Singh, Angela K (DOA)

From:	Colombie, Jody J (DOA)
Sent:	Tuesday, April 02, 2013 8:38 AM
To:	Singh, Angela K (DOA)
Subject:	FW: Fracking letter and attachment scanned and attached
Attachments:	11021100.PDF

From: Delice Calcote [mailto:aitc.dcalcote@gmail.com]
Sent: Monday, April 01, 2013 4:23 PM
To: Colombie, Jody J (DOA)
Subject: Fracking letter and attachment scanned and attached

I hope this process has a clearer picture. I'll also bring a copy to the public comment meeting.
Thank you Jody.
Delice

ALASKA INTER-TRIBAL COUNCIL

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April 1, 2013

Alaska Oil and Gas Conservation Commission
333 West 7th Avenue
Anchorage, Alaska 99501
Submitted online at www.doa.alaska.gov/ogc/ jody.colombie@alaska.gov
Fax#: 907-276-7542

Re: Proposed regulations on hydraulic fracturing and workover operations: 20 AAC §§ 25.280, 25.283, and 25.990

To Whom This Concerns:

Thank you for the opportunity for the other undersigned organizations to submit comments on the Alaska Oil and Gas Conservation Commission's proposed Amendments (Amendments) to its regulations concerning workover operations, hydraulic fracturing, and definitions for hydraulic fracturing applications, operations, and reporting. We appreciate your efforts to promote safe and responsible oil and gas development statewide, in both permafrost and non-permafrost areas. The proposed regulations support this goal and go a long way toward providing the public with critical information regarding fracturing. In addition to the comments provided below we, hereby, incorporate by reference, into this document, the comments submitted by the Wilderness Society on today's date.

Our specific comments include the following:

A. On behalf of Tribes and Tribal Communities in Alaska, Alaska Inter-Tribal council asserts, maintains and retains jurisdiction of water quantity, water quality and beneficial uses of water since time immemorial in particular AI-TC is concerned that the AOGCC proposed regulations have no mention of water flow impacts to Tribal lands, customary and traditional natural resources for fishing, hunting and gathering and the commercial economy: guiding and tourism. Fracking includes polluting enormous amounts of water with is considered taboo in many tribal societies. Stringent regulations requiring composition of fracking chemicals must be disclosed before hydrological fracking is approved. Please see the comments below that AI-TC has incorporated from the Center for Water Advocacy.

I. Pre And Post Hydraulic Fracturing Water Well Water Sampling And

Analysis

We are encouraged by the AOGCC's proposal to analyze the impacts of fracking operations on water quality as part of the amendments. However, he amount of water needed in the hydraulic fracturing process is typically substantial and depending on the type of formation (coalbed, shale, or tight sands) and the fracturing operations (e.g., well depth and length, fracturing fluid properties, and fracture job design) can range from 50,000 to 4 million gallons of water per horizontal well.[1]

Large volumes of water withdrawals for hydraulic fracturing are different from withdrawals for other purposes in that much of the water used for the fracturing process may not be recovered after injection. The impact from large volume water withdrawals varies not only with geographic area, but also with the quantity, quality, and sources of the water used and could stress drinking water supplies, especially in drier regions where aquifer or surface water recharge is limited. This could lead to lowering of water tables or dewatering of drinking water aquifers, decreased stream flows, and reduced volumes of water in surface water reservoirs which could impact the availability of water for drinking in areas where hydraulic fracturing is occurring.[2]

We, therefore, recommend that the Amendments include analysis of the impacts of water use from hydro-fracking including the following:

A. Analysis On How Much Water Is Used In Hydraulic Fracturing Operations, And The Sources Of This Water.

Source water for hydraulic fracturing operations can come from a variety of sources, including ground water, surface water, and recycled flowback.[3] Water acquisition has not been well characterized, so AOGCC should gain a better understanding of the amounts and sources of water being used for hydraulic fracturing operations.

The Rules should, therefore, require hydro-fracking operators to provide information on hydraulic fracturing fluid source water resources including information on the total volume, source, and quality of the base fluid needed for hydraulic fracturing at 350 hydraulically fractured oil and gas production wells. This analysis should produce the following:

• A list of volume and water quality parameters important for hydraulic fracturing operations.

• Information on source, volume, and quality of water used for hydraulic fracturing operations.

• Location-specific data on water use for hydraulic fracturing; and

[1] Holditch, 1993; Jeu et al., 1988; Palmer et al., 1991 and 1993; API, 2010a; GWPC and ALL Consulting, 2009; Satterfield et al., 2008.

[2] EPA Hydraulic Fracturing Study Plan at 25.

[3] EPA Hydraulic Fracturing Study Plan at 24.

• Location-specific examples of water acquisition, including data on the source, volume, and quality of the water.

The Rules should also require operators to monitor the volumes, sources, and quality of water needed for hydraulic fracturing operations. The data received from operators will inform AOGCC's understanding of the general water quantity and quality requirements for hydraulic fracturing.

B. How Water Withdrawals Affect Short- And Long-Term Water Availability In the Local Area

As the intensity of hydraulic fracturing activity increases within individual watersheds and geologic basins, it is important to understand the net impacts on water resources and identify opportunities to optimize water management strategies. The Rules should, therefore, require operators to compile data on water use and the hydrology of River Basins where fracking is expected to take place in Alaska. These data should include ground water levels, surface water flows, and water quality as well as data on hydraulic fracturing operations, such as the location of wells and the volume of water used during fracturing. A list of gallons being diverted by day to fracking activities is not available in a central location. This information being withheld will tend to limit the effectiveness of Tribal Communities to be fully informed of the natural resources they use and rely on.

Operators should also be required to provide simple water balance and geographic information system (GIS) analysis using existing data and information on hydrological trends over the same period of time. Operators should compare control areas with similar baseline water demands and no oil and gas development to areas with intense hydraulic fracturing activity, isolating and identifying any impacts of hydraulic fracturing on water availability. Further, the Rules should require that critical analysis of trends in water flows and water usage patterns be conducted in areas where hydraulic fracturing activities are occurring to determine whether water withdrawals alter ground and surface water flows. Such data collection would support the assessment of the potential impacts of hydraulic fracturing on water availability at various spatial scales (e.g., site, watershed, basin, and play) and temporal scales (e.g., days, months, and years).[4] Site specific impacts research should, therefore, include the following:

- Maps of recent hydraulic fracturing activity and water usage.
- Information on whether water withdrawals for hydraulic fracturing activities alter ground or surface water flows.
- Assessment of impacts of hydraulic fracturing on water availability at various spatial and temporal scales.
- Assessment of impacts of lessened water flows on impacts to subsistence resources: fish, marine life, land mammals and plant life.

Finally, the Rules should require operators to conduct scenario evaluations to assess potential long-term quantity impacts as a result of cumulative water withdrawals. The evaluations should focus on hydraulic fracturing operations at various spatial and temporal scales and should include at least two futures: (1) average annual conditions in 10 years based on the full exploitation of oil and natural gas resources; and (2) average annual conditions in 10 years based on sustainable water use in hydraulic fracturing operations. Both scenarios should build on predictions for land use and climate (e.g., drought, average, and wet). The spatial scales of analysis should reflect both environmental boundaries (e.g., site, watershed, river basin, and geologic play) and political boundaries (e.g., city/municipality, county, state, and AOGCC Region).

C. What Are The Possible Impacts Of Water Withdrawals For Hydraulic Fracturing Operations On Local Water Quality?

Withdrawals of large volumes of ground water can lower the water levels in aquifers or ground water in general.[5] This can affect groundwater quality by exposing naturally occurring minerals to an oxygen-rich environment, potentially causing chemical changes that affect mineral solubility and mobility, leading to salination of the water and other chemical contaminations. Additionally, lowered water tables may stimulate bacterial growth, causing taste and odor problems and an upwelling of lower quality water and other substances (e.g., methane from shallow deposits) from deeper within an aquifer and could lead to subsidence and/or destabilization of the geology.[6] Methane releases into the

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[4] EPA Hydraulic Fracturing Study Plan November 2011 26

[5] *Id.* at 27.

[6] *Id.*

atmosphere are a concern for the northern latitudes: National Geographic, published: December 2012: Good Gas, Bad Gas: "...The United States produces the bulk of its own gas, but U.S. production peaked in 1973. By 2005 the country seemed to be running short, and the industry was building expensive new tanker terminals to import liquefied natural gas. The fracking boom changed that. Since 2005 gas production from deep shales has increased more than tenfold; it now accounts for more than a third of total production, which last year surpassed the 1973 record. Within a decade, according to a Department of Energy (DOE) forecast, the U.S. will become a net exporter of gas.

Estimates of how much gas is locked up in shales and how long the boom can last have varied widely. In 2011 DOE put the amount of "unproved resources" of shale gas at 827 trillion cubic feet; in 2012 it cut that estimate by more than 40 percent. Production from fracked wells has declined faster than DOE analysts had expected. So some critics believe the boom is a bubble that will soon burst. But DOE still projects that U.S. gas production will rise rapidly and that shale gas will make up half the total by 2035."

Withdrawals of large quantities of water from surface water resources (e.g., streams, lakes, and ponds) can significantly affect the hydrology and hydrodynamics of these resources. Such withdrawals from streams can alter the flow regime by changing their flow depth, velocity, and temperature.[7] Additionally, removal of significant volumes of water can reduce the dilution effect and increase the concentration of contaminants in surface water resources.[8] Furthermore, it is important to recognize that ground and surface water are hydraulically connected[9] any changes in the quantity and quality of the surface water can affect ground water and vice versa.[10]

Finally, the Rules should require collection of data on the quality of ground and surface waters that may be used for hydraulic fracturing before and after water is removed for hydraulic fracturing purposes. Such data could be used to analyze changes in water quality in watersheds where hydro-fracking will take place to determine if any changes are due to surface or ground water withdrawals for hydraulic fracturing and if there are any changes in local water quality and if these changes are a result of water withdrawals associated with hydraulic fracturing.

II. The Use of Water Related to Temporary Water Use Permits

The Rules should address the, potential, impacts of the Division of Land, Water and Mining's (Division's) issuance of Temporary Water Use Permits (TWUPs), for hydro-fracking purposes, on water resources and human health and welfare. Under the Alaska Water Use Code:

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[7] Zorn et al., 2008

[8] Pennsylvania State University, 2010

[9] Winter et al., 1998

[10] EPA Hydraulic Fracturing Study Plan at 27.

Anyone who diverts, impounds, or withdraws a significant amount of water for use, without a permit, certificate, or authorization is guilty of a misdemeanor (AS 46.15.180). A significant amount of water is defined… as:

- the consumptive use of more than 5,000 gallons of water from a single source in a single day;
- the regular daily or recurring consumptive use of more than 500 gpd from a single source for more than 10 days per calendar year;
- the non-consumptive use of more than 30,000 gpd (0.05 cubic feet per second) from a single source; or
- any water use that may adversely affect the water rights of other appropriators or the public interest.[11]

The Division's issuance of a Temporary Water Use Authorizations (TWUPs) however, are often contrary to 11 AAC 93.035 because, as part of the TWUPs, it, often, authorizes the withdrawal of an amount of consumptive use that is over the prescribed 5,000 gpd. In addition, regardless of the fact that the "Commissioner will issue a permit only if he/she "finds that… the proposed appropriation is in the public interest."[12] TWUPs, often, negatively impact the water rights of other appropriators and/or the public interests. Based on the fact that, in the case of hydro-fracking, TWUPs are used to develop oil and gas resources, the primary impact of granting the Application would be to the local residents who live in the vicinity of the drilling operations and fish and wildlife habitat in the vicinity of the water withdrawals.

In determining the public interest in relation to TWUPs, therefore, the Division must comply with the following provisions of the Alaska Water Use Code:

a) Detriments to Fish and Game Resources

"In determining the public interest, the commissioner shall consider…the effect on fish and game resources and on public recreational opportunities…[13] Hydro-fracking operations, for example, typically result in the destruction of an average of nine acres of habitat. This does not include acreage lost to pipelines. On average, each well pad requires 1.65 miles of gathering pipelines, which carry the gas to a network of larger transportation pipelines.[14] The combination of the well pad, pipeline and other drilling related facilities, therefore, significantly threatens wildlife habitat in the area of the oil and gas drilling.

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[11] http://dnr.alaska.gov/mlw/water/wrfact.cfm. *See*, 11 AAC 93.035(a) and (b)
[12] AS 45.015.080(34).
[13] AS 45.015.080(b)(3).
[14] The Fracking of Racheal Carson, Silent Spring's lost legacy, told in fifty parts. http://www.orionmagazine.org/index.php/articles/article/7005

b). *Detriments to Public Health*

"In determining the public interest, the commissioner shall consider…the effect on public health…"[15] During all stages of hydro-fracking drilling, there is significant potential for fluids and/or naturally occurring substances to be introduced into drinking water resources resulting in toxicity and potential human health effects associated with these possible drinking water contaminants.[16] This exposure results from chemicals used in the fluids, naturally occurring substances that may be released from subsurface formations during the drilling process, and chemicals that are present in hydro-fracking operation wastewaters.[17] Worse, based on the number of chemicals, currently, known to be used in oil and gas drilling operations, there could be several hundred chemicals of potential concern for drinking water resources.[18]

d) Harm to other Persons

"In determining the public interest, the commissioner shall consider…harm to other persons resulting from the proposed appropriation."[19] As in the case of hydro-fracking:

> the impact from the removal of large volumes of water from hydrological systems could stress drinking water supplies and existing water rights and water uses. This could lead to lowering of water tables or dewatering of drinking water aquifers, decreased stream flows, and reduced volumes of water in surface water reservoirs and impact the availability of water for drinking. The lowering of water levels in aquifers can necessitate the lowering of pumps or the deepening or replacement of wells...[20]

In fact, there may be individual water right permittees who retain water rights or applicants who have applied for water rights in the same general location of the drilling operations related to TWUPs issued for fracking operations. If such individual applications retain an earlier priority date than the TWUPs in question and the point of diversion is from the same or a hydrologically connected source, this would be clearly contrary to the public interest standard of AS 45.015.080 and therefore, a violation of the significant use provisions of 11 AAC 93.035.

III. Impacts to Basic Human Rights

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[15] AS 45.015.080(b)(4).
[16] Plan to Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources, Office of Research and Development, US Environmental Protection Agency, Washington, D.C., p. 71, November 2011 (AOGCC Plan).
[17] *Id.*
[18] *Id.*
[19] AS. 45.015.080(b)(6).
[20] AOGCC Plan p. 25.

CWA is encouraged by the notification of landowners, surface owners, and operators within one-quarter mile of the wellbore trajectory; disclosure of the chemical makeup of hydraulic fracturing fluids; containment of hydraulic fracturing fluids; casing and cementing; and disclosure of the intent to use a well for hydraulic fracturing on an application for a permit to drill contained in the proposed rules. We encourage the AOGCC to expand these amendments to contemplate the fact that hydro-fracking permits, could result in negative impacts to human health, environmental impacts and the public interest. Issuance of hydro-fracking permits, therefore, potentially, impacts basic human rights as recognized in Alaska state law including the general reservation of surface and subsurface waters for fish and game and the protection of due process under the Alaska Constitution, the Public Trust Doctrine and water rights.

a. Alaska Constitution

The hydro-fracking permits are potentially contrary to the general reservation for fish and wildlife found in Alaska's Constitution's because they would deprive the public of the right to ground and surface water necessary to maintain economic, subsistence, commercial and sport resources[21] and, potentially interfere with the interests of existing water right permittees and applicants in retention of the original priority date over any potential conflicting water uses.[22]

b. The Public Trust Doctrine

Hydro-fracking operations, implicate Alaska's Public Trust Doctrine which calls for protection of in-stream flows and subsistence uses for state citizens. The U.S. Supreme Court, for example, concludes that "the ownership and dominion and sovereignty over lands…with…states, belong to the respective states…to use or dispose of any portion, thereof, when that can be done without substantial impairment of the interest of the public…"[23] That the Doctrine applies to TWUPs, therefore, is illustrated by the fact that "there can be no irrepealable contract in conveyance of property by a grantor in disregard of a public trust, under which he was bound to hold and manage it."[24]

Similarly, the public trust doctrine is implicitly supported by the Alaska Constitution which provides "[w]herever occurring in their natural state, fish, wildlife and waters are reserved to people for common use."[25] In addition, since statehood, decisions by the Alaska Supreme Court has recognized the force of the Public Trust Doctrine, has expanded its scope removing any question that the Doctrine and its role in the preservation of Alaska's natural resources is implicit in the Constitution. These implications are illustrated by the fact that the Alaska Supreme Court concludes that the

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21 *Id* at 14.

22 *Id* at 14-15. "Under the principle of 'prior appropriation,' when more than one application for water use competes for the same flow of water, whichever application was received by the administering agency earliest will be senior to the later application, and the junior user cannot use any water that would adversely affect the senior user." *See* Robert E. Beck & Owen L. Anderson, *Elements of Prior Appropriation*, *in* WATERS AND WATER RIGHTS § 12.01.

[23] *Illinois Cent Co v. State of Illinois City of Chicago v. Illinois Cent Co State of Illinois v. Illinois Cent*, 146 U.S. 387, 465 (1892) (emphasis added).

[24] *Id.*

[25] Article VIII, Section 3.

"common use" clause was unique in relation to other state constitutions and was established to avoid exclusive control over resources by the State by imposing a public trust duty to prevent such control.[26]

Conclusion

We are encouraged by the AOGCC's efforts to amend the State's hydro-fracking rules and to address water quality, disclosure and containment requirements for the protection of human health and the environment. We are concerned, however, that the Rules do not address the substantial impacts that fracking can have on water flow and availability for fish and wildlife habitat and subsistence uses. Similarly, we believe the rules should address the issuance of water right permits that may violate the Alaska State Water Use Code. Please contact Hal Shepherd with CWA (waterlaw@uci.net) if you have any questions regarding this letter or these requests.

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[26] *Owsichek v. State, Guide Licensing and Control Bd.*, 763 P.2d 488, 491 (Alaska,1988).

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[26] *Owsichek v. State, Guide Licensing and Control Bd.*, 763 P.2d 488, 491 (Alaska,1988).

Photo Gallery

Thiessen Photography

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Breaking Fuel From the Rock

U.S. energy industry innovators unlocked the natural gas found in deep shale rock by combining and supercharging old oil industry techniques.

Methane

Published: December 2012

Good Gas, Bad Gas

Burn natural gas and it warms your house. But let it leak, from fracked wells or the melting Arctic, and it warms the whole planet.

By Marianne Lavelle
Photograph by Mark Thiessen

The last rays of sun filter through the snow-covered spruces along the shore of Goldstream Lake, just outside Fairbanks, Alaska. Out on the lake Katey Walter Anthony stares at the black ice beneath her feet and at the white bubbles trapped inside it. Large and small, in layer upon layer, they spread out in every direction, like stars in the night sky. Walter Anthony, an ecologist at the University of Alaska Fairbanks, grabs a heavy ice pick and wraps the rope handle around her wrist. A graduate student holds a lighted match above a large bubble; Walter Anthony plunges the pick into it.

Gas rushing from the hole ignites with a *whoomp* that staggers her. "My job's the worst, because usually you catch on fire," she says, smiling. In the gathering twilight she and her team ignite one bubble after another.

The flames confirm that the bubbles are methane, the main component of natural gas. By counting and measuring them, Walter Anthony is trying to gauge how much methane is rising from Goldstream Lake—and from the millions of similar lakes that now occupy nearly a third of the Arctic region. The Arctic has warmed much faster than the rest of the planet in recent decades, and as the permafrost has melted, old lakes have grown and new ones have formed. Methane bubbles from their muddy depths in a way that is hard to quantify—until the first clear ice of fall captures a snapshot of the emissions from an entire lake.

Sometimes as Walter Anthony walks that ice, in Alaska, Greenland, or Siberia, a stamp of her boot is enough to release an audible sigh. Some lakes, she says, have "hot spots" where the methane bubbling is so strong that ice never forms, leaving open holes big enough to spot from an airplane. "It could be 10 or 30 liters of methane per day from one little hole, and it does that all year," she says. "And then you realize there are hundreds of spots like that and millions of lakes." By venting methane into the atmosphere, the lakes are amplifying the global warming that created them: Methane is a potent greenhouse gas. Carbon dioxide is the main one, because the atmosphere holds 200 times as much of it. But a given amount of methane traps at least 25 times as much heat—unless you burn it first. Then it enters the atmosphere as CO_2.

That's the other side of this Jekyll-and-Hyde story: A lot of methane is being burned these days. In the past decade the technology called hydraulic fracturing, "fracking" for short, has enabled drillers in the United States to extract natural gas from deeply buried shales they couldn't tap before. Natural gas supplies have surged, prices have plummeted. Fracking is now spreading around the world, and it's controversial. The gas boom has degraded landscapes and polluted water. But it has also had environmental benefits. Natural gas burns much cleaner than coal. In part because American power plants have been switching from coal to cheap gas, U.S. emissions of CO_2 from fossil fuels fell last year, even as the world set another record.

The catch is, methane emissions are rising. What's coming out of Arctic lakes is troubling, Walter Anthony says, because some of it seems to be coming not from bottom mud but from deeper geologic reservoirs that had hitherto been securely capped by permafrost—and that contain hundreds of times more methane than is in the atmosphere now. Still, most methane emissions today come from lower latitudes, and most are related more directly to human activities. A growing amount seems to be leaking, for instance, from gas wells and pipelines. Just how warm Earth gets this century will hinge in part on how we balance the good and bad of methane—on how much of it we capture and burn, and how much we inadvertently let loose.

Methane is the simplest hydrocarbon—a single carbon atom surrounded by four hydrogen atoms. It usually forms when larger organic molecules are broken down, either by microbes or by heat. The microbes produce it when they eat dead plant matter in wet, oxygen-poor environments. They're the source of the methane bubbling up from Goldstream Lake; from swamps and marshes all over; from human-made rice fields, landfills, and manure lagoons; and from the stomachs of cows and other ruminants. Termites emit a lot of methane too.

Most of the natural gas we tap for fuel, however, was formed not by microbes but by heat and pressure deep underground—as oil and coal were, and often in the same places. In coal mines methane is an explosion hazard; in oil fields it was long considered a nuisance to be burned off or, worse, vented directly into the atmosphere. Liquid oil was more valuable as fuel and much easier to transport to markets. Then pipelines built during the post–World War II construction boom made gas more transportable. The energy industry began to exploit massive natural gas reservoirs in places like Russia, Qatar, and Iran.

The United States produces the bulk of its own gas, but U.S. production peaked in 1973. By 2005 the country seemed to be running short, and the industry was building expensive new tanker terminals to import liquefied natural gas. The fracking boom changed that. Since 2005 gas production from deep shales has increased more than tenfold; it now accounts for more than a third of total production, which last year surpassed the 1973 record. Within a decade, according to a Department of Energy (DOE) forecast, the U.S. will become a net exporter of gas.

Estimates of how much gas is locked up in shales and how long the boom can last have varied widely. In 2011 DOE put the amount of "unproved resources" of shale gas at 827 trillion cubic feet; in 2012 it cut that estimate by more than 40 percent. Production from fracked wells has declined faster than DOE analysts had expected. So some critics believe the boom is a bubble that will soon burst. But DOE still projects that U.S. gas production will rise rapidly and that shale gas will make up half the total by 2035.

And deep shales are not the last methane source. DOE and the industry are trying to figure out how to tap the largest one of all—the methane hydrates that lie frozen under vast areas of seafloor and Arctic permafrost. Worldwide, hydrates may contain more energy than all other fossil fuels combined. They're usually snow-white and look like ice, but they're strange stuff, and extracting the methane is tricky. Each molecule is trapped in a cage of water molecules that's stable only at high pressure and low temperatures; change either just a bit, and the cage crumbles. The escaping methane balloons in volume by a factor of 164.

Oil companies working on continental margins have to take care that extracting oil through an overlying hydrate layer does not disrupt it and perhaps damage the well. Climate scientists worry that global warming could destabilize hydrate layers, on land or at sea, triggering a massive methane release that would amplify the warming. A few scientists take seriously a catastrophic scenario in which the release happens rapidly, within a human lifetime, and the planet's temperature spikes.

The atmospheric methane concentration has risen nearly 160 percent since preindustrial times, to 1.8 parts per million. For a few years, from 1999 to about 2006, it seemed to level off. Some researchers credit Asian rice farmers, who began draining their paddies during the growing season to conserve water—which reduced methane emissions as well. Another theory credits the oil industry, which started capturing and selling methane it used to simply vent. Since 2006, though, atmospheric methane has been rising again. Many observers believe it's no coincidence that the number of wells punched into deep shales has been soaring too.

The largest U.S. shale formation, the Marcellus, lies about a mile under the Appalachian Mountains, in an arc that runs from West Virginia to New York through Ohio and Pennsylvania. The Pennsylvania stretch is pretty country: rolling hills and pastures and, in the northwest, the forests of the Pennsylvania Wilds, which boast some 2,000 trout streams and one of the darkest night skies in the East.

These days tank trucks, sand haulers, flatbeds stacked with pipe, and cement mixers rumble continually over the winding two-lane roads. Here and there in patches cut from forest or farm are flattened, four-acre mounds of fresh dirt. For a few weeks at a time tall derricks rise from these drill pads, and the trucks and trailers congregate around them. Contaminated water from the new wells pours into tank trucks or into lagoons lined with dark plastic. The derricks soon disappear, but the wells stay, connected by clusters of green pipes and valves to permanent new pipelines, condensate tanks, and compressor stations. Much of Pennsylvania has been transformed since 2008.

The boom's roots go back to the 1980s and to Texas, where a wildcatter named George Mitchell, facing dwindling reserves, began probing the Barnett Shale near Dallas. Black shales, the compressed mud of ancient seas, were known as petroleum source rocks. But over geologic time much of the oil and gas had migrated out of the shales into porous sandstone traps—and that's where the industry sank its wells. Wells ending in shale never yielded much; the shales were too dense and impermeable to allow gas to flow.

Mitchell Energy's workaround, developed over 20 years with support from DOE, became the recipe for the fracking boom. It has two parts. First, drill down to the shale, then continue drilling horizontally for a mile or so inside it; that puts more gas close to the well. Second, inject millions of gallons of water, chemical lubricants, and sand at high pressure to shatter the shale, allowing methane to rush into the well.

The gas from fracked wells has benefited consumers. 55 percent of the homes in the U.S. have gas heat, and prices last winter reached a ten-year low. In Pennsylvania the boom has revived businesses; created some 18,000 jobs, by the state's reckoning; and paid millions of dollars in lease-signing bonuses and royalties. However, some landowners who leased their land to gas companies have since had second thoughts.

Sherry Vargson is one. In 2008 Chesapeake Energy began drilling on her family's 197-acre dairy farm in Granville Summit, in northeastern Pennsylvania. In June 2010, after a crew had been working on the well, Vargson turned on her kitchen tap to find it backed up with what she thought was air. "It was like drawing a glass of Alka-Seltzer, very sizzly and bubbly," she recalls. Testing showed the water contained more than twice the methane that's considered an explosion threat. Chesapeake has been supplying her with bottled water ever since, while arguing that the contamination is natural. Meanwhile Vargson's monthly royalty checks have shrunk from more than $1,000 to less than $100, as production from the gas well has plummeted.

The industry's main argument in attempting to reassure a worried public in Pennsylvania and elsewhere has been that shales typically lie thousands of feet below drinking-water aquifers. So contamination, whether by shale gas or fracking wastewater—which contains fracking chemicals, salt, heavy metals, and radioactive elements leached from the rock—should be physically impossible. The argument makes intuitive sense, but the jury is still out. Duke University scientists have recently reported evidence that fluids—albeit not fracking fluids—have migrated upward from the Marcellus Shale through natural fissures.

In an earlier study the Duke researchers sampled 60 private water wells in northeastern Pennsylvania and found no sign of fracking fluids. But they did find that methane levels were on average 17 times higher in wells near drilling sites and that some of the methane had the chemical signature of shale gas. It may have leaked into the shallow aquifers, they said, through faulty casings around the gas wells. The Pennsylvania Department of Environmental Protection (DEP) also blamed faulty casings in 2009 when it fined Cabot Oil & Gas for contaminating the drinking supplies of 19 homes in Dimock Township, 60 miles east of the Vargson farm. In that case the methane came not from the shale but from shallow deposits traversed by the gas wells. DEP has also fined gas companies for mishandling fracking wastewater and allowing spills that polluted creeks and rivers.

In Pennsylvania and elsewhere, shale-gas drilling has raced far ahead of efforts to understand and limit its impact. So far, however, its impact seems much smaller than that of coal mining—which in Pennsylvania has caused far worse river pollution, in West Virginia has lopped the tops off numerous mountains, and in the U.S. still kills hundreds of miners a year, mostly through black lung disease. The comparison is relevant because cheap natural gas is reducing coal burning. As recently as 2007, coal generated nearly half of U.S. electricity. Last March its share fell to 34 percent.

John Hanger, a Pennsylvania lawyer who helped author the state's renewable-energy standards, ran the DEP from 2008 to early 2011. Though he tightened regulations on the gas industry and handed out substantial fines, he was attacked by opponents who wanted a complete halt to fracking. Hanger believes such critics are missing the big picture. "The massive switching from coal to gas has done more to clean Pennsylvania's air, and America's air, than probably any other single thing we've ever done," he says.

Unlike coal, natural gas burns without spewing sulfur dioxide, mercury, or particulates into the air or leaving ash behind. And it emits only half as much carbon dioxide. The greenhouse gas inventory compiled by the U.S. Environmental Protection Agency (EPA) shows that the nation's CO_2 emissions in 2010 were lower than in 2005 by just over 400 million metric tons, or 7 percent. (Preliminary data for 2011 indicate a further decrease.) Reduced emissions from power plants, mostly because many have switched from coal to gas, accounted for a bit over a third of that.

Some environmentalists who once welcomed shale gas with precisely that expectation changed their minds after watching the boom in Pennsylvania. But Hanger hopes it spreads around the world, as it seems likely to. "In China they're sitting on potentially huge supplies of shale gas," he says. "It would be an enormous climate benefit if China were to substitute gas for some of its coal burning. And it's an immediate benefit—you don't have to wait until 2040 or 2050."

Unless too much methane leaks into the atmosphere. As U.S. CO_2 emissions fell between 2005 and 2010, methane emissions rose. By 2010, EPA says, the rise was equivalent in global warming potential to around 40 million metric tons of CO_2 annually, which means it offset 10 percent of the CO_2 decline. More than half of that methane increase, says EPA, came from the natural gas industry—the country's biggest emitter.

Judging by EPA's numbers, fracking still seems like a clear win for the climate. But some scientists, notably Robert Howarth and his coworkers at Cornell University, believe EPA has underestimated methane emissions and, more important, the global warming potential of each methane molecule. They argue that methane leaking from wells, pipes, compressors, and storage tanks actually makes shale gas worse for the climate than coal. Other researchers question Howarth's approach. The debate persists in part because methane numbers are so uncertain.

New rules issued by EPA this year will require the gas industry to measure its emissions and also to reduce them. One of the biggest leaks occurs when a fracked well is completed and high-pressure fracking fluids surge back up the well, bringing methane with them. The new rules will require gas companies to start capturing that methane by 2015, using technology that's already required in Wyoming, Colorado, and parts of Texas.

Some experts consider methane capture a great opportunity: an easier way than controlling CO_2 to slow global warming, at least in the short term, because small amounts of methane make a big difference and because it's a valuable fuel. China, for instance, the world's largest coal producer, vents huge amounts of methane from its mines to prevent explosions. In the 1990s, when Egyptian geologist Mohamed El-Ashry headed the Global Environment Facility, an agency created by the United Nations and the World Bank, it devoted ten million dollars to projects that siphoned methane from several Chinese mines and delivered it as fuel to thousands of nearby households. Hundreds of such projects await funding worldwide, El-Ashry says.

Drew Shindell, a climate scientist at NASA's Goddard Institute for Space Studies, recently led a global team of scientists in analyzing seven methane-reduction strategies, from draining rice fields to capturing the gas that escapes from landfills and gas wells. Unlike CO_2, methane affects human health, because it's a precursor of smog. When health impacts are included, Shindell's group found, the benefits of methane controls outweigh the costs by at least 3 to 1, and in some cases by as much as 20 to 1.

"There are some sources that are difficult, if not impossible, to control," says Shindell. "The Arctic emissions—I'd probably vote those as being near impossible. But then you have long-distance gas pipelines, and we know exactly how to control leaks from those: put in and maintain high-quality seals. And there are other places, especially in oil, gas, and coal production. It's really straightforward to get a substantial fraction of methane emissions under control."

Last spring, as the annual thaw began in Alaska, Katey Walter Anthony heard from her friend Bill Wetzen, who owns Goldstream Lake and sometimes brings her coffee out on the ice. When Wetzen bought the property 20 years ago, he built his bungalow about 30 yards from the lake; by last year it was nearly at the water's edge. Now, Wetzen said, with the permafrost thawing beneath it, the walls and floors were tearing apart. He was going to have to move.

Also last spring, DOE-funded researchers on Alaska's North Slope successfully tested a method of extracting methane from buried hydrates. Though the process "may take years" to become economically viable, said the DOE press release, "the same could be said of the early shale gas research ... that the Department backed in the 1970s and 1980s." If even a small fraction of methane hydrates becomes recoverable, DOE estimates, that could double U.S. gas resources.

Some of the methane bubbling from Arctic lakes, Walter Anthony says, might come from hydrates. Around 56 million years ago, in the Paleocene, a long planetary warming culminated in a sudden temperature spike of 9°F; many scientists suspect a massive destabilization of methane hydrates. Most, including Walter Anthony, do not think such a catastrophe is likely now. But Arctic methane could add a lot to global warming over the next few centuries.

"If we could only capture it, it would make a great energy source," Walter Anthony says.

Marianne Lavelle is the energy editor at nationalgeographic.com. Staff photographer Mark Thiessen has a professional fascination with fire.