NATURAL GAS AND WATER QUALITY RISKS

JESSIE J. GREEN

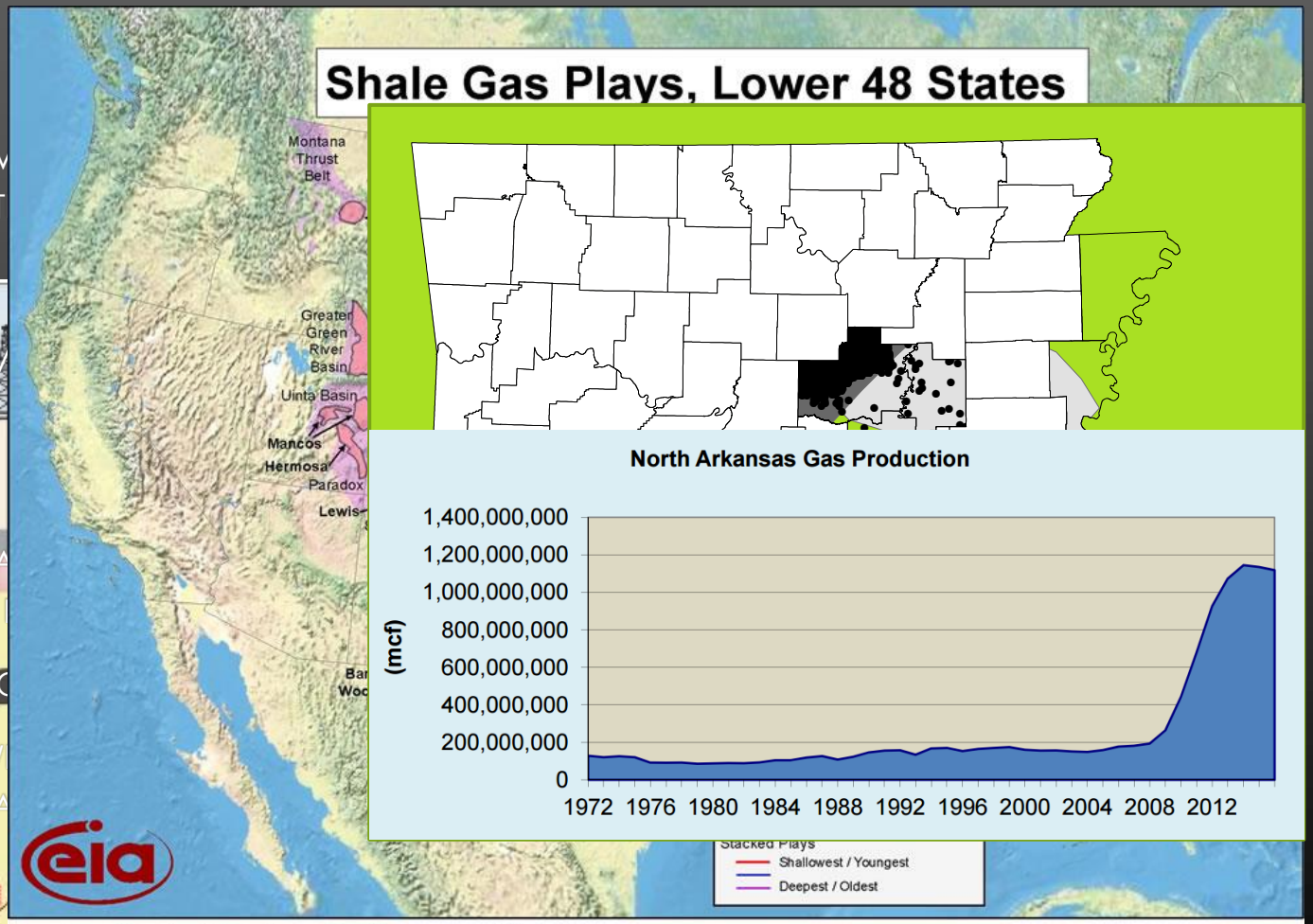
AQUATIC ECOLOGIST

ARKANSAS DEPARTMENT OF ENVIRONMENTAL QUALITY

greenj@adeq.state.ar.us

SCOPE OF TALK

- WHAT?
  - UNCONV
    GAS EXT
- WHERE?
  - FAYETTEV
    PLAY
- RISKS
  - POTENTIA
    QUALITY
  - ISSUES AC
  - WHAT W
    ARKANSA



HYDRAULIC FRACTURING WATER CYCLE

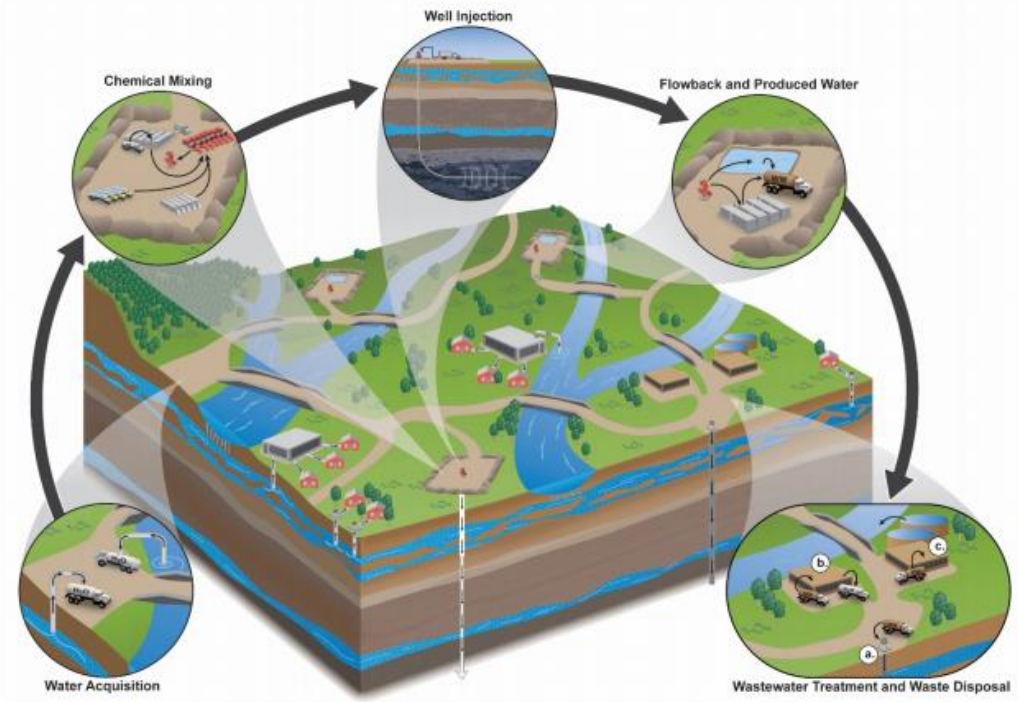


Figure ES-2. The stages of the hydraulic fracturing water cycle.

Shown here is a generalized landscape depicting the activities of the hydraulic fracturing water cycle and their relationship to each other, as well as their relationship to drinking water resources. Arrows depict the movement of water and chemicals. Specific activities in the "Wastewater Treatment and Waste Disposal" inset are (a)underground injection control (UIC) well disposal, (b) wastewater treatment and reuse, and (c) wastewater treatment and discharge at a centralized waste treatment (CWT) facility. Note: Figure not to scale.

U.S. EPA 2015*

TIMELINE OF COMMON WATER QUALITY RISKS

- **CONSTRUCTION**
  - Erosion
  - Physical Habitat Alteration
- **DRILLING/FRACKING**
  - Erosion
  - Spills
  - Water withdrawal
- **PRODUCTION**
  - Erosion
  - Spills
  - Waste Water Disposal
- **RECLAMATION**
  - Erosion

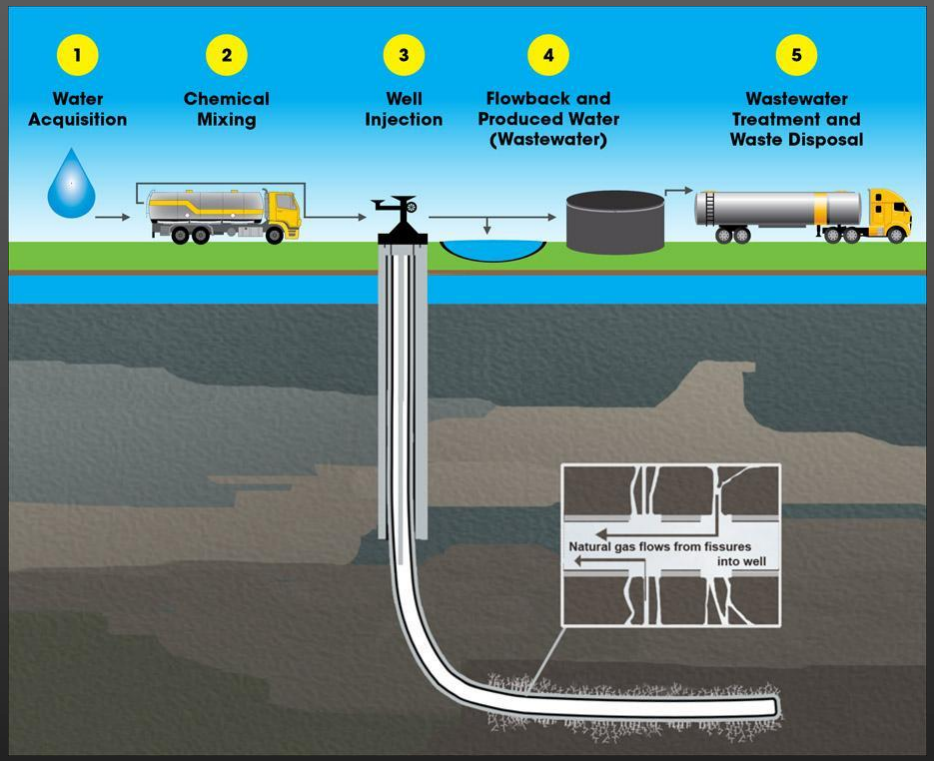
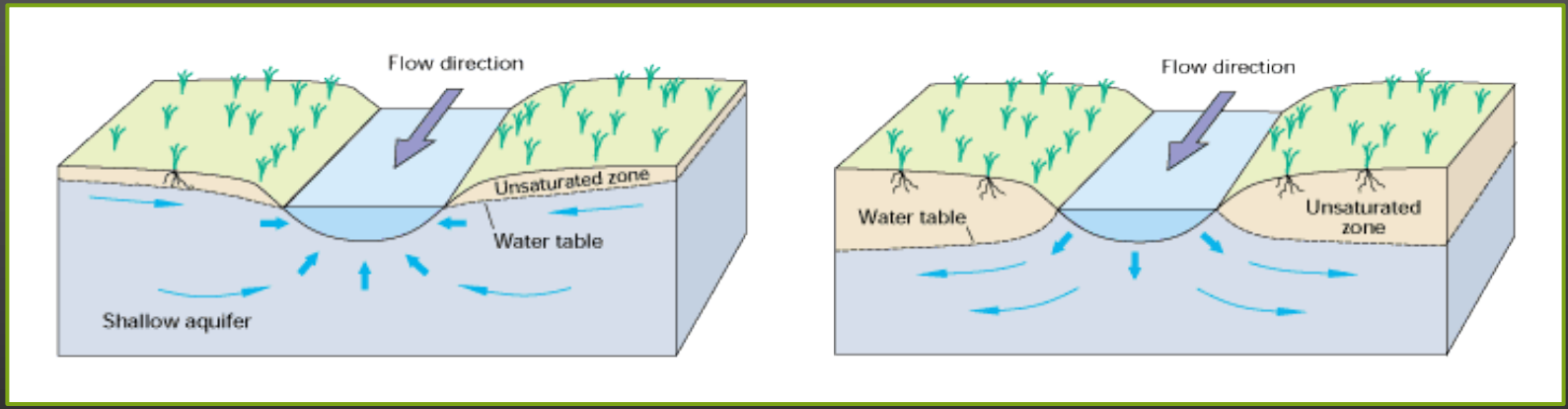


Image source: U.S. EPA

SURFACE AND GROUNDWATER INTERACTION



USGS 1998

SURFACE WATER RISKS

FEATURE

Hydraulic Fracturing and Brook Trout Habitat in the Marcellus Shale Region: Potential Impacts and Research Needs

Maya Weltman-Fahs

New York Cooperative Fish and Wildlife Research Unit, and Department of Natural Resources, 120 Bruckner Hall, Cornell University, Ithaca, NY 14853. E-mail: mw482@cornell.edu

Jason M. Taylor

New York Cooperative Fish and Wildlife Research Unit, and Department of Natural Resources, 120 Bruckner Hall, Cornell University, Ithaca, NY 14853

Activit

Sourc

Poten and

Organic matter

Sediment

Ecological endpoint

Stream eco

FIGURE 2
3 = high p

Ruptura hidráulica y el hábi
trucha de arrollo en la regió
cellus Shale: impactos pote
necesidades de investigación

RESUMEN: El crecimiento de las activi
foración de gas natural en la formación M
es una amenaza emergente para la conserv

Science of the Total Environment

CrossMark

Stream primary producers relate positively to watershed natural gas measures in north-central Arkansas streams

Bradley J. Austin [a,*], Natalia Hardgrave [b], Ethan Inlander [c], Cory Gallipeau [c], Sally Entrekin [b], Michelle A. Evans-White [a]

CrossMark

Concern has been raised in the scientific literature about the environmental implications of extracting natural gas from deep shale formations, and published studies suggest that shale gas development may affect local groundwater quality. The potential shipments of shale gas waste to treatment facilities, and water body characteristics. We exploit temporal and spatial variation in the location of wells and waste treatment facilities relative to water quality monitors to identify impacts on downstream water

503

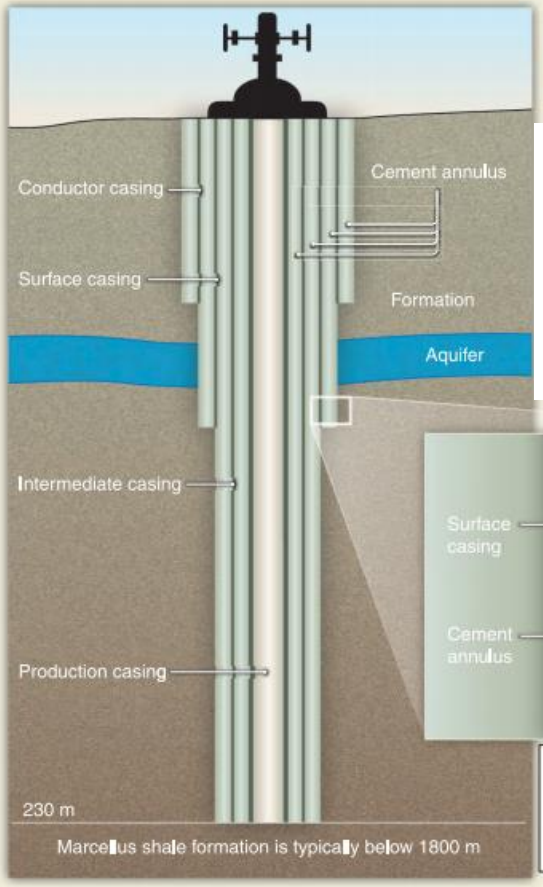
poses a threat to surface waters

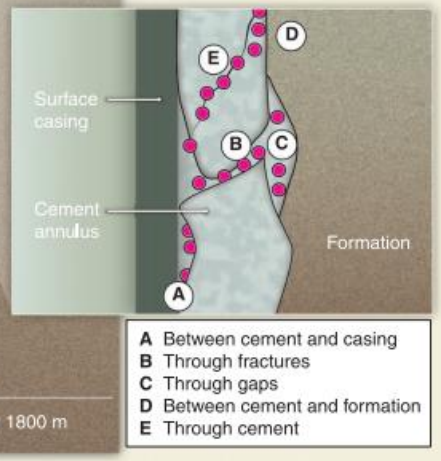
Sally Entrekin[1*], Michelle Evans-White[2], Brent Johnson[3], and Elisabeth Hagenbuch[4]

Hydraulic "Fracking": Are Surface Water Impacts An Ecological Concern?

G. Allen Burton Jr.,*† Niladri Basu,‡ Brian R. Ellis,§ Katherine E. Kapo,‖ Sally Entrekin,# and Knute Nadelhoffer††

GROUNDWATER RISKS





REVIEW SUMMARY

Impact of Shale Gas Development on Regional Water Quality

R. D. Vidic,[1]* S. L. Brantley,[2] J. M. Vandenbossche,[1] D. Yoxtheimer,[2] J. D. Abad[1]

READ THE FULL ARTICLE ONLINE
http://dx.doi.org/10.1126/science.1235009

Cite this article as R. Vidic *et al.*, *Science* **340**, 1235009 (2013). DOI: 10.1126/science.1235009

ENVIRONMENTAL SCIENCE & TECHNOLOGY

Article

pubs.acs.org/est

Evaluation of Water Quality in Private Drinking Water Wells Near ural Gas Extraction Sites in the Barnett Shale Formation

E. Fontenot,[†,⊥,∥] Laura R. Hunt,[†,⊥,∥] Zacariah L. Hildenbrand,[†,⊥] Doug D. Carlton Jr.,[†,⊥] olite Oka,[†] Jayme L. Walton,[†] Dan Hopkins,[‡] Alexandra Osorio,[§] Bryan Bjorndal,[§] Qinhong H. Hu,[†] evin A. Schug*,[†]

Marcellus Formation brine to fers in Pennsylvania

t B. Jackson[a,b], Thomas H. Darrah[a], Stephen G. Osborn[c], Adrian Down[b], Kaiguang Zhao[b], ngosh[a,1]

es, Nicholas School of the Environment, Duke University, Durham, NC 27708; [b]Center on Global Change, Nicholas niversity, Durham, NC 27708; and [c]Geological Sciences Department, California State Polytechnic University, Pomona,

Edited by Karl K. Turekian, Yale University, North Haven, CT, and approved May 10, 2012 (received for review January 5, 2012)

The debate surrounding the safety of shale gas development in the ble gas concentrations and an isotopic signature consistent with a

Biology Department, Duke University, Durham, NC 27708

Edited* by William H. Schlesinger, Cary Institute of Ecosystem Studies, Millbrook, NY, and approved April 14, 2011 (received for review January 13, 2011)

Directional drilling and hydraulic-fracturing technologies are dramatically increasing natural-gas extraction. In aquifers overlying

TIMELINE OF COMMON WATER QUALITY RISKS

- **CONSTRUCTION**
  - Erosion
  - Physical Habitat Alteration
- **DRILLING/FRACKING**
  - Erosion
  - Spills
  - Water withdrawal
- **PRODUCTION**
  - Erosion
  - Spills
  - Waste Water Disposal
- **RECLAMATION**
  - Erosion

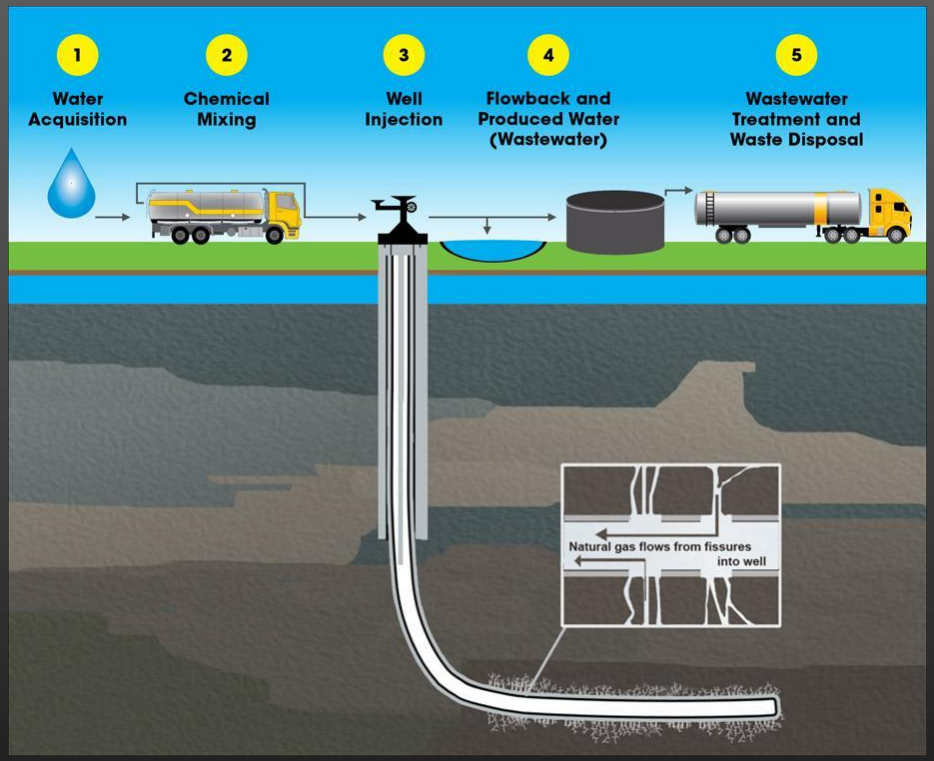


Image source: U.S. EPA

WATER QUALITY RISKS
EROSION

Photo credit: ADEQ O&G Inspectors

WATER QUALITY RISKS
EROSION → TURBIDITY

- ⬆ Sediment Runoff
- ⬆ Surface Water Turbidity
- Arkansas Laws & Regulations
  - A.C.A §8-4-217
    - (a)(1) – Cause pollution to waters of the state
    - (a)(2) – Place waste where likely to cause pollution to waters of the state
  - APC&EC Reg. no. 2
    - Reg. 2.503 – Turbidity
      - Specific Standards
      - "Shall be no distinctly visible increase"

Entrekin et al. 2011

WATER QUALITY RISKS

EROSION ⟶ DEPOSITED SEDIMENT


ADEQ Inspection #007349


Northwest Natural Imagery


ADEQ Inspection #007349

WATER QUALITY RISKS
INSTREAM SEDIMENT & AQUATIC LIFE

Photo Credit: Freshwater Illustrated

TIMELINE OF COMMON WATER QUALITY RISKS

- **CONSTRUCTION**
  - Erosion
  - Physical Habitat Alteration
- **DRILLING/FRACKING**
  - Erosion
  - Spills
  - Water withdrawal
- **PRODUCTION**
  - Erosion
  - Spills
  - Waste Water Disposal
- **RECLAMATION**
  - Erosion

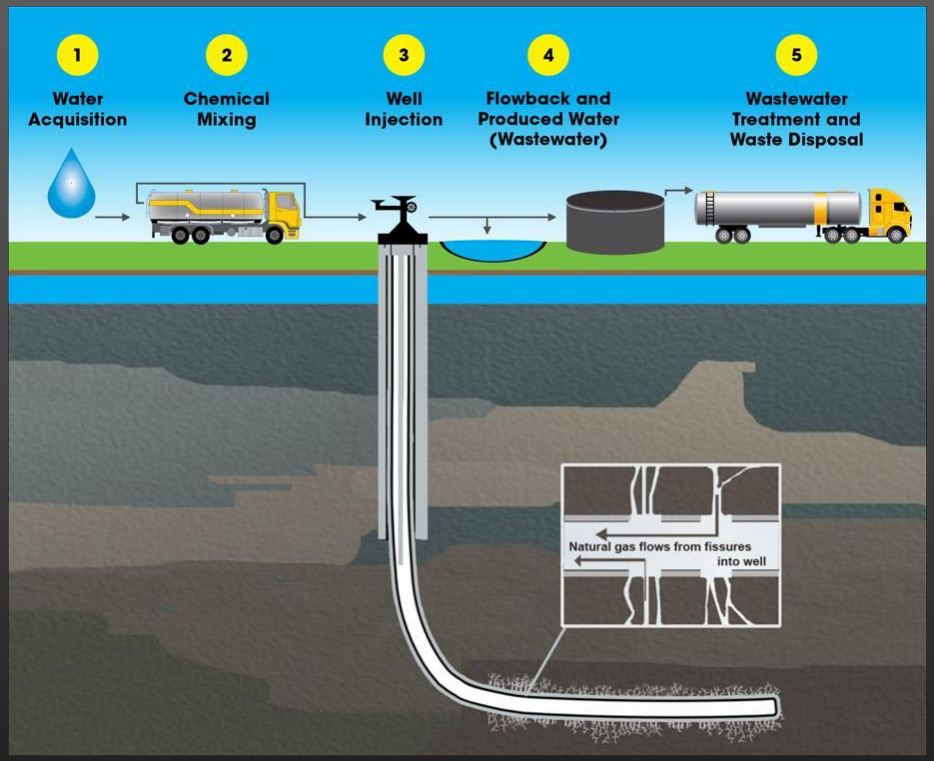


Image source: U.S. EPA

WATER QUALITY RISKS
PHYSICAL HABITAT ALTERATION

Photo Credit: Kerri McCabe

SHORT TERM ACTIVITY AUTHORIZATION (STAA)

- REG. 2.305 - AUTHORIZES **SHORT TERM** (24 - 96 HOURS) ACTIVITIES WHICH MIGHT CAUSE A VIOLATION OF THE ARKANSAS WATER QUALITY STANDARDS
- CONDITIONS
  - LIMIT CONSTRUCTION TO **LOW-FLOW** CONDITIONS (AS MUCH AS POSSIBLE)
  - TAKE ALL REASONABLE MEASURES TO **LIMIT EQUIPMENT & MACHINE USAGE IN WETTED AREA OF STREAM**
  - **UTILIZE BEST MANAGEMENT PRACTICES** (BMPS) TO MINIMIZE IMPACTS OF SEDIMENTATION AND TURBIDITY IN STREAMS IMPACTED BY PROJECT
  - TAKE ALL REASONABLE MEASURES TO **PREVENT CHEMICALS, OIL, GREASE, GASOLINE, DIESEL, OR OTHER FUELS FROM ENTERING WATERBODY**

*NO CONSTRUCTION ACTIVITY IS AUTHORIZED IN ANY STREAM DESIGNATED AS EXTRAORDINARY RESOURCE WATERS (ERW), ECOLOGICALLY SENSITIVE WATERBODIES (ESW), OR NATIONAL & SCENIC WATERWAYS (NSW)

TIMELINE OF COMMON WATER QUALITY RISKS

- **CONSTRUCTION**
  - Erosion
  - Physical Habitat Alteration
- **DRILLING/FRACKING**
  - Erosion
  - Spills
  - Water withdrawal
- **PRODUCTION**
  - Erosion
  - Spills
  - Waste Water Disposal
- **RECLAMATION**
  - Erosion

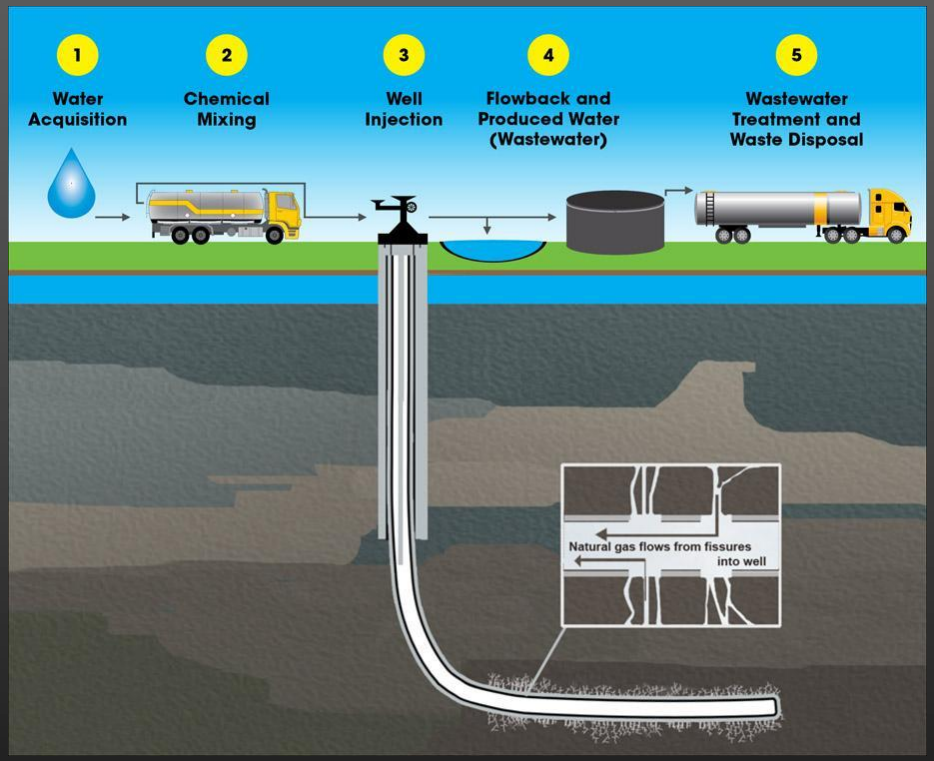


Image source: U.S. EPA

WATER QUALITY RISKS
SPILLS

Table 1. Categories of chemicals used in hydraulic fracturing, their purposes, and example(s) of a commonly used chemical[a]

Functional category	Purpose	Example(s) of chemical
Diluted acids	Improve injection and penetration; dissolve minerals and clays to minimize clogging, open pores, and aid gas flow	Hydrochloric acid
Biocide	Minimizes bacterial contamination of hydrocarbons, reduces bacterial production of corrosive by-products to maintain wellbore integrity and prevent breakdown of gellants	Glutaraldehyde
Breaker	Added near end of sequence to assist flowback from wellbore, breaks down gel polymers	Ammonium persulfate
Clay stabilizer	Establishes fluid barrier to prevent clays in formation from swelling, keeps pores open, creates a brine carrier fluid	Potassium chloride
Corrosion inhibitor	Maintains integrity of steel casing of wellbore by preventing corrosion of pipes and casings	*N,N*-Dimethylformamide
Crosslinker	Thickens fluid to hold proppant	Borate salts
Defoamer	Lowers surface tension and allows gas escape	Polyglycol
Foamer	Reduces fluid volume and improves proppant carrying capacity	Acetic acid (with NH_4 and $NaNO_2$)
Friction reducer	Improves fluid flow efficiency through wellbore by reducing friction between fluid and pipe, alleviates friction caused by high-pressure conditions	Polyacrylamide
Gel/gellant	Thickens fluid (water) to suspend proppant	Guar gum
Iron control	Prevents materials from hardening and clogging wellbore, prevents metal oxide precipitation	Citric acid
Oxygen scavenger	Maintains integrity of steel casing of wellbore, protects pipes from corrosion by removing oxygen from fluid	Ammonium bisulfate
pH adjusting agent/buffer	Controls pH of solution, protects pH-dependent effectiveness of other chemicals (e.g., crosslinkers)	Sodium carbonate, potassium carbonate
Proppant	Holds open (props) fractures to allow gas to escape from shale	Silica, sometimes glass beads
Scale control	Prevents mineral scale formation which can clog wellbore and block fluid or gas flow	Ethylene glycol
Solvents	Improve fluid wettability or ability to maintain contact between the fluid and the pipes	Stoddard solvent
Surfactant	Improves fluid flow through wellbore by reducing surface tension	Isopropanol

Burton et al. 2014

WATER QUALITY RISKS
SPILLS

- Onsite Storage, Mixing, and Pumping
- Truck accidents
- Flowback water
  - Lightening

ADEQ Inspection #069070

ADEQ ER #12-0804

TIMELINE OF COMMON WATER QUALITY RISKS

- **CONSTRUCTION**
  - EROSION
  - PHYSICAL HABITAT ALTERATION
- **DRILLING/FRACKING**
  - EROSION
  - SPILLS
  - WATER WITHDRAWAL
- **PRODUCTION**
  - EROSION
  - SPILLS
  - WASTE WATER DISPOSAL
- **RECLAMATION**
  - EROSION

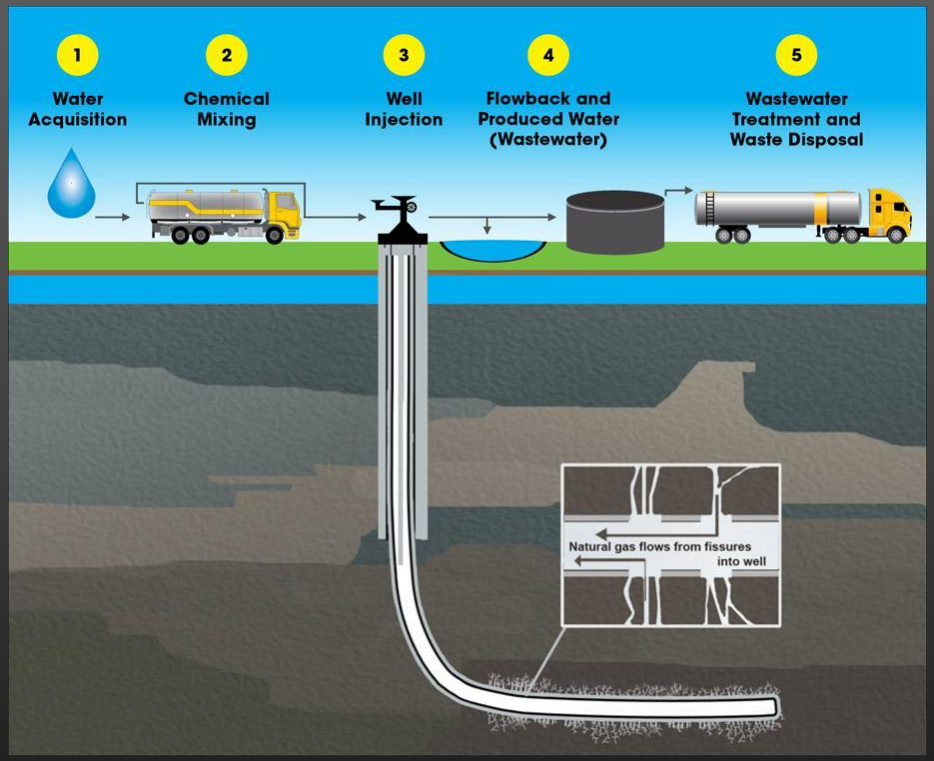
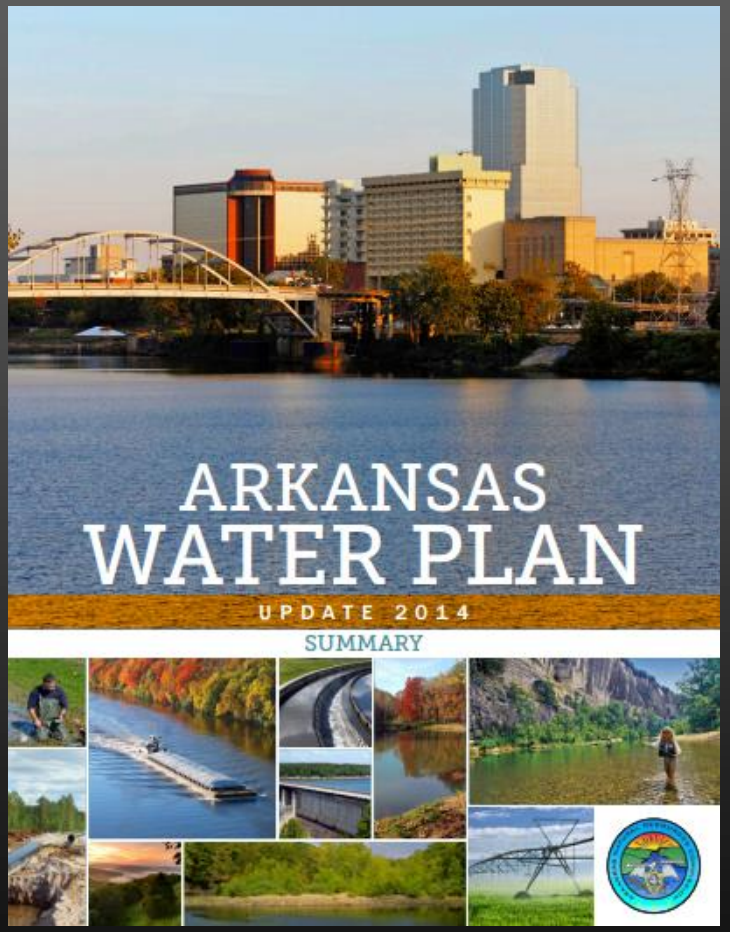


Image source: U.S. EPA

WATER QUALITY RISKS
WATER WITHDRAWAL

- ~ 4 Million Gallons/Well
- Potential to reduce groundwater and streamflow
- USEPA 2015* – "Southern and western Texas are two locations where hydraulic fracturing water use, low water availability, drought, and reliance on declining ground water has the potential to affect the quantity of drinking water resources."



TIMELINE OF COMMON WATER QUALITY RISKS

- **CONSTRUCTION**
  - EROSION
  - PHYSICAL HABITAT ALTERATION
- **DRILLING/FRACKING**
  - EROSION
  - SPILLS
  - WATER WITHDRAWAL
- **PRODUCTION**
  - EROSION
  - SPILLS
  - WASTE WATER DISPOSAL
- **RECLAMATION**
  - EROSION

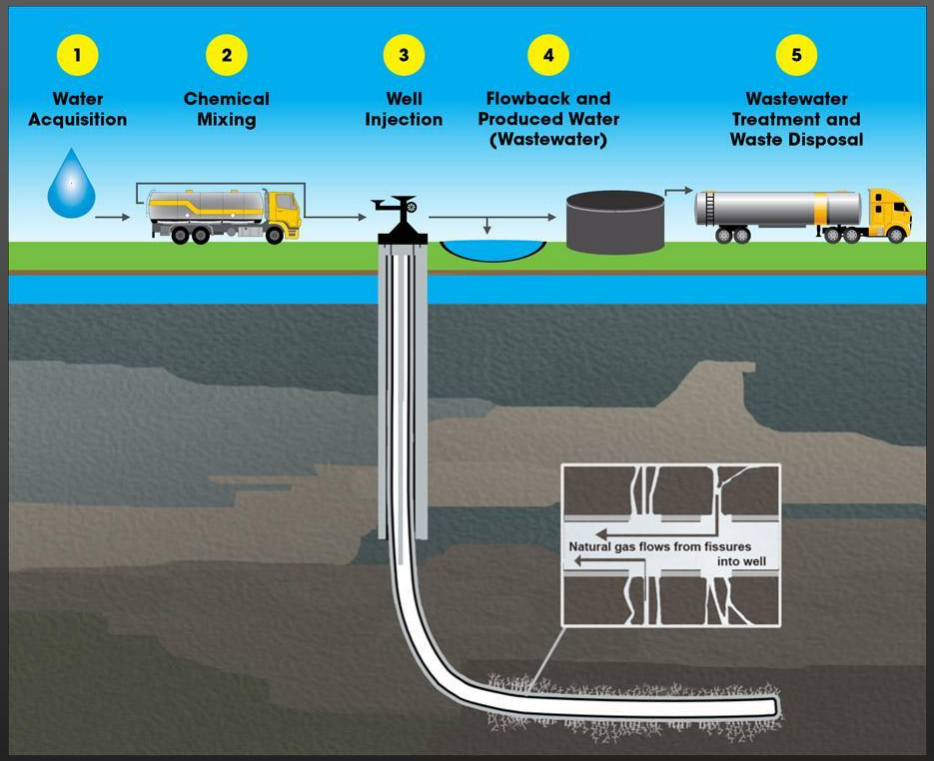


Image source: U.S. EPA

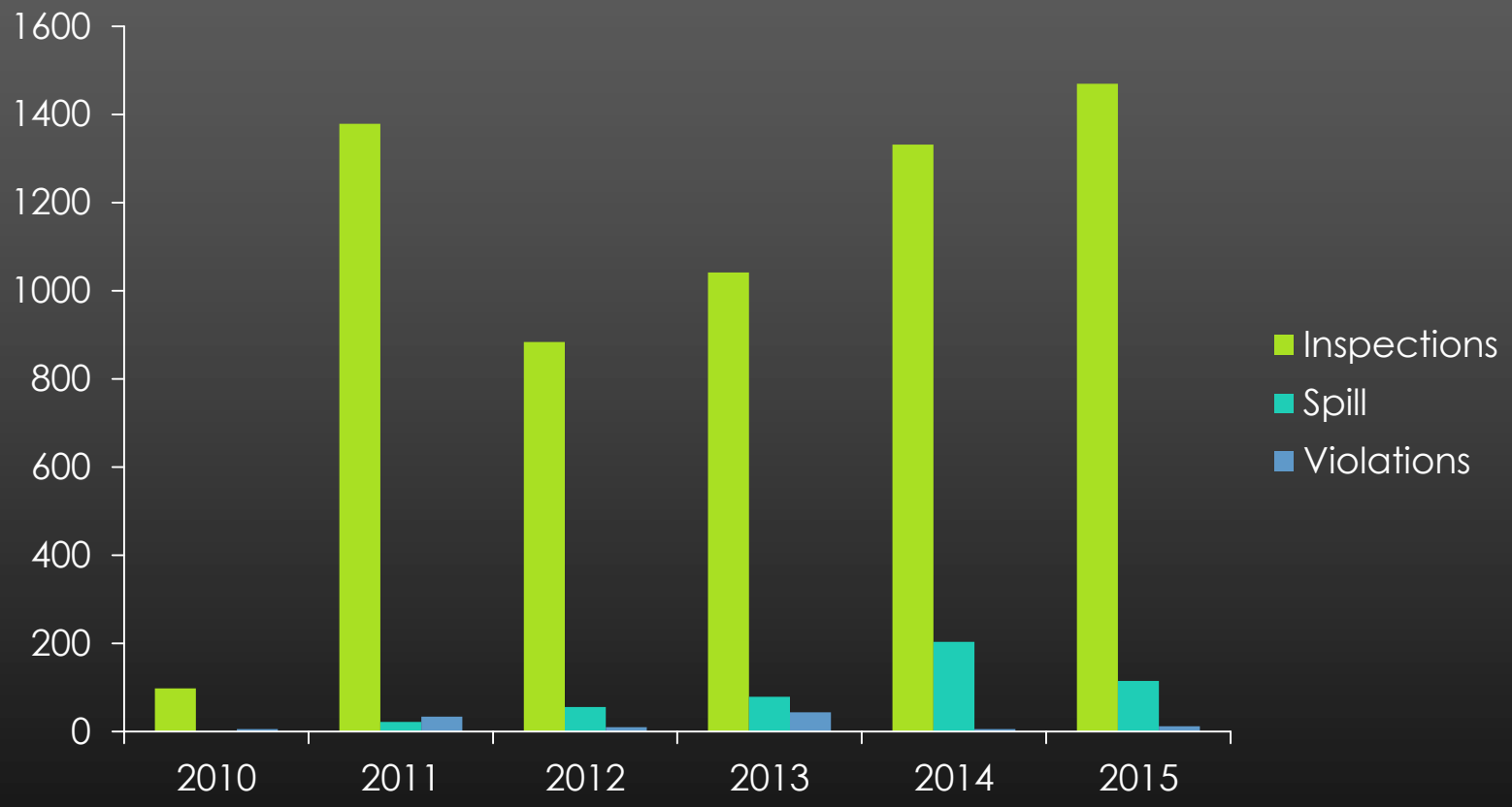
WATER QUALITY RISKS
WASTE WATER DISPOSAL

- Underground Injection Control Wells
- Land Application
- Waste Water Treatment

ADEQ O&G INSPECTIONS AT A GLANCE

- Types of Inspections
  - STAA
  - Drilling Pad
  - Gathering Line
  - Well Injection Site
  - Land Application Site
  - Water Quality Investigation
  - Emergency Response
  - Complaints
  - Enforcement Actions

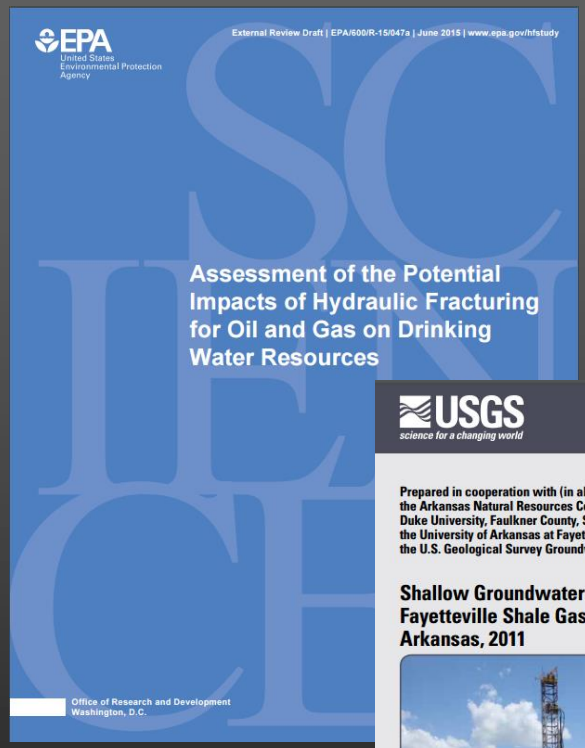
ADEQ INSPECTIONS AT A GLANCE
INSPECTIONS VS. VIOLATIONS

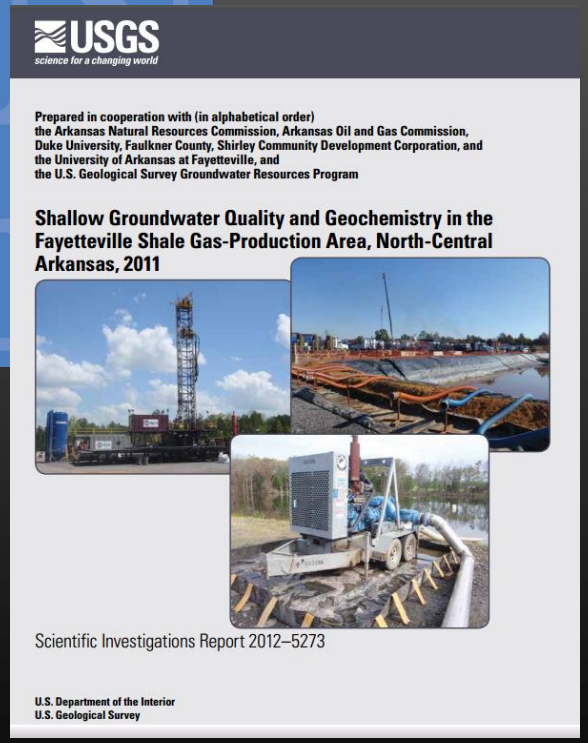


Note: Information presented from October 2010 to November 2015.

WATER QUALITY RISKS
CONTINUED RESEARCH

- USEPA and Drinking Water Resources – DRAFT Report
  - Before and After Studies
  - Information on Fracking Chemicals
- State of Arkansas Groundwater
  - USGS 2011 – No indication in Water Quality Degradation Related to Natural Gas Development





LITERATURE CITED

- AOGC (Arkansas Oil and Gas Commission). 2014. Annual Report of Production. http://www.aogc2.state.ar.us/OnlineData/reports/Annual_Report_of_Production_2014.pdf. (Accessed 14DEC2015)
- Austin, Bradley J., Natalia Hardgrave, Ethan Inlander, Cory Gallipeau, Sally Entrekin, and Michelle A. Evans-White. 2015. Stream primary producers relate positively to watershed natural gas measures in north-central Arkansas streams. *Science of The Total Environment,* **529**: 54-64.
- Burton, G. Allen, Niladri Basu, Brian R. Ellis, Katherine E. Kapo, Sally Entrekin, and Knute Nadelhoffer. 2014. Hydraulic "Fracking": Are surface water impacts an ecological concern? *Environmental Toxicology and Chemistry*, **33**: 1679-1689.
- Entrekin, Sally, Michelle Evans-White, Brent Johnson, and Elisabeth Hagenbuch. 2011. Rapid expansion of natural gas development poses a threat to surface waters. *Frontiers in Ecology and the Environment,* **9**: 503-511.
- Fontenot, Brian E., Laura R. Hunt, Zacariah L. Hildenbrand, Doug D. Carlton Jr, Hyppolite Oka, Jayme L. Walton, Dan Hopkins, Kevin A. Schug. 2013. An evaluation of water quality in private drinking water wells near natural gas extraction sites in the Barnett Shale Formation. *Environmental Science & Technology,* **47**: 10032-10040.
- Green, Jessie J. 2014. Examining effects of natural gas development on fishes of the Fayetteville Shale. Master's Thesis. University Of Central Arkansas.
- Johnson, Erica, Bradley J. Austin, Ethan Inlander, Cory Gallipeau, Michelle A. Evans-White, and Sally Entrekin. 2015. Stream macroinvertebrate communities across a gradient of natural gas development in the Fayetteville Shale. *Science of the Total Environment,* **530**: 323-332.

LITERATURE CITED

- Olmstead, Sheila M., Lucija A. Muehlenbachs, Jhih-Shyang Shih, Ziyan Chu, and Alan J. Krupnick. 2013. Shale gas development impacts on surface water quality in Pennsylvania. *Proceedings of the National Academy of Sciences,* **110**: 4962-4967.
- Osborn, Stephen G., Avner Vengosh, Nathaniel R. Warner, and Robert B. Jackson. 2011. Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing. *Proceedings of the National Academy of Sciences,* **108**: 8172-8176.
- U.S. EPA (United States Environmental Protection Agency). 2015. Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources (External Review Draft). U.S. EPA, Washington, DC, EPA/600/R-15/047.
- Vidic, R. D., S. L. Brantley, J. M. Vandenbossche, D. Yoxtheimer, and J. D. Abad. 2013. Impact of shale gas development on regional water quality. *Science,* **340**: 1235009.
- Warner, N. R., R. B. Jackson, T. H. Darrah, S. G. Osborn, A. Down, K. Zhao, A. White, and A. Vengosh. 2012. Geochemical evidence for possible natural migration of Marcellus Formation brine to shallow aquifers in Pennsylvania. Proceedings of the National Academy of Sciences **109**:11961-11966.
- Weltman-Fahs, Maya, and Jason M. Taylor. 2013. Hydraulic fracturing and brook trout habitat in the Marcellus Shale region: potential impacts and research needs. *Fisheries*, **38**: 4-15.
- Winter, Thomas. C., Judson W. Harvey, O. Lehn Franke, and William M. Alley. 1998. Ground water and surface water, A single resource. U.S. Geological Survey Circular 1139. 79 p.

QUESTIONS

SUBMIT A COMPLAINT

- CALL 501-682-0634
- ONLINE –
  - HTTPS://WWW.ADEQ.STATE.AR.US/COMPLAINTS/
- MOBILE APP

Get it on Google play

Available on the App Store