saidi and/or Tony Liao.
    - Metadata indicates the file was created on May 2, 2010.
    - Flow rates range from 1,194 to 95,336 BOPD depending on skin and reservoir thickness assumptions and choke sizes.

MAY 3:

- Exhibit 9446: Email from Tim Lockett to Trevor Hill, "Best estimate."
    - Lockett writes, "… I re-ran the cases to generate the attached xls which then uses that data to give a flowrate estimate as a function of pressure at the BOP, temperature at the BOP and D/s of the crimp, velocity of either liquid or mixed phase in the riser…."
    - Attachments contain graphs and charts of oil flowrates ranging, depending on orifice size, from approximately 2,500 to 37,700 BOPD.

MAY 5:

- Exhibit 9935: Email from John Sharadin to Brent Reeves, et al., "FW: DO NOT DISTRIBUTE: BP_MC252_Intercept_Kill_Operations_R1_5.5.10.doc."
    - Attached is BP Intercept & Kill Operations Plan Revision 1.0 - 5 May 2010.
    - Point 2.0: "Dynamic Kill Modeling" reports OLGA modeling was done to determine the estimated blowout assuming various flow paths. Table 1.0 summarizes Flow Scenarios & Kill Rates for oil rates of 146,000 bpd, 77,000 bpd, and 69,500 bpd.

MAY 6:

- Exhibit 9157: Email from Kelly McAughan to Bryan Ritchie "WCD Plots Request."
    - Attached is "WCD Plots – Macondo 1 -050510.ppt."
    - McAughan writes, "Andy Inglis requested WCD (worse case discharge) plots on various flow rate restrictions. Attached is the file, but like Jasper said please don't pass around. I have more data behind these plots on assumptions but jasper just wanted the plots."
    - Email from Jasper Peijs to Kelly McAughan states: "Both Tony and Andy have seen it and are impressed with the fast turn-around. This is exactly what they asked for. This information is sensitive, so please do not forward."
    - Attachment sets forth flowrates of 162k, 109k, 55k, 20k, 10k, and 5k bpd.

- Exhibits 9158 & 9330: Email from Jasper Peijs to Kelly McAughan, et al., "RE: WCD Plots."
    - Peijs asks McAughan to "run two more cases with initial flow rates of 40,000 and 60,000."
    - McAughan responds "ran the new cases." She also says "I attached the excel file as well so you can edit freely."

- Exhibit 9294: Email from Kelly McAughan to Cindy Yielding, et al., "Wednesday 5/5 Macondo Fluids Summary."
    - Reports "Kelly McAughan and Walt Bozeman provided WCD for Jasper Peijs requesting flowrates and volumes for 3 months on 6 cases for Andy Inglis. One for the old discharge rate of 162k bopd, new discharge of 109k, and then 60k, 20k, 10k, and 5k. Assumptions were made on restrictions for the lower flowrates."
    - "James Dupree asked for RE input on more gas flowing out of a riser."

MAY 7:

- Exhibit 11136: Email from Tony Liao to Thomas Boyd and Wayne Sutton, "RE: Mocondo."
    - Attaching: "PvsRate 5th May_tl.xlsm; Macondo_Flow 5h May.ppt." Reports flow rates up to 95,945 BOPD and includes flow path schematics.
    - Liao sends this PowerPoint in response to Mason's instructions to "get these guys the best data we have for temperature and pressure gradients."

MAY 8:

- Exhibit 9441: From Roberta Wilson to Mike Mason, "Holistic System Analysis rev 4.doc."
    - "Report summarises the analysis of the current state of Macondo well and riser utilising the data available to 6th May 2010."

  - "This modeling indicates a wide range of potential flow-rates. Flow behind casing (currently considered most likely) yields a feasible range of 2,000-47,000 stbpd, with a worst case of 52,000 stbpd. Unconstrained flow through the inside of the production casing string could reach 96,000 stbpd, but this is considered to be an unlikely rate."
  - *See also* Ex. 11169, Email from Trevor Hill to Jon Turnbull, attaching similar draft on same day.

MAY 9:

- Exhibit 9266: Email from Ole Rygg to Kurt Mix, "Blowout Rates."
  - Attached table showing flow rates at 3800 psi and 2244 psi of 37,000 to 43,000 BOPD (annulus), 55,000 to 63,000 BOPD (casing) and 74,000 to 87,000 BOPD (both), respectively.

- Exhibits 9159 & 9240: Memo from Hydraulic Kill Team: Kurt Mix, Ole Rygg, and William Burch to Jonathan Sprague.
  - Estimating flow rates at 37,000 -87,000 bopd.
  - Includes model calibration comparing OLGA-Well Kill to OLGA-ABC. Results are 38,000 BOPD and 53,500 BOPD, respetively.

MAY 10:

- Exhibit 8867: Doug Suttles letter to Mary Landry, "Re: MC252 Response – United States Coast Guard Request for Proprietary Information Regarding Potential Productive Capacity of the Maconda [sic] Well."
  - "The response is based on 2 scenarios: 1) the well continues to flow at the currently estimated rate of 5,000 barrels per day, and 2) the release form the well increases to its estimated full-stream capacity."
  - "The estimated unrestricted full stream capacity of the Well is approximately 55,000 barrels per day. This rate uses actual measured info from this well including reservoir permeability, gas- oil ratio, oil viscosity and the measured flowing pressure at the base of the BOP…and assumes there is no 'skin'…" This would be extremely rare and represents a theoretical downside."

- BP-HZN-2179MDL01962554-2632: Undated PDF of Excel Spreadsheet.
  - Contains model runs at 55,000 and 5,000 BOPD.
  - Same spreadsheet also contains model dated May 5 and May 6 with runs at 162K, 109K, 60K, 55K, 40K, 20K, 10K, 5K BOPD.

- Exhibit 9241: Email from Ole Rygg to William Burch, "FW: Updated presentation of blowout and dynamic kill results."
  - Contains updated modeling for dynamic relief well kill efforts.

  - Flow rates vary by pressure (2244 psi and 3800 psi) at 63,000 and 55,000 BOPD for flow inside casing, 43,000 and 37,000 BOPD for flow up the annular space, and 87,000 and 74,000 BOPD for flow in both casing and annular space.

- Exhibits 8866 & 10798: Email from Ole Rygg to Kurt Mix, et al., "Current flow out of riser."
  - "[B]ased on the observation from the video you sho[w]ed me Yesterday…I do not think it can be ruled out that the flow out at seabed is in the order of 40,000 bopd." It's "comparable" to a 1 ft/s velocity leaving the pipe.

- Exhibit 11164: "Effect of Oil Formation Volume Factor (FVF)" by Tony Liao.
  - Involves use of FVF of 2.77 and then updated from Pencor at 2.367. Oil Production rate calculated based on the new FVF is 53,963.5 STB/D versus 53,286.1 STB/D using the old FVF. Attaches screenshots of calculations.

- Exhibit 10492: Email from William Burch to David Barnett, "Emailing: Modeling Comparison.xlsx."
  - Attached is "Modeling Comparison.xlsx," a comparison of OLGA-ABC and OLGA-Well Kill, showing that for similar inputs OLGA-ABC gets 52,500 and Well Kill gets 38,000 bopd for an annular flowrate at FWHP 3,650 psi.

MAY 11:

- Exhibit 9267: Email from Ole Rygg to Kurt Mix, "Slides for the meeting."
  - Slides summarize modeling of dynamic kill for relief well.
  - Contains three scenarios of flow rates, varying by flow path and with differing pressures at BOP:
    - 2244 psi: 63,000, 43,000, 87,000
    - 3800 psi: 55,000, 37,000, 74,000

- Exhibit 9156: Email from Mike Mason to Jasper Peijs, "Meeting presentation May 11, 2010 (3).ppt."
  - The email was forwarded to Cindy Yielding, et al., with note: "Jasper's feedback after reviewing with Andy Inglis is very positive".
  - Attachment contains charts of "Maximum Reservoir Exposed, High K" case ranging from 21,000 to 96,000 BOPD, and "Partial Reservoir Exposed, Low K" case ranging from 14,000 to 65,000 BOPD.
  - Concludes, "the rate could be as high as ~ 100,000 barrels per day up the casing or 55,000 barrels per day up the annulus (low probability worst cases)."
  - Also contains slide for "The Case for 5000 BOPD at 3800 psi."

MAY 13:

- Exhibit 9448: Email from Tim Lockett to Trevor Hill, et al., "Re: Update of choke information."
  - The chart included has different oil flowrates based on a Well PI of 1, 2, 4, and 5. The resulting flowrates are 4,880, 9,758, 16,903, and 19,400 STbopd based on equivalent diameters of .074", 0.138", 0.238", 0.279".
  - Hill wrote to Lockett, "May I ask you to look back at the work you did previously on choke size vs flowrate please… this is needed to give an estimate of the sizes of orifice that would generate an 1150 psi pressure drop through the BOP stack for flowrates of 5, 10, and 15 Mbd."
  - Tim Lockett writes after the chart, "The answer is therefore that we would need a restriction down to a hole equivalent to 0.07 to 0.28 inch, so a small hole."
- Exhibit 10641: Email from Tim Lockett to Trevor Hill, et al., "Re: Update of choke information.
  - Updates Ex. 9448. Equivalent orifice diameters for target rates are 0.56" and 1.15."

MAY 14:

- Exhibits 10642 & 9449: Email from Tim Lockett to Trevor Hill, "Thoughts around 2700 psia reading."
  - Lockett re-runs a model for an upstream of BOP (kink) measurement of 2700 psi. Resulting flow rates range from 1482 BOPD to 48173 BOPD, though Lockett deems the low values not credible because periodic reverse flow has not been seen on the video.
  - He writes, "I was hoping for a flowrate which might be more in line with other indicators. Unfortunately, this still comes out with a number which looks rather too large, so this would suggest some further unexplained pressure loss in the remaining riser system."
- Exhibit 9940: Email from John Sharadin to Jeff Lott, et al., "New Plan."
  - Attached slides include Top Kill analysis involving flowrates of 5,000, 10,000, 15,000, and 25,000 BOPD.
- Exhibit 9309: Email from Mike Mason to Chris Cecil, "FW: May 14 Presentation (P O'Bryan).ppt"
  - Attached is PowerPoint regarding SIWHP and build up times.
  - Includes a graph for an MBAL model of Expected Reservoir Depletion looking at rates of 5,000 BOPD, 20,000 BOPD, and 60,000 BOPD.
- Exhibit 9243: Email from Ole Rygg to Mike Mason, "Blowout rates and shut-in."

  - Attaches power point presentation "MC252 Blowout Rates Shut-in 13 May 2010.pptx."
  - Flow rates vary by pressure (2244 psi and 3800 psi) at 63,000 and 55,000 BOPD for flow inside casing, 43,000 and 37,000 BOPD for flow up the annular space, and 87,000 and 74,000 BOPD for flow in both casing and annular space.

- Exhibit 10188: Email from Farah Saidi to Simon Bishop, Tony Liao, et al., "FW: Flow inside casing 3800 psi at wellhead."
  - Forwarding an email from Lee Norris dated May 14, 2010 with a table summarizing the well shut in pressure based on cases from Ole Rygg.
  - Farah Saidi confirmed that the attachment reflects flow rates from Norris' OLGA modeling from 3,853 BOPD to 37,338 BOPD assuming 88' of reservoir exposed, 300mD permeability, and a 3800 psi pressure at the bottom of the BOP.

MAY 15:

- Exhibits 3220, 6203 & 10779: Email from Mike Mason to Andy Inglis copying Jasper Peijs, "Macondo Oil Rate."
  - "We should be very cautious standing behind a 5,000 bopd figure as our modeling shows that this week could be making anything up to ~ 100,000 bopd…"

- Exhibit 2419: Email from James Dupree to Andy Inglis and Doug Suttles, "FW: BP flow observations."
  - Forwards an email and attachment Paul Tooms received from Trevor Hill attaching observations on the flow out the riser pipe resulting in a flow rate of 15,000 BOPD.
  - *See also* Exhibit 10334 for original email.

MAY 16:

- Exhibit. 8537, 9959, & 10511: Email from Ole Rygg to Kurt Mix, "Top Kill - 5000 and 15000 bopd."
  - Ole Rygg writes, "Kurt, look at the presentation. [I]nteresting results. Looks like with the 15000 bopd, you can not kill it with 50 bpm." Powerpoint slides are attached summarizing the modeling.

- Exhibit 9474: Email from Farah Saidi to Trevor Hill, "RE: Update."
  - In response to Trevor Hill's request for "indications on how the tube is working," Farah Saidi writes: "Since the rates are confidential and I was told by Mike Brown not to write anything about it, he advises to call Paul Tooms."

- Exhibit 11140- Email from Tony Liao to Mike Mason, "RE: Macondo SIWHP Build-up Rate Final Report.doc."
  - Attached are plots by Tony Liao regarding reservoir depletion pressure with excel file of cases run.

  - "To get [a] 700 psi depletion from 4/20/2010 15May2010, the rate required is 86,600 B/D."
  - Mason forwards to Gordon Birrell and James Dupree in Exhibit 9313.

- Exhibits 9329 & 11151: Email from Mike Mason to Debbie Kercho, et al., "5MBD Case Base plotsa (3).PPT."
  - Attachment not included.
  - Mason writes, "I sent this pack to Jasper yesterday - it is based on a new BOP pressure of 3100 versus 3800. We took the 5000bopd case at 3800 and have tried to describe how you can get 3100 psi at this starting rate (5mbd) by changing skin, height, water cut, a change in the completion - he is on board with what we have shown."

- Exhibits 11208 & 9250: Email from Ole Rygg to Trevor Hill, et al., "RE: Pressure build-up."
  - Rygg writes, "Be aware that we are working on the 5000 bopd case. That could be too optimistic."

MAY 17:

- Exhibit 8865: Email from Trevor Hill to Douglas Wood, "FW: Pressure build-up."
  - Email forwards Tim Lockett's email and points out his statement: "The apparent reliance on Ole's email on the 5 mbd number, which has little if no origin, is concerning. From all the different ways we have looked at flowrate, 5 mbd would appear to err on the low side."

- Exhibit 9475: Email from Adam Ballard to Farah Saidi and Norm McMullen, et al., "REQUEST: Daily Status Report?"
  - Adam Ballard wrote to Saidi and others that the "learnings" from the RITT would help drive longer term solutions and asked for a daily status report. Norm McMullen forwarded the email to Richard Lynch.
  - Lynch writes, "at this point we are not releasing any information that can be related to rate." Adam Ballard then asks for specific information. Lynch responds, "[W]e remain in a position where no flow related information can be released internally or externally."

MAY 18:

- Exhibits 9132 & 8553: BP Memo, " Summary Points from the Kill the Well on Paper Discussion."
  - "Modeling indicates that a dynamic kill cannot be successfully executed if the oil flow rate is 15000 STBpd."
  - "Knowledge of the flow rate is needed to form a view of the probability of success, as is knowledge of the position of flow restrictions."

- Exhibit 9255: Email from Douglas Wood to Ole Rygg, "BOP equivalent choke calcs."
  - Wood requests that Rygg confirm numbers orifice size equivalents for flow rates at 5,000 and 15,000 BOPD, for pressures of 3800 psi and 3000 psi.
- Exhibits 10655 & 9250: Email from Douglas Wood to Trevor Hill, copying Tim Lockett, "RE: Pressure build-up."
  - Wood replies to concerns expressed by Tim Lockett that "[t]he apparent reliance on Ole's email on the 5 mbd number, which has little if no origin, is concerning" by saying, "Tim's points are both valid and have an impact on the viability of the kill option working. Kate and I have passed our thoughts on the probability of success and the risks that may be introduced to Paul."

MAY 19:

- Exhibit 3218: Email from Doug Suttles to Adm. Landry and Adm. Allen, "FW: Flow Rate note?"
  - Email purports to summarize all BP's latest flowrate calculations.
  - Provides "updated range of possible flow rates" at 2,000 – 6,000 – 13,000 barrels per day."

MAY 20:

- Exhibit 9269: Email from Ole Rygg to Bill Kirton, et al.
  - Attached is presentation from May 20, 2010 meeting. Presentation models top kill at flow rates of 5,000, 10,000, and 15,000 bopd.
- Exhibit 11170: "Macondo Holistic System Analysis Report for MC-252."
  - Based on data to May 20, 2010, reports that BP collected ~ 5,000 bbls from the RITT, "thus suggesting that the flow rate from the well is higher than the original estimate." (p. 8).
  - "Flow behind the casing… yields a feasible range of 2,000-47,000 stbpd." (p. 8).

MAY 21:

- Exhibit 8544: Email from Richard Vargo to Erick Cunningham, et al., "Current Cementing program – Ver 5."
  - "Halliburton Intervention Case 7 Plan"
  - "The new change to the simulation" includes "flow rates are 30,000 bopd and 50 MMscf/day." (HAL_0507894).
- Exhibit 7247: Email from Morten Emilson to Kent Corser, "[D]ynamic kill slide pack."
  - Attached is "DynamiceModeling.ppt." and "add_wellflorw_Deepwater_Horizon.doc."
  - "Blowout potential 70 000 stb/d."

MAY 24:

- Exhibit 1651: Response to Chairman Markey's Correspondence, Dated May 14, 2010 to Mr. Lamar McKay, President and CEO of BP America, Inc."
  - BP's Response is sent to the Committee on Energy and Commerce with an estimate of 5,000 bpd with a range from 1,000 to 15,000 bopd.

MAY 25:

- Exhibit 9336: Email from Douglas Wood to Trevor Hill, et al., "Thoughts – Diagnostics Pressure Data vs. Flow Route and Rate."
  - Attaches PROSPER modeling for flow scenarios at ranges up to 24,000 BOPD.

MAY 27:

- Exhibit 9160: Text message from Kurt Mix to Jonathan Sprague.
  - "Too much flow rate – over 15000 and too large an orifice."
- Exhibit 9489: Email from Adam Ballard to Philip Maule and Derek Watson, et al., "RE: CDP Basis of Design (BOD) issued for use."
  - Ballard writes: "In terms of the questions below" (second bullet): "Also, note that we do not even know the rate of the well… been told from our SETA it could be anywhere from 5,000 - 60,000 stb/d… with most likely estimates at 20,000 stb/d."

MAY 28:

- Exhibit 9164: Email from Mark Mazella to Paul Tooms, et al., "RE: BJ and Halli Data."
  - This email responds to Paul Tooms' email that no one is to receive top kill data "outside the circle of trust".
- Exhibit 11165: Email from Tony Liao to Mike Mason, copying Oktay Gokdemir, "Updated Plot for Well Performance with BOP Pressure 3500 Case…".
  - Attaches "Situation Performance Curves V4 - TL Revision.xls."
  - Liao writes, "For the case we ran today for the well without the 3 1/5" drill pipe, the BOP pressure would be around 2600psi to 2900 psi for thee rate around 15,000 B/D. This should dismiss the assumption that the 3 1/2" drill pipe dropped."

MAY 31:

- Exhibit 7270: Add Energy Report, "Dynamic Simulations Deepwater Horizon Incident BP."
  - "A detailed dynamic Olga-Well-Kill network model has been build, used and found as a valuable tool to analyze and understand transients occurring in the wellbore right before the explosion." (p. v).

- “The worst case blowout rate to surface is calculated to be 68,000 stb/d assuming flow through the casing shoe and 47,000 stb/d assuming flow through the outer annulus.” (p. v).

Appendix B

Curriculum Vitae for John L. Wilson

Curriculum Vitae

JOHN L. WILSON

Consulting Engineer
12009 Caribou NE
Albuquerque, NM 87111

and

Professor of Hydrology
Department of Earth & Environmental Science,
New Mexico Institute of Mining and Technology, Socorro, NM 87801

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RESEARCH INTERESTS:

Environmental fluid flow and transport, using field & laboratory experiments and mathematical models, to examine the movement of fluids, chemicals, colloids, and bacteria through hydro geologic systems. Current research work is directed toward flow and solute transport, aquifer heterogeneity, stream-aquifer interaction, hyporheic science, cave science, and mountain-block hydrology, including characterization and estimation methods for properties, states and fluxes.

EDUCATION:

Ph.D., 1974, Hydrodynamics, Massachusetts Institute of Technology, Cambridge, MA.
Dissertation: Dispersive Mixing in a Partially Saturated Porous Medium

C.E. and S.M., 1970, Civil Engineering, Massachusetts Institute of Technology

B.C.E., 1968, Civil Engineering, Georgia Institute of Technology, Atlanta, GA

EXPERIENCE:

1984 - present	Professor of Hydrology and Senior Research Hydrologist, New Mexico Institute of Mining and Technology, Socorro, NM
1997 – 2003	Chair, 1999-2002, Vice Chair, 1997-99, 2002-03, Department of Earth & Environmental Science, New Mexico Institute of Mining and Technology, Socorro, NM
1997	Visiting Scientist, Commonwealth Scientific and Industrial Research Organization (CSIRO), Land & Water, Perth, Australia
1984 - 1996	Director of Hydrology Program, New Mexico Institute of Mining and Technology, Socorro, NM

1990	Visiting Professor, Waterloo Centre for Groundwater Research, University of Waterloo, Waterloo, Ontario, Canada
1982 - 1984	Senior Staff Contractor and Head of Sensitivity and Uncertainty Analysis, INTERA Technologies, Inc., Houston, TX
1973 - 1982	Assistant & Associate Professor of Civil Engineering, Massachusetts Institute of Technology, Cambridge, MA

SELECTED COMMITTEES, SERVICE, ETC.

1984 - 1997	Associate Editor of the Journal *Hazardous Waste*
1984 - 1992	Member (Chairman, 1986-90), Groundwater Hydrology Committee, American Geophysical Union
1985 - 1989	Associate Editor of the Journal *Transport in Porous Media*
1989 – 2000	Vice Chairman, Science Advisory Committee, EPA Western Region Hazardous Waste Research Center, Stanford University
1989 – 1999	Member, Program Development and Review Board, New Mexico Water Resources Research Institute, Las Cruces
1989 - 1990	Vice Chairman, 1990 Gordon Conference on *Fluid Flow in Permeable Media*
1991 – 2006	Member, External Advisory Board, NIEHS Superfund Basic Research Program, University of North Carolina, Chapel Hill
1992 - 1995	Associate Editor of the Journal *Ground Water*
1996 – 1998	Member, Horton Award Committee, American Geophysical Union
1996 – 1999	Member, Fellows Committee, Hydrology Section, American Geophysical Union
1998 – 2001	Member, Earth Sciences Review Panel, National Science Foundation
1998 – 1999	Member, Earth Science Council on Terrestrial Sequestration of CO2, Department of Energy
2000 – 2003	Member, Executive Committee, and Chair, Modeling Technical Committee, National Vadose Zone Roadmap, Department of Energy
2000 – 2004	Member, Union Fellows Committee, American Geophysical Union
2000 – 2004	Member, Committee on Hydrologic Sciences, National Research Council-National Academy of Science

2000 – 2004	Associate Editor of the Journal *Advances in Water Resources*
2001 – 2005	Board of Directors (Chair 2001-2004; Vice Chair, 2001) and NMIMT Representative (continuing to present), Consortium of Universities for the Advancement of Hydrologic Science Incorporated (CUAHSI)
2002	Member, Committee on Review of a Plan for a New Science Initiative on the Global Water Balance, National Research Council- National Academy of Science.
2003- 2005	Member, Advisory Committee for Geosciences (AC/GEO), National Science Foundation.
2003- 2005	Member and AC/GEO Liaison, Advisory Committee for Environmental Research and Education (AC/ERE), National Science Foundation.
2004	Member, SECURE Earth Initiative Panel, Board of Earth Resources/Board of Radioactive Waste Management, National Research Council- National Academy of Science.
2004 – 2008	Member, Honors and Recognitions Committee, American Geophysical Union
2005	Member, Review Team for the Interdisciplinary Program in Hydrologic Sciences, Office of the Provost, University of Nevada, Reno, Nevada.
2005	Chair, Earth Sciences Division Peer Review Panel, Lawrence Berkeley National Laboratory, Office of the Director, Berkeley, California.
2005 – 2008	Member, External Advisory Committee, Institute for Multidisciplinary Earth Studies, National Center for Atmospheric Research, Boulder, Colorado.
2005 – 2008	Member, External Advisory Committee, Earth & Sun Systems Laboratory, National Center for Atmospheric Research, Boulder, Colorado.
2005 – 2007	Chair, Science Planning Committee, CUAHSI
2005 – 2007	Member, WATERS Design Team, WATERS Joint CLEANER-CUAHSI Observatory Network
2006 – 2008	Chair, O.E. Meinzer Award Committee, Hydrogeology Division, Geological Society of America
2006 – 2008	President Elect, Hydrology Section, American Geophysical Union
2006 – 2010	Member, American Geophysical Union Council (Corporate Board of Directors)

2006 – 2008	Chair, AGU Hydrology Section Fellows Committee
2007	Department of Energy, Basic Research Needs for Geosciences Panel
2008 – 2010	President, Hydrology Section, American Geophysical Union
2010 – 2012	Past-President, Hydrology Section, American Geophysical Union
2008 – 2013	Member, Executive Committee, New Mexico EPSCoR

SELECTED HONORS:

1992	Darcy Lecturer, National Ground-Water Association and the Association of Ground-Water Scientists and Engineers
1992	Freeman Lecturer, Boston Society of Civil Engineers and Mass. Inst. of Technology
1993	Fred Holmsley Moore Distinguished Lecturer, University of Virginia
1994	Elected Fellow of the American Geophysical Union
1996	Elected Fellow of the Geological Society of America
1996	O.E. Meinzer Award, Geological Society of America
1998	Distinguished Research Award, New Mexico Institute of Mining & Technology
2006	Hydrologic Sciences Award, American Geophysical Union

SELECTED PUBLICATIONS of the last twelve years:
(out of over 120 publications)

Frisbee, M.D., J.L. Wilson and D.W. Sada, Climate Change and the Fate of Desert Springs, EOS, Transactions American Geophysical Union, 94(15), 144, 2013.

Gomez, J.D. and J.L. Wilson, Residence Time Distributions and Dynamically Changing Hydrologic Systems: Exploring Topographically-Driven Regional Groundwater Fow, Water Resources Research, 49, doi:10.1002/wrcr.20127, 2013.

Hendrickx, J.M.J, R.G. Allen, A. Brower, A.R. Byrd, S.H. Hong, F.L. Ogden, N.R. Pradhan, R.W. Stodt, T.G. Umstot and J.L. Wilson, Benchmarking Optical/Thermal Satellite Imagery for Retrieval of Evapotranspiration and Soil Moisture in Decision Support Tools, J. Amer. Water Resources Assoc., accepted, 2012.

Wilson, J.L. and K.K. Henry, Computational Fluid Dynamics Modeling of Karst Conduit-Matrix Exchanges with Relevance to Contaminant Transport and Chemical Reactions, Technical

Completion Report, Acct. No. 118598, New Mexico Water Resources Research Inst., Las Cruces, N.M., Dec. 2012.

Gomez, J. D., J. L. Wilson, and M. B. Cardenas, Residence Time Distributions in Sinuosity-Driven Hyporheic Zones and their Biogeochemical Effects, Water Resources Research, 48, 9, doi:10.1029/2012WR012180, 2012.

Frisbee, M. D., F. M. Phillips, G. S. Weissmann, P. D. Brooks, J. L. Wilson, A. R. Campbell, and F. Liu, Unraveling the Mysteries of the Large Watershed Black Box: Implications for the Streamflow Response to Climate and Landscape Perturbations, Geophys. Res. Lett., 39, L01404, doi:10.1029/2011GL050416, 2012.

Guan, H., J. Simunek, B.D. Newman, and J. L. Wilson, Modeling Investigation of Water Partitioning at a Semiarid Ponderosa Pine Hillslope, Hydrological Processes, 24(9), 1095-1105, 2010.

Neupauer, R. M., J. L. Wilson, and A. Bhaskar, Forward and Backward Temporal Probability Distributions of Sorbing Solutes in Groundwater, Water Resources Research, 45, W01420, doi:10.1029/2008WR007058, 2009

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Guan, H., and J. Wilson. A Hybrid Dual-Source Model for Potential Evaporation and Transpiration Partitioning, J. of Hydrology, 377 (3-4), 405-416, doi:10.1016/j.jhydrol.2009.08.037, 2009.

Cardenas, M. B., J. L. Wilson, and R. Haggerty, Residence Time of Bedform-Driven Hyporheic Exchange, Advances in Water Resources, 31(10), 1382-1386, 2008.

Guan, H., H-H Hsu, O. Makhnin, H. Xie, and J.L. Wilson, Examination of Selected Atmospheric and Orographic Effects on Monthly Precipitation of Taiwan Using the ASOADeK Model, Int'l J. Climatology, doi: 10.1002/joc.1762, 2008.

CUAHSI Scientific Advisory Team (J.L. Wilson, Chair), Hydrology of a Dynamic Earth, A Decadal Research Plan for Hydrologic Science, Consortium of Universities for the Advancement of Hydrologic Science, Washington, DC, 45pp., 2007.

Cardenas, M.B. and J.L. Wilson, The Thermal Regime of Dune-Covered Sediments Under Gaining and Losing Water Bodies, J. of Geophysical Research- Biogeosciences, 112, G04013, doi:10.1029/2007JG000485, 2007.

Cardenas, M.B. and J.L. Wilson, Exchange Across a Sediment-Water Interface with Ambient Groundwater Discharge, J. Hydrology, 346, 69-80, doi:10.1016/j.jhydrol.2007.08.019, 2007.

Cardenas, M.B. and J.L. Wilson, Driving while under the influence: Pumping-driven circulation under the influence of regional groundwater flow, in A New Focus on Groundwater-Seawater

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Murray, C. J., A. L. Ward, and J. L. Wilson, Influence of Clastic Dikes on Vertical Migration of Contaminants at the Hanford Site, Vadose Zone J., 6: 959-970, doi:10.2136/vzj2007.0004, 2007

Cardenas, M.B. and J.L. Wilson, The Effects of Current–Bed Form Induced Fluid Flow on the Thermal Regime of Sediments, Water Resources Research, 43, W08431, doi:10.1029/2006WR005343, 2007.

Cardenas, M.B. and J.L. Wilson, Dunes, Turbulent Eddies, and Interfacial Exchange with Permeable Sediments, Water Resources Research, 43, W08412, doi:10.1029/2006WR005787, 2007.

Cardenas, M.B. and J.L. Wilson, Hydrodynamics of Coupled Flow Above and Below a Sediment-Water Interface with Triangular Bedforms, Advances in Water Resources, 30, 301-313, doi:10.1016/j.advwatres.2006.06.009, 2007.

Cardenas, M.B. and J.L. Wilson, The Influence of Ambient Groundwater Discharge on Hyporheic Zones Induced by Current-Bedform Interactions, J. of Hydrology, 331, 103-109, doi:10.1016/j.jhydrol.2006.05.012, 2006.

Cardenas, M. B, and J.L. Wilson, Comment on Flow Resistance and Bed Form Geometry in a Wide Alluvial Channel by Shu-Qing Yang, Soon-Keat Tan, and Siow-Yong Lim, Water Resources Research, Vol. 42, W06601, doi:10.1029/2005WR004663, 2006.

Guan, H., J.L. Wilson and O. Makhnin, Geostatistical Mapping of Mountain Precipitation Incorporating Auto-searched Effects of Terrain and Climatic Characteristics, J. of Hydrometerology, Vol. 6, No. 6, p. 1018-1031, 2005.

Guan, H, E.R. Vivoni and J.L. Wilson, Effects of Atmospheric Teleconnections on Seasonal Precipitation in Mountainous Regions of the Southwestern U.S. : A case study in northern New Mexico, Geophysical Research Letters, 32, L23701, doi:10.1029/2005GL023759, 2005.

Water: Challenges at the Intersection of Human and Natural Systems, Pacific Northwest National Laboratory, PNWD-3597, Richland, WA, 50 pp., 2005

Advisory Committee for Environmental Research and Education, Complex Environmental Systems: Pathways to the Future, National Science Foundation, Washington, DC., 12pp., 2005

Neupauer R.M. and J.L. Wilson, Backward Probability Model Using Multiple Observations of Contamination to Identify Groundwater Contamination Sources at the Massachusetts Military Reservation, Water Resources Research, Vol. 41, W02015, doi:10.1029/2003WR002974, 2005.

Cardenas, M.B., J.L. Wilson and V. Zlotnik, Impact of Heterogeneity, Bed Forms and Channel Curvature on Subchannel Hyporheic Exchange, Water Resources Research, Vol. 40, No. 8, doi:10.1029/2004WR003008175-189, 2004

Wilson, J.L. and H. Guan, Mountain-Block Hydrology and Mountain-Front Recharge, in Groundwater Recharge in a Desert Environment: The Southwestern United States, edited by F. M. Phillips, J. Hogan, and B. Scanlon, 2004, American Geophysical Union, Washington, DC, 2004.

Neupauer R.M. and J.L. Wilson, Forward and Backward Location Probabilities for Sorbing Solutes in Groundwater, Advances in Water Resources, Vol. 27, No. 7, 689-705, July, 2004.

Neupauer R.M. and J.L. Wilson, Numerical Implementation of a Backward Probabilistic Model of Ground-Water Contamination, Ground Water, Vol. 42, No. 2, 175-189, 2004.

Committee on Hydrologic Science, Groundwater Fluxes Across Interfaces, National Academy Press, Washington, DC, 85 pp., 2004.

Neupauer R.M. and J.L. Wilson, Backward Location and Travel Time Probabilities for a Decaying Contaminant in an Aquifer, Contaminant Hydrology, Vol. 66, p.39-58, doi:10.1016/S0169-7722(03)00024-X, 2003.

Sigda, J. and J.L. Wilson, Are Faults Preferential Flow Paths through Semi-arid and Arid Vadose Zones?, Water Resources Research, Vol. 39, No. 8, 1225, doi:10.1029/2002WR001406, 2003.

Molz, F.J., C.L. Dinwiddie, and J.L. Wilson, What Does an Instrument Measure? A Physical Basis for Calculating Spatial Weighting Functions Applicable to Hydraulic Conductivity and Intrinsic Permeability Measurements, Water Resources Research, Vol. 39, No. 4, 1096, doi:10.1029/2001WR001220, 2003.

Holt, R.M., J.L. Wilson, R. Glass, Error in Unsaturated Stochastic-Models Parameterized with Field Data, Water Resources Research, Vol. 39, No. 2, doi:10.1029/2001WR000544, 2003.

Holt, R.M., J.L. Wilson, R. Glass, Spatial Bias in Field-Estimated Unsaturated Hydraulic Properties, Water Resources Research, Vol. 38, No. 12, 1311, doi:10.1029/2002WR001336, 2002.

Tidwell, V.C., and J.L. Wilson, Textural Attributes of a Rock and Their Relationship to Permeability: A Comparison of Digital Image and Minipermeameter Data, Water Resources Research, Vol. 38, No. 11, 1261, doi:10.1029/2001WR000932, 2002.

Neupauer R.M. and J.L. Wilson, Backward Probabilistic Model of Groundwater Contamination in Non-Uniform and Transient Flow, Advances in Water Resources, Vol. 25, No. 7, p. 733-746, 2002.

Daniel B. Stephens, et al., Letter to the Editor on a National Strategy for Vadose Zone Science and Technology, Vadose Zone J., Vol. 1, No. 1, p. 197-198, 2002.

Committee on Hydrologic Science, Review of USGCRP Plan for a New Science Initiative on the Global Water Balance, National Academy Press, Washington, DC, 32 pp., 2002

Committee on Hydrologic Science, Predictability & Limits-to-Prediction in Hydrologic Systems, National Academy Press, Washington, DC, 118 pp., 2002

Neupauer R.M. and J.L. Wilson, Adjoint Derived Location and Travel Time Probabilities for a Multi-dimensional Groundwater System, Water Resources Research, Vol. 37, No. 6, p. 1657-1668, 2001.

Rawling, G., L.B. Goodwin, and J.L. Wilson, Internal Architecture, Permeability Structure, and Hydrologic Significance of Contrasting Fault Zone Types, Geology, Vol. 29, No. 1, p. 43-46, January, 2001.

Wawersik, W.R., J.W. Rudnicki, P. Dove, J. Harris, J.M. Logan, L. Pyrak-Nolte, F.M. Orr Jr, P.J. Ortoleva, F. Richer, N.R. Warpinski, J.L. Wilson, and T-F. Wong., Terrestrial Sequestration of CO2 – An Assessment of Research Needs, Advances in Geophysics, Vol. 43, p. 97-177, 2000.

Tidwell, V.C. and J.L. Wilson, Heterogeneity, Permeability Patterns, and Permeability Upscaling: Physical Characterization of a Block of Massillon Sandstone Exhibiting Nested Scales of Heterogeneity, SPE Reservoir Evaluation and Engineering, Vol. 3, No. 4, p. 283-291, 2000.

Neupauer, R.M., B. Borchers, and J.L. Wilson, Comparison of Inverse Methods for Reconstructing the Release History of a Groundwater Contamination Source, Water Resources Research, Vol. 36, No. 9, p. 2469-2475, 2000.

Li, C.L. and J.L. Wilson, Heuristic Theory on Diffusive Mixing Behavior at Fracture Junctions, in Remediation in Rock Masses, H.I. Inyang and C.J. Bruell, Editors, Amer. Soc. of Civil Engineers, Reston, Va., 2000.

SELECTED INVITED PRESENTATIONS OF THE LAST TWELVE YEARS:

(out of over 200 invited and contributed talks)

Viability of Rapid in situ Measurement of Hydraulic Properties, Vadose Zone Characterization Meeting, Pacific Northwest National Laboratory, Richland, Washington, January, 2000.

Spatial Bias in Unsaturated Hydraulic Property Estimates: Origin, Impact and Relevance, (with R.M. Holt and R.J. Glass), Environmental Science Management Program Annual Meeting, Department of Energy, Atlanta, Georgia, April, 2000.

Hydrogeological Influence of Clastic Dikes on Vadose Zone Transport at the Hanford Site, Southcentral Washington, (with C. Murray, M. Fayer, D. Horton, P. Long, and W. Clement); Environmental Sedimentology: Hydrogeology of Sedimentary Aquifers, SEPM/IAS Research Conference, Santa Fe, September, 2000.

Relationship between Visual Attributes of Rocks and Their Permeability Structure: A Comparison of Digital Image and Minipermeameter Data , (with V. Tidwell), Environmental Sedimentology: Hydrogeology of Sedimentary Aquifers, SEPM/IAS Research Conference, Santa Fe, September, 2000.

Concepts and Principles for Backward-in-time-and-space Modeling of Location and Travel Time Probabilities (with R M Neupauer), AGU Spring Meeting, Boston, Massachusetts, June, 2001.

Travel Time Probabilities of Groundwater Tracers and Contaminants (with R M Neupauer), AGU Spring Meeting, Boston, Massachusetts, June, 2001.

Aqueous Phase Diffusion Coefficients of Environmental Tracers (with R.S. Bowman and P. Hu), GSA Annual Meeting, Boston, Massachusetts, November, 2001.

Vadose Zone: Past, Present, Future, Eighth Biannual Unsaturated Zone Interest Group Meeting, August, 2001 Idaho Falls, Idaho

Diffusion Coefficients of Hydrologic Tracers Measured by a Taylor Dispersion Technique, (with R.S. Bowman and P. Hu), GSA Annual Meeting, Boston, Massachusetts, November, 2001.

Gas Minipermeameters, GSA Annual Meeting, Boston, Massachusetts, November, 2001.

Building an Understanding of Mountain-Block Recharge (with H. Guan), 2nd Annual Meeting, SAHRA, Tucson, Arizona, February, 2002.

Receptor Based Modeling: Adjoint Methods for Flow and Transport, Gordon Conference on Flow and Transport in Permeable Media, Andover, New Hampshire, August 2002.

Synthetic Sediments and Stochastic Groundwater Hydrology, AGU Fall Meeting, San Francisco, California, December, 2002.

Receptor Based Modeling: Adjoint Methods for Flow and Transport, Distinguished Lecturer, Texas A&M University, College Station, March, 2003.

Receptor Based Modeling: Adjoint Methods for Flow and Transport in Hydrologic, Seminar, Ocean and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, Georgia, April, 2003.

Geostatistical Methods in Probabilistic Groundwater Models: Accomplishments and Failures, Keynote Presentation, Symposium on Probabilistic Approaches & Groundwater Modeling, EWRI 2003 World Water & Environmental Congress, ASCE, Philadelphia, Pennsylvania, June, 2003.

Hydrologic Impacts of Faults in Granular Media, Hydrology Keynote Presentation, Institute of Geophysics and Planetary Physics, Workshop on Fluid Flow and Transport Through Faulted Ignimbrites and other Porous Media, Santa Fe, New Mexico, September, 2003.

Revolutions in Observation Driven Hydrology, Then and Now, Session on Henry Darcy's 200th Birthday, GSA Annual Meeting, Seattle, Washington, November, 2003.

Twenty Years of Prejudice Toward Contaminant Hydrogeology, GSA Annual Meeting, Seattle, Washington, November, 2003.

A Scientific Perspective of Water Issues in the United States, Water, Science and Policy in the 21st Century, Knoxville, Tennessee, October 2004.

Mountain Block Hydrology and Mountain Front Recharge, GSA Annual Meeting, Denver, Colorado, November, 2004.

Barriers and Disincentives to Quality Groundwater Modeling in Practice, GSA Annual Meeting, Denver, Colorado, November, 2004.

Living with a Limited Water Supply, 85th Ann. Mtg. of American Meteorological Society, San Diego, January, 2005.

Water Percolation across the Soil-bedrock Interface in Mountainous Terrain (with H. Guan), GSA Annual Meeting, Salt Lake City, Colorado, November, 2004.

Mountain Front Recharge and the Role of Hillslope Processes above the Mountain Front, AGU Fall Meeting, San Francisco, California, December, 2005

Consortium of Universities for the Advancement of Hydrologic Science Inc. (CUAHSI) Science Plan: A Community-based Infrastructure, AGU Fall Meeting, San Francisco, California, December, 2005.

A Vision For Advancing Hydrologic Research, Int'l Seminar on Catchment Science, University of Sheffield, Sheffield, England, February, 2006.

Mountain Front Recharge: The Role Of Hillslope Processes Above The Mountain Front, Seminar, University of California, Merced, California, April, 2006.

Multiphysics Modeling Of Strongly Coupled Free-Flowing And Porous Fluid Flow, Seminar, Florida State University, Tallahassee, Florida, April, 2006.

Multiphysics Modeling Of Physical, Thermal And Chemical Processes Along Sediment-Water Interfaces: Towards Fundamental Understanding And Mechanistic Predictions (with B. Cardenas), AGU Fall Meeting, San Francisco, CA, December, 2006; Abstract B22C-01, Fall Meet. Suppl., Eos Trans. AGU, 87(52), 2006.

The River-Bed Hyporheic Zone, Symposium on River Terrace and Flood Plain Hydrology, Las Cruces, New Mexico, February, 2007.

Ground Water In An Interdisciplinary World, keynote address, 2007 Ground-Water Summit, National Ground Water Association, Albuquerque, New Mexico, April, 2007.

Can Hydrologic Scientists Learn To Speak Up And With One Voice?, European Geological Union Ann. Mtg, Vienna, Austria, April, 2007.

Driving While Under The Influence: Pumping-Driven Circulation Under The Influence of Regional Groundwater Flow (with Bayani Cardenas), IUGG XXIV General Assembly, Perugia, Italy, July, 2007.

Evolution of Hydrologic Science: the New Mexico Tech Example (with F.M. Phillips, R.S. Bowman, J.M.H. Hendrickx , and E.R. Vivoni), GSA Annual Meeting, Denver, Colorado, October, 2007; Geological Society of America Abstracts with Programs, Vol. 37(7), 240, 2007.

Cave Geophysical Fluid Dynamics, Seminar, Florida State University, Tallahassee, Florida, June, 2008.

Research Needs and Opportunities, Groundwater Depletion and Salinity Workshop, Stanford University, Palo Alto, California, December, 2008.

New Mexico's Observational Network, EPSCoR Tri-State Meeting, Boise, Idaho, March, 2009.

Residence Time Distributions in Dynamically Changing Hydrologic Systems, SAHRA Annual Meeting, Tucson, Arizona, September, 2009.

Groundwater Science in an Evolving Interdisciplinary World, Keynote Presentation, Hydrology in the 21st Century: Links to the past, and a vision for the future, Burges Symposium, University of Washington, Seattle, WA, March, 2010.

Exploring The Dynamics Of Sinuosity-Driven Hyporheic Zones (with J.D. Gomez and M.B. Cardenas), ASLO& NABS 2010 Summer Meeting, American Society of Limnology & Oceanography and North American Bethological Society, Santa Fe, NM, June, 2010.

Age Distributions and Dynamically Changing Hydrologic Systems (with J.D. Gomez), EPSCoR Tri-State Ann. Mtg, San Juan, NM, April, 2011.

Mountain Hydrology and Mountain Groundwater, Mountain-to-Valley Ecohydrology at Multiple Spatial and Temporal Scales, Western Tri-State Consortium IWG, Sun Valley, ID, May, 2012.

Modeling Age Distributions in Transient Groundwater Flow Systems (with J.D. Gomez, 39th IAH Congress, Niagara Falls, CA, September, 2012.

Karst Conduit-Matrix Exchange & the Karst Hyporheic Zone, Carbon & Boundaries in Karst, 2013 Karst Waters Institute (KWI) Conference, Carlsbad, NM, January, 2013.

Future Challenges to Bay-State Groundwater, Bay State Groundwater Forum, National Ground Water Association, Brookline, MA, September, 2013.

APPENDIX C - Consideration Materials List for Expert Report John Wilson

WALTER BOZEMAN DEPOSITION TRANSCRIPT
MATTHEW GOCHNOUR DEPOSITION TRANSCRIPT
MARK SOGGE DEPOSITION TRANSCRIPT
THAD ALLEN DEPOSITION TRANSCRIPT
SIMON BISHOP DEPOSITION TRANSCRIPT
OLE RYGG DEPOSITION TRANSCRIPT
LARS HERBST DEPOSITION TRANSCRIPT
ADAM BALLARD DEPOSITION TRANSCRIPT
ADMIRAL MARY LANDRY DEPOSITION TRANSCRIPT
MARCIA MCNUTT DEPOSITION TRANSCRIPT
TONY HAYWARD DEPOSITION TRANSCRIPT
JAMES DUPREE DEPOSITION TRANSCRIPT
RICHARD LYNCH DEPOSITION TRANSCRIPT
DAVID RAINEY DEPOSITION TRANSCRIPT
DOUGLAS SUTTLES DEPOSITION TRANSCRIPT
RICHARD VARGO DEPOSITION TRANSCRIPT
CHARLES HOLT DEPOSITION TRANSCRIPT
THOMAS HUNTER DEPOSITION TRANSCRIPT
TIMOTHY LOCKETT DEPOSITION TRANSCRIPT
FARAH SAIDI DEPOSITION TRANSCRIPT
TONY LIAO DEPOSITION TRANSCRIPT
TREVOR HILL DEPOSITION TRANSCRIPT
CLIFTON MASON DEPOSITION TRANSCRIPT
STEVEN CHU DEPOSITION TRANSCRIPT
MICHAEL LEVITAN DEPOSITION TRANSCRIPT
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APPENDIX C - Consideration Materials List for Expert Report John Wilson

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CLIP 01 (COUNCIL ON FOREIGN RELATIONS NOV 7 2011).WMV -Ref Ex 9178
CLIP 02 (CHARLIE ROSE AUG 18 2010 PT. 1).WMV -Ref Ex 9178
CLIP 03 (FACE THE NATION AUG 10 2010).WMV -Ref Ex 9178
CLIP 05 (WHITE HOUSE MAY 24 2010 PT. 1).WMV -Ref Ex 9178
CLIP 07 (WHITE HOUSE MAY 24 2010 PT. 3).WMV -Ref Ex 9178
CLIP 08 (CNN WOLF BLITZER MAY 24 2010).WMV -Ref Ex 9178
CLIP 10 (GW UNIVERSITY SEMINAR PLENARY MAY 21 2011).WMV -Ref Ex 9178
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APPENDIX C - Consideration Materials List for Expert Report John Wilson

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APPENDIX C - Consideration Materials List for Expert Report John Wilson

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APPENDIX C - Consideration Materials List for Expert Report John Wilson

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APPENDIX C - Consideration Materials List for Expert Report John Wilson

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APPENDIX C - Consideration Materials List for Expert Report John Wilson

Exhibit 10933
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APPENDIX C - Consideration Materials List for Expert Report John Wilson

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APPENDIX C - Consideration Materials List for Expert Report John Wilson

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APPENDIX C - Consideration Materials List for Expert Report John Wilson

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Exhibit 3372
Exhibit 3533
Exhibit 3624
Exhibit 3904
Exhibit 3907
Exhibit 4405
Exhibit 4423

APPENDIX C - Consideration Materials List for Expert Report John Wilson

Exhibit 4728
Exhibit 4996
Exhibit 5051
Exhibit 5054
Exhibit 5063
Exhibit 5231
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Exhibit 5370
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Exhibit 5533
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Exhibit 5666
Exhibit 5788
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Exhibit 5878

APPENDIX C - Consideration Materials List for Expert Report John Wilson

Exhibit 5878
Exhibit 6124
Exhibit 6194
Exhibit 6195
Exhibit 6196
Exhibit 6198
Exhibit 6203
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Exhibit 6212
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Exhibit 7104
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APPENDIX C - Consideration Materials List for Expert Report John Wilson

Exhibit 8636
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APPENDIX C - Consideration Materials List for Expert Report John Wilson

Exhibit 8686
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APPENDIX C - Consideration Materials List for Expert Report John Wilson

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APPENDIX C - Consideration Materials List for Expert Report John Wilson

Exhibit 8889
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APPENDIX C - Consideration Materials List for Expert Report John Wilson

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APPENDIX C - Consideration Materials List for Expert Report John Wilson

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APPENDIX C - Consideration Materials List for Expert Report John Wilson

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APPENDIX C - Consideration Materials List for Expert Report John Wilson

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APPENDIX C - Consideration Materials List for Expert Report John Wilson

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APPENDIX C - Consideration Materials List for Expert Report John Wilson

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APPENDIX C - Consideration Materials List for Expert Report John Wilson

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APPENDIX C - Consideration Materials List for Expert Report John Wilson

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Exhibit 9708A

APPENDIX C - Consideration Materials List for Expert Report John Wilson

Exhibit 9710
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Exhibit 9927
Exhibit 9928
Exhibit 9929
Exhibit 9935
GREG PERKIN PHASE II REPORT FOR PLAINTIFFS STEERING COMMITTEE
TREX 20043
HCG169-000284
NOA021-000123
HCG455-003430
LAL137-016402
S20006-000343

APPENDIX C - Consideration Materials List for Expert Report John Wilson

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