



Eugene Chiang &lt;chiang.eugene@gmail.com&gt;

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## order-of-magnitude estimate of Deep Horizon flow rate

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Eugene Chiang &lt;echiang@astro.berkeley.edu&gt;

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To: hsreenivasan@newshour.org

Cc: scyang@berkeley.edu, roxannem@berkeley.edu

Dear PBS NewsHour,

I was informed that you were interested in an order-of-magnitude estimate of the flow rate based on the Youtube video. My bottom-line answer is about 100,000 barrels per day coming out of this one pipe alone. I reasoned as follows.

If we knew the scale of the video footage (i.e., if we knew the cross-sectional radius of the pipe  $r$ ), the estimate would be relatively straightforward. The volume flow rate is simply  $F = A \cdot v$  where  $A = \pi r^2$  is the cross-sectional area of the pipe and  $v$  is the velocity of the oil. By viewing the video frame-by-frame and examining the video's timer, I would estimate that  $v$  is at least one pipe diameter every second. I'll multiply by two because what we see is actually oil that has been slowed by mixing with water, so my rough estimate of  $v$  is  $4r$  per second. Then  $F = \pi 4^3 r^3$  per second. Surely the company BP would know the radius of their own pipe, but I don't have access to that information, and I don't see any indication of a scale bar in the video.

So I will improvise as follows. I note that the oil is making approximately a 45 degree angle relative the horizontal. That means it's rising upward about as fast as it is traveling horizontally. It's rising upward because oil is less dense than water, by roughly 10%. So the upward acceleration of the oil is about 10% that of the Earth's surface gravity  $g$ . Over an elapsed time  $\Delta t$ , the upward velocity grows to about  $0.1 \cdot g \cdot \Delta t$ . From the video I'd estimate the time elapsed in traveling the 45-degree path is roughly  $\Delta t \sim 1$  second. So the upward velocity is about 100 cm/s, which means the horizontal velocity  $v$  is about this rate. Setting this equal to my rough estimate above of  $v \sim 4r$  per second, I find that  $r \sim 25$  cm. Then  $F \sim \pi 4^3 (25 \text{ cm})^3$  per second  $\sim 200,000$  cubic centimeters per second, which converts into English units of 50 gallons per second. Measured per day, that's about 5 million gallons. There are 42 gallons in a barrel, so my final estimate is about 100,000 barrels per day coming out of this one pipe alone.

This is 3–4 times larger than total estimated rates cited by the press during the past week.

There may be better ways of solving this problem and getting more accurate answers, but this is the best I could do after watching several hours of LOST.

Eugene Chiang

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Departments of Astronomy / Earth and Planetary Science  
University of California at Berkeley  
511 Campbell Hall (510) 642 2131 fax: (510) 642 3411

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<http://astro.berkeley.edu/~echiang>