BP Deepwater Horizon Oil Disaster

The Flow Rate Technical Group

Status update - June 10, 2010

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News Release

Admiral Allen; Dr. McNutt Provide Updates on Progress of Scientific Teams Analyzing Flow Rates from BP's Well

WASHINGTON -- Under the direction of National Incident Commander Admiral Thad Allen, the Flow Rate Technical Group (FRTG), which is led by United States Geological Survey Director Dr. Marcia McNutt, and a scientific team led by Energy Secretary Steven Chu are analyzing new data and bringing together several scientific methodologies to develop an updated estimate of how much oil is flowing from BP's leaking oil well in the Gulf of Mexico. The updated estimate, which will bring together the ongoing work of scientists and engineers from the federal government, universities, and research institutions, will be of how much oil has been flowing since the riser was cut on June 3.

"Developing accurate and scientifically grounded oil flow rate information is vital, both in regards to the continued response and recovery, as well as the important role this information may play in the final investigation of the failure of the blowout preventer and the resulting spill," said Admiral Allen, the National Incident Commander. "Top government and independent scientists are working non-stop to analyze all the information available and refine assessments being developed through numerous methodologies. I have directed Dr. McNutt and Secretary Chu to analyze the latest data and assess the various methodologies that are being used and bring them together into an updated best estimate of how much oil is now flowing from BP's well. They will have that updated best estimate in the coming days."

Dr. McNutt announced today that three of the scientific teams analyzing flow rates have reached updated assessments, based on new data or analysis, of flow rates from BP's well before the riser was cut on June 3. The Department of the Interior and the Department of Energy have also directed BP to provide precise differential pressure measurements inside and outside the top hat to allow federal scientists to develop another independent estimate of how much oil is flowing from BP's well.

"Each of the methodologies that the scientific teams is using has its advantages and shortcomings, which is why it is so important that we take several scientific approaches to solving this problem, that the teams continue working to refine their analyses and assessments, and that those many data points inform the updated best estimate that we are developing, " said Dr. McNutt.
Below is a summary of the independent scientific methodologies that are being used to develop

assessments of flow rates.

1. Analysis of Pressure Readings (DOE scientists led by Secretary Chu)
A team of federal scientists led by Energy Secretary Steven Chu is analyzing pressure readings from the BOP stack and the riser to assess flow rates and how flow rates may have changed as a result of the riser being cut. The Department of the Interior and the Department of Energy have directed BP to provide precise differential pressure measurements inside and outside the top hat to allow federal scientists to develop another independent estimate of how much oil is flowing from BP's well.

2. Flow Rate Technical Group
The Flow Rate Technical Group (FRTG), which was convened by Admiral Allen and which is led by USGS Director Dr. Marcia McNutt, is comprised of several Sub-Teams that are pursuing independent approaches to estimating the oil flow rate from the damaged well. The FRTG will soon have an assessment of how much oil has been flowing from BP's well since the riser was cut on June 3.

· **The Plume Modeling Team of the FRTG** is pursuing the approach of observing video of the oil/gas mixture escaping from the damaged well, using particle image velocimetry analysis to estimate fluid velocity and flow volume. On May 27, the Plume Modeling Team, which analyzed video obtained from BP, provided an initial lower bound estimate of 12,000 to 25,000 barrels of oil per day, but at that point were continuing their work to provide an upper bound estimate.Based on additional video that BP was directed to provide, members of the Plume Modeling Team have now calculated updated lower and upper bound range estimates for a period of time before the Riser Insertion Tube Tool was inserted and before the riser was cut. Most of the experts have concluded that, given the limited data available and the small amount of time to process that data, the best estimate for the average flow rate for the leakage prior to the insertion of the RITT is between 25,000 to 30,000 barrels per day, but could be as low as 20,000 barrels per day or as high as 40,000 barrels per day.

· **The Mass Balance Team of the FRTG** is using remote sensing data from deployment of the Airborne Visible InfraRed Imaging Spectrometer (AVIRIS) and satellite imagery to calculate the amount of oil on the ocean surface on a certain day. The team is correcting the value for oil evaporated, skimmed, burned, and dispersed up to that day and divided by time to produce an average rate. Based on observations on May 17th, and given the amount of oil observed and the adjusted calculations for the amount of oil that has been burned, skimmed, dispersed, or evaporated the initial estimate from the Mass Balance Team that was announced on May 27 was in the range of 12,000 to 19,000 barrels of oil per day. The team continued to refine its estimate and has concluded that the best estimate for the average flow rate was in the range of 12,600 to 21,500 barrels of oil per day.

· **The Reservoir Modeling Team of the FRTG** will describe the geologic formations as well as composition and pressures of the oil, natural gas, and other compounds that are being released. Using open-hole logs; pressure, volume, and temperature data; core samples; and analog well or reservoir data; the team will populate computer models and determine flow rate from targeted sands in the well as a function of bottomhole pressure. The reservoir modeling

team is continuing to work on independent estimates that will be completed later this month

The Nodal Analysis Team of the FRTG will use input from reservoir modeling (including pressure, temperature, fluid composition and properties over time) and pressure and temperature conditions at the leak points on the sea floor, along with details of the geometries of the well, BOP, and riser to calculate fluid compositions, properties, and fluxes from both before and after riser removal. The nodal analysis team is continuing to work on independent estimates that will be completed later this month

3. Woods Hole Analysis

In coordination with the Unified Command, a team of experts lead by Woods Hole Oceanographic Institution (WHOI) and assisted by researchers from Johns Hopkins University, University of Georgia and Massachusetts Institute of Technology used acoustic technologies to measure flow rates after the top-kill attempt ended and before the riser was cut. Using an ROV, flow estimates have been derived from three different view angles above the riser pipe and three different view angles above the BOP. Woods Hole Oceanographic's initial total flow rate estimate of 0.12m3/s to 0.23m3/s from before the riser was cut is a preliminary bulk flow estimate. This outflow may contain gases, liquids, and solids including natural gas, condensates, oil, sediments, and produced water.

For information about the response effort, visit www.deepwaterhorizonresponse.com.

STATEMENT OF THE PLUME TEAM OF THE FLOW RATE TECHNICAL GROUP

WRITTEN BY TEAM LEAD: Bill Lehr, National Oceanic and Atmospheric Administration

On May 19, the NIC Interagency Solutions Group established the Flow Rate Technical Group, including the Plume Team. This team contains experts on fluid dynamics, subsurface well blowouts, petroleum engineering and oil spill behavior as part of the larger effort to improve spill size estimation. The team consists of both government scientists and leading scholars at academic institutions throughout the United States.

On May 27, the Team issued an Interim Report that established an estimated range for the minimum possible spillage rate but did not issue an estimate for a possible maximum value because the quality and length of the video data could not support a reliable calculation. Instead, they requested, and received, more extensive videos from British Petroleum (BP). Based upon analysis of these new videos, the group has reached the following conclusions, recognizing that these estimates are only to aid the Response, not to determine the final Federal calculation of spillage. Other applications of these results are not authorized and are not considered valid.

Because of time and other constraints, only a small segment of the leakage time was examined, and assumptions were made that may through later information or analysis be shown to be invalid. For example, the Team assumes that the average flow between the start of the incident and the insertion of the RITT was relatively constant and the time frames that were included in the examined videos were representative of that average. If this were not true, then the actual spillage may differ significantly from the values stated below.

Most of the experts have concluded that, given the limited data available and the small amount of time to process that data, the best estimate for the average flow rate for the leakage prior to the insertion of the RITT is between 25 to 30 thousand bbl/day. However, it is possible that the spillage could have been as little as 20,000 bbl/day or as large 40,000 bbl/day. Further analysis of the existing data and of other videos not yet viewed may allow a refinement of these numbers.

The team has not estimated the flow rate during the period of active measures to reduce leakage such as the period after the insertion of the RITT or during and immediately after Top Kill. The team is still examining the video of flow shortly after severing of the riser and will produce an addendum, if appropriate, with an updated leakage estimate.

Each expert that contributed to this estimate reserves the right to alter his conclusions based upon further analysis or additional information

Pooling Expert Assessments

Antonio Possolo Pedro Espina

June 8th, 2010

1 Summary

In the course of the Plume Team telecon of Monday, June 7th, six experts produced estimates of the average number of barrels of oil leaked per day from all sources of leaks that had been evaluated. Applying a statistical procedure to reconcile assessments made by multiple experts produces an interval that, with 95 % confidence, should include the true value of that average: this interval ranges from 15 to 40 thousand barrels of oil per day.

2 Assessments

The following table summarizes the intervals (in thousands of barrels of oil per day) that six experts provided during the telecon, that each expert believes should include the true value that is sought (please let us know if any of the names or numbers are incorrect, or whether additional names and numbers ought to be included — we can rerun the analysis very quickly, if need be):

	LOW	HIGH
Alberto	20	30
Ira	20	34
Jim	20	30
Juan	20	30
Omer	25	40
Steve	15	34

3 Approach

We use probability distributions to model the uncertainty implied in each expert's assessment, and then apply a statistical method to reconcile these distributions that is due to Lindley [1983]. The result is a probability distribution that represents the group's collective state of knowledge about the spill.

Obviously, not all views held by team members are yet represented. In particular, and for the reasons that Pooji articulated in his eMail from yesterday at 9:40pm, we have not used his early assessment.

There also is an issue unresolved that Frank has brought up cogently: is the team estimating true average volume of oil spilled, or maximum volume? Listening to the discussion yesterday, it seems to us that all the experts but Frank are doing the former — that's why the preliminary results that Frank sent last evening are not included in the table above, or otherwise in this analysis.

4 Details

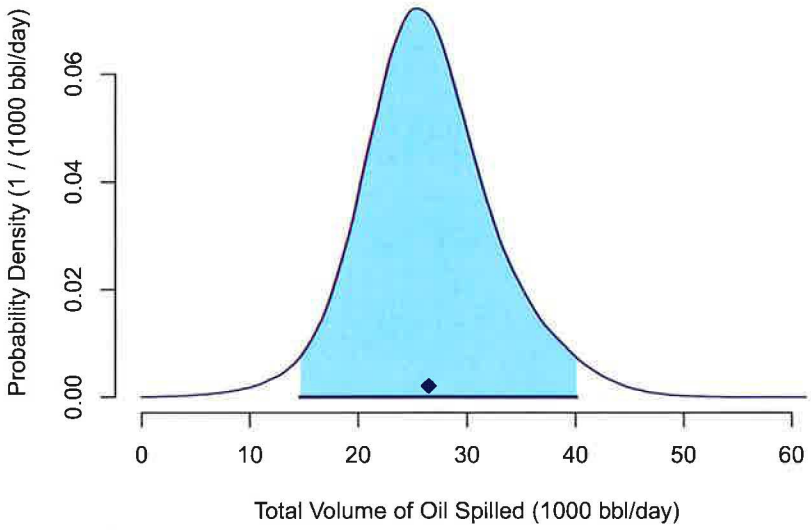
No one expressed quantitatively his level of confidence in the interval provided. Judging from the reaction our question prompted, when we asked if these might be more like 2σ confidence intervals or like 1σ intervals, or otherwise whether the experts were very confident in their results, it seems to us that we may fairly represent the sentiment of the majority by saying that these may represent assessments that the experts themselves consider *likely* to *very likely*.

According to the *Guidance Notes for Lead Authors of the IPCC Fourth Assessment Report on Addressing Uncertainties* that have been used by the Intergovernmental Panel on Climate Change in the preparation of their fourth assessment report [Solomon et al., 2007], *likely* is taken to mean confidence of at least 66 %, and *very likely* is taken to mean confidence of at least 90 %. We will use the geometric mean of these two values, and proceed on the tentative assumption that the intervals provided by the experts are like confidence intervals that cover their target with confidence level 77 %.

Further assuming that the confidence intervals purport to Gaussian situations, and using the confidence level just mentioned, we derived the means and standard deviations of the corresponding distributions: for example, for Juan's,

the implied mean is 25 000 bbl/day and the implied standard deviation is 4 159 bbl/day.

We produced a sample of size 500 000 by repeating the following steps this many times: select one expert uniformly at random; draw one value from the selected expert's distribution. The following figure is a smooth histogram of the results. The corresponding mean (dark blue diamond) is 26 500 bbl/day, and the standard deviation is 6 250 bbl/day. The shaded area comprises 95 % of the area under the curve: its projection onto the horizontal axis (thick, blue, horizontal line segment) is a 95 % confidence interval for the average total volume of oil spilled per day: it ranges from 15 000 bbl/day to 40 000 bbl/day.



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Preliminary Report from the WHOI Flow Rate Measurement Group
Prepared by Team Leader Richard Camilli, Woods Hole Oceanographic Institution
June 10, 2010

At the direction of the NIC's Flow Rate Technical Group and the U.S. Coast Guard Headquarters, the USCG Research and Development Center contracted the Woods Hole Oceanographic Institution (WHOI) to initiate on-site data collection and analysis of the DEEPWATER HORIZON oil spill. As a part of this effort a team of experts led by WHOI and assisted by experts from the Johns Hopkins University, the University of Georgia and the Massachusetts Institute of Technology used acoustic technologies to conduct a direct analysis of flow rates.

This analysis is based on measurements collected after the top-kill attempt had ended and before the riser was cut, during Maxx3 ROV Dive #35 on May 31, 2010. The ROV was operated by Oceaneering International and supplied to the team by BP. These measurements were recorded at two distinct sites, above the riser pipe and at the kink above the BOP. Flow estimates are derived from three different view angles above the riser pipe and three view angles above the BOP. These estimates are preliminary. This estimate is likely to undergo revision based upon further analysis of the remaining data.

Estimates are based on the following:

1. Velocity profiles from the acoustic Doppler current profiler (ADCP). This device provides a measurement of the fluid velocity for a series of bins along each of four beams. The preliminary velocity estimates represent an average for each bin. The averaged beam velocity is transformed into a vertical velocity assuming zero horizontal flow. The average flow velocity was calculated assuming an axisymmetric Gaussian distribution.
2. Plume cross sectional estimates from the 1.8MHz multibeam sonar. 300 cross-sectional estimates were averaged for each site to obtain composite horizontal cross sectional areas.
3. The flow velocity and area estimates were then multiplied to produce an ensemble estimate of the volumetric flow rate. This is a preliminary bulk flow estimate. The flow may contain gases, fluids, and solids including but not limited to natural gas condensate, oil, sediments, and brine.

Data quality

1. The signal quality of the ADCP measurements indicates that the Doppler velocity estimates are accurate. Likewise averaging the bins with respect to time and spatial transformations provides a representative figure for ensemble plume flow velocity.
2. The maximum jet velocity is measured by the 60 deg upward pointing ADCP beam and is therefore not co-planar with the imaging multibeam sonar cross-sectional data. Therefore, unless a turbulent jet model is invoked, the volumetric flow rate calculation will represent a lower bound. By approximating the flow as an axisymmetric turbulent jet, a rate at the height corresponding to the cross-sectional area estimated from the multibeam sonar can be determined; this represents the higher bound estimate.
3. A comprehensive understanding of the source composition (e.g., percentage gas, oil, sediment, brine) is needed to accurately estimate the petroleum leak rate and mass balance.
4. Source composition can be determined through the collection and analysis of end-member samples at the leak origin using gas-tight samplers.
5. Only a small subset of the data collected from field operations has been analyzed to produce this preliminary estimate.

Estimated flow rates:

Riser:	**0.076m^3/s to 0.15m^3/s**
BOP kink:	**0.040m^3/s to 0.079m^3/s**
Total flow rate:	**0.12m^3/s to 0.23m^3/s**

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National Incident Command's Flow Rate Technical Group
Sub-Team Outline

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FRTG Coordination:

Marcia McNutt, Director, US Geological Survey (Lead)

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Modeling Team Leads:

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George Guthrie, Nodal Analysis Team

Bill Lehr, Plume Analysis Team

Victor Labson, Mass Balance Team

Plume Modeling Team membership:

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The Mass Balance Team membership:

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Michael H. Powers, Research Geophysicist

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Reservoir Modeling Team membership includes:

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Other MMS engineers

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