Appendix C

Roads and Traffic

Contents

Introduction

Unconventional Gas Well Development (UGWD) through hydraulic fracturing requires a substantial amount of truck traffic. Typically, all materials, equipment, water, proppants, petroleum products, and chemicals are transported via truck to hydraulic fracturing sites (U.S. EPA, 2011, NYSDEC, 2011). Nearby communities will experience increases in road damage, traffic, noise, air pollution, and road construction. This section of the risk assessment will address the risks of damage to the existing road infrastructure, community impacts from increases in traffic, and ecological impacts from road construction. Sources, consequences, and mitigations of risk will be noted throughout. Other truck traffic impacts will be covered in the air pollution, noise and visual impacts, drilling, and hydraulic fracturing fluid sections of the report.

In this document, the road damage risk being evaluated is the combination of the probability and consequence of damage to roads by UGWD trucking. The community consequences of road damage include repair costs, impeded driving for short- or long-term periods, hindrance of emergency services, higher risk of rollover of trucks, and damage to residents' vehicles, among other impacts. Also considered are issues regarding compliance with safety regulations relating to trucks and the feasibility of recovering the costs of road repair from those responsible.

Next, the traffic risk being evaluated is the combination of the probability and consequence of traffic accidents and congestion on the community as a result of UGWD trucking. The community consequences of more truck traffic include injuries and fatalities from crashes, hindrance of emergency services, impeded driving for short- or long-term periods, change in the character of rural communities, and local cost increase to control traffic. Regulation of commercial trucks and truck drivers will also be discussed.

Finally, the ecological risk being evaluated is the combination of the probability and consequence of road construction and increased traffic on surface water, habitat, wildlife, and recreation. The consequences include sedimentation and pollution of surface water, forest loss and fragmentation, harm to fish and wildlife, and outdoor recreation impacts.

In the following sections, trucking activity associated with UGWD is examined, followed by a literature review on road damage and traffic risks. The truck traffic associated with each step of UGWD process is broken down, and applicable proposed best management practices are summarized. Finally, examples of issues associated with managing these risks are discussed, and risk is qualified and quantified where possible.

Number of truck trips

Damage and traffic risks discussed in this section of the report will be based on estimated numbers of truck trips provided by ALL Consulting (2010), as prepared for the Independent Oil and Gas Association of New York (Table 1). This ALL Consulting (2010) report was prepared in response to information requests from the New York Department of Environmental Conservation during development of its draft Supplemental Generic Environmental Impact Statement (EIS). MDE made certain modifications to account for hauling weight limitations and to standardize the numbers to this risk assessment's scenarios.

The values in Table 1, below, represent one-way, loaded truck trips estimated for one horizontal well on one well pad. To include empty truck trips, one can assume doubled values. (Empty trucks would contribute to traffic but are less likely to cause road damage.) The calculations are based on the assumption that all water will be delivered via trucks (no pipelines). The hydraulic fracturing of each well is assumed to require 5 million gallons of water, an amount deemed conservative (NYSDEC, 2011). Here, the relatively small volume of chemical additives is not assumed to be included in that total. It was assumed that all flowback and produced water would be removed from the well site by truck; however, Maryland is proposing to require substantial recycling and reuse of this water onsite.

Table 1. Estimated number of loaded, one-way truck trips for one well pad with one well.

** Modified from ALL Consulting 2010 to account for 5,000,000 gallons/well and 5,000 gallons/truck.*
*** Modified from ALL Consulting 2010 to account for 30% flowback volume.*
Sources: ALL Consulting, 2010; NTCC, 2011; NYSDEC 2011.

Well pad activity	**Early well pad scenario (All water transport by truck)**	
	Heavy trucks	Light trucks
Drill pad construction	45	90
Rig mobilization	95	140
Drilling fluids	45	0
Non-rig drilling equipment	45	0
Drilling (rig crew, etc.)	50	140
Completion chemicals	20	326
Completion equipment	5	0
Hydraulic fracturing equipment (trucks & tanks)	175	0
Hydraulic fracturing water hauling	1000*	0
Hydraulic fracturing sand	23	0
Produced water disposal	300**	0
Final pad prep	45	50
Miscellaneous	0	85
TOTAL truck trips per well pad (1 well)	**1848**	**831**

The original table from All Consulting (2010) listed the value for water hauling trips associated with hydraulic fracturing as 500 trips. However, delivering 5 million gallons of water in 500 trips would mean that each truck would carry 10,000 gallons. The weight of this water exceeds the standard commercial vehicle weight limit of 80,000 pounds (COMAR 11.04.01; 23 CFR 658.17):

$$\frac{10{,}000\ gal}{truck} \times \frac{8.3454\ lb}{1\ gal} = 83{,}454\,\frac{lb\ water}{truck}$$

This conversion is based on freshwater density, and shows weight exceedance even without the truck's tare weight. Instead, since high-volume options for water-hauling trucks vary from about 4,000 to 6,000 gallons, 5,000 gallons per truck was used to recalculate the number of water hauling trips (The Gasaway Co., 2002; J&J Truck Bodies & Trailers, 2008; Ledwell, 2014; Oilmen's Truck Tanks 2012). One thousand 5,000-gallon truck loads would be required to transport 5 million gallons of water.

Secondly, the original table assumed that 20% of the fracturing fluid pumped into the well would return as flowback (100/500 = 0.2). Adjusting this to reflect MDE's scenario assumption of 30% flowback results in 300 produced water disposal truck trips.

Finally, Table 2 was scaled to six wells per well pad to be consistent with estimates of the number of wells per pad in the two scenarios being evaluated. The same scaling factors were used from NTC Consultants' (2011) review of NYSDEC's Generic EIS. Following this approach, Table 2 below multiplies well-based activities by 6, drill rig activities by 2, and well pad activities by 1. The Miscellaneous light truck trips' scaling rationale could not be determined, so NTC's 8-well scenario number of 400 was applied to this 6-well scenario.

Table 2. Estimated number of loaded, one-way trips per well pad with six horizontal wells.

** Modified from ALL Consulting 2010 to account for 5,000,000 gallons/well and 5,000 gallons/truck.*
*** Modified from ALL Consulting 2010 to account for 30% flowback volume.*
Sources: ALL Consulting, 2010; NTC Consultants, 2011; NYSDEC, 2011.

Well pad activity	**Scaling Coefficient, 6 wells/pad**	**Early well pad scenario (All water transport by truck)**	
		Heavy trucks	Light trucks
Drill pad construction	1	45	90
Rig mobilization	2	190	280
Drilling fluids	6	270	0
Non-rig drilling equipment	2	90	0
Drilling (rig crew, etc.)	6	300	840
Completion chemicals	6	120	1956
Completion equipment	2	10	0
Hydraulic fracturing equipment (trucks & tanks)	2	350	0
Hydraulic fracturing water hauling	6	6000*	0
Hydraulic fracturing sand	6	138	0
Produced water disposal	6	1800**	0
Final pad prep	1	45	50
Miscellaneous	-	0	400
TOTAL truck trips per well pad (6 wells)		**9358**	**3616**

To check the reasonableness of these estimates, applications that had been filed to drill in Maryland's Marcellus Shale were reviewed. The values appear in Table 3. However, since the same values in this table appeared in more than one application despite millions of gallons of variation among stated water volumes), this is being used here only as a general comparison (Chief Oil & Gas LLC, 2010, 2011; Enerplus Resources, 2011).

Table 3. Trips generated in UGWD. Sources: Chief Oil & Gas LLC 2010, 2011; Enerplus Resources 2011.

** Does not include work crew trips.*

Phase	Duration	Estimated No. of Round Trips*
Initial Construction (Well pad or freshwater impoundment)	3-4 weeks	20-50
Drilling of Well	6 weeks, most traffic during first 2 weeks	200-400
Water Delivery / Fracturing Shale	4-6 weeks	1000-1500
Completion and Dismantling Site (includes disposal of wastewater)	2 weeks – 2 months	300-500
Reclamation of Site	2-4 weeks	20-40
Gas Generation	15 plus years	1 per 6 months

Of note, the number of round trips for water delivery and fracturing listed above (1,000 to 1,500 trips), is closer to MDE's modified trip number for this step (1,000) than to ALL Consulting's provided table (500). Similarly, the above completion and dismantling trips (300 to 500 trips) match MDE's modified produced water disposal value (300 trips) which, again, is closer than the value estimated by ALL Consulting (100 trips). Estimates of truck trips associated with initial construction as well as final pad preparation/reclamation of site numbers are similar in both tables. Truck trips associated with drilling, however, are lower in this table (200-400) than in ALL Consulting (sum of 1,970 trips). Although some values vary, this information provides valuable overall perspective for the magnitude of truck trips nearby communities can expect should Marcellus Shale UGWD move forward.

Each of these phases/activities occur over different periods of time, from days to years, which varies trucking intensity substantially through the process. See the "Steps" section below for discussion of duration.

Maryland roads

In previously filed UGWD permit applications, the following roads were specified for use by an applicant (Table 4). This gives some perspective of the possible roadway use to be expected in Western Maryland. The grade of some of these roads could reduce truck speeds. Drillers will also be building new access roads which will likely be unpaved.

Table 4. Roads and bridges for two drilling applications submitted to MDE.

Permit application	Road or bridge	Jurisdiction or weight limit
Chief Oil & Gas LLC 2010, Guard Unit	Friendsville-Addison Road and Maple Street	Garrett County roads
	MD-42/South Friendsville Road	State road
	I-68	Federal road
	Bridge over Mill Run stream near Mill Run Road, along Friendsville-Addison Road	Single-axle 62,000 lbs; Tandem-axle 80,000 lbs
	Bridge over Bear Creek stream in Friendsville, along Friendsville-Addison Road	Single-axle 50,000 lbs; Tandem-axle 80,000 lbs
	Bridge over Youghiogheny River in Friendsville, along Friendsville-Addison Road	Single-axle 58,000 lbs; Tandem-axle 80,000 lbs
Chief Oil & Gas LLC 2011, Farmer Unit	Old Morgantown Road West, Blooming Rose Road, and Fearer Road	Garrett County roads
	MD-42	State road
	US-40 National Pike and I-68	Federal roads
	Bridge over Buffalo Run stream near MD-42, along Old Morgantown Road West	Single-axle 62,000 lbs; Tandem-axle 80,000 lbs

Road damage

Impact of heavy truck traffic on roads

Higher truck trip frequency and weight leads to an increased rate of road deterioration. Roads are designed to sustain the amount and type of traffic projected at the time of construction (Abramzon et al., 2014, NYSDEC, 2011). Design parameters include frequency of trips, weight of vehicles, and size of vehicles. UGWD operations would be a substantial source of additional truck trips carrying heavier loads than what many roads are designed to handle, especially smaller roads, shortening the expected road life.

A little more vehicle weight leads to a lot more road damage, and trucks weigh tens of thousands of pounds more than cars. The Federal Highway Administration's review of pavement impact states that an increase in axle weight increases pavement deterioration exponentially, by approximately a power of three (FHWA, 2000). This means that, depending on differences such as axle weights and pavement characteristics, one truck trip can cause as much pavement damage as hundreds to thousands of car trips (Abramzon et al., 2014; Merriss, 2000, Alaska DOT & Public Facilities, 2004).

Road damage comes in the form of cracking, rutting, failure of the road structure, and potential damage to traffic control devices and stormwater infrastructure along road sides. Bridges can also be structurally harmed (NYSDEC, 2011). More axles, shorter spacing of axles, and dual tires on trucks are key ways to reduce the magnitude of downward force that loads exert on roads (FHWA, 2000). Though requiring the use of trucks with additional axles allows weight to distribute across a larger surface area, this does not eliminate road damage. In a study examining the impacts of different truck configurations on pavement, single- and tandem-axle trucks caused cracking, but additional axles caused rutting instead (Salama et al., 2006).

Different roadway types will experience different rates of deterioration. Due to their expected proximity to gas well sites, their smaller size, and their design specifications based on lower traffic and lighter loads, local roads would be expected to experience the greatest damage. Larger state roads built to sustain high frequencies of traffic including heavy trucks are generally expected to adequately support the many truck trips from well development. However, the thousands of projected heavy truck trips will incrementally deteriorate the roads, shortening pavement life. This means that state road repair and maintenance dates could come earlier than anticipated, resulting in additional cost to the state. The gradual nature of this process can make estimating additional cost and demonstrating causal attribution difficult (NYSDEC, 2011; Mitchell, 2010).

Valuation of road damage

Several case studies have calculated cost estimates associated with road damage from trucking operations for natural gas well development. Some factors that influence variation in cost estimates include truck axle configurations, miles driven, pipeline use assumptions, number of wells per pad, and amount of water, equipment, and materials needed. Characteristics that vary by state include roadway types, reconstruction and maintenance costs, and disposal distances (Abramzon et al., 2014).

A study focusing on Pennsylvania's Marcellus Shale estimated the impact of hydraulic fracturing well development on the damage to each of five classes for roads maintained by the state, ranging from Class A (Interstate Highways) to Class E (state-maintained roads that are not part of the national highway system and were designed for less than 2,000 average daily traffic). These classes did not include roads owned and maintained by boroughs and townships. Estimates of the cost (in 2012 dollars) of reconstructing one lane-mile ranged from $3.2 million for Class A to $2.3 million for Class E. The estimates for the amount of useful road life that would be consumed by trucks associated with hydraulic fracturing for each class, and an estimate of the damage cost per lane-mile for each well, are shown here (Table 5).

Using the truck trip numbers from the New York EIS and assuming that each trip is 20 miles, Abramzon estimated that, for all state roadway types, the consumptive road damage would be $13,000 to $23,000 per well for all state roadway types. Light truck trips, empty truck trips, and local roadways not maintained by the state were all excluded in this analysis, and the authors used the number of truck trips estimated in the New York EIS. In this risk assessment, we assume a higher number of truck trips. Scaling the cost to Maryland's estimates would change the estimate to $20,930 to $37,030 per well (Abramzon et al., 2014).

Table 5. Estimated consumptive road use and costs per lane-mile driven by trucks used for construction and operation of shale gas wells in Pennsylvania. Source: Abramzon et al., 2014.

	Road Class	A	B	C	D	E	Total
Low truck trip range (some water delivered by pipeline)	Consumptive roadway use per well	0.0001%	0.0001%	0.0015%	0.0036%	0.0077%	
	Damage Costs per lane mile for each well	$2	$3	$40	$92	$180	$315
High truck trip range (all water delivered by truck)	Consumptive roadway use per well	0.0001%	0.0002%	0.0027%	0.0066%	0.0142%	
	Damage Costs per lane mile for each well	$3	$5	$72	$168	$331	$580

Even though the lane-mile reconstruction cost for an interstate highway is higher than that for a Class E road, the damage from the additional truck trips is so minor on a state-maintained interstate compared to a Class E road that the cost per lane-mile damaged for each well is one hundred times higher for the Class E road ($331) than the cost for the interstate ($3) (Abramzon et al., 2014).

Second, a study in Keller, Texas estimated roadway damage maintenance costs from transportation of water for hydraulic fracturing. The estimate was in the form of a fee to offset expected damages per lane-mile of roadway. Varying by inclusion of pipelines and roadway characteristics, the fee ranged from $53 to almost $20,000 per lane-mile (Table 6). The roadways' base and surface material specifications had the greatest impact on this range of fees, as opposed to pipeline use assumptions. The costs only represent the reconstruction of the driving surface, and do not include the damage to drainage infrastructure or other residual components (Belcheff & Associates, 2010).

A study prepared for Rio Blanco County, Colorado estimated roadway costs per gas or oil well lifetime, including damage to roads as well as future growth and needed improvement required to maintain current levels of service. The cost per oil or gas well lifetime was determined to be $18,762 in 2007 dollars (Table 6) (RPI Consulting, 2008).

Depending on the type of work needed and the characteristics of the road, the cost of roadway repair can vary widely. In New York, low-level maintenance can start from under $100,000 per lane-mile, but higher-level maintenance can be nearly ten times that cost. Furthermore, "full-depth reconstruction" can surpass those costs. Bridges are also susceptible to damage. Bridges impacted by enough truck traffic may need to be completely replaced. In New York, 166 bridges with conditions from Fair to Poor were evaluated by the Department of Transportation for replacement; costs ranged from $100,000 to tens of millions, averaging $1.5 to $3.3 million (Table 6) (NYSDEC, 2011).

Table 6. Road and bridge cost summary by study.

State	Source	Cost
PA	Abramzon et al. 2014	$13,000 to $23,000 per well for all state roadway types ($2012)
TX	Belcheff and Associates 2010	$53 to $19,977 fee per lane-mile of road
CO	RPI Consulting 2008	$18,762 per gas or oil well lifetime ($2007)
NY	NYSDEC 2011	$70,000 to $790,000 repair cost per lane-mile of road
NY	NYSDEC 2011	$1.5 to $3.3 million average per bridge replacement

A Texas Transportation Institute study examined remaining roadway life following hydraulic fracturing activity. Findings suggested that a new rural road would have lost nearly 40% of its design life following the first year of development from one hundred horizontal gas wells. If the wells are refracked every five years, the rural road's pavement would fail in less than ten years (Quiroga et al., 2012).

A Pennsylvania State Department of Transportation spokesman for their District 3 Office, Rick Mason, said they observed "widespread, all-at-once wear and tear" on roads from natural gas extraction activity. Managing the road impacts required more paperwork, field work, and cost than anticipated; "we're spending tens of thousands of dollars just on signs," he said (Wilber, 2010).

The estimates discussed above considered damage from trucks that were not over-posted-weight. The Pennsylvania Department of Transportation requires an Excess Maintenance Agreement from haulers who may damage roads by using them for a significant number of over-posted-weight-vehicles (30 or more loads or more per day and/or 600 or more loads per year). The hauler must post a performance bond or irrevocable letter of credit in an amount based on the type of roadway; for example, $6,000 per linear mile for unpaved roadways and $12,500 per linear mile for paved roadways (Pennsylvania Department of Transportation DOT, 2011; 1 Pa. Code § 189).

Finally, community members' vehicles can be damaged by driving on roads in disrepair. For example, deep ruts along paved roads can mean that pavement between ruts extends high enough to scrape the bottom of vehicles. Potholes and other cracked pavement can damage cars' suspensions and wheels. The longer damaged roads persist, the more vehicle damage occurs.

Proposed mechanisms to help address roadway infrastructure damage from UGWD in Maryland are discussed in the Proposed Best Management Practices section.

Traffic

UGWD will mean markedly increased traffic in communities near well pads. Increased gas development traffic leads to congestion, a higher likelihood of vehicle collisions, and would impact the character of rural communities.

Traffic congestion and community character

Increased traffic exacts a social cost and has been identified as a major community concern in areas with natural gas development. Of 16 stakeholders from government, academia, industry, environmental groups, and community organizations interviewed by the Pacific Institute, six identified truck traffic on local roads as a concern (Cooley & Donnely, 2012). A study for New York State called trucking "extensive" and named it "one of the largest" impacts to community character (NTCC, 2011). Various citizen websites promote awareness of trucking issues associated with UGWD based on negative experiences in their towns.

The impact of trucks on traffic flow will depend upon a number of characteristics including trucks' routes, roadways' functional classes, timing, and community population. Especially near well pad access roads, traffic volumes could be substantial. Traffic could be heaviest during peak hours of the day, some well development steps are much more truck-intensive than others, and multiple wells could be completed in sequence. Increased employment in the area from well development will also increase vehicle traffic. Larger roads designed to be more heavily traveled will be less impacted by traffic, as with consumptive use damage. Conversely, smaller, more local roads are more susceptible to both traffic congestion and damage (NYSDEC, 2011). Finally, road slopes in western Maryland may impede traffic due to slow-climbing trucks.

On June 14, 2014, several members of Maryland's Marcellus Shale Safe Drilling Initiative Advisory Commission and the Risk Assessment team visited West Virginia UGWD drilling towns. Along US-50 to West Union, WV, the participants conducted an informal count and classification of vehicles traveling east between 10:20 and 10:25 a.m. Approximately 13% of vehicles were UGWD-related trucks hauling fluid, proppant, and other materials and equipment (11 UGWD trucks and 71-76 other vehicles). Though this survey cannot be considered representative, it gives some sense of traffic increase on a major highway. In rural communities we observed in and near West Union, most of the vehicles on some roads were UGWD trucks. Driving toward areas with active well pads, the MD group was stopped by flaggers for up to 20 minutes so that trucks could move on the narrow public road. The flaggers were employees of the UGWD companies who carried stop signs and walkie-talkies to coordinate two-way traffic on one-lane public roads. Trucks were seemingly constant throughout the day, and their traffic seemed to dominate movement in the communities.

In addition to the associated increase in costs, inconveniences, and concerns for safety, local vehicle response and public safety services may need to increase their capacities to respond. This includes ambulances, fire trucks, and police cars. Finally, greater need for traffic control may lead to required installation of additional traffic signals, signage, and turn lanes (NYSDEC, 2011).

Figure 1. Trucks associated with oil and gas extraction operations in Texas (TX DOT 2014).

Traffic accidents

An increase in traffic comes with a higher likelihood of accidents. A preliminary analysis indicates that during Pennsylvania's gas development boom in 2009-2010, counties with more than 20 shale gas wells experienced a marked increase in total accidents and accidents involving heavy trucks. The increase did not occur in counties with fewer than 20 or no gas wells. Prior to the gas development surge in 2009-2010, the counties' accident rates moved together; only after gas well development did the accident rate in counties with well development diverge (Figure 2; Muehlenbachs & Krupnick, 2014).

In counties that had, at the end of 2012, at least 20 gas wells, one additional well drilled in a county per month was associated with an average 2% increase in accidents per month involving a heavy truck, and a 0.6% increase in fatal accidents. Vehicle crash data were taken from Pennsylvania DOT's Crash Reporting System, and well data were obtained from the Pennsylvania Department of Environmental Protection and the Department of Conservation and Natural Resources (Muehlenbachs & Krupnick, 2014).

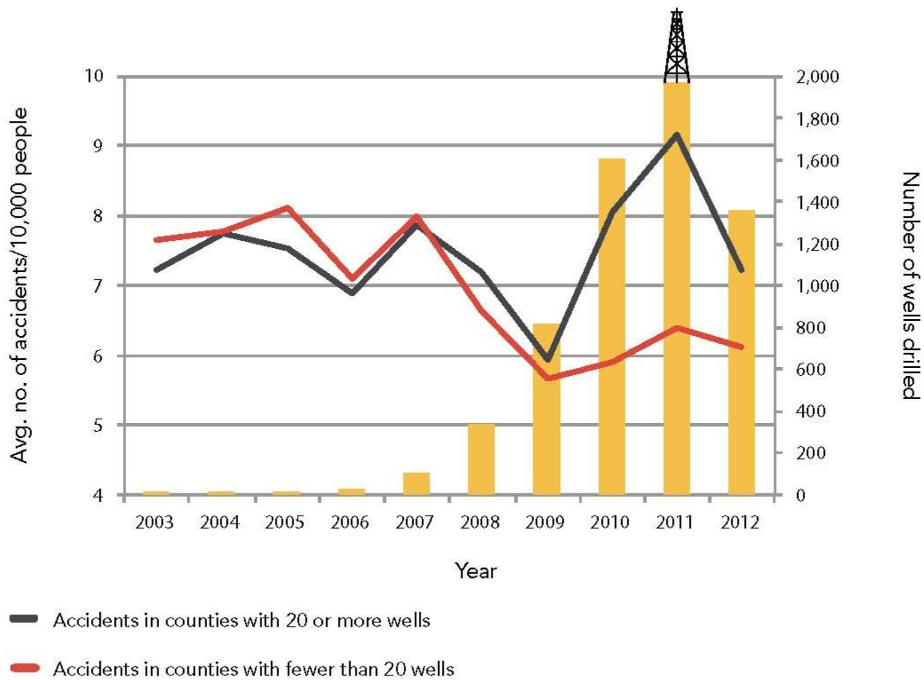

Figure 2. Number of truck-related accidents in Pennsylvania counties with and without 20 or wore shale gas wells, per year (Muehlenbachs & Krupnick 2014).

Under the more intense drilling scenario (450 wells) evaluated for this risk assessment, Allegany County would have one additional well drilled per month in year 2, and less than one per month in all other years. Garrett County, on average, would have between 1 and 5 wells drilled per month over the 10-year period.

An Associated Press article based on U.S. Census data has also found higher accident rates in counties with oil and natural gas drilling. Per mile driven, drivers in North Dakota faced nearly twice the likelihood of dying in a traffic accident in drilling counties compared to the rest of North Dakota counties. The likelihood is 2.5 times greater in one drilling district in Texas as compared to the statewide average. The authors noted, "Not all of the crashes involved trucks from drilling projects, and the accidents have been blamed on both heavy equipment drivers and ordinary motorists." Table 7 summarizes other findings (Begos & Fahey, 2014):

Table 7. Summary of findings from Begos and Fahey 2014.

State	Drilling counties	Non-drilling counties
North Dakota	Average death rate per 100,000 people up 148% from 2009-2013, compared with the previous five years	Average death rate per 100,000 people down 1% from 2009-2013 in the rest of the state
Texas	Average death rate per 100,000 people up 18%	Average death rate per 100,000 people down 20% in the rest of the state
Pennsylvania	Traffic fatalities up 4% from 2009-2013	Traffic fatalities down 19% from 2009-2013
New Mexico	Traffic fatalities down 5% from 2009-2013	Traffic fatalities down 29% from 2009-2013

Begos and Fahey (2014) did not identify the criteria used to distinguish drilling counties from others. The authors note that vehicle crashes often rise when the volume of traffic increases, but speculate that the large number of heavy trucks needed for hydraulic fracturing, and the rapid pace of development, have caused the rate of accidents to rise faster than the population or vehicle miles traveled.

In Texas' Permian Basin energy sector, the count of fatal crashes in 2012 increased by 27% from 2011, and 7% of reported 2012 crashes involving death or injury were with commercial trucks (TX DOT, 2013). Following their observed increase in traffic and crashes from oil and gas production, the Texas Department of Transportation and Department of Public Safety launched a public outreach campaign to promote roadway safety in oil and gas work zones:

> *Historically, west Texas has not been an area where traffic was a concern, but now with a re-energized oil and gas industry, driving conditions have changed. ... Passenger vehicles are now sharing rural roads with more and more heavy trucks, and that's a recipe for trouble when drivers don't obey traffic laws, slow down or pay attention.*
>
> *–John Barton, TX DOT deputy executive director (TX DOT, 2013)*

Proposed mechanisms to help address traffic concerns are discussed in the Proposed Best Management Practices section.

Ecological impacts

Creation and maintenance of roads sufficient to accommodate truck traffic can generate sediment pollution and increase forest loss. The potential changes to water quality from construction activities could impact aquatic species via sediment impacts to streams from road construction. Sedimentation will have a negative effect on rare fish and sensitive mussels. Dirt/dust from truck traffic can pollute streams. There is also potential for sediment impacts to streams from stormwater flows during and after road construction.

Clearing for access roads and pipelines can result in the loss of forest and can cause the creation of additional forest edge. Forest roads have been shown to reduce terrestrial salamander movement by 51% and with multiple roads dispersal could be reduced by up to 97% (Marsh et al., 2004). Habitat loss/fragmentation and adverse impacts to wildlife corridors could also occur. Forest interior dwelling species depend on large intact forested tracts. Forest clearing and additional creation of edge will affect native plant communities because of canopy loss and introduction of invasive species. Brush clearing could involve the removal of the riparian vegetation that is necessary to keep aquatic temperatures low.

Depending upon location of construction activities, there could be downstream impacts to state parks and water-based recreational activities. Increased heavy truck traffic will degrade the outdoor recreational experience not only near the site, but the outlying travel areas. Potential adverse impacts to water quality may affect streams and rivers (including wild and scenic rivers) used for recreation.

Steps

The magnitude of truck traffic varies considerably by step in the well development process, as broken down below. Where truck trip numbers are available, cumulative estimates are calculated based on the two scenarios: 150 wells on 25 well pads, and 450 wells on 75 well pads. Summing across steps, it is clear that hydraulic fracturing and well completion comprise by far the largest proportion of truck trips throughout the process (Figure 3).

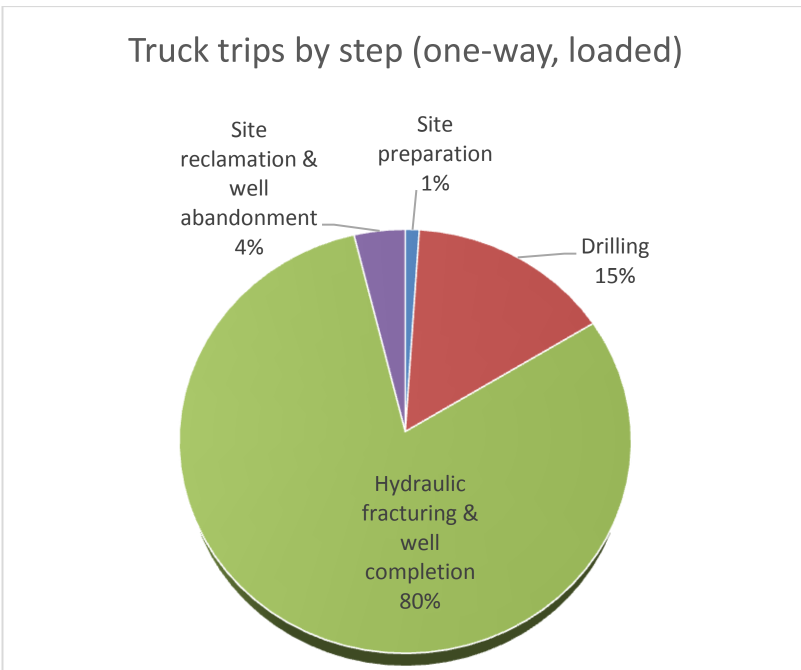

Figure 3. Percent of one-way, loaded truck trips attributable to each step in the UGWD process.

Site identification

The purpose of site identification is to locate natural gas deposits and determine the most appropriate well location. Developers conduct geologic exploration in areas identified as most likely to meet necessary site characteristics. Sound waves directed downward can help characterize geological structures such as faults, shallow wells may be drilled, and brush may be cleared to allow for equipment setup. A permit application submitted to MDE (Pennsylvania General Energy Company) was reviewed here to give perspective on activities involved in seismic assessment surveys. A 3.9-mile transect was delineated on foot. At intervals along this line, a drill buggy drilled 10- to 20-foot-deep “shotpoint” holes, which were filled with bentonite pellets. Finally, the crew laid receivers and geophones along the transect, detonated them individually, and took recordings. Equipment was then removed.

Trucking required during site identification is expected to be minimal and markedly less during site identification than in other steps (Sammons/Dutton LLC and Blackenship Consulting LLC 2010). The methods, time period, and type and amount of equipment and materials used vary. The duration of site identification may be up to 120 days, based on the maximum time indicated on a permit application to MDE.

Site preparation

Preparing a chosen site includes clearing land for the well pad, building the access road(s), possibly improving existing roads, possible excavation for a freshwater pond, and transport of equipment and materials. Site preparation is essentially a construction effort; trucks will be hauling construction equipment, gravel, pipe, erosion and sediment control material, and other supplies, as well as transporting construction crew and trailers. Approximate construction period estimates include three weeks, three months (Chief Oil & Gas LLC 2010 , 2011), and up to four weeks per well pad (NYSDEC, 2011).

The industry-estimated number of loaded, one-way truck trips required during site construction is 135 per well pad. For a well pad with six wells, assuming two drill rigs per well pad, this step represents 1% of the estimated total 12,974 truck trips (Figure 3, Table 2). This proportion is relatively small as compared to the rest of the process, but would be a noticeable increase in a rural setting. Structural reinforcement, widening, and other upgrading of existing roadway infrastructure as needed for the remainder of the UGWD operation would also be taking place where necessary during this period.

The following numbers of truck trips are estimated to occur during site preparation:

Scenario 1: 150 wells on 25 well pads in Maryland
25 well pads * 135 trucks per 6-well pad = 3,375 loaded, one-way truck trips
Doubled to include empty trips: 6,750 loaded and empty one-way truck trips

Scenario 2: 450 wells on 75 well pads in Maryland
75 well pads * 135 trucks per 6-well pad = 10,125 loaded, one-way truck trips
Doubled to include empty trips: 20,250 loaded and empty one-way truck trips

Drilling

During this step, natural gas rig(s) drill vertically from the prepared well pad, then the drill is turned to drill horizontally. The well is cased and cemented and prepared for fracturing. Overweight and/or oversized trucks hauling heavy equipment (e.g., drill rigs) will be traveling on the roads during this step. Among materials trucked in will be drilling fluids, acid, and cement. After these initial deliveries, fuel, maintenance supplies, and casing sections will be intermittently delivered (Chief Oil & Gas LLC 2010, 2011). The waste cuttings and liquids drilled out from the well will be trucked out to disposal facilities. Vertical and horizontal drilling could last between one and two months per well (NYSDEC, 2011).

The four activities relevant to drilling in Table 1 total 1,970 one-way, loaded truck trips per six-well pad. Rig mobilization and non-rig drilling equipment trips account for 28% of drilling trips and are scaled based on the assumption of two drill rigs per well pad. Drilling fluids and drilling (rig crew, etc.) account for 72% of the drilling trips and are proportional to the number of wells (six) on the pad. Combining all truck trips estimated by the industry for UGWD, 15% is attributed to drilling activities, making it the second-most-intensive step in trucking operations (Figure 3). The increase in truck traffic from site preparation will be clear to nearby communities.

The following numbers of truck trips are estimated to occur during drilling:

Scenario 1: 150 wells on 25 well pads in Maryland
25 well pads * 1,970 trucks per 6-well pad = 49,250 loaded, one-way truck trips
Doubled to include empty trips: 98,500 loaded and empty one-way truck trips

Scenario 2: 450 wells on 75 well pads in Maryland
75 well pads * 1,970 trucks per 6-well pad = 147,750 loaded, one-way truck trips
Doubled to include empty trips: 295,500 loaded and empty one-way truck trips

Hydraulic fracturing and well completion

The main step in the UGWD process is hydraulic fracturing. During this step, the horizontal length of the well is perforated with small explosives in stages to make pathways for fractures to form. Fracturing fluid comprised of water, chemicals, and solid proppants is then pumped into the well and pressurized, forcing fluid and proppants into the shale formation through fractures. Once the fractures are formed, a portion of the fluid returns to the surface, followed by natural gas.

Trucks haul millions of gallons of freshwater from freshwater source(s) to impoundments or other water storage facilities located at the drill site. Though the actual hydraulic fracturing may take up to 5 days per individual well (NTCC, 2011), the delivery of the large volume of freshwater requires approximately two to three weeks prior, and comprises the largest category of truck trips (46%). Sand and chemical additive are subsequently delivered (Chief Oil & Gas LLC 2010, 2011). Equipment is also trucked to the site throughout the process. This preparation period of hauling takes approximately one to two months per well (NYSDEC, 2011).

After fracturing and well completion, hauls from the site will mainly transport produced water to the disposal or treatment location. Since some of the fluid and proppants remain in the well after hydraulic fracturing, the volume of produced water is less than the volume originally pumped into the well. Hauling the produce water generally takes 2-8 weeks per well (NYSDEC, 2011). The duration of hauling materials in, hydraulic fracturing, and hauling produce water out combines to approximately 3 to 5.3 months per well for this step.

Once equipment has been used, it will be dismantled and trucked off the site, most likely to another gas well. Dismantling is over a “more staggered” time period than assembly (Chief Oil & Gas LLC 2010, 2011).

All together, truck trips during hydraulic fracturing and well completion make up 80% of truck trips required for UGWD, mainly due to the large volumes of water required (Figure 3). These large water volumes are unique to high volume hydraulic fracturing as compared to other hydrocarbon extraction operations. For a well pad with six wells, this means more than 10,000 truck trips (Table

2) over the time period that all these wells would be developed. Therefore, the most roadway infrastructure damage and traffic risks exist during these steps.

The following numbers of truck trips are estimated to occur during hydraulic fracturing and well completion:

Scenario 1: 150 wells on 25 well pads in Maryland
25 well pads * 10,374 trucks per 6-well pad = 259,350 loaded, one-way truck trips
Doubled to include empty trips: 518,700 loaded and empty one-way truck trips

Scenario 2: 450 wells on 75 well pads in Maryland
75 well pads * 10,374trucks per 6-well pad = 778,050 loaded, one-way truck trips
Doubled to include empty trips: 1,556,100 loaded and empty one-way truck trips

Production/Processing, site reclamation, and well abandonment

Natural gas that emerges from a hydraulically fractured well must be processed and transported by pipelines, either to a central processing plant offsite or to other transmission lines. The sections of pipe are transported by truck and installed underground to connect the well to the gas distribution network. Onsite, the gas may need to be processed by heaters, oil/water/gas separators, and dehydrators to prevent condensation or crystallization of liquids in the gas. Onsite and offsite compressors are used to maintain pressurization required to transport the gas the distance needed through the pipelines.

Once the natural gas flow from the well has reduced significantly, liquid may periodically accumulate within the well and hinder the flow of gas. Purging this liquid is called well unloading, and trucks are needed to periodically transport this liquid offsite (Allen, 2013; U.S.EPA, 2006). Well unloading events may occur 6 to 33 times per year (Allen, 2013). Additionally, some wells output condensate. Collected condensate liquid is periodically trucked to refineries, approximately weekly (NYSDEC, 2011).

It is not clear whether truck trips in this step are included in Table 1 or Table 2 since “Final pad prep” and “Miscellaneous” activity categories are not further explained in the primary source (ALL Consulting, 2010). Here, these values are being used as estimates for this step, comprising 4% of truck trips required to develop a 6-well pad (Figure 3).

Wells typically produce natural gas for many years and can continue for decades, especially if the natural gas fields are “amenable to enhanced recovery techniques” (Sammons/Dutton LLC & Blackenship Consulting LLC, 2010). The gas production rate will decrease over time. During production, the operation will be dramatically less industrial, greatly reducing its impact on a community’s character (Sammons/Dutton LLC & Blackenship Consulting LLC, 2010).

When a well is deemed no longer economically viable, a period which gradually overlaps with the end of the production phase, it will be abandoned in accordance with regulations and the site will be reclaimed. Trucking activity required for these activities is expected to be low. Following hydraulic fracturing and completion, remaining truck activity at well sites will be “insignificant” over the long term (NYSDEC, 2011), and will have “no appreciable impact on local traffic” (Chief Oil & Gas LLC 2010, 2011). Finally, general site maintenance such as lawn-mowing would occur approximately twice a year (NYSDEC, 2011).

The following numbers of truck trips are estimated to occur during production/processing, site reclamation, and well abandonment:

Scenario 1: 150 wells on 25 well pads in Maryland
25 well pads * 495 trucks per 6-well pad = 12,375 loaded, one-way truck trips
Doubled to include empty trips: 24,750 loaded and empty one-way truck trips

Scenario 2: 450 wells on 75 well pads in Maryland
75 well pads * 495 trucks per 6-well pad = 37,125 loaded, one-way truck trips
Doubled to include empty trips: 74,250 loaded and empty one-way truck trips

Proposed Best Management Practices

Many road damage and traffic risks can be mitigated through implementation of best management practices (BMPs). In June 2013, the Maryland Department of Environment and Maryland Department of Natural Resources proposed BMPs for natural gas production from Marcellus Shale in Maryland. Thousands of public comments were received and the Interim Final Best Practices Report was released in July 2014. This risk assessment will assume that the best practices in the Interim Final report are in place and followed if and when Marcellus Shale drilling begins in Maryland. If appropriate, based on this risk assessment, the health report, or other information, additional or strengthened best practices may be recommended in the Departments' third report under the Executive Order.

Fewer trips

Some practices in the UGWD process will inherently reduce the number of required truck trips in comparison to vertical-only gas wells. The placement of multiple wells on a single well pad decreases the amount of truck traffic among wells, various hauling sources, and destinations. Furthermore, horizontal wells allow for more shale access than vertical-only wells allow, requiring distinctly fewer wells and well pads to extract an equivalent amount of natural gas. Though the number of hauls required per horizontal well is greater than that for vertical wells, truck traffic per area of land developed is cumulatively less with horizontal wells (NYSDEC 2011). Also, a required BMP in Maryland will be the treatment and reuse of at least 90% of flowback water on the well pad "unless the permittee can demonstrate that it is not practicable" (MDE & MDNR, 2014). Because recycling reduces the demand for fresh water and reduces the amount of wastewater to be disposed, it can substantially reduce the number of trucks hauling fresh water to the pad and wastewater from the well pad (NYSDEC, 2011).

The transportation plan should consider moving heavy equipment by rail, if possible. Using pipelines to transfer water to the site can also reduce truck trips. Pipelines could reduce truck traffic by 30% if moving water between sites, but introduce right-of-way controversies, the risk of leaks (Cooley & Donnely, 2012), and ecological impacts. Though using railways and pipelines would transfer some risk to those pathways instead (NYSDEC, 2011), the reduction in road damage and traffic collisions would make these safer alternatives for the nearby communities. Since each of these can only substitute for some materials' transport and a portion of overall truck routes, they cannot be complete substitutes. In this risk assessment, all water is assumed to be hauled by truck, making it a worst-case, but plausible, scenario.

Transportation planning and road construction

Travel routes will be identified in the Comprehensive Gas Development Plan and incorporated into individual permits as conditions. This planning can be used to establish truck routes that, to the extent possible, avoid roads that are very close to homes, businesses, public buildings, and high use recreational areas and direct traffic away from roads that cannot bear the traffic. Hours of road use can also be specified to avoid peak hours and times when school buses are transporting students. Once a transportation plan is approved and incorporated into the permit, it would become enforceable (MDE & MDNR, 2014).

Transportation planning will occur during the CGDP process as well as the process for considering an application for a drilling permit. The routes, hours, and times of travel should be restricted to avoid or minimize conflicts with the public as well as sensitive wildlife migratory or mating seasons. Participation by the public, state and county roads departments is encouraged. State public land managers are also encouraged to participate so that consideration can be given to periods of heavy public use such as hunting season or trout season, the impassability of roads during certain weather conditions, and the increased risk of road damage during traditionally wet periods and the spring frost breakup (MDE & MDNR, 2014).

Maryland's BMPs specify that existing roads should be used wherever possible and that roads constructed by private parties for access to gas exploration and production facilities should avoid adverse environmental impacts and minimize those that cannot be avoided. The BMPs require that the design, construction and maintenance of unpaved roads be at least as protective of the environment as the guidelines adopted by the Pennsylvania Department of Conservation and Natural Resources, Bureau of Forestry, for roads in leased State forest land (PA DCNR, 2013). This includes modifying road elevation to restore drainage, sufficient compacting and top dressing, geotextiles where required, dust control, and prompt stabilization of disturbed areas to prevent erosion, among other specifications (PA DCNR, 2011). Additionally, forest fragmentation and disturbance at stream crossings should be minimized. Existing Maryland sediment and erosion control plans and stormwater management plans address this as well (MDE & MDNR, 2014).

Emergency response planning will include disclosure of the hazardous materials being transported and advance consultation with emergency response personnel. This will reduce the risk to emergency responders and the public in the event of a vehicle incident involving hazardous chemicals (MDE & MDNR, 2014).

Road agreements

Applicants for gas well permits will be required to enter into agreements with the county and/or municipality to restore the roads which it makes use of to the same or better condition the roadways had prior to the commencement of the applicant's operations, and to maintain the roadways in a good state of repair during the applicant's operations (MDE& MDNR, 2014). A common form for such an agreement is a Road Use and Maintenance Agreement or RUMA.

The components of RUMAs vary, and the counties and/or municipalities will have to negotiate their RUMAs with the drilling companies. It is common to require the company to post a bond to reimburse the local jurisdiction in the event performance is not satisfactory. Additionally, RUMAs can include requirements to improve and reinforce existing roads, bridges, clearance at intersections, drainage facilities, and other relevant infrastructure along the truck route prior to the start of natural gas development (NYSDEC, 2011).

Existing tools

The costs for State road repair and maintenance for the increased traffic associated with UGWD may be partially offset by the payment by trucks of fees and taxes, such as registration fees (apportioned under the International Registration Plan) and motor fuel taxes (apportioned according to the International Fuel Tax Agreement) (MDDOT, 2012). Where permits are obtained for overweight or oversized vehicles, the State can require a contractual liability agreement to indemnify the State Highway Administration of Maryland and the State of Maryland for all loss arising from damage to the road beds and wearing surfaces of any highways and structures used by the permittee and all sub-surface installations, and/or signs, signals, etc. (MDDOT, 2008). Counties also have programs for overweight or oversized vehicles.

In Table 8, these tools are broken down by truck weight and type of road.

Table 8. Regulatory tools charging trucking operators for road damage.

Truck weight	State roads	County and municipal roads
Overweight and/or oversized	• Overweight/oversize vehicle permit fee, plus payment for all damage caused[1] • State roadway taxes and fees (meant to provide for road upkeep)[2]	• Overweight/oversize vehicle weight restrictions and/or charges: Garret County[3], possibly others • Expected RUMAs with operators to maintain roads and return to original conditions[4]
Not overweight or oversized	• State roadway taxes and fees (meant to provide for road upkeep)[2]	• Expected RUMAs with operators to maintain roads and return to original conditions[4]

1 (COMAR 11.04.01)
2 (MDE 2014)
3 (Garret County, MD Code of Ordinances 1971)
4 (MDE & MDNR, 2014), sample agreement: (Town of Windsor, 2010)

Flowback disposal onto roads not permitted

Finally, though Resources for the Future listed wastewater application to roads for deicing and dust suppression as a risk (Krupnick et al., 2013), this practice will be not be allowed in Maryland. This pathway is not explicitly addressed in the BMP document; however, the state will only allow flowback disposal through authorized treatment and disposal facilities. Furthermore, the state proposes that records be kept of flowback volumes at the well pad and the delivery facility to ensure the arrival of all waters. These records will be made available for audits and/or inspections (MDE & MDNR, 2014). Since flowback water will not be used for deicing and dust suppression in Maryland, this risk is not applicable and was not examined in this document.

Risk Mitigation

Traffic and road damage issues have been documented in natural gas drilling areas even in the presence of road agreements and safety requirements. Three main sources of these problems are: 1) issues with road use agreements, 2) safety compliance problems with trucks, and 3) the high rate of highway accidents in the oil and gas industry.

Road use agreement issues

During the literature review for this risk assessment, some additional measures were specified that could improve the structuring and enforcement of RUMAs. New York DEC recommended creating video and photo road surveys to document prior road conditions (NYSDEC, 2011; Randall, 2010). Other studies mentioned contracting with an engineering company to create plans or traffic impact assessments prior to the start of trucking to help ensure cost accountability (Mitchell, 2010; Randall, 2010; Wilber, 2010). Enforcement of truck weight restrictions via periodic unannounced enforcement sweeps, for example, is also recommended. RUMAs should be legally vetted to help ensure their effectiveness (Mitchell, 2010; Randall, 2010). Collaboration among jurisdictions and guidance from the state can prevent legal issues later on (Mitchell, 2010).

Passing a road preservation law is an alternative option. The legislature of Tompkins County, NY adopted a County Road Preservation Law in 2011. Posting, permitting, and bonding requirements are triggered when more than 1,000 truck trips are made by trucks weighing more than 30 tons ("News Details – Legislature Adopts Road Preservation Law," 2011).

A road and bridge impact report prepared for Rio Blanco County, Colorado, recommended a road impact fee schedule for residential, nonresidential, and gas or oil well development. The fee for gas or oil well varied from $10,918 to $18,762 per well, in 2007 dollars (RPI Consulting, 2008).

As part of Cornell University Law School's Environmental Law Online Resource Center, a shale gas drilling guide was prepared to advise local jurisdictions on road impact (Mitchell, 2010). As reported in this document, the city of Fort Worth, Texas encountered issues with collecting bonds from the UGWD companies and paying for road damage, despite a negotiated agreement in 2001. These issues occurred despite the fact that the city hired engineers to photograph the roads both before and after the drilling process had been completed. Small road repairs were paid by some drillers; however, bonds had not yet been collected as of 2010 "because it has been too difficult to point the finger at gas drillers for long-term road destruction." Details of the agreement were not specified. A subsequent effort to implement a permit fee instead was not adopted due to strong gas industry opposition. Fort Worth attorney Sarah Fullenwider said that the city had not yet found a solution to paying for road damage (Mitchell, 2010).

If counties, municipalities, and/or the state are left with infrastructure damage or reduced roadway life unpaid for by the drillers, this will represent a negative externality. The cost, both monetary and in terms of quality of life, will be borne by those jurisdictions and roadway users. As stated in the Rio Blanco County, Colorado, road and bridge impact report:

> *If the County does not charge new development for its fair share of the costs, then existing taxpayers will bear the burden of building capacity related improvements. This results in a de-facto subsidy of new growth by the taxpayers at large.*
> *(RPI Consulting 2008)*

Compliance

Noncompliance by trucks associated with natural gas development has been common in parts of Pennsylvania. Pennsylvania State Police (PA Police) Commissioner Frank Pawlowski and Pennsylvania DOT Secretary Allen Biehler reported that drilling has brought more truck traffic, traffic violations, road damage, and crime. An enforcement effort in Susquehanna County, PA conducted on February 9, 2010 found that 56% of 194 inspected trucks exceeded the weight limit. Of those overweight trucks, 50% were also cited for safety violations. Also, road damage has not always been repaired quickly, and has resulted in road closures due to safety concerns from "extensive damage." Additional state and local government resources were needed to address this increased need for enforcement (PA DOT, 2010b).

In response to the observed increase in traffic and noncompliance of state laws, the PA Police partnered with the Pennsylvania Department of Environmental Protection (PA DEP) in September 2010 to fund FracNet, an enforcement effort of unannounced roadside inspections for trucks supporting natural gas extraction. In 2009, PA Police and the PA DEP inspected more than 4,300 trucks associated with drilling in the Marcellus shale as well as trash trucks. Of the 4,300, 62% were issued citations and 18% were taken out of service. In June 2010, a joint effort to inspect trucks hauling fracturing waste water carried out by PA Police, PA DEP, the Pennsylvania Public Utility Commission (PA PUC), and the federal Motor Carrier Safety Administration resulted in 250 trucks being placed out of service for safety deficiencies (PA DEP 2010b). Local newspapers have also reported on inspected trucks exceeding weight limits, sometimes by many tons, and operating with other safety violations (Wilber 2010; Whong 2010a, 2010b, 2010c).

In a letter to the PA PUC, PA Police Lieutenant Raymond J. Cook described safety issues "caused by the recent influx of heavy trucks in the Marcellus Shale region." From the significantly higher truck traffic, he said the road infrastructure has crumbled to the point of posing "an immediate safety concern." Not only does this considerably hinder emergency service vehicles, but heavy trucks, especially those with unsecured loads, "are more prone to rollover and crash when driven on an unstable road surface." From April 1 to June 7, 2010, more than 400 trucks supporting drilling operations were inspected; either the driver or the vehicle was placed out of service in 56% of inspections due to "serious safety violations" (Cook, 2010). In comparison, the expected federal out-of-service violation rate of a Level I (full) inspection is 25 to 27% (FMCSA, 2014). Also concerning was that 66% of trucks hauling hazardous materials were placed out of service. Additionally, PA Police encountered the following issues (Cook, 2010):

- Single-trip Special Hauling Permits were being used multiple times;
- Weights exceeded permitted limits;
- Trucks operated after sunset;
- Trucks were found off their permitted travel routes;
- Defective brakes were "common" safety violations;
- Log records of duty status were at issue;
- Loads were improperly secured.

To increase enforcement efforts and reduce violations, cost has increased. Resources have been used to train more than 100 personnel, purchase additional weight scales, and educate stakeholders including members of the industry, local district judges, and local law enforcement (Cook, 2010).

Roadway accidents in the industry

Transportation incidents are the most common fatal event in U.S. industries overall. In 2012, for example, transportation incidents accounted for 42% of the workplace fatalities (USBLS 2012). From 2003 to 2009, the Bureau of Labor Statistics' Census of Fatal Occupational Injuries reported that 716 oil and gas extraction workers were killed on the job. This resulted in an annual fatality rate of 27.5

deaths per 100,000 workers, seven times higher than 3.9 per 100,000 for all U.S. workers. Of these 716 deaths, 29% were highway motor vehicle crashes (CDC, 2012).

The CDC noted that there was a correlation between fatality rates and the number of active drilling rigs. It speculated, “This could be a result of an increase in the proportion of inexperienced workers, longer working hours (more overtime), and the utilization of all available rigs (older equipment with fewer safeguards).” Fatigue is obviously an important risk factor in motor-vehicle crashes. Oil and gas workers may be especially fatigued for a number of reasons. Many operations on the drill pad go on 24 hours a day, 7 days a week. During drilling, workers often work 8 or 12 hour shifts and work for up to 14 days in a row before taking a lengthy break. The Federal Motor Carrier Safety Administration (FMCSA) sets hour of service rules for commercial motor vehicles (CMV) (49 CFR 395). Drivers in the oil and gas industry are exempt from some of the hours of service rules that otherwise apply to CMV drivers. This is referred to as the “oilfield exception.”

Oil and gas industry drivers, like other CMV drivers, must have 10 consecutive hours off-duty before starting a work day. That work day may not extend beyond 14 hours, 11 hours of which may be driving time. Oil and gas industry drivers, like other CMV drivers, are limited to being on duty for no more than 60 hours in any consecutive period of 7 days or 70 hours in any consecutive period of 8 days. Drivers of commercial motor vehicles used exclusively in the transportation of oilfield equipment and servicing of field operations of the natural gas and oil industry, however, may “reset” the work week with an off-duty period of 24 or more successive hours, compared to 34 consecutive hours for other CMV drivers. This “reset” rule applies to trucks carrying water and sand, as well as other material used in the servicing of field operations (49 CFR 395.1(d)(1)). The work day limits still apply.

Another part of the oilfield exception applies to a subset of CMV drivers in the oil and gas industry – “specially trained drivers of commercial motor vehicles that are specially constructed to service” natural gas or oil wells. This exemption addresses whether waiting time is on-duty time or off-duty time (49 CFR 395.1(d)(2)). These drivers are allowed to accumulate the requisite 10 hours of off-duty time before beginning a work day in shorter rest periods. These rest periods are not counted against the next 14-hour workday, although the 11-hour driving time still applies. This exception does not apply to drivers of CMV who are delivering supplies, including water and sand. It was apparent that some drivers and states were misinterpreting the scope of the oilfield exemption. In guidance, FMCSA clarified this exception:

> *The “waiting time” provision in Section 395.1(d)(2) is available only to operators of those commercial motor vehicles (CMVs) that are (1) specially constructed for use at oil and gas well sites, and (2) for which the operators require extensive training in the operation of the complex equipment, in addition to driving the vehicle. In many instances, the operators spend little time driving these CMVs because "leased drivers" from drive away services are brought into move the heavy equipment from one site to another. These operators typically may have long waiting periods at well sites, with few or no functions to perform until their services are needed at an unpredictable point in the drilling process. Because they are not free to leave the site and may be responsible for the equipment, they would normally be considered "on duty" under the definition of that term in § 395.2. Recognizing that these operators, their employers, and the well site managers do not have the ability to readily schedule or control these driver’s periods of inactivity, Section 395.1(d)(2) provides that the "waiting time" shall not be considered on-duty (i.e., it is off-duty time). During this "waiting time," the operators may not perform any work related activity. To do so would place them on duty. Examples of equipment that may qualify the operator/driver for the "waiting*

> *time exception" in Section 395.1(d)(2) are vehicles commonly known in oilfield operations as heavy-coil vehicles, missile trailers, nitrogen pumps, wire-line trucks, sand storage trailers, cement pumps, "frac" pumps, blenders, hydration pumps, and separators. This list should only be considered examples and not all-inclusive. Individual equipment must be evaluated against the criteria stated above: (1) Specially constructed for use at oil and gas well sites, and (2) for which the operators require extensive training in the operation of the complex equipment, in addition to driving the vehicle infrequently. Operators of CMVs that are used to transport supplies, equipment, and materials such as sand and water to and from the well sites do not qualify for the "waiting time exception" even if there have been some modifications to the vehicle to transport, load, or unload the materials, and the driver required some minimal additional training in the operation of the vehicle, such as running pumps or controlling the unloading and loading processes. It is recognized that these operators may encounter delays caused by logistical or operational situations, just as other motor carriers experience delays at shipping and receiving facilities. Other methods may be used to mitigate these types of delays, which are not the same types of waiting periods experienced by the CMV operators who do qualify for the waiting time exception.*
> *(77 FR 33098)*

The FMCSA confirmed this interpretation in 2013 (78 FR 48817).

In 2000, the FMCSA proposed to alter the oilfield exemption to become more consistent “with the modern understanding of fatigue” and thereby reduce fatigue-induced crashes. These modifications were intended to “allow those drivers to get the restorative sleep the research suggests they need to ensure their own safety and that of others” (65 FR 85). The industry opposed these changes and the oilfield exemption remains in place.

In 2010, FMCSA proposed changes to the hours of service rules (75 FR 249). In commenting on the proposed regulations, the National Transportation Safety Board, the federal agency responsible for investigating accidents, supported some of the changes, but repeated its strong opposition to leaving in place special provisions that exempt some drivers from the hours of service requirements, including the oilfield exception. It noted, “Such exemptions are likely to lead to increased risk for the exempted population and the driving public” (Hersman, 2011).

Kenny Jordan, executive director of the Association of Energy Service Companies, stated that the problem comes not from the exemption, but that “it is the enforcement of the existing rule that is the issue” (Jordan, 2010; Urbina, 2012). The Consumer Energy Alliance, co-chaired by the American Petroleum Institute (API), National Tank Truck Carriers, and the American Trucking Associations, produced recommendations for improving road safety and traffic management in the oil and natural gas industry. They include promotion of continued driver education, meetings with communities and emergency responders, fatigue prevention, requiring proof of compliance, and minimizing wait times. This was an educational campaign developed in 2013 and is voluntary (Consumer Energy Alliance, 2013a, 2013b). The API and American National Standards Institute also produced general “Community Engagement Guidelines” that mention truck traffic in communities (ANSI and API, 2014).

There is general agreement that driver fatigue issues exist and persist in the industry. The combination of driver fatigue and documented low rates of compliance with truck safety rules in some locations raises the risk of transportation incidents that can kill or injure not only the worker, but also members of the public who use the same roads.

Conclusion

Overall, UGWD will bring a significant increase in truck traffic to nearby communities. This will lead to roadway infrastructure damage as well as corresponding increases in traffic hindrances and accidents. BMPs will help mitigate these risks, but they cannot be eliminated. Residents living along a truck route near a well pad could expect to see many thousands of trucks going by their homes over years of well development:

Scenario 1: 150 wells on 25 well pads in Maryland
25 well pads * 12,974 trucks per 6-well pad = 324,350 loaded, one-way truck trips
Doubled to include empty trips: 648,700 loaded and empty one-way truck trips

Scenario 2: 450 wells on 75 well pads in Maryland
75 well pads * 12,974 trucks per 6-well pad =973,050 loaded, one-way truck trips
Doubled to include empty trips: 1,946,100 loaded and empty one-way truck trips

Prevention and repair of road damage on county and municipality roads will be dependent on agreed-upon transportation plans and road use agreements. Legal vetting of the local RUMAs and documentation of road conditions before, during, and after the activity will be critical to ensuring drillers' performance of their obligations, as will communication and transparency among parties. Short term, there will likely be road damage prior to time of repair. That damage may not be promptly repaired if disagreements among parties (UGWD operators and local jurisdictions) occur concerning responsibility and extent of payment on a case-by-case basis. Larger state roads will experience some level of reduced roadway life, but repair is financially supported by state taxes and fees, not road use agreements. Whether the full cost of the reduced roadway life will be covered by the state taxes and fees is unclear. The estimation of probability and consequence, and risk ranking appears in Table 10. Cumulative risks across phases appear in Table 11.

The projected increase in trucking accidents could result in injuries or fatalities. This occurs in other industries as well, but part is unique to UGWD due to the large volume of water required and the fatigue that workers and drivers experience, as documented by federal agencies. As stated in a study for New York state, "One of the largest and most obvious potential impacts on community character is the issue of trucking" (NTCC, 2011). This risk needs to be weighed against the overall benefits of UGWD in Maryland. A summary of the sources of the risk, the harm, and the BMPs appears in Table 9. The estimation of probability, consequence, and risk ranking appears in Table 10.

Finally, the ecological impacts of road construction and traffic include habitat loss, fragmentation, increased sedimentation, stormwater runoff, and recreation impacts. The estimation of probability and consequence, and risk ranking appears in Table 10. Cumulative risks across phases appear in Table 11.

Table 9. Summary of causes, effects, and BMPs.

	Road damage	**Traffic impacts to community**	**Ecological impacts**
Sources of Risk	• Number of truck trips • Truck weight, both in and out of compliance • Potential issues with payment for road infrastructure repairs	• Number of truck trips • Safety violations like unsecured loads, defective brakes • Worker and driver fatigue	• Number of truck trips • Road construction and modification
Results / Consequences of Risk	• Road damage and associated repair costs of varying magnitudes, short-term and potentially long-term • Higher risk of rollover of heavy/ unsecured trucks on damaged roads • Hindrance to emergency services including ambulances, police, fire • Congestion and detriment to travel for community residents • Damage to residents' vehicles driving on cracked and/or rutted roads	• Injuries, fatalities from crashes • Hindrance to emergency services including ambulances, police, fire • Congestion and detriment to travel for community residents • Change in character of rural communities • Local cost to increase enforcement and traffic control infrastructure	• Sedimentation, pollution of surface water • Forest fragmentation and loss • Corresponding detriments to fish and wildlife • Outdoor recreational impacts
Proposed BMPs	• Fewer trucks via: multiple wells per wellpad (HVHF), use of horizontal wells, reuse of flowback water, and use of rail and pipelines • Road agreements to reduce costs, prevent damage and/or reduce time that roads are in disrepair • Transportation plans to define routes and timing	• Fewer trucks via: multiple wells per wellpad (HVHF), use of horizontal wells, reuse of flowback water, and use of rail and pipelines • Road agreements to help prevent damage and/or reduce time that roads are in disrepair • Transportation plans to define routes and timing	• Location of access roads considered in CGDP • Road construction must minimize environmental impacts via construction standards for forest roads • Transportation plans to define routes and timing • Forest loss and stream crossing disturbance should be minimized

Table 10. Summary of probabilities, consequences, and risk rankings. In each cell, probability (Low, Medium, or High) is listed first; consequence (Minor, Moderate, or Serious) is listed second; and overall risk is represented by the color. White is Low, orange is Moderate, and red is High risk.

Aspect	**Agent/chemical**	**Impact on**	**Phase**				
			Site identification /preparation	**Drilling, casing and cementing**	**HVHF / Well completion**	**Production**	**Well abandonment/ reclamation**
Traffic, road damage	Injury and death from traffic accidents	Community	Low/Serious	Medium / Serious	High/ Serious	Low/ Serious	Low/ Serious
Road damage	Cost of repair of road damage	Community	Low/Minor	Medium / Minor	High/ Minor	Low/ Minor	Low/ Minor
Road damage	Damage to resident's vehicles from road damage	Community	Low/ Minor	Medium/ Minor	High/Minor	Low/ Minor	Low/Minor
Road damage	Increased risk of roll-over, etc. from road damage	Community	Low/ Moderate	Medium / Moderate	High/ Moderate	Low/ Moderate	Low/Moderate
Traffic, road damage	Delay of emergency vehicles	Community	Low/ Moderate	Medium/ Moderate	High/ Moderate	Low/ Moderate	Low/ Moderate
Traffic, road damage	Delays and inconvenience (non-emergency vehicles)	Community	Low/ Minor	Medium / Minor	High/ Minor	Low/ Minor	Low/Minor
Traffic, road damage	Increased cost of policing	Community	Low/ Minor	Medium / Minor	High/ Minor	Low/ Minor	Low/Minor
Traffic	Loss of rural character	Community	Low/ Minor	Medium / Minor	High/ Minor	Low/ Minor	Low/Minor
Traffic	Interference with outdoor recreation	Community	Low/ Minor	Medium / Minor	High/ Minor	Low/ Minor	Low/Minor
Road construction, traffic, road damage	Sedimentation, pollution of surface water	Ecological	Medium / Minor	Low/Minor	Low/ Minor	Low/ Minor	Low/Minor
Road construction, traffic, road damage	Forest fragmentation, harm to wildlife	Ecological	Medium / Moderate	Low/ Moderate	Low/ Moderate	Low/ Moderate	Low/ Moderate

Suggestions for Additional Mitigation

It is clear that a major risk factor in high-volume hydraulic fracturing is truck traffic, especially trucks carrying water to the well pad. The use of central water impoundments and pipelines to transfer the water to the well pad could reduce the amount of traffic, but large impoundments must still be filled with water, and pipelines have ecological impacts. A better solution would be use of a different technology that allows fracturing without the use of such large quantities of water. The Departments and the Advisory Commission have learned that such technologies are being developed, although it is not clear whether they are suitable for the Marcellus Shale in Maryland or what impacts they might have. They include the use of liquid CO_2 as the fracturing fluid or the use of solid rocket propellant in place of the fluid. If such technologies are feasible, Maryland could require their use in place of water-based fracturing fluid.

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