CHALLENGES ASSOCIATED WITH ASSESSING THE IMPACTS OF BUREAU OF LAND MANAGEMENT'S PROPOSED HYDRAULIC FRACTURING RULE

43 CFR PART 3160, OIL AND GAS; HYDRAULIC FRACTURING ON FEDERAL AND INDIAN LAND, RIN 1004-AE26

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For the

American Petroleum Institute

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EXECUTIVE SUMMARY

The Bureau of Land Management (BLM) has recently released a revised draft proposed rule on hydraulic fracturing of oil and gas wells on Federal and Indian lands.

In terms of the potential cost impact of this proposal, the greatest concerns relate to requirements for operators to:

- Isolate "usable water" aquifers with total dissolved solids (TDS) up to 10,000 parts per million (ppm).
- Submit a cement evaluation log (CEL) on surface and intermediate casing to ensure that "usable water" has been properly isolated.
- Perform a successful mechanical integrity test (MIT) before fracturing is allowed.
- Continuously monitor and record pressure during stimulation.

Economic impact assessments performed to date show a wide range of estimated cost impacts associated with the BLM proposal, which largely result from the considerable uncertainty about the "usable water" definition of protected aquifers, the costs to implement the requirement for CELs for surface and intermediate casing, and whether current industry guidelines and state requirements to demonstrate casing/cement integrity would be sufficient to meet BLM's proposed requirement for a MIT.

This paper characterizes the analytical challenges associated with estimating cost impacts of the proposed BLM rule. We examine four key challenges and characterize the factors that may influence the number of impacted wells and the incremental costs and delays borne by impacted wells. These are:

- Compared to the traditional underground source of drinking water (USDW) definition for protected aquifers, the BLM definition of "usable water" aquifers could require the isolation of numerous water-bearing zones over a substantial vertical thickness - causing significant cost and delay.

- Cement evaluation logs, though required by the draft proposed rule, are not commonly run on surface and intermediate casing unless other indicators of an unsuccessful cement job are present. CELs are interpretive, diagnostic tools usually used in the context of other data. The additional potential cost and delay for CELs adds little additional assurance of cement integrity and protection of ground water.

- Cement evaluation logs are required to be run on the casings that protect usable water on each "type" well in a field where the geologic characteristics that pertain to usable water are substantially similar, as well as on wildcat wells that are not part of an approved field development plan. The criteria for identifying "type" wells are undefined. Moreover, a successful cement bond log (CBL) on a "type" well has no bearing on the success of the cement job on the next well.

- The intent of current well construction and completion technology and best practices for hydraulic fracturing are to protect USDWs and ensure well integrity. Allowing operators to demonstrate that site-specific well construction and operating practices are consistent with these objectives could provide an acceptable alternative to imposing BLM's proposed requirements on all development on Federal land.

In 2012, BLM reports that 3,022 wells were spud during the year on federal lands. Over the last 5 years, an average of 3,552 wells was spud per year. BLM estimates that about 3,000 wells are hydraulically fractured annually, which assumes that 84% of the wells were fractured.

Taking into consideration uncertainties in the range in potential compliance costs per well and the number of wells that would be subject to these requirements, estimated costs associated with this rule could range from as low as $30 million per year to as much as $2.7 billion per year.

Background

The Bureau of Land Management (BLM) has recently released a revised draft proposed rule on hydraulic fracturing oil and gas wells on Federal and Indian lands. The proposed rule contains three key components: well integrity and isolation of usable water zones, chemical disclosure, and management of flow back water.

In terms of the potential cost impact of the proposed rule, the greatest concerns relate to requirements for operators to:

- Isolate "usable water" aquifers with total dissolved solids (TDS) up to 10,000 parts per million (ppm)
- Submit a cement evaluation log (CEL) on surface and intermediate casing to ensure that "usable water" has been properly isolated
- Perform a successful mechanical integrity test (MIT) before hydraulic fracturing is allowed
- Continuously monitor and record pressure during stimulation

Implementation of the rule as currently proposed by BLM may lead to considerable uncertainty in field operations, making the estimation of cost impacts associated with this rule especially difficult. Primary areas of uncertainty include the impact of incremental regulatory requirements and corresponding delays in drilling and well completion schedules; the number of impacted wells; additional requirements resulting from the "usable water" definition of protected aquifers (especially as compared to the more traditional USDW definition); and the cost to implement the requirement for CELs for surface and intermediate casing.

Objective of this Analysis

To estimate the potential cost impacts of the proposed rule, a number of analytical inputs require estimation or reasonable assumptions. The objective of this assessment is to characterize the analytical challenges and uncertainty associated with defining these inputs, thus estimating the potential costs associated with the draft proposed rule. In this regard, the following are most important:

- Implications of the BLM definition of "usable water," rather than the traditional USDW designation for protected aquifers.
- Determining the number of wells that can be represented by a "type well" to demonstrate the isolation and protection of "usable waters."
- The cost of meeting the new BLM requirements including:
    - The cost of cement evaluation logs
    - The cost impact of drilling and completion delays associated with meeting the new compliance requirements

- The portion of field operations that would be subject to the new requirement, taking into consideration the portion of operations that already comply with the new BLM requirements.

Summary of Relevant Revisions to the Proposed Rule

On May 16, 2013, BLM issued a "Supplemental Notice of Proposed Rulemaking." Key revisions to the proposed rule would require operators to conduct a MIT on 100% of wells prior to hydraulic fracturing.[1] Prior to hydraulic fracturing, operators would be required to run a "cement evaluation log," or CEL, on the casing strings that protect "usable water" on each "type" well in a field where the geologic characteristics that pertain to "usable water" are "substantially similar", as well as on wildcat wells that are not part of an approved field development plan, and on wells where there is evidence of a problem with the cement job.[2]

The proposed rule would also require that all fracturing and re-fracturing operations must isolate all zones bearing "usable water" behind cemented surface or intermediate casing. "Usable water" is defined in the discussion of the proposed revisions as follows:

> *"Usable water includes fresh water (often defined as water containing less than 5,000 parts per million (ppm) of total dissolved solids (TDS)) and water that is of lower quality than fresh water… Water with up to 10,000 ppm TDS may be used for some agricultural or industrial purposes, often with some treatment, and thus would continue to be protected under this revised proposed rule….*
>
> *… for purposes of the hydraulic fracturing regulations, usable water includes underground sources of drinking water, zones actually used for water supply for industrial or agricultural purposes (unless the operator shows that the industrial or agricultural user would not be harmed by failure to protect or isolate), and zones designated by the State or the tribe as requiring isolation or protection from oil and gas operations. The BLM has also revised the section to specify that, for the purposes of the hydraulic fracturing regulations, usable water does not include the zone authorized for hydraulic fracturing, zones designated as "exempted aquifers" under the Safe Drinking Water Act (SDWA), and zones that the State or tribe have explicitly designated as exempt from any requirement for oil and gas operators to isolate or protect. Any other zones containing water that does not exceed 10,000 ppm TDS would be considered usable water."*

[1] Section 3162.3-3(f) – pertains to mechanical integrity testing
[2] Section 3162.3-3(d) – pertains to type well; Section 3162.3-3(e) – pertains to monitoring of cementing operations and cement evaluation log prior to hydraulic fracturing

Discussion of Key Issues

Issue: Compared to the traditional USDW definition for protected aquifers, the BLM definition of protected aquifers as containing "usable water" with total dissolved solids up to 10,000 ppm could require the isolation of numerous water-bearing zones over a substantial vertical thickness - causing significant cost and delay.

The U.S. Environmental Protection Agency (EPA) Underground Injection Control (UIC) program defines a USDW as an aquifer which contains "fewer than 10,000 mg/l total dissolved solids and is currently used as a drinking water source, or which is of sufficient volume and adequate quality to be a future source for a public water system of 25 or more connections".[3] The important distinction between the UIC program definition of a USDW and the BLM definition of "usable water" is that all usable water has TDS < 10,000 ppm, but not all usable water aquifers are designated as USDWs.

Important issues and uncertainties pertaining to the BLM definition of usable water include the following:

1) In many geologic basins, the total depth and thickness of aquifers containing water with up to 10,000 ppm TDS can be substantial. In some basins, the entire vertical thickness above the oil and gas reservoir may contain numerous usable water-bearing zones.
2) The areal extent and down dip limit of usable water varies for many aquifers and may be poorly defined for many of the oil and gas plays on Federal land.
3) Not all regional aquifers are adequately characterized in all areas, especially under Federal lands, to the level of detail needed for site-specific well design and operations planning. Published geologic data may provide initial screening-level estimates of the regional thickness and extent of usable water aquifers; but such data may not be sufficient for designing field-level well completions. In many operating areas, water sampling and testing would be needed to characterize water-bearing zones that may have limited likelihood of future "use" being too deep, too thin, too remote, or having insufficient fluid conductivity.
4) Uncertainty in the characterization of usable water aquifers could profoundly impact drilling and completion costs. For example, how many porous and permeable water-bearing zones would require isolation? How much surface and intermediate casing and how many separate cement jobs would be needed to cover all usable water-bearing zones? How much rig time must be added to isolate multiple usable water zones? What is the down-dip limit of usable water in the field?

Discussion. Under current practice, most wells have 1,000 to 2,000 feet of cemented surface casing to protect USDWs, which generally have TDS of less than 1,000 ppm. The BLM requirement to isolate all aquifers with TDS up to 10,000 ppm may require very thick vertical sections, possibly several thousand feet, of a well to be cased and

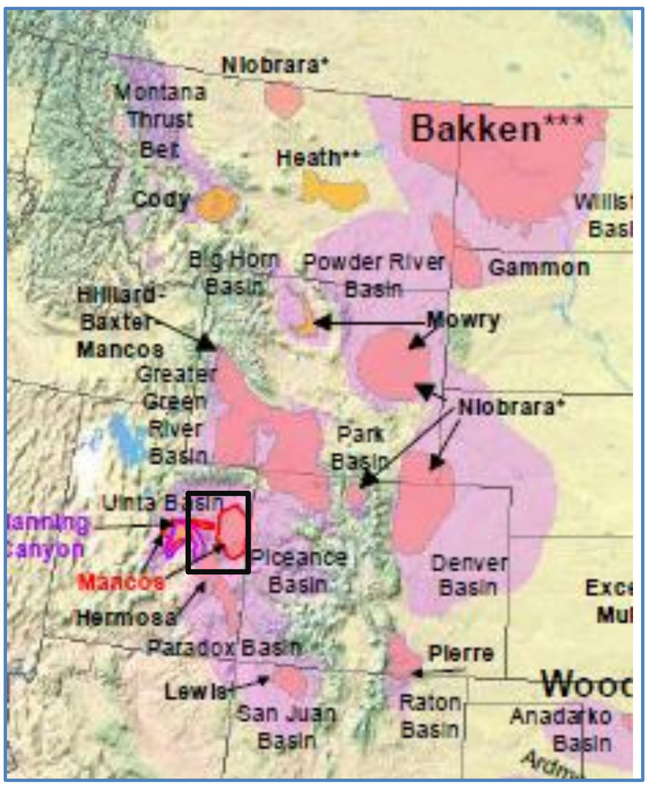
[3] United States Environmental Protection Agency, Region 6, Underground Injection Control Program, "Frequently Asked Questions"; http://www.epa.gov/region6/water/swp/uic/faq2.htm

cemented. In areas where the regional aquifers are poorly characterized, operators may be required to log and sample a vertical well for the sole purpose of characterizing the aquifers.

Following is an example for the Mancos Shale Play in the Uinta Basin, a large portion of which underlies Federal lands, that illustrates the potential uncertainty and complexities in characterizing and isolating all usable water. For gas development in the Mancos Shale, an operator would need to obtain water quality characteristics for as many as seven geologic formations over several thousand vertical feet, and possibly for multiple sandstones within one or more of the formations. Multiple usable water-bearing horizons would likely need to be isolated.

Figure 1 shows a portion of a recent map of Lower-48 shale plays published by the U.S. Energy Information Administration, in which current shale plays are indicated in dark pink and basin outlines are indicated in light pink.[4] The area of the Mancos shale play in the Uinta Basin is shown by the black box. In the Uinta Basin, surficial alluvial aquifers are generally less than 100 feet thick. The most important regional aquifers to consider for the Mancos shale play are the Uinta-Animas aquifer and the Mesaverde aquifer, both part of the Colorado Plateaus Aquifer System (**Figure 2**).

Figure 1; Rocky Mountain Region Shale Plays
(From U.S. Energy Information Administration, <u>Lower-48 Shale Plays</u>*)*



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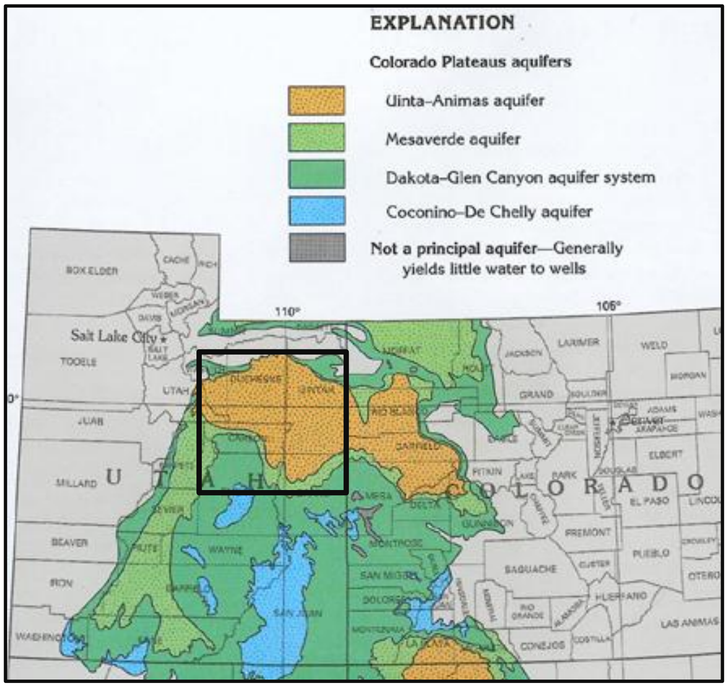
4 U. S. Energy Information Administration, *Map of Lower-48 Shale Plays* , updated May 9, 2011

Figure 2; Four Principal Aquifers of the Colorado Plateaus Aquifer System
(from Figure 107, Ground Water Atlas of the United States)



The Uinta-Animas aquifer is comprised of four geologic formations. Total thickness of the Uinta-Animas aquifer ranges from approximately 500 feet along the southern margin of the Uinta Basin to more than 9,000 feet in the north-central part of the basin. Total dissolved solids concentrations generally range from 500 to 3,000 ppm but can exceed 10,000 ppm in the deeper parts of the basin. The underlying Mesaverde aquifer includes multiple water bearing sandstones in three geologic formations. Total thickness of the Mesaverde aquifer in the Uinta Basin is 2,000 to 4,000 feet. Water quality is extremely variable, ranging from drinking water quality of less than 1,000 ppm in basin margin areas to more than 35,000 ppm in the central Uinta Basin.[5] Total combined thickness of the Uinta-Animas and Mesavede aquifers could range up to 13,000 feet thick, although net thickness of multiple water bearing sandstones and conglomerates that comprise the two aquifer systems would be much less.

The geologic work required to characterize the down dip limit of usable water in both these aquifer systems would not be trivial, especially for exploratory wells and new field developments. In addition to researching and mapping available water quality data, new water samples and analyses might be needed, preferably from new vertical wells. For new gas shale development, the exploratory wells might need one or more drill stem tests to obtain water samples and define the usable water zones.

[5] Robson, S.G. and E. R. Banta, 1995, Ground Water Atlas of the United States, United States Geological Survey publication HA 730-C. Available online at http://pubs.usgs.gov/ha/ha730/gwa. Accessed 5/23/2013.

Potential Costs Impacts. *The most significant uncertainty pertains to the effort required to define "usable waters" that will need to be protected by cement.*

At a minimum, site-specific geologic characterization of usable water aquifers using existing aquifer data would require 2 to 3 days of effort by a geoscientist at an approximate cost of $4,000 - $5,000.[6] Drill stem testing and laboratory analysis to acquire and test new formation water samples could cost as much as $200,000 per drill stem test.[7] These are field-level costs, which would not be imposed on individual wells, but rather on the field development or operating area as a whole. Because the BLM does not consider the usable water definition to be a change from existing requirements, this requirement is not directly addressed in the economic analysis of the Proposed Rule, so a BLM estimate of potential cost impacts of the requirements was not made.[8]

Other industry analyses have focused on the potential incremental cost to extend surface casing and run intermediate casing to isolate usable water zones. Current drilling and completion practices for horizontal gas shale wells are designed to isolate the target reservoir from productive intervals and over-pressured intervals above. It is uncertain whether the current practice provides acceptable isolation of usable water zones under the BLM proposed rule.

For most gas shale plays, intermediate casing is not typically required by regulation, but is run anyway to keep the upper wellbore stabilized below the surface casing while drilling the horizontal laterals. Sometimes more than one intermediate string is run. When cementing intermediate casing, the cement is usually required to be returned to a height of 500 feet above the intermediate casing shoe by volumetric calculation - not all the way up to the surface casing shoe. The fracture gradient of the reservoir may not have adequate strength to allow cement returns to above the surface casing shoe.

Usually, a minimum height of cement above the uppermost zone of interest in the well is required. The minimum height is often 500 feet, or is determined by the calculated or measured fracture height growth of well stimulations in the area. In this way, the intermediate casing covers and isolates the target zone for the horizontal lateral from any productive intervals above including unitized intervals, over pressured zones, or other zones required by regulation to be isolated. A CBL is typically not required unless problems during pumping the cement job suggest that the 500-foot minimum height of cement was not achieved.[9]

The uncertainty around requirements to isolate usable water zones is considerable. For the "typical" horizontal gas shale well described above, in which intermediate casing would be run to stabilize the vertical well bore, additional cement might be required by BLM requirements to isolate one or more usable water aquifers. In this scenario, the

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[6] Advanced Resources International estimate

[7] Comments of Devon Energy Corporation to BLM's Proposed Rule to Regulate Hydraulic Fracturing on Public and Indian Lands, September 10, 2012 (Docket 1004-AE26)

[8] United States Bureau of Land Management, 2013, *Well Stimulation Proposed Rule: Economic Analysis and Initial Regulatory Flexibility Analysis.*

[9] Forgoing description of typical completion practice for gas shale development wells is based on engineering review by Advanced Resources International of gas shale developments in multiple North American shale basins.

incremental cost impact would include the incremental cost of cement and additional rig time for the cementing operations. Even with new, faster-setting cement, multiple delays of 8 to 12 hours each to wait on cement could soon add up to significant additional rig time. Assuming $750/hour for idle rig time, the cost to wait on cement could be $6,000 to $9,000 per single cement job.[10] In the Uinta Basin example, if four zones were required to be isolated separately, the increased time just to wait on cement would be 32 to 48 hours or $24,000 to $36,000. Add to that additional time and cost to rig up and rig down tools, trip in and out of the hole, etc., and the incremental rig time could extend for 1 to 4 days. For conventional vertical wells, or other well design configurations where intermediate casing might not otherwise be run, the incremental impact to isolate deep usable water zones could include up to $250,000 for intermediate casing and as much as 10 to 20 days of additional rig time, depending upon the depth of the water zones.[11] Onshore daily rig rates are estimated at $18,000 to $20,000 per day.[12]

Issue: Cement evaluation logs (CELs) are not commonly run on surface and intermediate casing unless other indicators of an unsuccessful cement job are present. Cement bond logs (CBLs) are interpretive diagnostic tools best used in context with other data. The additional cost and delay for CELs adds little incremental assurance of cement integrity.

Nearly all states require operators to verify a good bond between the surface casing string and the drilled well bore. Pressure testing of the surface casing string and confirmation that cement has properly returned to surface has long been used by operators and regulators to confirm the integrity of surface cement jobs. Important issues and uncertainties pertaining to the BLM proposal to require CELs for surface and intermediate casing include:

- Current operating practice maintains that the best practical indication of poor cement occurs during the cement job, at which point it is easiest to remediate any problems. A CEL is not necessary to confirm a good cement job and causes additional delay.
- If intermediate string and multiple cement jobs are required to isolate multiple zones, the proposed rule requires CELs after setting each casing string. The BLM definition of a CEL includes a CBL with enhanced displays, ultrasonic imaging tool, magnetic resonance imaging, and isolation scanners; but does not

[10] Hourly idle rig cost estimate from Ablett, J. 2013, Cost effective alternative to cased hole bond logging: full waveform capture using open hole sonic tool, available online from Recon, www.reconpetro.com

[11] Comments of Devon Energy Corporation to BLM's Proposed Rule to Regulate Hydraulic Fracturing on Public and Indian Lands, September 10, 2012 (Docket 1004-AE26)

[12] Onshore rig rates estimated to be $750/ hour or $18,000/per day in Ablett, J. 2013, *Cost effective alternative to cased hole bond logging: full waveform capture using open hole sonic tool*, available online from Recon, www.reconpetro.com.

Average daily rig rate estimated to be $20,000 per day in Evans, R. and J. Dearmon, 2013, *Individual well costs from proposed rule changes to oil and natural gas operations on BLM lands: comments and a Monte Carlo specification,* Oklahoma City University, Economic Research & Policy Institute, prepared for Devon Energy, Oklahoma City.

include temperature surveys and pressure testing -- traditional tools used to demonstrate cement bond integrity.

- CELs are diagnostic tools that BLM has historically not interpreted. Operators are concerned that CEL results could lead to disagreements between operators and the BLM about the need to conduct remedial “repairs” on cement jobs, because the cement job monitoring report and CEL would be reviewed by BLM as late as 30 days after the hydraulic fracturing job is completed. In this case, casing interventions would be time-consuming and costly and may compromise the integrity of well casing, increasing the risk of ground water contamination.

Discussion. Under current practice, most wells have 1,000 to 2,000 feet of cemented surface casing to protect USDWs, which generally have TDS of less than 1,000 ppm. In addition, many states now require conductor casing to be cemented to surface if the conductor is drilled in by any manner, i.e. auger drill, hammer drilled or rotary drilled, with the conductor casing then lowered into the hole. Some states require conductor pipe to be at least 100 feet; in effect, the conductor pipe is being used as another surface string of pipe over shallow fresh water zones (< 100+ feet). The practice of “grouting” cement around the conductor pipe has been industry standard in the past. Now that some states require longer conductor pipe of over 100 feet, they also require the conductor pipe to be cemented just as other strings of casing would be in the well, with the cement pumped down the casing and displaced around the conductor back to surface.

Some states require a waiting period for the cement to reach 500 pounds per square inch (psi) compressive strength before any work inside the pipe is allowed. In the past, common industry practice has been to use auger rigs and small water well type rigs to set conductor pipe before the primary drill rig moved on location. New requirements for cementing long conductor pipe also require larger rigs for setting the pipe. These larger rigs typically continue drilling in the surface pipe and intermediate casing strings before the large primary rig moves in to drill the horizontal portion of a shale well. Surface casing is typically run below the lowermost USDW, and may be set from 150 to 1,000 feet deeper than the lowermost USDW as a precaution.

To cement the surface casing, the cement job is designed with enough volume to return cement back to surface plus a designated excess. Many states require a “waiting on cement” time which corresponds to the time for cement to reach 500 psi compressive strength before any activity is allowed inside the surface casing string. A CBL should not be necessary if cement is returned back to surface during the job and only minor “fall back” occurs after the job. Where cement is not returned to surface during the cement job, a CBL would be appropriate to confirm zone isolation or the need for remedial measures. In either case, a “shoe test” is required to confirm cement isolation around the casing shoe. During a shoe test, the open hole below the casing shoe (after it is drilled out) is pressured to an equivalent of a calculated mud weight to confirm that no leak-off occurs above the casing shoe.[13] It is unclear in the proposed rule if a casing

[13] For example, a 10 pound per gallon (ppg) mud weight shoe test would be the equivalent of the column weight of fluid in the hole plus the equivalent pressure to equal a simulated 10 ppg mud filling the wellbore. A 10 ppg shoe test on a 300-ft hole would be: 10 ppg * 0.052 psi/ppg conversion = 0.52 psi/ft

shoe test of this type provides sufficient evidence of cement integrity to remove the need for a MIT.

When cementing intermediate casing, the cement is usually required to be returned to a height above the intermediate casing shoe, by volumetric calculation – not all the way up to the surface casing shoe. Usually, a minimum height of cement above the uppermost target reservoir is required. The minimum height is often 500 feet, or is determined by the calculated or measured fracture height growth of well stimulations in the area. A temperature log may be run to identify the top of cement, but a CBL is typically not required unless problems during pumping the cement job suggest that the desired height of cement was not achieved. Again, a casing shoe test is done by pressuring the open hole below the bottom of the intermediate casing to make sure that no leak-off occurs above the cement that anchors the intermediate string.

The proposed BLM rule lists a variety of logs and imaging tools, which would be acceptable alternatives to a basic CBL. These various logs are categorized in the rule as "cement evaluation logs", or CELs. The "VDL" (variable density log) and "CBL with directional receiver array" described in the proposed rule are enhancements of the basic CBL that are designed to improve the diagnostic value of the CBL. A modern CBL will typically include the variable density display of acoustic waveforms. The basic CBL log will typically be run with a radial or directional receiver array allowing the display of a "cement map" to pinpoint channels, contamination and missing cement. Such logs cost a minimum of $3,500 - $5,700.[14]

The ultrasonic image log and ultrasonic pulse echo logs mentioned in the proposed rule are advanced acoustic imaging devices and would cost significantly more than the basic CBL. The ultrasonic imager is a state-of-the-art acoustic cased hole imaging tool. This tool uses a rotating head and a pulsed echo technique. Transducers emit ultrasonic energy in a 300 – 600 kHz band, which covers the resonant frequency range of most oilfield casing thickness. The ultrasonic imager not only provides a high resolution circumferential map of the cement integrity, but it offers a unique casing inspection capability. Such logs have greater value for evaluating the casing and cement integrity in older wells before re-fracturing, than in new wells with new casing and cement.

<u>Potential Costs Impacts.</u> *The most significant uncertainties related to cost impacts pertain to the approaches BLM determines to be sufficient for determining cement integrity*.

Current operating practices to confirm the integrity of a cement job include monitoring the cement job diagnostics such as volume pumped, pressure and cement returns; running temperature surveys to confirm top of cement; and pressure testing below the casing shoe. CBLs are not typically run unless a poor cement job is indicated. The

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gradient and, 0.52 psi/ft. *x* 300 ft. = 156 psi, Since, a water filled hole to 300 ft. would equal 0.433 psi/ft * 300 = 130 psi; 26 psi pressure would be added at the surface for 30 minutes to conduct the 156 psi shoe test.

[14] Advanced Resources International estimate based on basic CBL ordered for recent field evaluation projects in the southeastern United States. Also, Ablett, 2013, Table 1. Comparison of published logging rates for cement bond logs and open hole sonic logs. Price may not include all service fees, truck, travel & crew fees.

BLM's proposed requirement for a CEL on an otherwise successful cementing operation represents an incremental cost impact. The estimated cost of a single cement evaluation depends upon the type of log, and the depth of the casing. For example, a CEL run on surface casing will cost less than a CEL on intermediate casing because the intermediate string will be longer and deeper than the surface string. The BLM estimates the average cost for a CEL at $9,000.[15] Other estimates range from $5,000 - $6,500[16] for a surface casing cement bond log to $20,000[17] for an intermediate string cement bond log. Associated time delays are estimated to range from 1 to 5 days depending upon the number of casing strings and CELs, so the rig delay cost could range up to $100,000. By one industry estimate, ancillary equipment and personnel could similarly incur delay costs of more than $800 per hour. These might include delay costs for mud loggers and rented trailers, tanks, pumps, and generators.

The potential number of cement jobs that BLM would require to be remediated is also unknown. Contributing to uncertainty could also be the extent to which a CEL indicates a potential problem with a cement job which in fact may not exist.

Remediation costs are expected to be large, but the number of wells that might be affected is highly uncertain. Typical costs for cement remediation could include: perforating casing - $12,000; squeeze cementing - $30,000; post-squeeze CBLs - $6,000 - $20,000. One cement squeeze is estimated to require 4 days; 9 days for two squeezes. By one estimate, the minimum total cost for a single cement squeeze would be approximately $128,000, considering rig delay time and direct remediation costs only; estimated minimum cost for two cement squeezes could be $284,000.[18] Under the proposed rule, a cement monitoring report and CELs must be submitted 30 days after hydraulic fracturing is complete. Thus, it is uncertain how many cement remediation jobs for usable water aquifers would be required "after the fact".

Issue: CELs will be run on the casing strings that protect usable water on each "type" well in a field where the geologic characteristics that pertain to usable water are substantially similar, as well as on wildcat wells that are not part of an approved field development plan. The criteria for identifying "type" wells are undefined. Moreover, a successful CBL on a "type" well has no bearing on the success of the cement job on the next well.

The proposed rule states that CELs would be required on a "type" well only, but the rule is vague about how many development wells can be adequately represented by a "type well." The criteria which determine "substantially similar" geologic characteristics are undefined. For field developments, it is easy to contemplate that the type well

[15] U.S. BLM, ~~2013~~2012, *Well Stimulation Proposed Rule: Economic Analysis and Initial Regulatory Flexibility Analysis, Table 3, p. ~~97~~67*

[16] Advanced Resources International estimate based on basic CBL ordered for recent field evaluation projects in the southeastern United States. Also, Ablett, 2013, Table 1. Comparison of published logging rates for cement bond logs and open hole sonic logs. Price may not include all service fees, truck, travel & crew fees.

[17] Evans, R. and J. Dearmon, 2013, *Individual well costs from proposed rule changes to oil and natural gas operations on BLM lands: comments and a Monte Carlo specification,* Oklahoma City University, Economic Research & Policy Institute, prepared for Devon Energy, Oklahoma City.

[18] Ibid, p. 13

designation might evolve into a field-specific requirement for one type well to represent "x" number of surrounding wells or surrounding acres. For example, if development wells are drilled on 80 acres, one type well might be required per 640-acre section, in which case the type well would represent 8 wells. It is unclear from the proposed rule if a type well could represent an entire field or unitized area, in which case the type well might represent 10's or 100's of wells.

Operators may need to seek a determination from BLM of the "type well(s)" for their operating areas, which could contribute to uncertainty in operations planning, as well as to delays. A common industry practice in the early wells in a gas shale development is to drill the vertical section of the well through the "target reservoir" as a stratigraphic hole to collect core and open-hole logs after the intermediate casing is run and cemented. Next, kick-off plugs are set above the target shale reservoir so the build section for the horizontal lateral can be designed. Such early development wells might be excellent candidates for "type well" designation.

Discussion. The "type well" approach in the proposed rule seems to be an arguably misguided attempt to reduce the potential cost and delay burden of the CEL requirement. This is because a successful cement job and a sound CEL for a type well does nothing more than demonstrate a good cement job on that well only. A type well CEL might imply favorable subsurface conditions for successful aquifer isolation; however, the type well cannot prove the success of cement jobs on subsequent wells before the fact, even if the subsurface geology is similar. A problem cement job on a nearby well will still need to be fixed, whether or not a type well CEL exists. A better approach might be to require CBLs to only be run as needed based on data obtained during routine monitoring of the cement job.

Potential Costs Impact. *The most significant uncertainties related to cost impacts pertain to the number of "type wells" BLM determines to be sufficient for characterizing potential well integrity.*

For field development wells, uncertainty about the number of type wells that would be required is the driver of the "per well" potential cost impact. This is illustrated by the following example, which assumes a hypothetical gas shale development of ten 640-acre sections. Well spacing is 80 acres so there are 8 wells per section. One type well is required per section, so this hypothetical gas shale development has a total of 10 type wells. All the development wells in this example would already be required to run surface and intermediate casing to isolate two usable water aquifers. So, for the type wells, the incremental requirements are two CELs, one for the surface casing and one for the intermediate casing. In addition, there would be the possibility of at least one type well needing to remediate a cement job based on evaluation of the CBL.

Assuming a cost of $5,000 per CBL, the CEL cost for the type wells is $10,000 per well. An incremental drilling delay of 24 hours to run a CBL for each casing string is assumed for this example. If a daily rig rate of $20,000 per day is assumed, the total incremental delay cost attributable to the two CBLs would be $40,000 per type well. Total estimated incremental cost to run CBLs in the type wells is $50,000 per type well and $500,000 for the entire 10–section field. If the total incremental CEL cost for the type wells of $500,000 is distributed over 80 wells, the effective CEL cost would be approximately

$6,250 per well. Requiring fewer type wells would further reduce the "per well" effective CEL cost. On the other hand, additional costs of $128,000 or more could be added to the total field cost if remediation of a cement job was required based on CEL interpretation for at least one of the type wells.[19]

Issue: The intent of current well construction technology and industry best practices for hydraulic fracturing is to protect USDWs and ensure well integrity. Allowing operators to demonstrate that site-specific well construction and operating practices are consistent with these objectives could be an acceptable alternative to imposing the requirements of BLM's proposed rule on all development on Federal Land.

The above discussion has described well construction design and completion practices for gas shale wells that have evolved to maintain well bore integrity and protection of USDWs. Such practices and technologies include:

- Extended, cemented conductor pipe
- Surface casing extended below the lowermost USDW
- Routine, cemented intermediate casing to stabilize and isolate the vertical well bore from the hydraulically fractured target reservoir
- Casing pressure tests and leak-off tests to demonstrate casing/cement integrity
- Routine cement monitoring, confirmatory temperature surveys
- Improved formulations increase cement strength and reduce wait times for cement jobs
- Improved CBLs include variable density displays and radial array logs to allow cement maps
- Ultrasonic imaging tools diagnose casing quality in addition to cement bond
- Improved predictive tools and models for hydraulic fracture height and extent.

In total, current industry practice is intended to protect drinking water supplies and to maintain wellbore integrity for hydraulic fracturing, while striving for safe, effective, and economically and technically efficient oil and gas production on Federal lands. The above discussion has illustrated that the potential costs of the proposed rule could be substantial due the inherent variability of oil and gas operations, the potential costs are highly variable, and there is considerable uncertainty about how individual wells would be impacted. Furthermore, one can construct reasonable field development scenarios in which the proposed BLM regulations impose requirements that are redundant to current industry practices, resulting in significant cost and little or no additional protection of ground water resources.

Discussion. A case in point is BLM's proposed requirement for a mechanical integrity test (MIT) of casing before hydraulic fracturing is allowed. As the foregoing discussion has shown, per typical operating practice and the requirements of several states, the integrity of casing and cement is confirmed prior to hydraulically fracturing a new well. This is generally accomplished by using new casing, by confirming that cement has

[19] To remediate a cement job on intermediate casing might require approximately $12,000 for perforating the casing, $30,000 for a single cement squeeze, $6,000 for a confirmatory cement bond log, and approximately 4 days of daily rig cost of at a total cost of $72,000 - $80,000. Approximate costs from Evans and Dearmon, 2013.

properly returned to surface (for surface casing) or successfully reached an appropriate height in the annulus (for intermediate casing); by hydraulically pressure testing the casing string prior to drilling out; and by taking immediate measures to remediate any casing/ cement integrity issues before resuming drilling operations. Requirements for MITs and CBLs that may not be evaluated by regulators until weeks after hydraulic fracturing occurs imposes redundant costs that do not improve the protection of USDWs.

A cost-effective, flexible alternative might be for operators to submit, as part of the permitting process, field-specific casing design and cementing plans that address unique concerns pertaining to USDW protection in their specific geographic area. Then, following the casing and cementing operations, operators would submit evidence confirming a successful cement job, measures taken to correct deficiencies, and verification of casing/ cement integrity before resuming drilling operations. Per industry best practices, such verification would likely be a leak-off test or a casing pressure test that meets American Petroleum Institute or state guidelines.[20]

Potential Cost Impacts. The BLM estimate of the average cost of MIT is $10,000. [21] It is easy to presume that the MIT requirement would rapidly add large incremental costs to field development depending upon the field development plan. An alternative to an MIT might be provided by ultrasonic imaging, which provides precise acoustic measurements of cement, casing thickness, and internal casing dimensions. For wells that require re-fracturing, ultrasonic imaging, run as both a cement and casing evaluation tool, might offer a cost-effective alternative to an MIT, when combined with other data.

Summary of Potential Costs

Table 1 summarizes the range of potential compliance costs that are mentioned in the foregoing discussion. Potential compliance costs of the proposed rule fall into three categories according to where the cost would be applied. The cost categories are:

- Field-level costs distributed among all the wells of the developed field
- Costs applied to all individual wells within the field
- Costs applied to exploratory wells and type wells within a field.

The potential cost for field-specific geologic characterization of usable water aquifers would be borne by the entire field development. These could range from negligible ($3,200 per field development) to significant ($408,000 per field development). An example of a negligible cost for usable water characterization would be the shale development in the Appalachian Basin, where the aquifers are well characterized with

[20] For an example of state guidelines, see 25 PA code 78.84 *Casing Standards*. Per API guidelines, "After the surface casing cement has achieved the appropriate compressive strength and prior to drilling out, the surface casing should be pressure tested (commonly known as a casing pressure test). This test should be conducted at a pressure that will determine if the casing integrity is adequate to meet the well design and construction objectives." American Petroleum Institute, 2009, *Hydraulic Fracturing Operations- Well Construction and Integrity Guidelines*, API Guidance Document HF1.

[21] United States Bureau of Land Management, 2013, *Well Stimulation Proposed Rule: Economic Analysis and Initial Regulatory Flexibility Analysis.* Table 3.

existing data, and for the most part, no usable ground water occurs below the surficial alluvial and fractured USDWs. An example of potential high cost for aquifer characterization would be Western basins where multiple ground water aquifer systems occur and the limits of usable water within these aquifer systems may not be well-defined.

Compliance costs that would be borne by all individual wells include the cost for a MIT prior to hydraulic fracturing, which BLM estimates at approximately $10,000 per MIT and incremental costs to isolate usable water aquifers behind casing and cement. The incremental cost to isolate usable water aquifers is highly variable, ranging from $0 (no usable water aquifers below surface USDWs; the Appalachian Basin example) to "extreme", ($776,000 is the maximum cost incremental cost estimated for the scenario presented in Table 1.) Potential compliance costs depend on the depth, thickness and number of usable water aquifers that must be isolated. The range of potential high compliance cost is determined, on the low end, by simply extending surface casing and, on the high end, by running one or more intermediate casings that would otherwise not be included in the well design.

The final compliance cost category consists of the costs that would be borne by type wells and by exploratory wells. These costs have the greatest uncertainty because the criteria for selecting type wells and the number of type wells are not specified in the rule. Would the operator or the regulator "select" the type well? Unless a field development is unitized, how can an operator decide which well should bear the additional costs of a "type" well. The process for selecting "type" wells will need to be transparent and fair to all parties with an interest in the well(s). The compliance costs borne by type wells include the incremental cost to run CELs on all the casings that protect usable water, plus the potential cost to remediate a cement job that would be required after the fact based on regulator evaluation of the CEL. Under the proposed rule, the cost to run CELs will be universally applied to all type wells. These range from an estimated low cost of approximately $24,000 per type well (for the cost of the log and one day of additional rig time) to approximately $109,000 per type well, which assumes surface and one or more intermediate casings, and a CEL after each casing is set.

The requirement to remediate a cement job based on regulator evaluation of a type CEL has a high cost, but also a highly uncertain application. The estimated cost for a single cement squeeze in Table 1 ranges from $120,000 to $142,000 determined by the rig daily rate and the cost of a confirmatory cement evaluation log. In practice, a problem cement job will likely be identified during the monitoring of the cementing operation, and would be corrected before drilling resumes. Under the proposed rule, evaluation of the CELs run on type wells could occur "after the fact", possibly weeks following hydraulic fracturing operations on the well. It is very uncertain how many questionable CELs will ultimately result in a remedial cement squeeze of the type well, as there may be other options by which operators could demonstrate that usable water remains protected.

Not only do substantial uncertainties exist as what various actions would cost, uncertainties also exist in terms of the number of wells that will be considered type or exploratory wells, and the number of wells to which various field wide analyses could be allocated.

In 2012, BLM reports that 3,022 wells were spud during the year on federal lands. Over the last 5 years, an average of 3,552 wells was spud per year. BLM estimates that about 3,000 wells are hydraulically fractured annually, which assumes that 84% of the wells were fractured.

The range in the number of wells to which various field wide analyses could be allocated was assumed in this analysis to range for 10 to 20 wells per field. Also, the portion of wells drilled that would be considered type or exploratory wells could range from 1 in 3 to 1 in 10. Taking into consideration the costs ranges reported in Table 1, along with these other ranges in uncertain parameters, estimated costs associated with this rule could range from as low as $30 million per year to as much as $2.7 billion per year, as shown below.

	Estimated Industry Costs on Federal Lands ($ Millions)		
	Low	**High - Lower**	**High - Upper**
10 wells per field			
1/3 wells are exploratory/type	$31	$1,634	$2,731
1/10 wells are exploratory/type	$31	$1,534	$2,556
20 wells per field			
1/3 wells are exploratory/type	$30	$1,573	$2,670
1/10 wells are exploratory/type	$30	$1,472	$2,495
30 wells per field			
1/3 wells are exploratory/type	$30	$1,553	$2,650
1/10 wells are exploratory/type	$30	$1,452	$2,474

Table 1. Potential Compliance Costs to Protect Usable Water and Demonstrate Well Integrity

Compliance Cost Element	Compliance Scenarios and Range of Potential Costs				Cost Category; Cost Applied To:	Comments:
	Low Potential Cost		High Potential Cost			
Site-specific geologic characterization of usable water aquifers using existing data	Geoscientist level of effort: 16 hours x $200/hour	**$3,200**	Geoscientist level of effort: 40 hours x $200/hour	**$8,000**	Entire Developed Field	
Obtain/ analyze water samples from DST	No water sampling required. Usable water zones well-defined	**$0**	Drill stem tests of 2 wells defines downdip limit of usable water 2 DST x $200,000/DST	**$400,000**	Entire Developed Field	
Incremental cost to cement 2 hypothetical usable water aquifers behind casing. (Casing is already in well design)	Usable water aquifers are sufficiently isolated by existing casing/ cement design	**$0**	Extend surface casing to isolate 1 hypothetical usable water zone. Additional cement behind intermediate string to isolate hypothetical usable water zone #2. Estimated rig time to run additional cement job: 3 days X ($18,000 - $20,000)/day = $54,000 - $60,000 Wait on cement: 2 x 10 hr x $800/hr = $16,000	**$70,000 - $76,000**	Individual Wells	
Incremental cost of casing to isolate 2 hypothetical usable water aquifers behind casing (intermediate string would not otherwise be included in well design)	Usable water aquifers are sufficiently isolated by existing casing/ cement design	**$0**	Intermediate casing string(s): (1 – 2) x $250,000 = $250,000 - $500,000 Additional rig time to run intermediate: 7 – 10 days x $18,000 - $20,000/day = $126,000 - $200,000	**$376,000 - $700,000**	Individual Wells	Rig time to run casing is highly variable depending on well depth, hole conditioning, etc.
Mechanical integrity test (MIT) required on all wells before hydraulic fracturing	BLM estimates $10,000/MIT	**$10,000**	BLM estimates $10,000/MIT	**$10,000**	Individual Wells	Also required before refracturing producing wells
Run cement evaluation log (CEL) on each casing string that isolates usable water	Well is not a type well, so no CEL required for surface or intermediate casing	**$0**	Surface casing CEL: 1 x ($6,000 - $9,000) = $6,000 - $9,000 Intermediate casing CEL: (0 – 2) logs x $20,000/CEL = $0 - $40,000 Incremental rig time to run CELs: (1 – 3) days x ($18,000 - $20,000)/day = $18,000 - $60,000	**$24,000 - $109,000**	Type Wells & Exploratory Wells.	Incremental costs for type wells should be distributed over the entire developed field.
Incremental cost for remedial cement squeeze required based on CEL interpretation	No remedial cement squeeze because no CEL required	**$0**	Perforate casing = $12,000 Cement squeeze = $30,000 CEL = $6,000 - $20,000 Estimated rig time for 1 squeeze: 4 day x (18,000 - $20,000)/day = $72,000 - $80,000	**$120,000 - $142,000**	Type Wells & Exploratory Wells	Applies only to remedial cement squeeze required by BLM based on interpretation of CELs. Very uncertain how often this would occur.