Well to Well Communication “Frac Hits”

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Well to Well Communications “Frac Hits”

I. Visual References and Context
II. What are Frac Hits?
III. Mechanisms Involved
IV. Consequences and Opportunities
V. Management Considerations
VI. Existing Regulatory Landscape
VII. Summary and Conclusions
VIII. Appendix

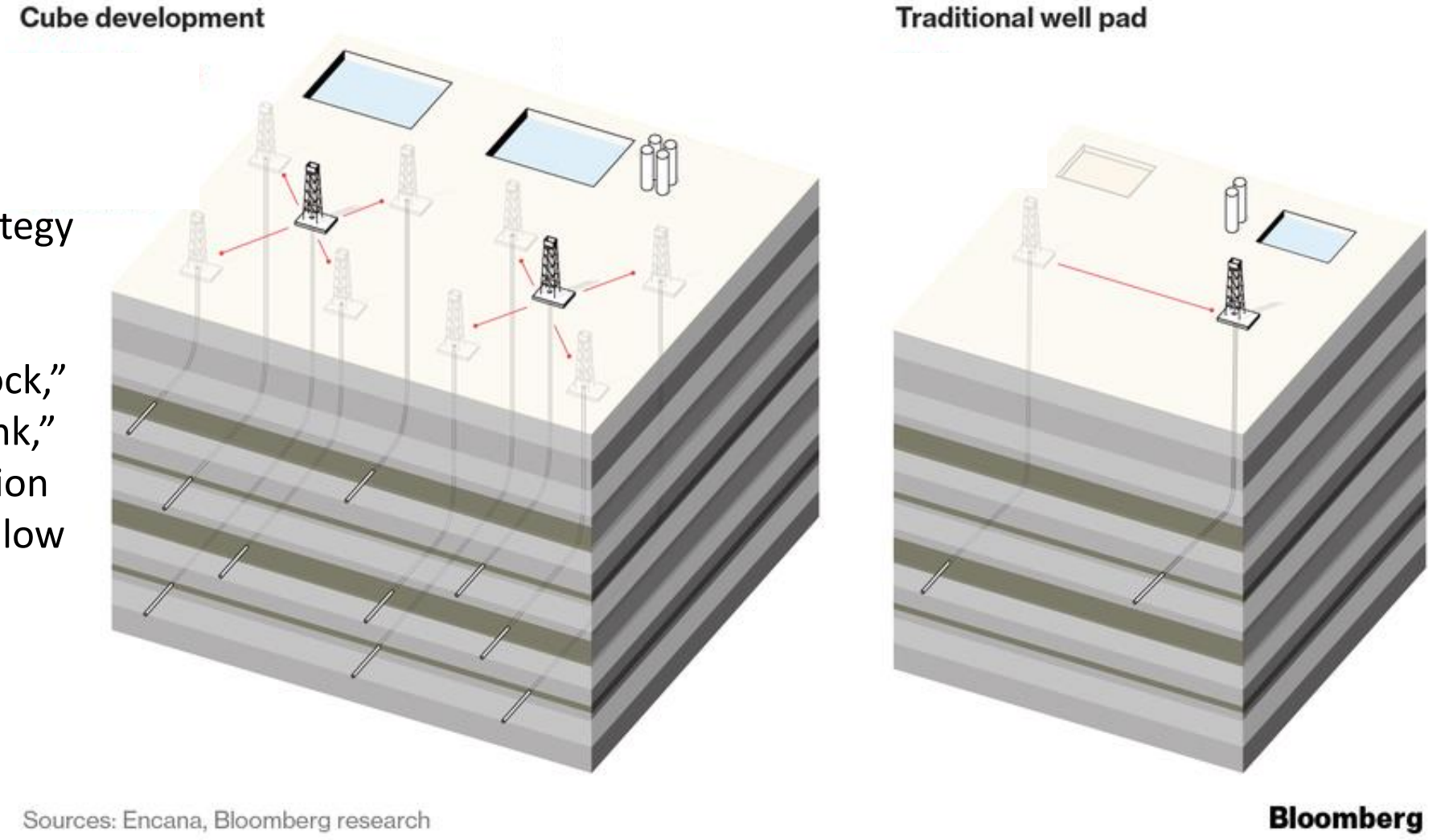
I. Shale Formation Outcrops are Most Revealing

- Complexity of shale formations is fairly obvious
- Natural fractures tend to follow weakness in the rock
- Natural fractures appear to be more disconnected than connected

I. Resource Play Development Drilling

I. Resource Play Development Strategies

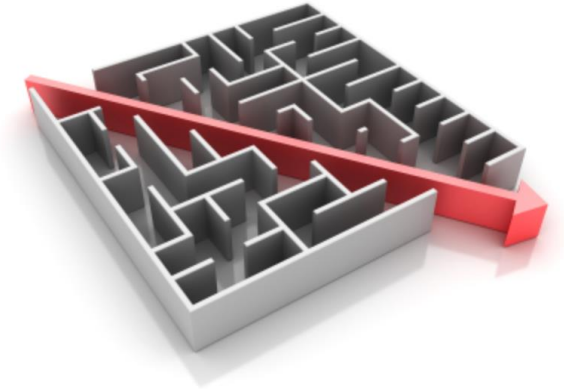
Emerging strategy is to drill development wells in a “block,” “cube” or “tank,” then completion operations follow

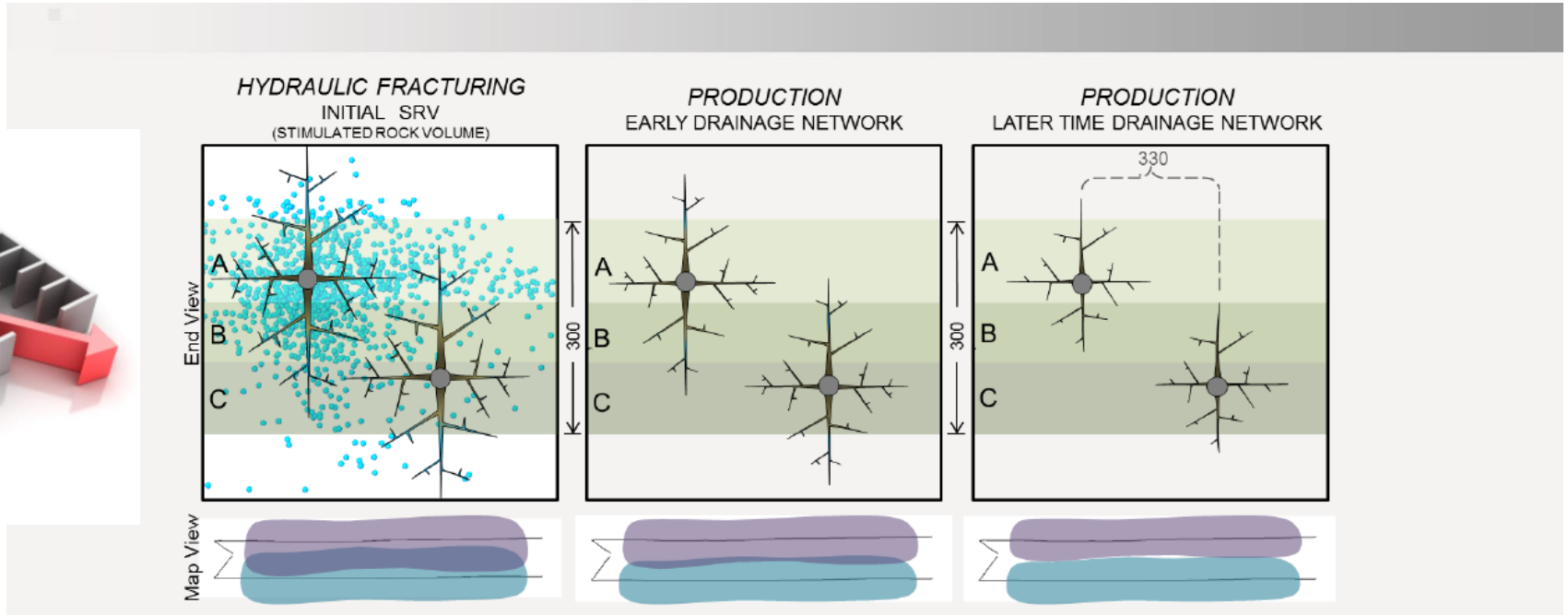


Traditional strategy starts with a leasehold or evaluation well (parent) with subsequent development wells (children) drilled a year or more later

I. Hydraulic Fracture Networks Diminish Over Time

Drainage Network Geometry by Noble Energy's Underground Labs, 2015—Dave Koskella, et al



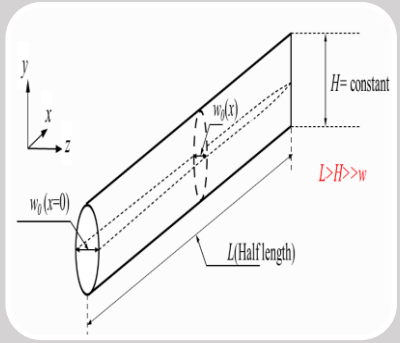


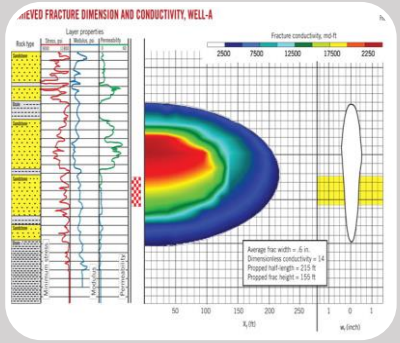
after pressure pumping …. few months later …… year later

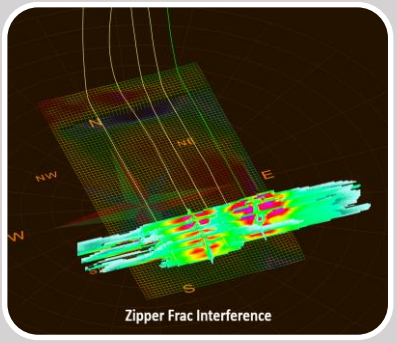
"Fracture networks such as these presented by Noble are not as conductive and durable as originally thought after extensive investigations in the Permian, Marcellus, Eagle Ford, Barnett, Bakken, Haynesville, Three Forks, Niobrara and other Basins"

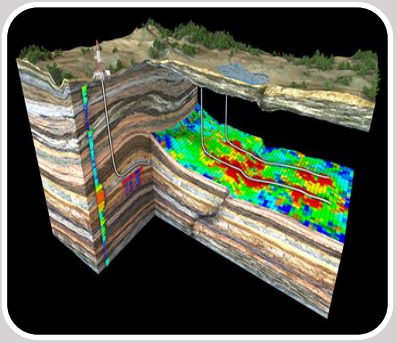
Mike Vincent, Fracwell - 2018

I. Fracture Models are Evolving to Match Physical Observations









2D Models

- KGD
- PKN

Pseudo 3D

- Fracpro
- Mfrac
- Stimplan

Fully 3D

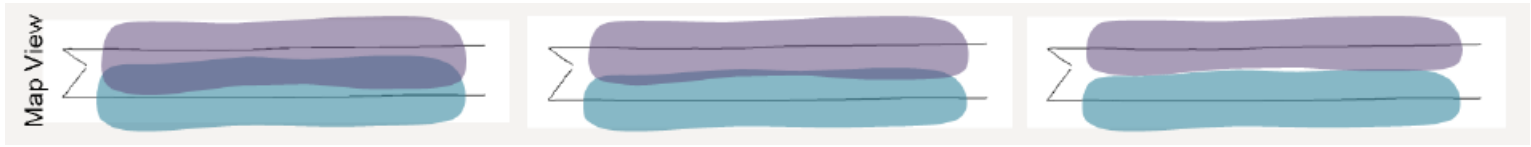
- GOHFER
- Stimplan 3D

Integrated

- Fracgeo
- Elfen
- Kinetix
- 6X

II. What are Frac Hits?

- Well to well or frac to frac communication by
  - Pressure
  - Pressure and fluid
  - Pressure and fluid with proppant delivered
- Short duration events, directly related to stage pumping
- Many cases have neutral or positive impacts, will provide data that supports this
- Can be managed to minimize the negative impacts
- Offer significant learning opportunities for improved resource developments



after pressure pumping | few months later | year later

III. Mechanisms Involved

- Within the formation
  - Hydrologic changes due to pore pressure
  - Structural changes due to rock stress
  - Chemical changes due to fluid compatibility
  - Combination of the above
- Within the wellbore
  - Mechanical restrictions if fluid or proppant placement occurs

IV. Consequences and Opportunities

Table 1—Probability of effects from child wells fractured <2,000 ft and more than 18 months from parent well's date of first production.

	Bakken	Eagle Ford	Haynesville	Woodford	Niobrara
Positive Hit - Long Term	17%	9%	20%	2%	0%
Positive Hit - Short Term	33%	14%	38%	2%	6%
Positive Hit Total	**50%**	**24%**	**58%**	**4%**	**6%**
No Change	**35%**	**36%**	**24%**	**32%**	**38%**
Negative Hit Total	**15%**	**41%**	**19%**	**64%**	**56%**
Negative Hit - Short Term	7%	13%	5%	20%	19%
Negative Hit - Long Term	6%	17%	5%	41%	31%
Shut-in Post Offset Hit	2%	10%	9%	3%	6%
Instances Included	**649**	**1,210**	**366**	**259**	**32**
Original No. of Instances	827	1,561	449	283	49
Instances with Invalid Data	178	351	83	24	17

33%

33%

34%

SPE-180200-MS Miller, Lindsay, Baihly, Xu

IV. Consequences and Opportunities

- Frac hit data successes
  - Provides our only direct measure for fracture geometry
  - Fluid transport distances, both vertically and laterally
  - Provides an indirect measure for fracture complexity and conductivity
  - Leads to better well spacing and stage designs

- Frac hit data non-successes
  - Assumes that all frac hits are bad, losing the learnings
  - Assumes that initial fracture complexity and conductivity to be long-lasting

V. Management Considerations

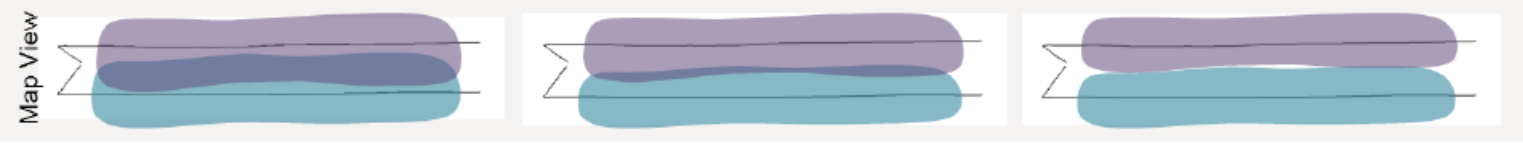
- Clarity of development goals
- Appropriate level of subsurface evaluation and well planning
- Notification to offset operators
- Protect and monitor offset wells during pressure pumping
- Learnings from offset well observations
- Management approach should not be to achieve zero frac hits, rather to achieve a better understanding of their impacts on resource developments

VI. Existing Regulatory Landscape

- Pre-planning generally includes
  - Area of interest “AOI” reviews
  - Notifications to offset operators
  - Notification timing from 5 to 90 days in advance
- If well to well communication is observed
  - Actions are required to prevent releases
  - Actions are required to prevent damage
  - Agency notification is recommended or required

VII. Summary and Conclusions

- Well to well communication
  - Has both positive and negative potential
  - Both outcomes offer significant learning opportunities
- These learnings
  - Will lead to safer operations and improved resource recovery
  - Are quickly advancing and being shared by operators
- Operators and regulators working together can
  - Minimize negative outcomes
  - Maximize hydrocarbons recovered



VIII. Appendix

VIII. Appendix—Contents

- Abbreviated list of technical references
  - Relevant industry publications
  - Specific to development strategies
- Regulatory status
  - Environmental Defense Fund
- Hydraulic fracturing related concerns that are now less concerning
  - Drinking water threats
  - Chemical disclosure for fluids pumped
  - Impacts on climate change

VIII. Appendix—Technical References, abbreviated list

- **SPE papers**
  - 119636 Diversion techniques
  - 119896 Barnett path complexity
  - 140426 Interaction of close spacing
  - 145949 Real data on frac height
  - 164898 Forecasting hits
  - 175917 Well communication
  - 179172 Diagnostic value of hits
  - 179173 Interconnectivity
  - 180200 Not all hits are negative
  - 181328 Frac interaction
  - 184812 Improving hit analysis
  - 185819 STACK multi pad performance
  - 187192 Evaluating hits
  - 189853 Production impacts
  - 191671 Reducing interference
  - 191712 Successful mitigations

- **SPE papers**
  - 191722 Preventing hits
  - 191767 Diagnostic value of hits
  - 191789 Machine learning applied to hits

- **URTeC papers**
  - 2645414 Leveraging offset well data
  - 2662893 Understanding impact of hits
  - 2668100 Well interference
  - 2670079 Haynesville frac interference
  - 2688841 Modeling interference
  - 2690466 Well spacing and interference
  - 2691375 EagleFord well interference
  - 2691962 Wolfcamp well interference
  - 2693373 Parent well depletion
  - 2695433 EagleFord well spacing
  - 2902400 Remediating hits in Woodford

VIII. Appendix—Technical References for Development Strategies

- Parent / child
  - "**Frac Hits: Sensing, Preventing and Recovery of Production Rate**" George King

    https://www.youtube.com/watch?v=x551qxe5Dqc

- Tank, block or cube
  - **"In the Battle Against Frac Hits, Shale Producers Go to New Extremes"** Trent Jacobs, JPT Digital Editor | 01 August 2018
  - **"Permian's Mammoth Cubes Herald Supersized Future for Shale"** Alex Nussbaum, Bloomberg Businessweek, February 22, 2018 6:30 AM
  - **"QEP Sees Benefits Of 'Tank-style' Development Method"** Velda Addison, Digital News Group Hart Energy, Monday, August 27, 2018 - 4:05pm

VIII. Appendix—Regulatory approaches: Alaska

- 20 AAC 25.283 (2014):
  - Offset operator notification to one-half mile
  - The location, the orientation, and a report on the mechanical condition of each well that may transect the confining zones, and information sufficient to support a determination that the well will not interfere with containment of the hydraulic fracturing fluid within the one-half mile radius of the proposed wellbore trajectory;
  - The location of, orientation of, and geological data for each known or suspected fault or fracture that may transect the confining zones, and information sufficient to support a determination that the known or suspected fault or fracture will not interfere with containment of the hydraulic fracturing fluid within the one-half mile radius of the proposed wellbore trajectory

VIII. Appendix—Regulatory approaches: California

- § 1784. Well Stimulation Treatment Area Analysis and Design (2015)
  - Determination of “axial dimensional stimulation area”
  - Identification of all wells within 2x ADSA, with integrity analysis of casing and cement, and wellbore path
  - Review of geological features within 5x ADSA and their likelihood of communication
  - Design treatment to ensure treatment fluids and hydrocarbons do not migrate
- Note also requirement to monitor stimulation for signs of communication and terminate if discovered

Information Courtesy of the EDF - Adam Peltz apeltz@edf.org

VIII. Appendix—Regulatory approaches: Colorado

- 317r. Statewide Wellbore Collision Prevention (2015)
  - Evaluate active wells within 150’, provide notice
- 317s. Statewide Fracture Stimulation Setback (2015)
  - Waivable ban on stim within 150’ of existing wellbore’s stimulated zone

VIII. Appendix—Regulatory approaches: Colorado

- Interim Statewide Horizontal Offset Policy (2014)
  - Operators submit form with all wells within 1500’ of wellbore, including cement information
  - COGCC evaluates whether those wells have adequate isolation to prevent communication
  - Four mitigation options for “wells of concern”
    - Remedial cement to isolate problematic zones
    - Plug well to isolate problematic zones
    - If well is PA/DA, re-enter and isolate
    - Alternative mitigation or showing that offset well is not of concern
  - Offset wells must be equipped to withstand 5000 PSI
  - 90 day offset operator notice
  - Offset well operators “shall not refuse to have their well appropriately mitigated to meet the requirements of this Policy”

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VIII. Appendix—Regulatory approaches: New Mexico

- Aztec District III Request for Information (2013)
  - The Oil Conservation Division … is requesting operators to provide information relating to wellbore(s) that have … been in communication of any kind through drilling, completion, stimulation or production operations relating to both vertical and horizontal wells.
  - For future operations: Operators will be expected to immediately report any instances of unintended inter-well communication or other impacts which may result from stimulation operations.

http://www.emnrd.state.nm.us/OCD/documents/Oct2013RequestforInformationInterwellCommunication.pdf

VIII. Appendix—Regulatory approaches: North Dakota

- 43-02-03-28. SAFETY REGULATION (2014, rev. 2016)
  - The operator conducting any well stimulation shall give prior written notice, up to ten days and not less than seven business days, to any operator of a well completed in the same pool, if publicly available information indicates or if the operator is made aware, if the completion intervals are within one thousand three hundred twenty feet [402.34 meters] of one another.

VIII. Appendix—Regulatory approaches: Ohio

- ODNR policy, starting in mid-2010s
  - Agency conducts analysis of well applications in the Rose Run field, which has vertical wells penetrating the Utica formation, to determine risk
  - Wells posing risk receive permit conditions that include offset wellbore monitoring; isolation of zones in offset wellbores; P&A of offset wells; modification of HF design (e.g. skipping stages)
  - More recently, since the emergence of induced seismicity in OH, wells near faults/fractures are subject to microseismic monitoring requirements that can pick up communication events

Information Courtesy of the EDF - Adam Peltz apeltz@edf.org

VIII. Appendix—Regulatory approaches: Oklahoma

- 165:10-3-1(a), 2017
  - As part of APD, plat w/ location and TD of all wells within 1/4 mile of completion interval of proposed well
- 165:10-3-10(b), 2017, rev. 2018
  - Five days' notice to offset operators within 1/2 mile of completion interval and completed in same common source of supply
  - If offset operator has evidence that HF ops have impacted its well(s), the operator may report to OCC via designated form

VIII. Appendix—Regulatory approaches: Pennsylvania

- § 78a.52a. Area of review (2016)
  - Operator identifies surface and bottomhole locations of all wells with wellbores within 1000’ feet of proposed wellbore, using official records, historical records, and landowner questionnaire
  - Operator provides a monitoring plan for at-risk offset wellbores
    - Per guidance, can include automatic shut-off devices, pressure gauges, tanks, gas detectors, visual monitoring

VIII. Appendix—Regulatory approaches: Pennsylvania

- § 78a.73. General provision for well construction and operation (2016)
  - Notification to operators with wells that penetrate within 1500’ of stim zone
  - Non-producing wells (orphaned, abandoned, P&A) that penetrate within 1500’ of stim zone must be visually monitored during stim
  - Operator must cease HF and notify agency immediately if there are indications at the well being stimulated or at offset wells of a communication incident (via treatment pressures, volumes, or surface expression)
    - Per guidance, rapidity of notification depends on severity of communication incident
  - Any non-producing well impacted by HF must be plugged or returned to production by operator
    - Per guidance, adoption may occur prior to HF
- See also Guidelines for Implementing Area of Review (AOR) Regulatory Requirement for Unconventional Wells (2016)

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VIII. Appendix—Regulatory approaches: Model Regulatory Framework

- Operator analysis of proximate wellbores and known faults and fractures that transect the stimulation zone, including anti-collision evaluation
- Attestation to regulator that any such wells, faults or fractures will not be a conduit for movement of fluids into a source of protected water
- Pre-stim offset operator notification

Information Courtesy of the EDF - Adam Peltz apeltz@edf.org

VIII. Appendix—Regulatory approaches: Alberta

- AER Directive 83 (2013)
  - HF plan that includes identification of each offset well, examination of integrity of those wells and determination of risk
  - Well control plan for each offset well
  - Notification plan for each offset well operator
  - Must attempt to make mutually acceptable well control plan ("Licensees of both offset and subject wells are responsible for maintaining control of its licensed wells at all times.")
  - Notification to offset well operator in case of communication event

Information Courtesy of the EDF - Adam Peltz apeltz@edf.org

VIII. Appendix—Former High Concern for Drinking Water

"EPA found scientific evidence that hydraulic fracturing activities can impact drinking water resources under some circumstances"… during

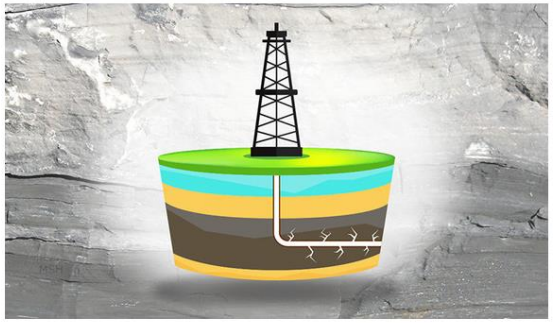
- **drought conditions (over use),**
- **poor handling of chemicals at the surface (spills),**
- **poor disposal of produced water**

VIII. Appendix—Former High Concern for Drinking Water

YaleNews EXPLORE TOPICS

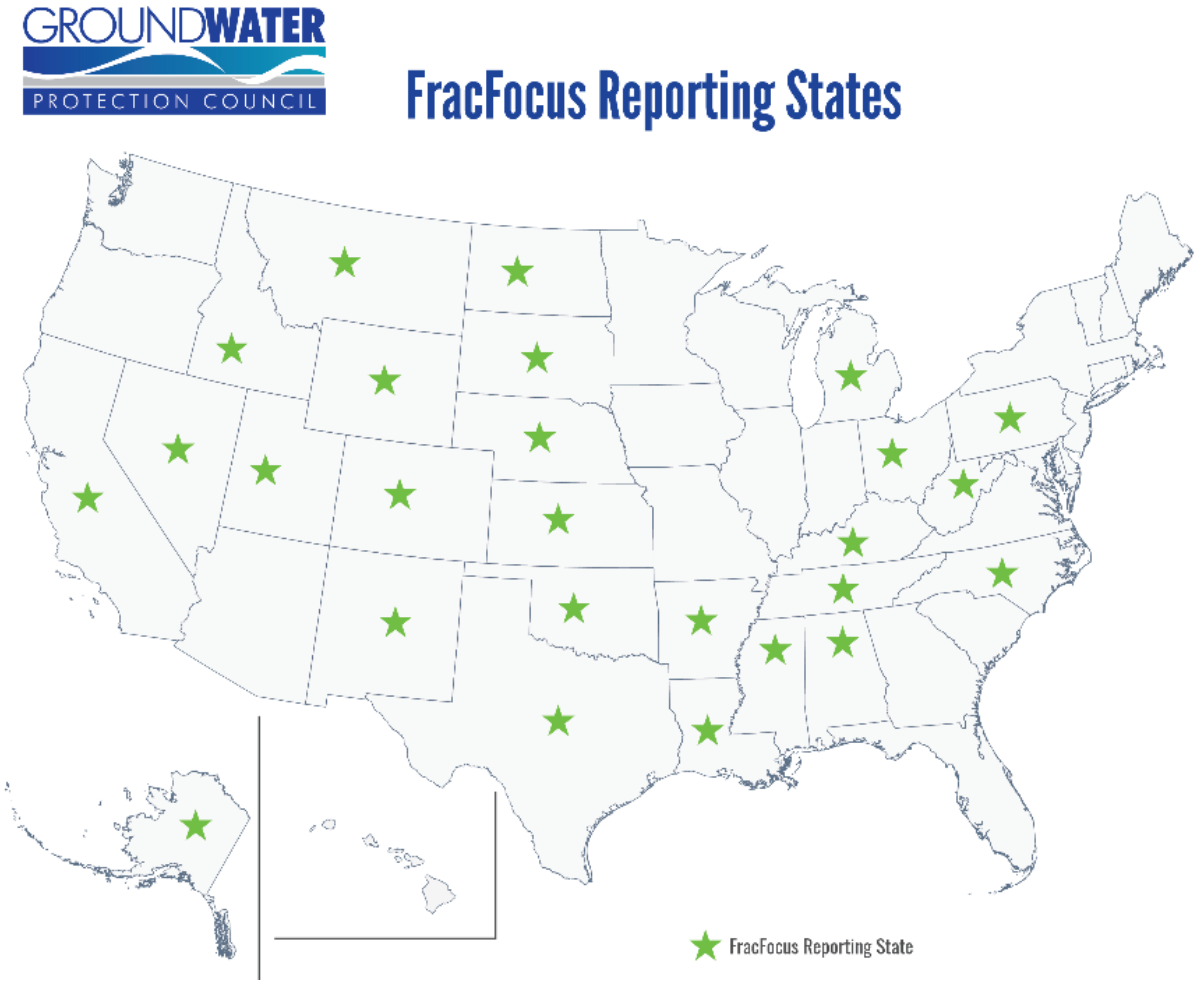
Study: Elevated organic compounds in Pennsylvania drinking water from hydraulic fracturing surface operations, not gas wells

By William Weir | OCTOBER 12, 2015



"In the largest study of its kind, a Yale-led investigation found no evidence that trace contamination of organic compounds in drinking water wells near the Marcellus Shale in northeastern Pennsylvania came from deep hydraulic fracturing…"

VIII. Appendix—Former High Concern for Chemical Disclosure



VIII. Appendix—Continuing High Concern for Climate Change

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  - Sources of Greenhouse Gas Emissions
  - Global Emissions
  - National Emissions
  - Facility-Level Emissions
  - Carbon Footprint Calculator
  - GHG Equivalencies Calculator

Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2016

View the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2016* (published 2018), developed by the U.S. Government to meet annual U.S. commitments under the United Nations Framework Convention on Climate Change (UNFCCC). EPA plans to publish responses to comments from public review of the *Inventory* on this page soon.

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