CENTER for BIOLOGICAL DIVERSITY
Because life is good.
working through science, law and creative media to secure a future for all species, great or small, hovering on the brink of extinction.

September 14, 2015

VIA FAX (303-239-3799)

Ruth Welch, State Director
Colorado State Office
BLM
2850 Youngfield St.
Lakewood, CO 80215

Dear Ms. Welch:

The Center for Biological Diversity (the "Center") hereby files this Protest of the Bureau of Land Management ("BLM")'s planned November 12, 2015 oil and gas lease sale and Environmental Assessment DOI-BLM-CO-F020-2015-0061 DN pursuant to 43 C.F.R. § 3120.1-3. The Center formally protests the inclusion of each of the following parcels, covering 89,534.3 acres in the Royal Gorge Field Office, including the Pawnee National Grasslands:

COC77247	COC77271	COC77295	COC77319	COC77343
COC77248	COC77272	COC77296	COC77320	COC77344
COC77249	COC77273	COC77297	COC77321	COC77345
COC77250	COC77274	COC77298	COC77322	COC77346
COC77251	COC77275	COC77299	COC77323	COC77347
COC77252	COC77276	COC77300	COC77324	COC77348
COC77253	COC77277	COC77301	COC77325	COC77349
COC77254	COC77278	COC77302	COC77326	COC77350
COC77255	COC77279	COC77303	COC77327	COC77351
COC77256	COC77280	COC77304	COC77328	COC77352
COC77257	COC77281	COC77305	COC77329	COC77353
COC77258	COC77282	COC77306	COC77330	COC77354
COC77259	COC77283	COC77307	COC77331	COC77355
COC77260	COC77284	COC77308	COC77332	COC77356
COC77261	COC77285	COC77309	COC77333	COC77357
COC77262	COC77286	COC77310	COC77334	COC77358
COC77263	COC77287	COC77311	COC77335	COC77359
COC77264	COC77288	COC77312	COC77336	COC77360
COC77265	COC77289	COC77313	COC77337	COC77361
COC77266	COC77290	COC77314	COC77338	COC77362
COC77267	COC77291	COC77315	COC77339	COC77363

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COC77268	COC77292	COC77316	COC77340	COC77364
COC77269	COC77293	COC77317	COC77341	COC77365
COC77270	COC77294	COC77318	COC77342	COC77366
				COC77367

PROTEST

1. Protesting Party: Contact Information and Interests:

This Protest is filed on behalf of the Center for Biological Diversity and their board and members by:

Wendy Park
Staff Attorney
Center for Biological Diversity
1212 Broadway #800
Oakland, CA 94612
wpark@biologicaldiversity.org

The Center is a non-profit environmental organization with 50,400 member activists, including members who live and recreate in the Royal Gorge planning area, including the Pawnee National Grasslands. The Center uses science, policy and law to advocate for the conservation and recovery of species on the brink of extinction and the habitats they need to survive. The Center has and continues to actively advocate for increased protections for species and habitats in the planning area on lands managed by the BLM and Forest Service. The lands that will be affected by the proposed lease sale include habitat for listed, rare, and imperiled species that the Center has worked to protect including the mountain plover, ferruginous hawk, bald eagle, and sharp-tailed grouse. The Center's board, staff, and members use the lands within the planning area, including the lands and waters that would be affected by actions under the lease sale, for quiet recreation (including hiking and camping), scientific research, aesthetic pursuits, and spiritual renewal.

2. Statement of Reasons as to Why the Proposed Lease Sale Is Unlawful:

BLM's proposed decision to lease the parcels listed above is substantively and procedurally flawed for the reasons discussed below.

A. The Lease Sale Should Be Suspended Until BLM Has Had the Opportunity to Consider a No-Leasing-No-Fracking Alternative in its Update of the Eastern Colorado Resource Management Plan.

On July 31, 2015, the Center, Food & Water Watch, Colorado 350, and John Fielder submitted a scoping comment letter requesting consideration of a "no-leasing-no-fracking" alternative in BLM's update of the Eastern Colorado Resource Management Plan. The comment

letter is attached hereto and incorporated by reference. As described in the letter, halting all new leasing and fracking within the Eastern Colorado planning area would be an important step towards slowing the effects of climate change:

> The internationally agreed-on target for avoiding dangerous climate change and its disastrous consequences is limiting average global temperature rise caused by greenhouse gas pollution to two degrees Celsius (2°C), or 3.6 degrees Fahrenheit.[18] Climate experts have estimated that the world can emit 1,000 gigatons of carbon dioxide (1,000 $GtCO_2$ or 1 trillion tons of CO_2) after 2010 to have a reasonable chance of staying below 2°C of warming.[19] Given uncertainties, coupled with the dire predictions of climate change impacts, a more conservative carbon budget would be more prudent. Nonetheless, using this budget, the IPCC has found that proven fossil fuel reserves amount to **four to seven times more** than what we can afford to burn, to have only a *likely* chance of staying within the 2°C target.[20] In short, the vast majority of proven reserves must be kept in the ground for preserving a livable planet. Minimizing new fossil fuel production is critical. Opening up new areas to extraction and allowing more fracking, on the other hand, runs completely counter to slowing the effects of climate change.

According to a recent report by EcoShift Consulting commissioned by the Center and Friends of the Earth, unleased federal fossil fuels represent a significant source of potential greenhouse gas emissions:

- Potential GHG emissions of federal fossil fuels (leased and unleased) if developed would release up to 492 gigatons (Gt) (one gigaton equals 1 billion tons) of carbon dioxide equivalent pollution (CO2e); representing 46 percent to 50 percent of potential emissions from all remaining U.S. fossil fuels.
- Of that amount, up to 450 Gt CO2e have not yet been leased to private industry for extraction;
- Releasing those 450 Gt CO2e (the equivalent annual pollution of more than 118,000 coal-fired power plants) would be greater than any proposed U.S. share of global carbon limits that would keep emissions below scientifically advised levels.[1]

Fossil fuels within the Eastern Colorado planning area are a significant portion of the federal carbon estate. According to the Eastern Colorado Reasonably Foreseeable Development Scenario, operators could extract over 47 million barrels of oil, over 1 trillion cubic feet of conventional natural gas, and over 152 billion cubic feet of coalbed natural gas within the planning area over the next two decades.[2] At least 1.2 billion tons of federal coal could be extracted. These vast reserves—some of which underlie the nearly 90,000 acres of fluid minerals

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[1] EcoShift Consulting et al., The Potential Greenhouse Gas Emissions of U.S. Federal Fossil Fuels (Aug. 2015), available at http://www.ecoshiftconsulting.com/wp-content/uploads/Potential-Greenhouse-Gas-Emissions-U-S-Federal-Fossil-Fuels.pdf,

[2] http://www.blm.gov/style/medialib/blm/co/programs/oil_and_gas/Lease_Sale/2015/november_2015.Par.28735.File.dat/RGFO_Nov_15_EA.pdf.

available for lease—represent a significant opportunity to lock away millions of tons of greenhouse gas emissions.

As BLM has not yet had a chance to consider a no-leasing-no-fracking-alternative as part of the Eastern Colorado RMP planning process, BLM should suspend new leasing until it properly considers this alternative in the EIS. BLM has *never* comprehensively considered the cumulative climate change impacts of *all* potential fossil fuel extraction within the Eastern Colorado planning area. But climate change is a problem of regional and global proportions resulting from the cumulative greenhouse gas emissions of countless individual sources, which cannot simply be addressed piecemeal on a project-by-project basis. BLM would be remiss to continue leasing when it has never stepped back and taken a hard look at this problem at the appropriate scale. Before allowing more oil and gas extraction in the planning area, BLM must: (1) comprehensively analyze the total greenhouse gas emissions which result from fossil fuel leasing and all other activities within the planning area, (2) consider their cumulative significance in the context of global climate change, carbon budgets, and other greenhouse gas pollution sources outside the planning area, and (3) formulate measures that avoid or limit their climate change effects. By continuing leasing in the absence of any overall plan addressing climate change BLM is effectively burying its head in the sand.

BLM's mandate to ensure "harmonious and coordinated management of the various resources *without permanent impairment of the productivity of the land and the quality of the environment*" requires BLM to limit the climate change effects of its actions. *See* 43 U.S.C. §§ 1701(a)(7), 1702(c), 1712(c)(1), 1732(a) (emphasis added); *see also id.* § 1732(b) (directing Secretary to take any action to "prevent unnecessary or undue degradation" of the public lands). Those effects have already taken a significant toll on public lands in the form of more severe droughts and wildfires, reduced snowmelt and stream flows, and degraded habitat for species. Suspension of new leasing would maximize BLM's options for slowing the effects of climate change and preventing degradation of the public lands. Once parcels are leased for oil and gas development, BLM will be more constrained in its ability to limit greenhouse gas emissions from oil and gas operations in the planning area. Under BLM's interpretation of its regulations, absent a no surface occupancy stipulation, a lessee has the right to surface use of the leased parcel once the lease is final. *See Richardson*, 565 F.3d at 718 (citing 43 C.F.R. § 3101.1-2 ["A lessee shall have the right to use so much of the leased lands as is necessary to explore for, drill for, mine, extract, remove and dispose of all the leased resource in a leasehold subject to: Stipulations attached to the lease . . . [and other] reasonable measures . . . ."]). With a no surface occupancy stipulation, drilling operations and extraction could still occur remotely off-site. BLM should preserve all of its options for managing climate change effects, which threaten "permanent impairment of the productivity of the land and the quality of the environment."

Suspension of new leasing would also avoid the adverse effects of hydraulic fracturing, detailed in the Center's July 31 scoping comment, until BLM fully considers these impacts, and balances other competing resource uses in a comprehensive planning process. Conditions have dramatically changed since 1991 and 1996, when the Northeast and Royal Gorge RMPs last considered oil and gas leasing, due to climate change, rapid population growth along the Front Range, and increasing water scarcity and other climate- and human-induced strains on natural resources. Fracking and horizontal drilling are relatively new and dangerous extraction methods

that the current RMPs do not address. All of these changed conditions require a fresh look at the public health, environmental, environmental justice, and industrialization impacts of fossil fuel extraction and especially fracking across the entire Eastern Colorado planning area. Furthermore, they require a re-evaluation of conservation needs and objectives for increasingly scarce and/or fragile natural resources. Piecemeal analyses of individual APDs or lease sales do not provide the appropriate perspective for examining the cumulative effects of fracking at the regional and landscape scale and for making such land management decisions. Proceeding with new leasing and fracking proposals *ad hoc* in the absence of a comprehensive plan that addresses these changed conditions is premature and risks irreversible damage before the agency and public have had the opportunity to weigh the full costs of oil and gas extraction and consider necessary limits on fracking.

B. BLM's Proposed Finding of No Significant Impact and Determination of NEPA Adequacy Are Arbitrary and Capricious.

BLM's proposed Finding of No Significant Impact ("FONSI") for the sale of BLM parcels (which includes split-estate parcels), and its proposed Determination of NEPA Adequacy ("DNA") for the sale of Forest Service parcels, lack any evidentiary support with respect to the lease sale's impacts on wildlife. BLM's Environmental Assessment ("EA") does not adequately analyze the impacts of leasing BLM parcels on the Ferruginous Hawk and other raptors, Mountain Plover, and Mule Deer. The DNA also erroneously relies on the Forest Service's Pawnee National Grasslands Oil and Gas Leasing Analysis Final Environmental Impact Statement ("PNG FEIS") to determine that the proposed sale of the Forest Service parcels complies with NEPA. The PNG FEIS fails to consider effective measures to mitigate the impacts of oil and gas development on raptors, including the Ferruginous Hawk, and BLM fails to discuss or impose any such measures.

Ferruginous Hawks and Other Raptors

Ferruginous Hawk habitat is found throughout the RGFO, including the Pawnee National Grasslands, and many parcels overlap this habitat. *See* Rocky Mountain Wild Mapping for Colorado November 2015 Lease Sale ("RMW Maps") and RMW ABI Screen.[3] In addition

[3] Maps available at: http://rockymountainwild.org/_site/wp-content/uploads/15-109_CONov2015Sale_Map_1.pdf; http://rockymountainwild.org/_site/wp-content/uploads/15-109_CONov2015Sale_Map_2.pdf; http://rockymountainwild.org/_site/wp-content/uploads/15-109_CONov2015Sale_Map_3.pdf; http://rockymountainwild.org/_site/wp-content/uploads/15-109_CONov2015Sale_Map_4.pdf; http://rockymountainwild.org/_site/wp-content/uploads/15-109_CONov2015Sale_Map_5.pdf; http://rockymountainwild.org/_site/wp-content/uploads/15-109_CONov2015Sale_Map_6.pdf; http://rockymountainwild.org/_site/wp-content/uploads/15-109_CONov2015Sale_Map_7.pdf; http://rockymountainwild.org/_site/wp-content/uploads/15-109_CONov2015Sale_Map_8.pdf; http://rockymountainwild.org/_site/wp-content/uploads/15-109_CONov2015Sale_Map_9.pdf; http://rockymountainwild.org/_site/wp-content/uploads/15-109_CONov2015Sale_Map_10.pdf; http://rockymountainwild.org/_site/wp-content/uploads/15-109_CONov2015Sale_Map_11.pdf; http://rockymountainwild.org/_site/wp-content/uploads/15-109_CONov2015Sale_Map_12.pdf; http://rockymountainwild.org/_site/wp-content/uploads/15-109_CONov2015Sale_Map_13.pdf. RMW's ABI Screen is available at http://rockymountainwild.org/_site/wp-content/uploads/15-109_CONov2015SaleNoticeScreen.xlsx. The habitat data in these maps and screen are sourced from Colorado Parks and Wildlife.

However, while the EA notes that existing 1/8-mile stipulations to protect the Ferruginous Hawk are inadequate, and that the "best available science" requires a one-mile buffer to protect Ferruginous Hawks, it nevertheless makes no changes to these stipulations, such that a FONSI is untenable.

The EA provides the following discussion of impacts to the Ferruginous Hawk:

> Raptors are protected by a suite of stipulations (CO-03, CO-18, and RG-05) that require no surface occupancy within one-eighth of a mile of nests and a timing limitation to protect raptor nesting and fledgling habitat. *It is widely noted that 1/8 of a mile buffer for ferruginous hawk is highly ineffective protection based on the best available science, and that this does not protect inactive nests which may be used in alternate years.* This species is very sensitive to disturbance during breeding season, and such actions would cause nest failure, including abandonment of chicks; *best available science emphasizes a one-mile buffer. New stipulations developed for this species for a 1/2 mile buffer may be incorporated into future leases.*

EA 53-54 (emphases added).

CO-03 directs that "[n]o surface occupancy or use is allowed…[t]o protect raptor nests within a one-eighth mile radius from the site." CO-18 is a timing stipulation prohibiting surface use, except operation and maintenance of production facilities, from February 1 through August 15, "[t]o protect raptor (this includes golden eagles, all accipiters, falcons [except the kestrels], all butteos, and owls) nesting and fledgling habitat during usage for one-quarter mile around the nest site." BLM appears to interpret these stipulations to prohibit disturbance within one-eighth mile of a raptor nest or within one-quarter mile of nesting and fledgling habitat. *See* EA at 53. Numerous BLM parcels are subject to CO-03 and CO-18, suggesting that significant levels of potential Ferruginous Hawk habitat and nesting sites are located within these areas. *See* BLM Lease Sale Notice, Attachment A. (RG-05 appears to be a timing stipulation similar to CO-18, but RG-05 has not been applied to any parcel).

Despite BLM's clear recognition that 1-mile buffers are necessary to avoid Ferruginous Hawk nest failure and abandonment of chicks, the EA cryptically notes that "[n]ew stipulations developed for this species for a *1/2 mile* buffer *may* be incorporated into *future* leases." EA at 54 (emphases added). In other words, BLM seems to anticipate the possible imposition of improved but still inadequate half-mile buffers on future leases, but not on the leases currently at issue. No provision is made for one-mile or even half-mile buffers on the instant leases. Given the potential for numerous failed nests within the lease sale area, and the uncertain numbers of nests on the BLM parcels which are mostly split-estate parcels, *see* EA at 58, 59 (noting lack of raptor nesting information), BLM cannot reasonably claim that "no significant impact" will result from the lease sale.

A one-eighth mile buffer (equivalent to 0.125 miles or 201 meters) is also inadequate to protect raptors in general. Before the PNG EIS, the Pawnee National Grasslands land-use plan

required a minimum 500-meter buffer (approximately 1/3 mile) from all raptor nests. The PNG EIS, however, notes that even this buffer could be inadequate to protect raptors:

> The Forest Service nest buffer of 500 meters...provides some measure of protection albeit potentially inadequate compared to more recent literature. Colorado Parks and Wildlife suggests a buffer of 800 meters [0.50 miles] and Environment Canada (2009) suggests a buffer of 1000 meters [0.62 miles]. Keeley and Bechard (2011) found that hawks flush at distances of greater than 600 meters [0.37 miles].

PNG EIS Final Wildlife Report ("FWR") at 44. A mere one-eighth-mile buffer could therefore lead to adverse effects on numerous raptors that nest on leased parcels and result in significant effects on raptors. BLM cannot properly make a FONSI determination, when the number of nesting raptors within the project area is unknown, and is potentially large since many BLM parcels may include raptor nesting habitat. *See* EA at 58, 59.

BLM's Determination of NEPA Adequacy regarding Forest Service parcels on the Pawnee National Grasslands is also flawed. In the PNG EIS, the Forest Service adopted for each and every parcel within the Grasslands, an NSO prohibiting any surface disturbance on the entire parcel. But even with this NSO applying to all Grasslands parcels, numerous impacts on ferruginous hawks could result from development on neighboring non-federal lands, including: the short-term loss of 508 acres of habitat within (unspecified) nest buffers during the construction phase; the long-term loss of 63 acres of nesting habitat after reclamation; loss or degradation of breeding, nesting, rearing and foraging habitats for hawks and their prey resulting from approximately 16 miles of road construction; direct mortality or injuries due to vehicle collisions; and disturbance from vehicles and noise resulting in nest abandonment. FWR at 44-45.

The PNG EIS, however, notes that the Forest Service "would not have the ability to impose restrictions on non-PNG lands," and "[a]ny protective measures would have to be negotiated and are not guaranteed." *Id.* at 44, 46. No description of potential measures to reduce these impacts is provided. The most the EIS states on this topic is: "Examples of proactive measures are in the district files but a key opportunity to promote and maintain hawks is early coordination with PNG program managers, other federal agencies (BLM), Colorado Parks and Wildlife, energy development companies, and other land owners." *Id.* at 46. This description utterly fails to inform the public of what "proactive measures" exist and whether they will be effective.

Elsewhere, however, in response to public objections to the EIS, the PNG EIS admits that BLM could require operators to adjust siting of operations to mitigate wildlife and other environmental impacts. *See* Forest Service Response to Wild Earth Guardians' Objection, File Code 1570, 15-02-00-0057-21SB (Feb. 6, 2015) ("[I]t is acknowledged that regulation of both surface and subsurface operations on federal land may, in some cases, influence configuration of operations on adjacent land, and the impacts from those operations on NFS land. Where this is the case, the Forest Service and BLM work with operators to configure facilities and operations in a manner that avoids adverse impacts."). Nonetheless, again, the EIS still fails to identify any

measures that could be incorporated into surface-use plans for operations on non-federal lands to reduce impacts to Ferruginous Hawks.

Along the same lines, the DNA acknowledges that the NSO may not adequately protect raptor nests on the Grasslands or on nearby private parcels, but again fails to identify specific measures that would address this gap in protection:

> Several raptor species described as BLM sensitive species have a history of nesting within or immediately adjacent to the Pawnee National Grasslands. These raptors include: ferruginous hawk, golden eagle, prairie falcon, bald eagle and burrowing owl. The analysis for those species completed for the Pawnee National Grassland Oil and Gas Leasing Analysis is sufficient [sic], the No Surface Occupancy described in the Pawnee National Grassland Oil and Gas Leasing Analysis may not be adequate to maintain [sic] however it is recognized that reproductive success of raptors nesting near or on the National Grassland boundary could be affect [sic] by future development of those parcels even with a No Surface Occupancy. Potential effects would be discussed on a more site specific basis during the Application for Permit to Drill (APD) phase.

DNA at 5. Besides being incoherent, this explanation neither discusses particular measures that could be applied to oil and gas development on non-federal lands to avoid, reduce, or compensate impacts to the Ferruginous Hawk. Accordingly, the DNA erroneously concludes that the "PNG FEIS fully covers the [Forest-Service-parcel lease sale] and constitutes BLM's compliance with the requirement of NEPA."

Mountain Plover

BLM's FONSI is also unjustified because it fails to adequately discuss the impacts of oil and gas development on mountain plover, despite the occurrence of mountain plover within the lease sale area. *See* RMW Maps. The EA's analysis of impacts is extremely cursory, compared to the PNG EIS's discussion of oil and gas development impacts on mountain plover, which is much more detailed and comprehensive. *Compare* EA at 53 (limiting discussion to impacts from vehicle collisions) *with* FWR at 49-52 (discussing habitat fragmentation, loss of habitat, and human disturbance impacts of oil and gas development). The EA further fails to discuss or adopt any mitigation measures addressing those impacts that are discussed, merely noting that "mitigation (plover nesting survey, timing limitations, etc.) to prevent take would be implemented at the APD stage," and that "if development is to occur April 10 through July 10, a survey for nesting mountain plover would be required where habitat exists. *Id.* at 53, 54. This cursory discussion of the lease sale's impacts on mountain plover does not comply with NEPA, and BLM's FONSI lacks adequate evidentiary support. Further, neither the EA nor the PNG EIS appear to place timing limitations on oil and gas development to protect breeding plovers, although such stipulations have been previously required under the Pawnee National Grasslands land-use plan.

Mule Deer

BLM's FONSI is also flawed in that it fails to take into account mule deer habitat losses that will result from oil and gas production within winter habitat. A recent study shows that oil and gas development causes significant habitat loss in the Piceance Basin of Colorado:

> Energy development drove considerable alterations to deer habitat selection patterns, with the most substantial impacts manifested as avoidance of well pads with active drilling to adistance of at least 800 m. Deer displayed more nuanced responses to other infrastructure, avoiding pads with active production and roads to a greater degree during the day than night. In aggregate, these responses equate to alterationof behavior by human development in over 50% of the critical winter range in our study area during the day and over 25% at night.[4]

The only protections provided for mule deer are a timing limitation stipulation (CO-09), which prohibits surface disturbance during the winter months, but this measure does nothing to offset the impacts of the substantial habitat loss that may occur with increased oil and gas infrastructure throughout the region. This is especially problematic, because extensive winter mule deer habitat is found within the lease sale areas. *See* RMW ABI Screen. The EA's failure to discuss these habitat loss impacts and adopt any mitigation measures to offset these losses render BLM's FONSI invalid.

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For all of the reasons stated above, as well as in the attached and cited documents incorporated by reference herein, the lease sale, will, if adopted unchanged, result in violations of BLM's obligations under NEPA, the Endangered Species Act, Federal Land Policy and Management Act, and Mineral Leasing Act. An appropriate response to this protest would be for BLM to withdraw the lease sale notice, prepare an EIS, and issue a new lease sale notice consistent with statutory obligations as outlined above.

Please do not hesitate to contact me if you have any questions or to schedule a protest resolution meeting.

Sincerely,

Wendy Park
Staff Attorney
Center for Biological Diversity

[4] Northrup, J. M. et al. Quantifying spatial habitat loss from hydrocarbon development through assessing habitat selection patterns of mule deer, Global Change Biology (Aug. 2015), available at http://onlinelibrary.wiley.com/doi/10.1111/gcb.13037/epdf.

CENTER for BIOLOGICAL DIVERSITY Because life is good.

working through science, law and creative media to secure a future for all species, great or small, hovering on the brink of extinction.

Attachments to Center for Biological Diversity Protest Letter Re Nov. 2015 Lease Sale.

July 31, 2015

VIA E-MAIL (ECRMP.comments@blm.gov)

John Smeins
Bureau of Land Management
3028 East Main Street
Cañon City, CO 81212

Re: Eastern Colorado Resource Management Plan Scoping Comments

Dear Mr. Smeins:

The Center for Biological Diversity, Food & Water Watch, 350 Colorado, and Colorado nature photographer John Fielder, write to submit public scoping comments on the proposed Eastern Colorado Resource Management Plan ("RMP"), which will govern the management of 6.6 million acres of federal mineral estate throughout the eastern half of Colorado ("planning area"). We are deeply concerned that continued extraction of fossil fuels worsens the climate crisis, endangers water, air, wildlife, public health, and local communities, and undermines the protection of our public lands. We propose that BLM consider a "no-leasing-no-fracking" alternative that would avoid these dangers altogether: BLM should end new fossil fuel leasing and ban new hydraulic fracturing and other unconventional well stimulation activities in the planning area.

Vast fossil fuel resources underlie the planning area, the extraction of which could occur over millions of acres of private and public land. The potential development of over 13,000 new oil and gas wells, as well as new underground coal and strip coal mines, will irreversibly damage the environment and harm local communities. As BLM's Analysis of the Management Situation for the Eastern Colorado Resource Management Plan ("AMS") indicates, continued fossil fuel development—most of which would be accomplished through hydraulic fracturing—will worsen the northern Front Range's unhealthy air quality, accelerate soil erosion, pollute and deplete shrinking water resources, scar and despoil scenic landscapes, fragment and degrade habitat for imperiled species, and diminish the biological diversity of natural communities. The AMS acknowledges that climate change threatens to exacerbate these effects, through warmer temperatures, less snowfall, earlier and less runoff, and more frequent and severe drought and wildfire. And plainly, more fossil fuel extraction will result in more global warming pollution further contributing to the climate crisis and the degradation of our public lands.

In light of this context, the only truly reasonable alternative to current management direction—that would both protect public health and preserve public lands for future

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generations—is to (1) suspend all new leasing of fossil fuels in the planning area, including oil, natural gas, coalbed methane, and coal and (2) disallow new hydraulic fracturing (or "fracking") or other unconventional well stimulation operations on existing leases, including acidization and gravel packing. Unconventional well stimulation refers to any activities that extract natural gas and oil from rock formations. As discussed below, keeping all unleased fossil fuels in the ground and banning fracking and other unconventional well stimulation methods would lock away millions of tons of greenhouse gas pollution and limit the destructive effects of these practices, and strip and underground coal mining.

The discussion below both serves to describe the many unacceptable risks of fossil fuel development which compel the consideration of a "no-leasing-no-fracking" alternative and serves to identify issues that must be addressed in the RMP and EIS, including (1) the climate change impacts of new fossil fuel development; (2) the ecological and public health impacts of unconventional oil and gas well stimulation, including hydraulic fracturing; and (3) similar impacts with respect to coal mining. We request BLM to fully consider these issues in its development of a reasonable range of alternatives, adopt no-leasing-no-fracking as the preferred alternative, and address each of the issues below in the EIS.

I. More Fossil Fuel Development Will Fuel Climate Change

Expansion of fossil fuel production will substantially increase the volume of greenhouse gases emitted into the atmosphere and jeopardize the environment and the health and well being of future generations. In order to avoid catastrophic climate change, BLM should be looking for ways to reduce, rather than increase, greenhouse gas emissions. A no-leasing alternative is not only reasonable but also imperative.

The harms from continued anthropogenic greenhouse emissions are nothing short of catastrophic. A rise in global average temperature by just a few degrees Celsius would likely result in a wide range of devastating consequences. Climate change will lead to: sea level rise and population displacement, increased frequency of extreme weather events, change in weather patterns, extreme floods and droughts, ocean acidification, mass species extinction, loss of biodiversity, spread of vector-born disease, and reduction of food and water security.[1]

BLM cannot ignore the mounting evidence about the potential for oil and gas development to contribute to the climate crisis. Full development and combustion of the planning area's oil, gas, and coal resources will fuel climate disruption and undercut the needed transition to a clean energy economy. Approximately 5,241,000 acres are available to lease for oil and natural gas development, on top of the 405,000 acres that are currently leased.[2] Within this area as many as 13,041 additional oil and gas wells (including coalbed methane) could be drilled between 2012 and 2030, according to the Reasonably Foreseeable Development Scenario for the Royal Gorge Field Office ("RFD").[3] The total output of these new wells is potentially over 47

[1] Hansen, James and Makiko Sato, Greenhouse Gas Growth Rates, 101 Proc. Natl. Acad. Sciences 46 (2004); Hansen, James et al., Climate Change and Trace Gases, Phil. Trans. R. Soc. A 365, doi: 10.1098/rsta.2007.2052 (2007) ; Whiteman G. et al., Climate Science: Vast Costs of Arctic Change, 499 Nature 401 (2013); Shindell, Drew et al., Simultaneously Mitigating Near-Term Climate Change and Improving Human Health and Food Security, 335 Science 183 (2012). The references cited herein have been submitted via overnight delivery.
[2] BLM, Royal Gorge Field Office, Analysis of the Management Situation for the Eastern Colorado Resource Management Plan, 166 (June 2015) ("AMS").
[3] BLM, Reasonably Foreseeable Development Scenario for Oil and Gas, Royal Gorge Field Office, Colorado

million barrels of oil, over 1 trillion cubic feet of conventional natural gas, and over 152 billion cubic feet of coalbed natural gas. Likewise, immense coal reserves could be mined within the Denver and Raton Basins.[4] One area — the Trinidad Known Recovery Coal Resource Area, in Las Animas and Huerfano Counties — contains over 1.2 billion tons of Federal coal on 131,000 acres of land.[5]

Every step of the lifecycle process for development of these resources results in significant carbon emissions, including but not limited to:

End-user oil and gas combustion emissions. The combustion of extracted oil, gas, and coal will add vast amounts of carbon dioxide to the atmosphere, further heating the climate and moving the Earth closer to catastrophic and irreversible climate change. Though much of the oil is used as gasoline to fuel the transportation sector, the produced oil may also be used in other types of products. The EIS should study all end-uses as contributors to climate change.

Combustion in the distribution of product. To the extent that distribution of raw and end-use products will rely on rail or trucks, the combustion of gasoline or diesel to transport these products will emit significant greenhouse gas emissions.

Emissions from Refineries and Production. Oil and gas must undergo intensive refinery and production processes before the product is ready for consumption. Refineries and their auxiliary activities constitute a significant source of emissions.

Vented emissions. As discussed in Section II.D.1-2, oil and gas wells and coal mining operations may vent gas that flows to the surface at times where the gas cannot otherwise be captured and sold. Vented gas is a significant source of greenhouse gas emissions and can also pose a safety hazard.

Combustion during construction and extraction operations. Operators rely on both mobile and stationary sources of power to construct and run their sites. The engines of drilling or excavation equipment, pumps, trucks, conveyors, and other types of equipment burn large amounts of fuel to operate. Carbon dioxide, methane, and nitrous oxide (another potent greenhouse gas) are emitted from oxidized fuel during the combustion process. Engines emit greenhouse gases during all stages of oil and gas recovery, including drilling rig mobilization, site preparation and demobilization, completion rig mobilization and demobilization, well drilling, well completion (including fracking and other unconventional extraction techniques), and well production. Transportation of equipment and chemicals to and from the site is an integral part of the production process and contributes to greenhouse gas emissions. Gas flaring is another important source of carbon dioxide emissions.

Fugitive emissions. Potent greenhouse gases can leak as fugitive emissions at many different points in the production process, especially in the production of gas wells. Recent studies suggest that previous estimates significantly underestimate leakage rates.[6]

("RFD"), 32 (March 22, 2012).
[4] AMS at 179-182.
[5] AMS at 182.
[6] Brandt, A. R. et al., Methane leaks from North American natural gas systems, 343 Science 733 (2014); Miller, S. M. et al. Anthropogenic Emissions of Methane in the United States, Proc. Natl. Acad. Sci. Early Edition, DOI:

New research shows methane leakage from some gas wells may be as high at 17.3 percent.[7] Moreover, new research has shown that unconventional gas wells are up to 2.7 times more likely than a conventional well to have a cement or casing impairment, which can lead to methane leaks.[8] Leakage can also occur during storage, processing, and distribution to customers.[9] Along similar lines, methane emitting activities can occur with coal handling at underground coal mines, during "crushing, separation of impurities, size classification, drying, transportation, and storage."[10]

Methane emissions make a big difference in part because the greenhouse gas warming potential of methane is 87 times that of carbon dioxide over a 20-year period.[11] The oil and gas sector is a leading source of global methane emissions, accounting for approximately 30 percent of U.S. methane emissions,[12] and is expected to be one of the most rapidly growing sources of anthropogenic methane emissions in the coming decades.[13] That proportion is based on an estimated calculation of methane emissions, rather than measured actual emissions, which indicate that methane emissions may be much greater in volume than calculated.[14] Contrary to BLM's claims in other RMP planning processes, the displacement of coal with natural gas does not necessarily result in reduced global warming pollution, due to high rates of methane leakage in natural gas production and methane's global warming potency.[15] Best estimates of the national rate of fugitive methane emissions throughout the natural gas system are that it amounts to about 3% of production.[16] This level of leakage puts coal-to-gas fuel switching near a breakeven point with respect to global warming, and, at best, efforts to reduce methane leaks translate to only marginally less climate damage.

10.1073/pnas.1314392110 (2013) ("Miller 2013").

[7] Caulton, Dana R. et al., Toward a Better Understanding and Quantification of Methane Emissions from Shale Gas Development, 111 Proc. Natl. Acad. Sciences 17 (2014); Schneising, Oliver, *et al.*, Remote Sensing of Fugitive Methane Emissions from Oil and Gas Production in North American Tight Geologic Formations, Earth's Future 2, doi:10.1002/2014EF000265 (2014); Allen, D. T. et al., (2013), Measurements of Methane Emissions at Natural Gas Production Sites in the United States, 110 Proc. Natl. Acad. Sci. 44 (2013) ("Allen 2013").

[8] Ingraffea, Anthony R, et al, Assessment and Risk Analysis of Casing and Cement Impairment in Oil and Gas Wells in Pennsylvania, 2000 – 2012, 111 Proc. Natl. Acad. Sciences 30 (2014).

[9] Howarth, R. W. A bridge to nowhere: methane emissions and the greenhouse gas footprint of natural gas, Energy Science and Engineering 2014; 2(2): 47–60, 49 ("Howarth 2014").

[10] Kirchgessner, D.A., *et al.*, An improved inventory of methane emissions from coal mining in the United States, 6, available at http://www.epa.gov/ttn/chief/ap42/ch14/related/mine.pdf (accessed July 30, 2015).

[11] Intergovernmental Panel on Climate Change, Chapter 8: Anthropogenic and Natural Radiative Forcing in Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Table 8.7 (2013) ("IPCC WG1 2013, Table 8.7").

[12] U.S. Environmental Protection Agency, Climate Change Overview of Greenhouse Gases, http://epa.gov/climatechange/ghgemissions/gases/ch4.html (accessed July 30, 2015).

[13] Institutional Investors Group on Climate Change et al, Controlling Fugitive Methane Emissions in the Oil and Gas Sector (2012), available at http://www.ceres.org/files/methane-emissions/investor-joint-statement-on-methane-emissions.

[14] Miller 2013.

[15] Howarth 2014; ; Caulton 2014; Brandt, A. R. et al. "Supplementary materials for 'Methane leaks from North American natural gas systems'." Science. Vol. 343, Iss. 733. February 14, 2014 at 29 ("Brandt 2014").

[16] Miller, Scot M. et al. "Anthropogenic emissions of methane in the United States." *Proceedings of the National Academy of Sciences*. Vol. 110, Iss. 50. December 10, 2013 at 5; Brandt 2014.

A no-leasing-no-fracking alternative would curb all of the above sources of greenhouse gas emissions within the planning area, consistent with national policies to reduce climate-warming pollution. As stated in the President's Climate Action Plan:

> While no single step can reverse the effects of climate change, we have a moral obligation to future generations to leave them a planet that is not polluted and damaged. Through steady, responsible action to cut carbon pollution, we can protect our children's health and begin to slow the effects of climate change so that we leave behind a cleaner, more stable environment.[17]

Halting all new leasing within the planning area would be a responsible step towards slowing the effects of climate change. The internationally agreed-on target for avoiding dangerous climate change and its disastrous consequences is limiting average global temperature rise caused by greenhouse gas pollution to two degrees Celsius (2°C), or 3.6 degrees Fahrenheit.[18] Climate experts have estimated that the world can emit 1,000 gigatons of carbon dioxide (1,000 $GtCO_2$ or 1 trillion tons of CO_2) after 2010 to have a reasonable chance of staying below 2°C of warming.[19] Given uncertainties, coupled with the dire predictions of climate change impacts, a more conservative carbon budget would be more prudent. Nonetheless, using this budget, the IPCC has found that proven fossil fuel reserves amount to **four to seven times more** than what we can afford to burn, to have only a *likely* chance of staying within the 2°C target.[20] In short, the vast majority of proven reserves must be kept in the ground for preserving a livable planet. Minimizing new fossil fuel production is critical. Opening up new areas to extraction and allowing more fracking, on the other hand, runs completely counter to slowing the effects of climate change.

The EIS must weigh the no-leasing-no-fracking alternative's climate-change benefits against the impacts of allowing new leasing and fracking, and address the following:

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[17] Executive Office of the President, THE PRESIDENT'S CLIMATE ACTION PLAN 4 (June 2013).

[18] The Copenhagen Accord forged under the United Nations Framework Convention on Climate Change talks formally recognized the international objective of limiting warming to 2°C above pre-industrial.

[19] The Intergovernmental Panel on Climate Change (IPCC) is the leading international body for the assessment of climate change, established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO). In its Fifth Assessment Report, the IPCC reported that the remaining carbon budget to have a "likely" (at least 66%) chance of staying below 2°C is 1000 GtCO2. See IPCC Climate Change 2014 Synthesis Report 63-64, available at http://ar5-syr.ipcc.ch/ipcc/ipcc/resources/pdf/IPCC_SynthesisReport.pdf.

[20] *Id.* at 63. In addition, a recent analysis by some of the world's leading climate scientists estimated that burning the Earth's proven fossil fuel reserves (i.e., those that are currently economically recoverable) would emit 4196 $GtCO_2$, over four times the 1000 $GtCO_2$ budget. *See* Raupach M. et al. Sharing a quota on cumulative carbon emissions. Nature Climate Change 4, 873-79 (2014), available at http://www.nature.com/nclimate/journal/v4/n10/full/nclimate2384.html. Analyses by the Carbon Tracker Initiative and Australian Climate Commission estimated that 80% of proven fossil fuel reserves must be kept in the ground to have a reasonable probability (75-80%) of staying below 2°C. This estimate includes only the fossil fuel reserves that are considered currently economically recoverable with a high probability of being extracted. *See* Carbon Tracker Initiative, Unburnable Carbon – Are the world's financial markets carrying a carbon bubble? (2011), available at http://www.carbontracker.org/wp-content/uploads/2014/09/Unburnable-Carbon-Full-rev2-1.pdf; Steffen, Will et al., Australian Climate Commission. The Critical Decade 2013: Climate Change Science, Risks and Responses (2013), available at http://apo.org.au/files/Resource/ClimateCommission_The-Critical-Decade-2013.pdf

1. Sources of Greenhouse Gases

BLM should perform a full analysis of all gas emissions that contribute to climate change, including methane and carbon dioxide. The EIS should calculate the amount of greenhouse gas that will result on an annual basis from (1) each of the fossil fuels that can be developed within the planning area, (2) each of the well stimulation or other extraction methods that can be used, including, but not limited to, fracking, acidization, acid fracking, and gravel packing, and (3) cumulative greenhouse gas emissions expected over the long term (expressed in global warming potential of each greenhouse pollutant as well as CO_2 equivalent), including emissions throughout the entire fossil fuel lifecycle discussed above.

2. Effects of Climate Change

As earlier noted, new fossil fuel development will intensify climate disruption and its ecological and social consequences, which must be studied in the EIS. *See* p. 2 above. Although cost-benefit analysis is not necessarily the ideal or exclusive method for assessing contributions to an adverse effect as enormous, uncertain, and potentially catastrophic as climate change, BLM does have tools available to provide one approximation of external costs and has previously performed a "social cost of carbon" analysis in prior environmental reviews.[21] Its own internal memo identifies one available analytical tool: "For federal agencies the authoritative estimates of [social cost of carbon] are provided by the 2013 technical report of the Interagency Working Group on Social Cost of Carbon, which was convened by the Council of Economic Advisers and the Office of Management and Budget."[22] As explained in that report:

> The purpose of the "social cost of carbon" (SCC) estimates presented here is to allow agencies to incorporate the social benefits of reducing carbon dioxide (CO_2) emissions into cost-benefit analyses of regulatory actions that impact cumulative global emissions. The SCC is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year. It is intended to include (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services due to climate change.[23]

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[21] *See High Country Conserv'n Advocates v. United States Forest Serv.*, 2014 U.S. Dist. Lexis 87820 (D. Colo. 2014) (invalidating environmental assessment ["EA"] for improperly omitting social cost of carbon analysis, where BLM had included it in preliminary analysis); Taylor, P. "BLM crafting guidance on social cost of carbon -- internal memo," Greenwire, April 15, 2015, available at http://www.eenews.net/greenwire/stories/1060016810/; BLM Internal Memo from Assistant Director of Resources and Planning Ed Roberson ("Roberson Internal Memo"), April 2015, available at http://www.eenews.net/assets/2015/04/15/document_gw_01.pdf (noting "some BLM field offices have included estimates of the [social cost of carbon] in project-level NEPA documents") (accessed July 29, 2015); *see also* Council on Environmental Quality, Revised Draft Guidance for Greenhouse Gas Emissions and Climate Change Impacts, p. 18, available at www.whitehouse.gov/administration/eop/ceq/initiatives/ncpa/ghg-guidance (accessed Jul 29, 2015) (quantitative analysis required if GHGs > 25k tons/yr).

[22] BLM, Roberson Internal Memo.

[23] *See* Interagency Working Group on Social Cost of Carbon, United States Government, Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis - Under Executive Order 12866, May 2013, available at https://www.whitehouse.gov/sites/default/files/omb/inforeg/social_cost_of_carbon_for_ria_2013_update.pdf (accessed July 29, 2015); *see also* Interagency Working Group on Social Cost of Carbon, United States Government, Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866, Feb. 2010, available at http://www.epa.gov/otaq/climate/regulations/scc-tsd.pdf (accessed July 29, 2015).

While the Eastern Colorado RMP's GHG emissions have not yet been quantified, its SCC is potentially in the billions of dollars. The White River Oil and Gas RMPA—which projects a comparable 15,000 new wells in the White River planning area over 20 years—is expected to result in annual emissions of 4,195,058 metric tons of CO_2e - *not* including end-use combustion emissions outside the planning area.[24] Applying the 2013 SCC estimates to the RMPA's CO_2e emissions, by 2035, the White River RMPA's annual social cost of carbon would be $83.9 to $784.5 million, in 2011 dollars and potentially in the range of a billion dollars over the plan's lifetime. Clearly, new leasing and development of unconventional wells in the planning area will exact extraordinary costs to communities and future generations, setting aside the immeasurable loss of irreplaceable, natural values that can never be recovered.

II. Unconventional Oil and Gas Development Causes Significant Harms to Public Health and the Environment

The advent of improved well stimulation technologies within the last decade, including horizontal drilling, "massive" hydraulic fracturing, and multi-stage fracturing, has increased the overall capacity for new oil and gas development in Colorado. These technologies have opened up new areas that would otherwise remain untouched and prolonged the life of existing well fields. Multi-well pads and a higher density of wells are now viable with these techniques, allowing operators to maximize the surface area exposed by widespread fracturing of underlying rock formations. Consequently, oil and gas development within the state has rapidly expanded—over 53,000 active wells are operating in the state as of May 2015[25]—and wells are "completely surrounding the metro area," as one Colorado Oil and Gas Conservation Commission ("COGCC") official has noted."[26]

With thousands of new oil and gas wells projected in the planning area, this trend of oil and gas operations encroaching on communities will certainly continue. For example, numerous wells could be developed in the South Park Basin: as of November 2011, 27,832 acres of federal mineral estate had been leased within the proposed South Park Master Leasing Plan area.[27] One

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[24] BLM White River Proposed Resource Management Plan and Final Environmental Impact Statement, Ch. 4, 4-24 (2015).

[25] Colorado Oil and Gas Conservation Commission ("COGCC"), Colorado Weekly & Monthly Oil & Gas Statistics 11 (May 4, 2015), available at https://cogcc.state.co.us/documents/data/downloads/statistics/CoWklyMnthlyOGStats.pdf (accessed July 29, 2015).

[26] Johnson, Kirk, Drilling in Fast-Growing Areas Ushers in New Era of Tension, N.Y. TIMES, October 25, 2011, at A16, available at http://www.nytimes.com/2011/10/25/us/oil-drilling-in-new-areas-ushers-in-era-of-tension.html (accessed July 24, 2015) ("Drilling permits in suburbs, parks and even in lakes have made the local news. Using hydrofracturing technologies—breaking the shale with water, sand and chemicals to release the oil—and horizontal, spiderlike tentacle borers that can spin out beneath communities, the still-emerging boom is bringing energy exploration to some of the fastest-growing counties in the nation, and to places with no experience whatsoever in dealing with it. 'It's completely surrounding the metro area,' said Thom Kerr, the permit and technical services manager at the Colorado Oil and Gas Conservation Commission, which regulates the industry.")

[27] Johnson, Jara, Coalition for the Upper South Platte. 2011 Groundwater and Surface Water Monitoring Project: Baseline Monitoring to Address Oil and Gas Development in South Park 13 (Sept. 2012) ("Johnson 2012"), available at http://www.cusp.ws/wp-content/uploads/2014/10/CUSP%202011%20Groundwater%20and%20Surface%20Water%20Baseline%20Monitoring%20Project.pdf; *see also* South Platte Basin Implementation Plan, Metro Basin Roundtable, South Platte Basin Roundtable at 1-2 (April 17, 2015) (noting 3.5 million people in the South Platte River Basin, or approximately 80% of the state's population), available at

federal well indicates that a 24-foot section of the Apache Creek sandstone could yield 195 million cubic feet per day of pipeline quality gas, and total gas reserves in the formation are 1.4-2.3 trillion cubic feet of gas.[28] Development of these reserves could occur dangerously close to drinking water sources and high-quality recreational waters. South Park serves as the headwaters of the South Platte River, and approximately 85% of Colorado's residents count wholly or in part on water that comes from the river basin (either native or transmountain diversion waters) for drinking, industrial, and agricultural use.[29] Many streams in South Park are "Gold Medal" waters that provide exceptional fishing opportunities.

The proximity of projected new oil and gas development to many communities, pristine recreational areas, and important drinking water sources within the planning area is all the more reason for BLM to end new leasing and fracking of oil and gas. Nearly every peer-reviewed study on fracking—96 percent—concludes that there are actual or potential human health risks attributable to this dangerous practice.[30] After reviewing the more than 400 peer-reviewed scientific studies on fracking, four independent panels of public health scientists have reached the same conclusion—due to the known and unknown risks, fracking cannot be conducted safely.[31] Following this science, and acknowledging the experiences of those affected by fracking and related activities, many state and local governments have adopted bans or approved moratoriums on fracking, including New York, Vermont, Maryland, Boulder County, Fort Collins, Los Angeles, and several California counties.[32] Clearly, an end to new leasing and unconventional oil and gas extraction is a reasonable approach to protecting public health and the environment.

BLM should similarly recognize that the environmental and public health hazards of these increasingly widespread extraction techniques are too great to continue allowing them to be used in the planning area. These risks include contamination of water resources and increased surface runoff, over-depletion of dwindling water resources, deterioration of air quality, human health and safety risks, radioactive contamination, induced seismicity, harm to wildlife, and industrialization of landscapes and changes in land use.

A. Hydraulic Fracturing and Other Unconventional Stimulation Methods Contaminate Water Resources

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https://www.colorado.gov/pacific/sites/default/files/SouthPlatteBasinImplementationPlan-04172015.pdf.

[28] Johnson 2012 at 13.

[29] *Id.* at 15,

[30] Hays, Jake & Seth B. Shonkoff, Toward an Understanding of the Environmental and Public Health Impacts of Shale Gas Development: an Analysis of the Peer-Reviewed Scientific Literature, 2009-2014, Physicians Scientists and Engineers (rev. January 2015) ("Hays and Shonkoff 2015") at 9.

[31] *See* New York State Department of Health, A Public Health Review of High Volume Hydraulic Fracturing for Shale Gas Development (Dec. 2014); Concerned Health Professionals of New York, Compendium of Scientific, Medical, and Media Findings Demonstrating Risks and Harms of Fracking (Dec. 2014) ("CHPNY"); Hays and Shonkoff 2015; *see also*, Vendeville, Geoffrey, Fracking Provides Few Benefits to Quebec, Environmental Review Says, Montreal Gazette Dec. 15, 2014, http://montrealgazette.com/news/quebec/fracking-provides-few-benefits-to-quebec-environmental-review-says (accessed July 29, 2015).

[32] Food & Water Watch, Local Actions Against Fracking, available at http://www.foodandwaterwatch.org/water/fracking/anti-fracking-map/local-action-documents/(accessed July 29, 2015); Keep Tap Water Safe, List of Bans Worldwide, available at http://keeptapwatersafe.org/global-bans-on-fracking/ (accessed July 29, 2015).

Across the U.S., in states where fracking or other types of unconventional oil and gas recovery has occurred, surface water and groundwater have been contaminated. Recent studies have concluded that water contamination attributed to unconventional oil and gas activity has occurred in several states, including Colorado,[33] Wyoming,[34] Texas,[35] Pennsylvania,[36] Ohio,[37] and West Virginia.[38]

I. **Surface water contamination**

Surface waters can be contaminated in many ways from unconventional well stimulation. In addition to storm water runoff, surface water contamination may also occur from chemical and waste transport, chemical storage leaks, and breaches in pit liners.[39] As described below, contaminated surface water can result in many adverse effects to wildlife, agriculture, and human health and safety. It may make waters unsafe for drinking, fishing, swimming and other activities, and may not always be infeasible to restore the original water quality once surface water is contaminated.

A water quality study of the South Park region provides useful information about existing hydrology and water quality in South Park as of 2012 (for both groundwater and surface waters).[40] BLM should consider this analysis in the EIS.

i. *Chemical and Waste Transport*

Massive volumes of chemicals and wastewater used or produced in oil and gas operations have the potential to contaminate local watersheds. Between 2,600 to 18,000 gallons of chemicals are injected per hydraulically fracked well depending on the number of chemicals

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[33] Trowbridge, A. *Colorado Floods Spur Fracking Concerns*, CBS News, Sept. 17, 2013, available at http://www.cbsnews.com/8301-201_162-57603336/colorado-floods-spur-fracking-concerns/ ("Trowbridge 2013") (accessed July 30, 2015).

[34] U.S. Environmental Protection Agency, Draft Investigation of Ground Water Contamination near Pavillion, Wyoming (2011) ("USEPA Draft Pavillion Investigation").

[35] Fontenot, Brian et al., An Evaluation of Water Quality in Private Drinking Water Wells Near Natural Gas Extraction Sites in the Barnett Shale Formation, Environ. Sci. Technol., 47 (17), 10032–10040 DOI: 10.1021/es4011724, available at http://pubs.acs.org/doi/abs/10.1021/es4011724 ("Fontenot 2013").

[36] Jackson, Robert et al., Increased Stray Gas Abundance in a Subset of Drinking Water Wells near Marcellus Shale Gas Extraction, Proc. Natl. Acad. of Sciences Early Edition, doi: 10.1073/pnas.1221635110/-/DCSupplemental (2013) ("Jackson 2013").

[37] Ohio Department of Natural Resources, Report on the Investigation of the Natural Gas Invasion of Aquifers in Bainbridge Township of Geauga County, Ohio (Sep. 2008) ("ODNR 2008").

[38] Begos, K, *Four States Confirm Water Pollution*, Associated Press, January 5, 2014, http://www.usatoday.com/story/money/business/2014/01/05/some-states-confirm-water-pollution-from-drilling/4328859/ (accessed July 29, 2015); *see also* U.S. EPA, Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources, External Review Draft (June 2015) ("EPA 2015"), available at http://ofmpub.epa.gov/eims/eimscomm.getfile?p_download_id=523539 (accessed July 30, 2015)..

[39] Vengosh, Avner et al., A Critical Review of the Risks to Water Resources from Unconventional Shale Gas Development and Hydraulic Fracturing in the United States, Environ. Sci. Technol., DOI: 10.1021/es405118y (2014) ("Vengosh 2014").

[40] Johnson, Jara, Coalition for the Upper South Platte. 2011 Groundwater and Surface Water Monitoring Project: Baseline Monitoring to Address Oil and Gas Development in South Park, (Sept. 2012), available at http://www.cusp.ws/wp-content/uploads/2014/10/CUSP%202011%20Groundwater%20and%20Surface%20Water%20Baseline%20Monitoring%20Project.pdf.

injected.[41] Approximately 2,019 billion gallons of wastewater are produced by oil and gas production per year in Colorado.[42]

Unconventional well stimulation relies on numerous trucks to transport chemicals to the site as well as collect and carry disposal fluid from the site to processing facilities. A U.S. GAO study found that up to 1,365 truck loads can be required just for the drilling and fracturing of a single well pad[43] while the New York Department of Conservation estimated the number of "heavy truck" trips to be about 3,950 per horizontal well (including unloaded and loaded trucks).[44] Accidents during transit may cause leaks and spills that result in the transported chemicals and fluids reaching surface waters. Chemicals and waste transported by pipeline can also leak or spill.

In the last five years, over 1900 accidental releases have been reported in the counties of the Eastern Colorado planning area. In 2015 alone, so far, at least 42 of those spills contaminated groundwater; at least two reached surface water.[45] Indeed, EPA has estimated that for every 100 hydraulically fractured wells in Colorado, 1.3 spills occurred on or near the well pad (including spills of fracking chemicals and produced water), based on operator's self-reported data.[46] The number could actually be higher, as spills commonly go unreported.[47] Further, this figure is based on an estimate of spills occurring over a limited time period and not the entire lifetime of the well.[48] Thus, at minimum, 170 *additional* spills (1.3% x 13,041 wells) can be expected to occur in the Eastern Colorado planning area, many of which could reach surface waters.

Produced waters that fracking operations force to the surface from deep underground can contain high levels of total dissolved solids, salts, metals, and naturally occurring radioactive materials.[49] Flowback waters (i.e., fracturing fluids that return to the surface) may also contain

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[41] EPA 2015 at ES-12.

[42] EPA 2015 at 8-5.

[43] U.S. Government Accountability Office, *Oil and Gas: Information on Shale Resources, Development, and Environmental and Public Health Risks*, GAO 12-732 (2012) at 33.

[44] New York Department of Environmental Conservation, *Revised Draft Supplemental Generic Environmental Impact Statement on the Oil, Gas and Solution Mining Regulatory Program*, Ch. 6 Potential Environmental Impacts (2011) at 6-303.

[45] COGCC, Colorado Oil and Gas Information System – Inspection/Incident Inquiry (July 14, 2015), available at http://cogcc.state.co.us/data.html#/cogis (click on spill/release, select counties and dates 7/14/10-7/14/15, and run search) (results attached hereto as COGCC Spill Data 2010-2015).

[46] EPA 2015 at E-11, 36.

[47] Souther, Sara et al. Biotic Impacts of Energy Development from Shale: Research Priorities and Knowledge Gaps, Front Ecol Environ 2014; 12(6): 330-338, p. 332 (noting that companies routinely violated Pennsylvania's spill reporting requirement; only 59% of documented spills were reported by the drilling company); Gulf Monitoring Consortium Report on Activities from April 2011 to October 20, pp. 3-6, available at http://skytruth.org/gmc/wp-content/uploads/2012/05/Gulf-Monitoring-Consortium-Report.pdf (uncovering evidence of non-reporting and chronic under-reporting of oil spills in Gulf of Mexico 2012, using analysis of National Response Center reports and comparison with satellite imagery); Daneshgar et al., Chronic, Anthropogenic Hydrocarbon Discharges in the Gulf of Mexico, Deep-Sea Research II, Dec. 2014, available at http://www.sciencedirect.com/science/article/pii/S0967064514003725 (peer-reviewed study by scientists at Florida State University validating previous report's analysis); Kunzelman, M. Secrecy Shrouds Decade Old Oil Spill in Gulf of Mexico, Washington Post, April 16, 2015, available at http://www.washingtonpost.com/national/energy-environment/secrecy-shrouds-decade-old-oil-spill-in-gulf-of-mexico/2015/04/16/6f8f9070-e449-11e4-ae0f-f8c46aa8c3a4_story.html (noting vastly underestimated amount of oil leaked from reported spill).

[48] EPA 2015 at E-11, n.1.

[49] Brittingham, Margaret C. et al. Ecological Risks of Shale Oil and Gas Development to Wildlife, Aquatic

similar constituents along with fracturing fluid additives such as surfactants and hydrocarbons.[50] Given the massive volumes of chemicals and wastewater produced and their potentially harmful constituents, the potential for environmental disaster is real.

The EIS should evaluate how often accidents can be expected to occur, and the effect of chemical and fluid spills. Such analysis should also include identification of the particular harms faced by communities near oil and gas fields. The EIS must include specific mitigation measures and alternatives based on a cumulative impacts assessment, and the particular vulnerabilities of environmental justice communities in both urban and rural settings.

ii. *On-site Chemical Storage and Processing*

Thousands of gallons of chemicals can be potentially stored on-site and used during hydraulic fracturing and other unconventional well stimulation activities.[51] These chemicals can be susceptible to accidental spills and leaks. Natural occurrences such as storms and earthquakes may cause accidents, as can negligent operator practices. Floods in Colorado have shown that weather events may result in uncontrolled chemical spills and leaks on a massive scale.[52]

Some sites may also use on-site wastewater treatment facilities. Improper use or maintenance of the processing equipment used for these facilities may result in discharges of contaminants. Other spill causes include equipment failure (most commonly, blowout preventer failure, corrosion and failed valves) and failure of container integrity.[53]

The EIS should examine and quantify the risks to human health and the environment associated with on-site chemical and wastewater storage, including risks from natural events and negligent operator practices. Again, such analysis must also include an analysis of potential impacts faced by environmental justice communities in both rural and urban settings.

2. Groundwater Contamination

Studies have reported many instances around the country of groundwater contamination due to surface spills of oil and gas wastewater, including fracking flowback.[54] Fracking and other unconventional techniques likewise pose inherent risks to groundwater due to releases below the surface, and these risks must be properly evaluated.[55] Once groundwater is contaminated, it is very difficult, if not impossible, to restore the original quality of the water. As a result, in communities that rely on groundwater drinking water supplies, groundwater contamination can deprive communities of usable drinking water. Such long-term contamination necessitates the costly importation of drinking water supplies.

Groundwater contamination can occur in a number of ways, and the contamination may persist for many years.[56] Surface spills and poorly constructed or abandoned wells are recognized as one of the most likely ways by which contaminants may reach groundwater. Improper well

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Resources and their Habitats. *Environ. Sci. Technol.* 2014, 48, 11034-11047, p. 11039.
[50] *Id.*
[51] EPA 2015 at ES-10.
[52] Trowbridge 2013.
[53] EPA 2015 at ES-11.
[54] *See, e.g.*, Fontenot 2013, Jackson 2013.
[55] Vengosh 2014.
[56] Myers, Tom, Potential Contamination Pathways from Hydraulically Fractured Shale to Aquifers, National Groundwater Association (2012).

construction and surface spills are cited as a confirmed or potential cause of groundwater contamination in numerous incidents at locations across the U.S. including but not limited to Colorado,[57] Wyoming,[58] Pennsylvania,[59] Ohio,[60] West Virginia,[61] and Texas.[62]

Mechanical integrity, which refers to an absence of leakage pathways through the casing and cement, can degrade over time, eventually leading to mechanical integrity failures that may impact groundwater. Older wells that may not have been designed to withstand the stresses of hydraulic fracturing but which are reused for this purpose are especially vulnerable.[63] A well in which stimulation operations are being conducted may also "communicate" with nearby wells, which may lead to groundwater contamination, particularly if the nearby wells are improperly constructed or abandoned.[64]

Current federal rules do not ensure well integrity. The well casing can potentially fail over time and potentially create pathways for contaminants to reach groundwater. Well casing failure can occur due to improper or negligent construction. The EIS should study the rates of well casing failures over time and evaluate the likelihood that well casing failures can lead to groundwater contamination.

Chemicals and naturally occurring substances can also migrate to groundwater through newly created fractures underground. Many unconventional techniques intentionally fracture the formation to increase the flow of gas or oil. New cracks and fissures can allow the additives or naturally occurring elements such as natural gas to migrate to groundwater. "[T]he increased deployment of hydraulic fracturing associated with oil and gas production activities, including techniques such as horizontal drilling and multi-well pads, may increase the likelihood that these pathways could develop," which, "in turn, could lead to increased opportunities for impacts on drinking water sources."[65] Fluids can also migrate through pre-existing and natural faults and fractures that may become pathways once the fracking or other method has been used.

Further, according to the EPA, "evidence of any fracturing-related fluid migration affecting a drinking water resources...could take years to discover."[66] The EIS must consider

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[57] Gross, Sherilyn A. et al., Abstract: Analysis of BTEX groundwater concentrations from surface spills associated with hydraulic fracturing operations, 63 J. Air and Waste Mgmt. Assoc. 4, 424 doi: 10.1080/10962247.2012.759166 (2013).

[58] USEPA Draft Pavillion Investigation.

[59] Darrah, Thomas H. et al., Noble Gases Identify the Mechanisms of Fugitive Gas Contamination in Drinking-Water Wells Overlying the Marcellus and Barnett Shales, Proc. Natl. Acad. Of Sciences Early Edition, doi: 10.1073/pnas.1322107111 (2014) ("Darrah 2014").

[60] Begos, Kevin, *Some States Confirm Water Pollution from Oil, Gas Drilling*, Seattle Times Jan. 6, 2014, http://www.seattletimes.com/business/some-states-confirm-water-pollution-from-oil-gas-drilling/ (accessed July 29, 2015) ("Begos, Seattle Times, Jan 6, 2014"). *See also*, ODNR 2008, *supra*.

[61] Begos, Seattle Times, Jan 6. 2014.

[62] Darrah 2014.

[63] EPA 2015 at 6-11.

[64] *See* Detrow, Scott. (2012) *Perilous Pathways: How Drilling Near An Abandoned Well Produced a Methane Geyser*, StateImpact Pennsylvania, National Public Radio (October 9, 2012), available at https://stateimpact.npr.org/pennsylvania/2012/10/09/perilous-pathways-how-drilling-near-an-abandoned-well-produced-a-methane-geyser/ (accessed July 29, 2015); Alberta Energy Board, Directive 083: Hydraulic Fracturing – Subsurface Integrity, Alberta Energy Regulator (2013), *available at* http://www.aer.ca/documents/directives/Directive083.pdf.

[65] EPA 2015 at 6-55.

[66] EPA 2015 at 6-56 – 6-57.

long-term studies on the potential for fluid migration through newly created subsurface pathways. Fluid migration is of particular concern when oil and gas operations are close to drinking water supplies.

Unfiltered drinking water supplies, such as drinking water wells, are especially at risk because they have no readily available means of removing contaminants from the water. Even water wells with filtration systems are not designed to handle the kind of contaminants that result from unconventional oil and gas extraction.[67]

In some areas hydraulic fracturing may occur at shallower depths or within the same formation as drinking water resources, resulting in direct aquifer contamination.[68] The EIS must disclose where the potential for such drilling exists.

Setbacks may not be adequate to protect groundwater from potential fracking fluid contamination. A recent study by the University of Colorado at Boulder suggests that setbacks of even up to 300-feet may not prevent contamination of drinking water resources.[69] The study found that 15 organic compounds found in hydraulic fracturing fluids may be of concern as groundwater contaminants based on their toxicity, mobility, persistence in the environment, and frequency of use. These chemicals could have 10 percent or more of their initial concentrations remaining at a transport distance of 300 feet, the average "setback" distance in the U.S.

A review of the Royal Gorge and Northeast Colorado RMPs reveals no minimum distance at which oil and gas operations must be sited from underground drinking water sources. The effectiveness and feasibility of any setbacks considered as part of the PRMP must be evaluated.

3. Disposal of Drilling and Fracking Wastes

Finally, disposal of wastes from oil and gas operations can also lead to contamination of water resources. Potential sources of contamination include:

- leaching from landfills that receive drilling and fracking solid wastes;
- spreading of drilling and fracking wastes over large areas of land;
- wastewaters discharged from treatment facilities without advanced "total dissolved solids" removal processes, or inadequate capacity to remove radioactive material removal; and
- breaches in pits or underground disposal wells.[70]

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[67] Physicians Scientist & Engineers for Healthy Energy, Letter from Robert Howarth Ph.D. and 58 other scientists to Andrew M. Cuomo, Governor of New York State re: municipal drinking water filtration systems and hydraulic fracturing fluid (Sept 15, 2011), *available at* http://www.psehealthyenergy.org/data/Cuomo_ScientistsLetter_15Sep20112.pdf (accessed July 29, 2015).
[68] EPA 2015 at ES-15.
[69] University of Colorado--Boulder, New study identifies organic compounds of potential concern in fracking Fluids (July 1, 2015), available at http://www.colorado.edu/news/releases/2015/06/30/newstudyidentifiesorganiccompoundspotentialconcernfrackingfluids (accessed July 29, 2015).
[70] EPA 2015, 8-20, 8-36, 8-48, 8-65, 8-70.

The EIS must evaluate the potential for contamination from each of these disposal methods.

B. More Intensive Oil and Gas Development Will Increase Storm Water Runoff

Oil and gas operations require land clearance for access roads, pipelines, well pads, drilling equipment, chemical storage, and waste disposal pits. As a result, new oil and gas development will cause over 71,000 acres of short-term disturbance within the planning area, as well as over 25,000 acres of long-term disturbance.[71] While undisturbed land can retain greater amounts of water through plants and pervious soil, land that has been disturbed or developed may be unable to retain as much water, thereby increasing the volume of runoff. The area of land that is able to retain water will be significantly decreased if unconventional oil and gas extraction methods are permitted to expand.

Water from precipitation and snowmelt can serve as an avenue through which contaminants travel from an operation site to sensitive areas, including population centers. Contaminated water runoff may seep into residential areas, polluting streets, sidewalks, soil, and vegetation in urban areas, adversely affecting human health. Thus, not only do these oil and gas activities create pollution, they create greater conduits for storm water runoff to carry those pollutants from the operation site, into areas in which significant harm can be caused.

Rapid runoff, even without contaminants, can harm the environment by changing water flow patterns and causing erosion, habitat loss, and flooding. Greater runoff volumes may also increase the amount of sediment that is carried to lakes and streams, affecting the turbidity and chemical content of surface waters. Because a National Pollutant Discharge Elimination System permit is not required for oil and gas operations,[72] it is particularly important that the impact of runoff is considered as part of the NEPA process. The RFD for the Royal Gorge Field Office estimates average surface disturbance per well, the total number of wells to be developed through 2030, and predicts the likely distribution of new oil and gas development, all of which should inform the EIS's analysis of storm water runoff impacts within local watersheds.[73]

To the extent that the RFD assumes that disturbed areas will eventually be reclaimed, these assumptions are unreliable given the current RFD's extremely vague standards regarding the timing of reclamation activities ("as soon as possible") and BLM's and COGCC's overall poor record in ensuring that operators follow-through on reclamation.[74] The EIS must justify any assumptions regarding the reclamation of disturbed areas by addressing the rate of operator compliance with reclamation standards, timeliness of compliance, effectiveness of reclamation, and proposed or existing monitoring and enforcement mechanisms that assure successful reclamation. The EIS must also address any differences in BLM's imposition of reclamation standards on split estate and non-split estate lands. Presumably, "BLM has the authority to

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[71] RFD, Tables 14a & 14b.
[72] 33 U.S.C. § 1342(l)(2).
[73] *See, e.g.*, RFD, Table 14a.
[74] BLM, Royal Gorge Resource Area, Draft Resource Management Plan and Environmental Impact Statement (Sept. 1993) ("Royal Gorge RMP") G-20; Olmstead, Stan, Report of oil & gas well abandonment and reclamation on federal lands administered by BLM-Utah (March 14, 2015); Finley, Bruce, Colorado land impact of oil and gas boom: scars spread and stay, Denver Post (March 1, 2015), available at http://www.denverpost.com/environment/ci_27618385/colorado-land-impact-oil-and-gas-boom-scars (accessed July 30, 2015) (reporting that operators have failed to fully restore land around half of the 47,505 inactive wells in Colorado, and that 72 percent of those un-restored sites have been in the process for more than five years).

require the same mitigation on the private surface as it does on Federal lands."[75] However, the EIS for the Northeast RMP Oil and Gas Leasing Amendments notes that "[r]eclamation requirements on private surface lands are negotiated with the landowner and the oil and gas operator. For this reason, there is no certainty that the land would be returned to its former condition."[76] The EIS must clarify whether BLM requires reclamation on split-estate lands, and indeed, should require full reclamation in every instance.

C. *Fossil Fuel Development Depletes Enormous Amounts of Water*

Some unconventional extraction techniques, most notably fracking, require the use of tremendous amounts of freshwater. The freshwater in the area subject to the RMP would be greatly affected by the increased demand for water if fracking and other unconventional oil and gas extraction are permitted.

According to EPA, median water use for development of hydraulically fractured wells is 1.5 million gallons of water per well,[77] with higher water use required for horizontal wells.[78] Between January 2011 and February 2013, median water use per hydraulic fracturing event in Weld, Larimer, Broomfield, and Boulder Counties ranged from 225,000 to 410,000 gallons, with some wells requiring over 2 million gallons of water to frack.[79] Cumulatively, fracking in Weld County required 2.34 billion gallons of water during this period.[80] Such volumes are likely to increase. Horizontal drilling in Colorado has increased greatly within the past few years, and this trend is likely to continue in the Wattenberg area and north of the area.[81] Overall water use by hydraulic fracturing in Colorado is expected to rise to 6 billion gallons of water in 2015, over twice the amount that the entire city of Boulder uses for municipal purposes.[82]

Such high levels of water use are unsustainable. Colorado is currently experiencing one of the worst sustained droughts in history, including within southeastern Colorado and the Colorado River Basin, which supplies some water to the Eastern Colorado planning area. About 97% of hydraulically fractured wells in Colorado are located in areas of high or extremely high water stress, such as Weld County.[83] A no-leasing-no-fracking alternative would preserve scarce water resources and keep critical sources of drinking water in the South Platte River and South Park Basins safe and clean.

Water used in large quantities may lead to several kinds of harmful environmental impacts. The EIS must analyze where water will be sourced, how much, and the effects on water sources under different alternatives. All of these effects must be analyzed in the context of

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[75] Royal Gorge RMP at 2-59.
[76] BLM Colorado State Office, Colorado Oil and Gas Leasing and Development Final Environmental Impact Statement (January 1991), 4-2.
[77] EPA 2015 at 4-6 – 4-7.
[78] *Id.*; USGS, Water Used for Hydraulic Fracturing Varies Widely Across United States (June 30, 2015), available at http://www.usgs.gov/newsroom/article.asp?ID=4262#.VZ7ujvlVlkr.
[79] EPA, State-level Summaries of FracFocus 1.0 Hydraulic Fracturing Data, p 15 (March 2015), available at http://www2.epa.gov/sites/production/files/2015-03/documents/ff_statesummarysheets_final_508.pdf.
[80] *Id.*
[81] COGCC 2015; RFD, p. 19-20, 28.
[82] Freyman, Monika and Ryan Salmon, Hydraulic Fracturing and Water Stress: Growing Competitive Pressures for Water, CERES, 9 (2013) ("Freyman 2013"), available at http://www.ceres.org/resources/reports/hydraulic-fracturing-water-stress-water-demand-by-the-numbers (accessed July 29, 2015).
[83] *Id.* at 6.

increasing water scarcity in Colorado due to climate change, drought, and increasing population growth.

1. **Reduced Stream Flow**

Withdrawal of large quantities of freshwater from streams and other surface waters will undoubtedly have an impact on the environment.[84] Withdrawing water from streams will decrease the supply for downstream users, such as farmers or municipalities. Rising demand from oil and gas operators has already led to increased competition for water between farmers and oil and gas operators. In some regions of the state, farmers have had to fallow fields due to astronomical water prices.[85] For example, in prior years, farmers in Colorado have paid at most $100 per acre-feet of water in auctions held by cities with excess supplies, but in 2013 energy companies paid $1200 to $2,900 per acre-feet.[86]

Reductions in stream flows may also lead to downstream water quality problems by diminishing the water bodies' capacity for dilution and degradation of pollutants. The EIS must examine these issues.

2. **Harm to Aquatic Life and Habitats**

When streams and other surface waters are depleted, the habitat for countless plants and animals will be harmed, and the depletion places tremendous pressure on species that depend on having a constant and ample stream of water. Physical habitats such as banks, pools, runs, and glides (low gradient river sections) are important yet susceptible to disturbance with changing stream flows. Altering the volume of water can also change the water's temperature and oxygen content, harming some species that require a certain level of oxygenated water. Decreasing the volume of streamflow and stream channels by diverting water to fracking would have a negative impact on the environment and should be included in the EIS.

The physical equipment itself that is designed to intake and divert water may also pose a threat to certain wildlife. If not properly designed, such equipment and intake points may be a risk to wildlife.

3. **Harm to Wetlands**

High volume removal of surface or groundwater can result in damage to wetlands, which rely on ample water supplies to maintain the fragile dynamics of a wetland habitat. Damage can also occur from spills of chemicals or wastewater, filling operations, and sediment runoff.[87]

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[84] *See* Entrekin, Sally et al., Rapid Expansion of Natural Gas Development Poses a Threat to Surface Waters, 9 Front Ecol. Environ. 9, 503 (2011); EPA 2015 at 4-16.

[85] Healy, Jack. For Farmers in the West, Oil Wells are Thirsty Rivals, The New York Times (Sept. 5,2012), available at http://www.nytimes.com/2012/09/06/us/struggle-for-water-in-colorado-with-rise-in-fracking.html?_r=0 (accessed July 29, 2015); Burke, Garance. Fracking fuels water fights in nation's dry spots, Associated Press (June 17, 2013), available at http://news.yahoo.com/fracking-fuels-water-fights-nations-dry-spots-133742770.html.

[86] *Id.*

[87] U.S. Department of Justice, *Trans Energy Inc. to Restore Streams and Wetland Damaged by Natural Gas Extraction Activities in West Virginia* (Sep. 2, 2014), http://www.justice.gov/opa/pr/trans-energy-inc-restore-streams-and-wetland-damaged-natural-gas-extraction-activities-west (accessed July 29, 2015); *See also,* Pennsylvania Department of Environmental Protection, Commonwealth of Pennsylvania, *DEP Fines Seneca Resources Corp. $40,000 for Violations at Marcellus Operation in Tioga County* (Jul. 10, 2010), http://www.portal.state.pa.us/portal/server.pt/community/newsroom/14287?id=14655&typeid=1 (accessed July 29, 2015).

Many plant and animal species depend on wetland habitats, and even small changes can lead to significant impacts. Wetlands provide a variety of "eco-service" functions, including water purification, protection from floods, and functioning as carbon sinks.[88] The ecological importance of wetlands is unquestionable, and their full protection is paramount. The EIS must analyze these potential impacts to wetlands, and the related, potential indirect impacts that may stem from such impacts.

4. Aquifer Depletion

Withdrawing large quantities of water from subsurface waters to supply oil and gas production will likely deplete and harm aquifers. Removing water from surface water or directly from underground sources of water faster than the rate that aquifers can be replenished will lower the volume of water available for other uses. Depletion can also lead to compaction of the rock formation serving as an aquifer, after which the original level of water volume can never be restored.[89] Depleted aquifer water resources may also adversely affect agriculture, species habitat and ecosystems, and human health.

D. Oil and gas development will harm air quality

Unconventional well stimulation is a large contributor to local and regional air quality problems. The RMP covers a number of counties that already have poor air quality, including many days with unhealthy levels of ozone.[90] The northern Front Range, including Denver, Boulder, Greeley, Fort Collins, Loveland, and the Greater Wattenberg area are designated non-attainment for ozone.[91] Permitting fracking and other well stimulation techniques will greatly increase the release of harmful air emissions in these and other regions. On the other hand, a no-leasing-no-fracking alternative would prevent further degradation of local air quality, along with respiratory illnesses, premature deaths, hospital visits, and missed school and work days.

1. Sources of Air Emissions

Harmful air pollutants are emitted in all stages of unconventional oil and gas recovery, including drilling, completion, well stimulation, production, and disposal.

Drilling and casing the wellbore require substantial power from large equipment. The engines used typically run on diesel fuel, which emits particularly harmful types of air pollutants when burned. Similarly, high-powered pump engines are used in the fracturing and completion phase. This too can amount in large volumes of air pollution.

Flaring, venting, and fugitive emissions of gas are also a potential source of air emissions. Gas flaring and venting can occur in both oil and gas recovery processes when underground gas rises to the surface and is not captured as part of production. Fugitive emissions can occur at every stage of extraction and production, often leading to high volumes of gas being released into the air. Methane emissions from oil and gas production is as much as 270 percent greater than previously estimated by calculation.[92] Recent studies show that emissions from

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[88] U.S. Environmental Protection Agency, Wetlands and People, http://water.epa.gov/type/wetlands/people.cfm (accessed July 29, 2015).
[89] Freyman 2013.
[90] *See*, American Lung Association, State of the Air 2015 (2015) ("ALA State of the Air 2013"), available at http://www.stateoftheair.org/2015/states/colorado/ (accessed July 29, 2015).
[91] RFD, Figure 2; AMS at 20.
[92] Miller 2013.

pneumatic valves (which control routine operations at the well pad by venting methane during normal operation) and fugitive emissions are higher than EPA estimates.[93]

Evaporation from pits can also contribute to air pollution. Pits that store drilling waste, produced water, and other waste fluid may be exposed to the open air. Chemicals mixed with the wastewater—including the additives used to make fracking fluids, as well as volatile hydrocarbons, such as benzene and toluene, brought to the surface with the waste—can escape into the air through evaporation. Some pits are equipped with pumps that spray effluents into the air to hasten the evaporation process. Even where waste fluid is stored in so-called "closed loop" storage tanks, fugitive emissions can escape from tanks.

As mentioned above, increased truck traffic will lead to more air emissions. Trucks capable of transporting large volumes of chemicals and waste fluid typically use large engines that run on diesel fuel. Air pollutants from truck engines will be emitted not only at the well site, but also along truck routes to and from the site.

2. Types of Air Emissions

As a result of drilling, well stimulation or completion, production of a well, open pits, truck traffic, flaring and venting, and fugitive emissions, the emission of several air pollutants will undoubtedly increase, further harming Colorado's already poor air quality and endangering the health of vulnerable populations that are already exposed to high levels of air pollution.

Unconventional oil and gas operations are likely to result in the emissions of air toxics. For example, reporting requirements recently implemented by the California South Coast Air Quality Management District (SCAQMD) have shown that at least 44 chemicals known to be air toxics have been used in fracking and other types of unconventional oil and gas recovery in California.[94] Through the implementation of these new reporting requirements, it is now known that operators have been using several types of air toxics in California, including crystalline silica, methanol, hydrochloric acid, hydrofluoric acid, 2-butoxyethanol, ethyl glycol monobutyl ether, xylene, amorphous silica fume, aluminum oxide, acrylic polymer, acetophenone, and ethylbenzene. Many of these chemicals also appear on the U.S. EPA's list of hazardous air pollutants.[95]

The EIS should study the potential for oil and gas operations sites in the planning area to emit such air toxics and any other pollutants that may pose a risk to human health, paying particular attention to the impacts of air pollution on environmental justice communities that already bear the burden of disproportionately high levels of air pollution.

EPA has identified six "criteria" air pollutants that must be regulated under the National Ambient Air Quality Standards (NAAQS) due to their potential to cause primary and secondary health effects. Concentrations of these pollutants—ozone, particulate matter, carbon monoxide,

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[93] Allen 2013; Harriss, Robert et al. Using Multi-Scale Measurements to Improve Methane Emission Estimates from Oil and Gas Operations in the Barnett Shale Region, Texas, Environ. Sci. Technol., 2015, 49 (13), pp 7524–7526.

[94] Center for Biological Diversity, Air Toxics One Year Report, p. 1 (June 2014).

[95] U.S. Environmental Protection Agency, The Clean Air Act Amendments of 1990 List of Hazardous Air Pollutants, Technology Transfer Network Air Toxics Web Site, http://www.epa.gov/ttnatw01/orig189.html (accessed July 29, 2015).

nitrogen oxides, sulfur dioxide and lead—will likely increase in regions where unconventional oil and gas recovery techniques are permitted.

Volatile organic compounds, though not listed as a criteria pollutant, can form ground-level (tropospheric) ozone when combined with nitrogen oxides and sunlight. This reaction can diminish visibility and air quality and harm vegetation. VOCs can be emitted from car and truck engines as well as the drilling and completion stages of oil and gas production. Tropospheric ozone can also be caused by methane as it interacts with nitrogen oxides and sunlight.[96] Methane is leaked and vented at various stages of unconventional oil and gas development. Recent studies and reports confirm the pervasive and extensive amount of VOCs emitted by unconventional oil and gas extraction.[97] In particular, a study covering sites near oil and gas wells in five different states found that concentrations of eight volatile chemicals, including benzene, formaldehyde and hydrogen sulfide, exceeded risk-based comparison values under several operational circumstances.[98] Another study determined that vehicle traffic and engine exhaust were likely the sources of intermittently high dust and benzene concentrations observed near well pads.[99]

Recent studies have found that oil and gas operations are likely responsible for elevated levels of hydrocarbons such as benzene downwind of the Denver-Julesburg Fossil Fuel Basin, north of Denver.[100] Another study found that oil and gas operations in this area emit approximately 55% of the VOCs in northeastern Colorado.[101]

The EIS should rely on the most up-to-date information regarding the contribution of oil and gas operations to VOC and air toxics levels. Recent studies in Weld County show that existing emissions inventories likely underestimate the contribution of oil and gas operations to VOC levels by a factor of two.[102] Further, researchers have found that existing emissions inventories vastly underestimate the contribution of oil and gas operations to hazardous air pollution concentrations in Weld County, suggesting that the health risk assessments conducted using these inventories are similarly inaccurate and therefore underestimate exposures and health risks.[103] This study estimated benzene emission rates and other VOCs using air quality

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[96] Fiore, Arlene et al., Linking Ozone Pollution and Climate Change. The Case for Controlling Methane, 29 Geophys. Res Letters 19 (2002).

[97] McCawley, M., Air, Noise, and Light Monitoring Plan for Assessing Environmental Impacts of Horizontal Gas Well Drilling Operations (ETD-10 Project), West Virginia University School of Public Health, Morgantown, WV (2013) ("McCawley 2013"), available at http://www.dep.wv.gov/oil-and-gas/Horizontal-Permits/legislativestudies/Documents/WVU%20Final%20Air%20Noise%20Light%20Protocol.pdf; Center for Biological Diversity, Dirty Dozen: The 12 Most Commonly Used Air Toxics in Unconventional Oil Development in the Los Angeles Basin (Sept. 2013).

[98] Macey, G.P. et al., (2014). Air Concentrations of Volatile Compounds Near Oil and Gas Production: A Community-Based Exploratory Study, 13 Environmental Health 82 (2014) at 1.

[99] McCawley 2013.

[100] Pétron, G. et al., Hydrocarbon Emissions Characterization in the Colorado Front Range – A Pilot Study, 117 J. GEOPHYSICAL RESEARCH D04304 (2012), at 8, 13 ("Pétron 2012).

[101] Gilman, J.B. et al., Source Signature of Volatile Organic Compounds from Oil and Natural Gas Operations in Northeastern Colorado, 47 ENVTL. SCI & TECH. 1297, 1303 (2013).

[102] *Id.* at 1302; Pétron 2012 at 1, 18 (noting state and federal inventories likely underestimate hydrocarbon emissions from oil and gas operations by as much as factor of two).

[103] Pétron, G. et al., A New Look at Methane and Non-Methane Hydrocarbon Emissions from Oil and Natural Gas Operations in the Colorado Denver-Julesburg Basin, accepted for publication, online May 7, 2014, J. GEOPHYSICAL RESEARCH: ATMOSPHERES, available at

measurements taken from an airplane over Weld County. Current inventories estimating benzene emissions from oil and gas operators in the study area underestimated emissions by four to nine times. The study suggests that other hazardous air pollutants (such as toluene, ethylbenzene, etc.) could similarly be underestimated and that oil and gas sites could be a bigger source of benzene than vehicle emissions, previously thought to be the largest source in the area.

3. *Impact of Increased Air Pollution*

The potential harms resulting from increased exposure to the dangerous air pollutants described above are serious and wide ranging. The negative effects of criteria pollutants are well documented and are summarized by the U.S. EPA's website:

> *Nitrogen oxides* (NOx) react with ammonia, moisture, and other compounds to form small particles. These small particles penetrate deeply into sensitive parts of the lungs and can cause or worsen respiratory disease, such as emphysema and bronchitis, and can aggravate existing heart disease, leading to increased hospital admissions and premature death. NO_x and volatile organic compounds react in the presence of heat and sunlight to form ozone.
>
> *Particulate matter* (PM) - especially fine particles - contains microscopic solids or liquid droplets that are so small that they can get deep into the lungs and cause serious health problems. Numerous scientific studies have linked particle pollution exposure to a variety of problems, including: premature death in people with heart or lung disease, increased mortality, nonfatal heart attacks, irregular heartbeat, aggravated asthma, decreased lung function, and increased respiratory symptoms, such as irritation of the airways, coughing or difficulty breathing.[104]
>
> *Sulfur Dioxide* (SO_2) – has been shown to cause an array of adverse respiratory effects including bronchoconstriction and increased asthma symptoms.[105] Studies also show a connection between short-term exposure and increased visits to emergency departments and hospital admissions for respiratory illnesses, particularly in at-risk populations including children, the elderly, and asthmatics.[106]
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> *Carbon Monoxide* (CO) can cause harmful health effects by reducing oxygen delivery to the body's organs (like the heart and brain) and tissues. At extremely high levels, CO can cause death.[107] Exposure to CO can reduce the oxygen-carrying capacity of the blood. People with several types of heart disease already have a reduced capacity for pumping oxygenated blood to the heart, which can cause them to experience myocardial ischemia (reduced oxygen to the heart), often accompanied by chest pain (angina), when exercising

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http://onlinelibrary.wiley.com/doi/10.1002/2013JD021272/abstract.

[104] U.S. Environmental Protection Agency, Particulate Matter, (PM) http://www.epa.gov/airquality/particlepollution/health.html (accessed July 30, 2015); Ostro, Bart et.al., Long-term Exposure to Constituents of Fine Particulate Air Pollution and Mortality: Results from the California Teachers Study, 118 Environmental Health Perspectives 3 (2010)

[105] U.S. Environmental Protection Agency, Sulfur Dioxide http://www.epa.gov/airquality/sulfurdioxide/health.html, available at (accessed July 29, 2015).

[106] *Id.*

[107] U.S. Environmental Protection Agency, Carbon Monoxide, available at http://www.epa.gov/airquality/carbonmonoxide/health.html (accessed July 29, 2015).

or under increased stress.[108] For these people, short-term CO exposure further affects their body's already compromised ability to respond to the increased oxygen demands of exercise or exertion.[109]

Ozone (O_3) can trigger or worsen asthma and other respiratory ailments.[110] Ground level ozone can have harmful effects on sensitive vegetation and ecosystems. Ozone may also lead to loss of species diversity and changes to habitat quality, water cycles, and nutrient cycles.

Air toxics and hazardous air pollutants, by definition, can result in harm to human health and safety. The full extent of the health effects of exposure is still far from being complete, but already there are numerous studies that have found these chemicals to have serious health consequences for humans exposed to even minimal amounts. The range of illnesses that can result are summarized in a study by Dr. Theo Colburn, which charts which chemicals have been shown to be linked to certain illnesses.[111]

Natural gas drilling operations result in the emissions of numerous non-methane hydrocarbons (NMHCs) that have been linked to numerous adverse health effects. A recent study that analyzed air samples taken during drilling operations near natural gas wells and residential areas in Garfield County, detected 57 chemicals between July 2010 and October 2011, including 44 with reported health effects.[112] For example:

> Thirty-five chemicals were found to affect the brain/nervous system, 33 the liver/metabolism, and 30 the endocrine system, which includes reproductive and developmental effects. The categories with the next highest numbers of effects were the immune system (28), cardiovascular/blood (27), and the sensory and respiratory systems (25 each). Eight chemicals had health effects in all 12 categories. There were also several chemicals for which no health effect data could be found.[113]

The study found extremely high levels of methylene chloride, which may be used as cleaning solvents to remove waxy paraffin that is commonly deposited by raw natural gas in the region. These deposits solidify at ambient temperatures and build up on equipment.[114] While none of the detected chemicals exceeded governmental safety thresholds of exposure, the study noted that such thresholds are typically based on "exposure of a grown man encountering

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[108] *Id.*
[109] *Id.*
[110] U.S. Environmental Protection Agency, Ground Level Ozone, available at http://www.epa.gov/airquality/ozonepollution/health.html (accessed July 29, 2015).
[111] Colborn, Theo et al., Natural Gas Operations from a Public Health Perspective, 17 Human and Ecological Risk Assessment 1039 (2011) ("Colborn 2011"); Colborn, Theo, et al., An Exploratory Study of Air Quality near Natural Gas Operations, Human and Ecological Risk Assessment: An International Journal doi:10.1080/10807039.2012.749447 (2012); *see* note 120 & accompanying text below.
[112] Colborn et al. An Exploratory Study of Air Quality Near Natural Gas Operations, Human and Ecological Risk Assessment: An International Journal, Vol. 20, Iss. 1, 2014, pp. 21-22 (pages refer to page numbers in attached manuscript and not journal pages) ("Colborn 2014), available at http://www.tandfonline.com/doi/full/10.1080/10807039.2012.749447.
[113] Colborn 2014, p. 11.
[114] *Id.*, p. 10.

relatively high concentrations of a chemical over a brief time period, for example, during occupational exposure."[115] Consequently, such thresholds may not apply to individuals experiencing "chronic, sporadic, low-level exposure," including sensitive populations such as children, the elderly, and pregnant women.[116] For example, the study detected polycyclic aromatic hydrocarbon (PAH) levels that could be of "clinical significance," as recent studies have linked low levels of exposure to lower mental development in children who were prenatally exposed.[117] In addition, government safety standards do not take into account "the kinds of effects found from low-level exposure to endocrine disrupting chemicals…, which can be particularly harmful during prenatal development and childhood.[118]

The EIS should incorporate a literature review of the harmful effects of each of these chemicals known to be used in fracking and other unconventional oil and gas extraction methods. Without knowing the effects of each chemical, the EIS cannot accurately project the true impact of unconventional oil and gas extraction.

4. Air Modeling

BLM should use air modeling to understand what areas and communities will most likely be affected by air pollution. It is crucial to gather independent data rather than relying on industry estimates, which may be inaccurate or biased. Wind and weather patterns, and atmospheric chemistry, determine the fate and transport of air pollution over a region, over time. The EIS should be informed by air modeling to show where the air pollution will flow.

E. Oil and Gas Development Poses Significant Human Health and Safety Risks

Ample scientific evidence indicates that well development and well stimulation activities have been linked to an array of adverse human health effects, including carcinogenic, developmental, reproductive, and endocrine disruption effects. This is all the more alarming when considering how close wells may be developed to schools, residences, and businesses in Colorado. Just as troubling, is how much is unknown about the chemicals used in well stimulation activities.[119] The potential human health dangers and the precautionary principle should further compel BLM to consider not allowing further development of oil and gas minerals in the planning area. In comparing a no-leasing-no-fracking alternative to leasing and continued unconventional well development scenarios, the EIS should include a health impact assessment, or equivalent, of the aggregate impact that unconventional extraction techniques, including fracking, will have on human health and nearby communities.

While all phases of oil and gas production put people at risk, in recent years attention has focused on the new dangers of fracking and other forms of well stimulation which use hundreds of chemicals, the majority of which are known to have adverse human health effects. A study of gas production in Colorado yielded 632 chemicals used in 944 different products known to have been used.[120] Of these chemicals, 75 percent have been shown to cause harm to the skin, eyes,

[115] *Id.*, pp. 11-12.
[116] *Id.* p. 12.
[117] *Id.*, p. 10-11.
[118] *Id.*, p. 12.
[119] *See, e.g.* EPA 2015 at 5-73, 10-7.
[120] Colborn 2011 at 1045.

and other sensory organs; approximately 40-50 percent could affect the brain/nervous system, immune and cardiovascular systems, and the kidneys; 37 percent could affect the endocrine system; and 25 percent could cause cancer and mutations.[121] These chemicals must be transported, mixed, stored, injected, captured and disposed of. Each step creates a risk for communities that are nearby the well site, transportation route, or disposal site. Chemicals used during the drilling process showed many of the same dangers.[122] Chemicals identified in evaporation pits also were linked to the same array of harms.[123]

Due to the heavy and frequent use of chemicals, proximity to fracked wells is associated with higher rates of cancer, birth defects, poor infant health, and acute health effects for nearby residents who must endure long-term exposure:

- In one study, residents living within one-half mile of a fracked well were significantly more likely to develop cancer than those who live more than one-half mile away, with exposure to benzene being the most significant risk.[124]

- Another study found that pregnant women living within 10 miles of a fracked well were more likely to bear children with congenital heart defects and possibly neural tube defects.[125] A separate study independently found the same pattern; infants born near fracked gas wells had more health problems than infants born near sites that had not yet conducted fracking.[126, 127]

- A study analyzed Pennsylvania birth records from 2004 to 2011 to assess the health of infants born within a 2.5-kilometer radius of natural-gas fracking sites. They found that proximity to fracking increased the likelihood of low birth weight by more than half, from about 5.6 percent to more than 9 percent.[128] The chances of a low Apgar score, a summary measure of the health of newborn children, roughly doubled, to more than 5 percent.[129] Another recent Pennsylvania study found a correlation between proximity to unconventional gas drilling and higher incidence of lower birth weight and small-for-gestational-age babies.[130]

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[121] *Id.* p. 1046.
[122] *Id.*
[123] *Id.* at 1048.
[124] McKenzie, L. et al., Human Health Risk Assessment of Air Emissions from Development of Unconventional Natural Gas Resources, 424 Science of the Total Environment 79 (2012) ("McKenzie 2012").
[125] McKenzie, L. et al., Birth Outcomes and Maternal Residential Proximity to Natural Gas Development in Rural Colorado, Advance Publication Environmental Health Perspectives (Jan. 28, 2014), http://dx.doi.org/10.1289/ehp.1306722 ("McKenzie 2014").
[126] Hill, Elaine L., Unconventional Natural Gas Development and Infant Health: Evidence from Pennsylvania, Cornell University (2012).
[127] Whitehouse, Mark, *Study Shows Fracking Is Bad for Babies*, Bloomberg View, Jan. 4, 2014, available at http://www.bloombergview.com/articles/2014-01-04/study-shows-fracking-is-bad-for-babies.
[128] *Id.*, citing Janet Currie of Princeton University, Katherine Meckel of Columbia University, and John Deutch and Michael Greenstone of the Massachusetts Institute of Technology.
[129] *Id.*
[130] Stacy, Shaina L. et al. (2015) Perinatal Outcomes and Unconventional Natural Gas Operations in Southwest Pennsylvania. PLoS ONE 10(6): e0126425. doi:10.1371/journal.pone.0126425, available at http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0126425.

- A recent study found increased rates of cardiology-patient hospitalizations in zip codes with greater number of unconventional oil and gas wells and higher well density in Pennsylvania.[131] The results suggested that if a zip code went from having zero wells to well density greater than 0.79 wells/km^2, the number of cardiology-patient hospitalizations per 100 people (or "cardiology inpatient prevalence rate") in that zip code would increase by 27%. If a zip code went from having zero wells to a well density of 0.17 to 0.79 wells/km^2, a 14% increase in cardiology inpatient prevalence rates would be expected. Further, higher rates of neurology-patient hospitalizations were correlated with zip codes with higher well density.

- Recently published reports indicate that people living in proximity to fracked gas wells commonly report skin rashes and irritation, nausea or vomiting, headache, dizziness, eye irritation and throat irritation.[132]

- In Texas, a jury awarded nearly $3 million to a family who lived near a well that was hydraulically fractured.[133] The family complained that they experienced migraines, rashes, dizziness, nausea and chronic nosebleeds. Medical tests showed one of the plaintiffs had more than 20 toxic chemicals in her bloodstream.[134] Air samples around their home also showed the presence of BTEX — benzene, toluene, ethylbenzene and xylene —colorless but toxic chemicals typically found in petroleum products.[135]

Chemicals used for fracking also put nearby residents at risk of endocrine disruption effects. A study that sampled water near active wells and known spill sites in Garfield, County Colorado found alarming levels of estrogenic, antiestrogenic, androgenic, and antiandrogenic activities, indicating that endocrine system disrupting chemicals (EDC) threaten to contaminate surface and groundwater sources for nearby residents.[136] The study concluded:

> [M]ost water samples from sites with known drilling-related incidents in a drilling-dense region of Colorado exhibited more estrogenic, antiestrogenic, and/or antiandrogenic activities than the water samples collected from reference sites[,] and 12 chemicals used in drilling operations exhibited similar activities. Taken together, the following support an association between natural gas drilling

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[131] Jemielital, T. et al. Unconventional Gas and Oil Drilling Is Associated with Increased Hospital Utilization Rates. PLoS ONE 10(7): e0131093, available at http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0131093.
[132] Rabinowitz, P.M. et al , Proximity to Natural Gas Wells and Reported Health Status: Results of a Household Survey in Washington County, Pennsylvania. Environmental Health Perspectives Advance Publication (2014); Bamberger, Michelle and R.E. Oswald, Impacts of Gas Drilling on Human and Animal Health, 22 New Solutions 51 (2012); Steinzor, N. et al., Gas Patch Roulette: How Shale Development Risks Public Health in Pennsylvania, Earthworks Gas & Oil Accountability Project (2012).
[133] *Parr v. Aruba Petroleum, Inc.*, Case No. 11-01650-E (Dallas Cty., filed Sept.13, 2013).
[134] Deam, Jenny, *Jury Awards Texas family Nearly $3 million in Fracking Case*, Los Angeles Times (Apr. 3, 2014) http://www.latimes.com/nation/la-na-fracking-lawsuit-20140424-story.html.
[135] *Id.*
[136] Kassotis, Christopher D. et al., Estrogen and Androgen Receptor Activities of Hydraulic Fracturing Chemicals and Surface and Ground Water in a Drilling-Dense Region, Endocrinology, March 2014, 155(3):897–907, pp. 905-906, available at http://press.endocrine.org/doi/full/10.1210/en.2013-1697.

> operations and EDC activity in surface and ground water: [1] hormonal activities in Garfield County spill sites and the Colorado River are higher than those in reference sites in Garfield County and in Missouri, [2] selected drilling chemicals displayed activities similar to those measured in water samples collected from a drilling-dense region, [3] several of these chemicals and similar compounds were detected by other researchers at our sample collection sites, and [4] known spills of natural gas fluids occurred at these spill sites.

The study also noted a linkage between EDCs and "negative health outcomes in laboratory animals, wildlife, and humans":

> Despite an understanding of adverse health outcomes associated with exposure to EDCs, research on the potential health implications of exposure to chemicals used in hydraulic fracturing is lacking. Bamberger and Oswald (26) analyzed the health consequences associated with exposure to chemicals used in natural gas operations and found respiratory, gastrointestinal, dermatologic, neurologic, immunologic, endocrine, reproductive, and other negative health outcomes in humans, pets, livestock, and wildlife species.
>
> Of note, site 4 in the current study was used as a small-scale ranch before the produced water spill in 2004. This use had to be discontinued because the animals no longer produced live offspring, perhaps because of the high antiestrogenic activity observed at this site. There is evidence that hydraulic fracturing fluids are associated with negative health outcomes, and there is a critical need to quickly and thoroughly evaluate the overall human and environmental health impact of this process. It should be noted that although this study focused on only estrogen and androgen receptors, there is a need for evaluation of other hormone receptor activities to provide a more complete endocrine-disrupting profile associated with natural gas drilling.[137]

Harmful chemicals are also found in the flowback fluid after well stimulation events. Flowback fluid is a key component of oil-industry wastewater from stimulated wells. A survey of chemical analyses of flowback fluid dating back to April 2014 in California revealed that concentrations of benzene, a known carcinogen, were detected at levels over 1,500 times the federal limits for drinking water.[138] Of the 329 available tests that measured for benzene, the chemical was detected at levels in excess of federal limits in 320 tests (97 percent).[139] On average, benzene levels were around 700 times the federal limit for drinking water.[140] Among

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[137] *Id.*, p. 905.

[138] California Department of Conservation Division of Oil, Gas, & Geothermal Resources, California Well Stimulation Public Disclosure Report, available at http://www.conservation.ca.gov/dog/Pages/WellStimulationTreatmentDisclosure.aspx. The highest concentration was 7,700 parts per billion (ppb) for a well with API number 03052587. The US EPA's maximum contaminant level for benzene is 5 ppb.

[139] *Id.*

[140] *Id.*, *see also* Cart, J., High Levels of Benzene Found in Fracking Wastewater, Los Angeles Times, Feb. 11, 2015, http://www.latimes.com/local/california/la-me-fracking-20150211-story.html#page=1.

other carcinogenic or otherwise dangerous chemicals found in flowback fluid from fracked wells are toluene and chromium-6.[141] These hazardous substances were detected in excess of federal limits for drinking water in over one hundred tests. This dangerous fluid is commonly disposed of in injection wells, which often feed into aquifers, including some that could be used for drinking water and irrigation.

Acidizing presents similarly alarming risks to public health and safety. In acidizing operations, large volumes of hydrochloric and hydrofluoric acid are transported to the site and injected underground. These chemicals are highly dangerous due to their corrosive properties and ability to trigger tissue corrosion and damage to sensory organs through contact.

While many risks are known, much more is unknown about the hundreds of chemicals used in fracking. The identity and effects of many of these additives is unknown, due to operators' claims of confidential business information. But, as the EPA recognizes, chemical identities are "necessary to understand their chemical, physical, and toxicological properties, which determine how they might move through the environment to drinking water resources and any resulting effects."[142] Compounds in mixtures can have synergistic or antagonistic effects, but again, it is impossible to know these effects without full disclosure.[143] The lack of this information also precludes effective remediation: "Knowing their identities would also help inform what chemicals to test for in the event of suspected drinking water impacts and, in the case of wastewater, may help predict whether current treatment systems are effective at removing them."[144]

Even where chemical identities are known, chemical safety data may be limited. In EPA's study of the hazards of fracking chemicals to drinking water, EPA found that "[o]ral reference values and oral slope factors meeting the criteria used in this assessment were not available for the majority of chemicals used in hydraulic fracturing fluids [87%], representing a significant data gap for hazard identification."[145] Without this data, EPA could not adequately assess potential impacts on drinking water resources and human health.[146] Further, of 1,076 hydraulic fracturing fluid chemicals identified by the EPA, 623 did not have estimated physiochemical properties reported in EPA's toxics database, although this information is "essential to predicting how and where it will travel in the environment."[147] The data gaps are actually much larger, because EPA excluded 35% of fracking chemicals reported to FracFocus from its analysis because it could not assign them standardized chemical names.[148]

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[141] *Id.*; *see also* Center for Biological Diversity, Cancer-causing Chemicals Found in Fracking Flowback from California Oil Wells (2015) Feb. 11, 2015, available at http://www.biologicaldiversity.org/news/press_releases/2015/fracking-02-11-2015.html.
[142] EPA 2015 at 10-18.
[143] Souther 2014, p. 334.
[144] EPA 2015 at 10-18.
[145] *Id.* at 10-7, 9-7.
[146] *Id.* at 9-37-38.
[147] *Id.* at 5-73.
[148] *Id.* at 9-38.

Similarly, poor understanding exists as to how fracking wells perform. For example, information about the performance and subsurface movement of wells is limited due to confidential business information claims by operators, poor recordkeeping, and lack of baseline data collection, hindering any understanding of the "design and performance of individual wells or wells in a region" and groundwater impacts.[149]

Despite the known and unknown human health risks, wells, tanks, separators, and other related industrial equipment are commonly allowed in areas very close to people. Colorado law only mandates a 500-foot setback from schools and residential areas for oil and gas wells, and even then, exceptions may be allowed. [150] A 2013 review of active and prospective well data in Adams, Boulder, Broomfield and Weld counties found nearly 200 wells within 2,000 feet of a public school.[151] 87 active and proposed oil and gas wells were within 1,000 feet of a public school.[152] Likewise, a 2014 COGCC Staff Report revealed that statewide at least 10 buildings were less than 150 feet from a well spot, 230 were 150 to 300 feet from a well spot, 383 were 350 to 500 feet from a well spot, and 1,211 were within 500 to 1000 feet of a well spot – large portions of which were in Weld County.[153] The report also showed that at least two residences were less than two hundred feet from wells in Weld County.[154] Notably, Red Hawk Elementary school in Erie, Colorado (part of the Boulder metropolitan area) hosts over 400 students and is located within a 2-mile radius of 66 well pads, including 8 which were drilled within 600 yards of the school.[155] Without further restrictions on oil and gas development near schools and residences, health risks to children and other vulnerable populations will only increase with increased oil and gas drilling. The EIS must fully assess the risk to local communities, including vulnerable populations.

The EIS should also study the human health and safety impacts of noise pollution, light pollution, and traffic accidents resulting from oil and gas development. A recent study found that automobile and truck accident rates in counties in Pennsylvania with heavy unconventional oil and gas extraction activity were between 15 and 65 percent higher than accident rates in counties without unconventional oil and gas extraction activities.[156] Rates of traffic fatalities and major injuries may be higher in areas with heavy drilling activity than areas without.[157]

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[149] *Id.* at 6-56 – 6-57.
[150] 2 Colo. Code Regs. § 404-1(604)(a)(1).
[151] See Western Resource Advocates, Fracking, http://www.westernresourceadvocates.org/land/fracking.php (last accessed July 30, 2015).
[152] *Id.*
[153] COGCC, Staff Report (Jan. 27, 2014) at 20, available at https://cogcc.state.co.us/Staff_Reports/2014/201401_StaffReport.pdf" (accessed July 30, 2015).
[154] *Id.* at 21.
[155] *See generally*, Federal Regulation: Economic, Job and Energy Security Implications of Federal Hydraulic Fracturing Regulation: Oversight Field Hearing before the H. Subcomm. On Energy and Mineral Resources, 112th Cong. at 1 (2012) (statement of Jennifer Palazzolo, parent of a Red Hawk Elementary school student), http://democrats.naturalresources.house.gov/sites/democrats.naturalresources.house.gov/files/2012-05-02_PalazzoloTestimony.pdf. Lighthousesolar, Fracking at the Erie Elementary School Photo Shoot, http://www.lighthousesolar.com/blog/fracking-at-the-erie-elementary-school-photo-shoot/
[156] Graham, J., Irving et al., Increased Traffic Accident Rates Associated with Shale Gas Drilling in Pennsylvania. 74 Accident Analysis and Prevention 203 (2015).
[157] *Id.*

F. *Oil and Gas Drilling Increases Risks of Exposure to Radioactive Material*

Naturally occurring radioactive materials can be brought to the surface through drilling and extraction processes, yet neither COGCC nor BLM rules appear to require any testing for radioactive materials whatsoever before waste fluids are disposed. The buildup of radioactive materials in pipes and equipment can accumulate to amounts that are harmful to workers who interact with the pipes and equipment. Studies have found high concentrations of the element radium, a highly radioactive substance, in water samples from streams in Pennsylvania where treated shale gas wastewater was disposed.[158] Concentrations were roughly 200 times higher than background levels. Given the potential for radioactive substances to be present in treated wastewater and the high potential for accidental spills and releases, the EIS should assess the amount, the type, and the potency of radioactive elements that are naturally occurring in the landforms subject to the RMP and evaluate the likely risks that stem from bringing such materials to the surface. This analysis should address how radioactive materials could impact the specific areas in which wastewaters are treated, disposed, or accidentally released.

G. *Unconventional Extraction Techniques and Underground Wastewater Disposal Pose Seismic Risks*

If oil and gas development is allowed to proliferate in the planning area, increased unconventional oil and gas extraction and underground waste injection will increase the risk of induced seismicity. Induced seismic events could damage or destroy property and cause injuries or even death, especially in a state where earthquakes are rare and communities are typically not prepared for them. A no-leasing-no-fracking alternative would minimize these risks, while continued leasing and unconventional well development would increase them.

Research has shown that in regions of the central and eastern United States where unconventional oil and gas development has proliferated in recent years, earthquake activity has increased dramatically.[159] More than 300 earthquakes with magnitude (M) $\geq$ 3 occurred between 2010 through 2012, compared with an average of 21 per year between 1967 and 2000.[160] Moreover, although earthquakes with magnitude (M) $\geq$ 5.0 are very uncommon east of the Rocky Mountains, the number per year recorded in the midcontinent increased 11-fold between 2008 and 2011, compared to 1976 to 2007.[161] Mid-continent states experiencing elevated levels of seismic activity include Arkansas, Colorado, New Mexico, Ohio, Oklahoma, Texas, and Virginia.[162]

Research has linked much of the increased earthquake activity and several of the largest earthquakes in the U.S. midcontinent in recent years to the disposal of wastewater into deep

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[158] Warner, Nathaniel R. et al., Impacts of Shale Gas Wastewater Disposal on Water Quality in Western Pennsylvania, Environ. Sci. Technol. dx.doi.org/10.1021/es402165b (Sept 10, 2013); *see also* Stromberg, Joseph, *Radioactive Wastewater from Fracking Is Found in a Pennsylvania Stream*, Surprising Science, Smithsonian.com, http://blogs.smithsonianmag.com/science/2013/10/radioactive-wastewater-from-fracking-is-found-in-a-pennsylvania-stream/ (Oct 2, 2013).

[159] Ellsworth, W.L. Injection-Induced Earthquakes, 341 Science 1225942 (2013) ("Ellsworth 2013"); Keranen, Katie et al., Potentially Induced Earthquakes in Oklahoma, USA: Links Between Wastewater Injection and the 2011 Mw5.7 Earthquake Sequence, Geology doi:10.1130/G34045.1 (March 26, 2013) ("Keranen 2013").

[160] Ellsworth 2013.

[161] Keranen 2013.

[162] Ellsworth 2013.

injection wells, which is well-established to pose a significant seismic risk.[163] Earthquakes at magnitudes (M) that are felt (M3 and M4) or destructive (M4 and M5) have been attributed to wastewater injection wells in at least five states - Arkansas, Colorado, Ohio, Oklahoma, and Texas. The largest of these was a M5.7 earthquake in Prague, Oklahoma, which was the biggest in the state's history, destroying 14 homes and injuring two people.[164] Other large earthquakes attributed to wastewater injection include an M5.3 in Colorado,[165] M4.9 in Texas,[166] M4.7 in Arkansas,[167] and M3.9 in Ohio.[168]

The proliferation of unconventional oil and gas development, including increases in extraction and injection, will increase earthquake risk in Colorado. Accordingly, the EIS must fully assess the risk of induced seismicity cause by all unconventional oil and gas extraction and injection activities, including wastewater injection wells.

The analysis should assess the following issues based on guidance from the scientific literature, the National Research Council,[169] and the Department of Energy[170]:

(1) whether existing oil and gas wells and wastewater injection wells in the area covered by the RMP have induced seismic activity, using earthquake catalogs (which provide an inventory of earthquakes of differing magnitudes) and fluid extraction and injection data collected by industry;

(2) the region's fault environment by identifying and characterizing all faults in these areas based on sources including but not limited to the USGS Quaternary Fault and Fold database and the most recent Colorado Geological Survey Fault Activity Map GIS layer. In its analysis, BLM should assess its ability to identify all faults in these areas, including strike-slip faults and deep faults that can be difficult to detect;

(3) the background seismicity of oil- and gas-bearing lands including the history of earthquake size and frequency, fault structure (including orientation of faults), seismicity rates, failure mechanisms, and state of stress of faults;

(4) the geology of oil- and gas-bearing lands including pore pressure, formation permeability, and hydrological connectivity to deeper faults;

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[163] *Id.*

[164] Ellsworth 2013, Keranen 2013.

[165] Rubinstein, J.L. et al., The 2001–present triggered seismicity sequence in the Raton Basin of southern Colorado/northern New Mexico, 104 Bull. Seismol. Soc'y of America 5 (2014).

[166] Brown, W.A. et al. Abstract: Investigating the cause of the 17 May 2012 M4.8 earthquake near Timpson, East Texas, Abstract 84 Seismol. Res. Lett 374 (2013).

[167] Horton, S., Disposal of Hydrofracking Waste Fluid by Injection into Subsurface Aquifers Triggers Earthquake Swarm in Central Arkansas with Potential for Damaging Earthquake, 83 Seismol. Res. Lett. 2 (2012).

[168] Kim, Won-Young, Induced Seismicity Associated with Fluid Injection into a Deep Well in Youngstown, Ohio, 118 J. of Geophys. Res.: Solid Earth 3506 (February 1, 2013).

[169] National Research Council, *Induced Seismicity Potential in Energy Technologies.* National Academies Press (2012).

[170] U.S. Department of Energy, *Protocol for Addressing Induced Seismicity Associated with Enhanced Geothermal Systems*, DOE/EE-0662 (2012); U.S. Department of Energy, *Best Practices for Addressing Induced Seismicity Associated with Enhanced Geothermal Systems - Draft* (2013).

(5) the hazards to human communities and infrastructure from induced seismic activity; and

(6) the current state of knowledge on important questions related to the risk and hazards of induced seismicity from oil and gas development activities, including:

(a) how the distance from a well to a fault affects seismic risk (i.e., locating wells in close proximity to faults can increase the risk of inducing earthquakes);

(b) how fluid injection and extraction volumes, rates, and pressures affect seismic risk;

(c) how the density of wells affects seismic risk (i.e., a greater density of wells affects a greater volume of the subsurface and potentially contacts more areas of a single fault or a greater number of faults);

(d) the time period following the initiation of injection or extraction activities over which earthquakes can be induced (i.e., studies indicate that induced seismicity often occurs within months of initiation of extraction or injection although there are cases demonstrating multi-year delays);

(e) how stopping extraction or injection activities affects induced seismicity (i.e., can induced seismicity be turned off by stopping extraction and injection and over what period, since studies indicate that there are often delays—sometimes more than a year—between the termination of extraction and injection activities and the cessation of induced earthquake activity);

(f) the largest earthquake that could be induced by unconventional oil and gas development activities in areas covered by the RMP, including earthquakes caused by wastewater injection; and

(g) whether active and abandoned wells are safe from damage from earthquake activity over the short and long-term.

H. Oil and Gas Development Is Incompatible with Preserving Wildlife

Colorado's rich and diverse wildlife already suffer innumerable harms from urban development, grazing, agriculture, water impoundments, climate change, invasive species, hunting, roads, logging, and industrial development, which new oil and gas leasing and unconventional well stimulation methods in the planning area will only exacerbate. Depending on the area and the species, wildlife can be affected from oil and gas activity in a variety of ways.[171] The expansion of oil and gas development activities will harm wildlife through habitat destruction and fragmentation, stress and displacement caused by development-related activities (e.g., construction and operation activities, truck traffic, noise and light pollution), surface water depletion leading to low stream flows, water and air contamination, introduction of invasive species, and climate change. These harms can result in negative health effects and population declines. Studies and reports of observed impacts to wildlife from unconventional oil and gas

[171] *See generally* Northrup, Joseph M. & George Wittemyer, Characterising the Impacts of Emerging Energy Development on Wildlife, With an Eye Towards Mitigation, 16 Ecology Letters 112 (2013).

extraction activities are summarized in Appendix A.[172] Because the allowance of destructive oil and gas extraction runs contrary to BLM's policy of managing resources in a manner that will "protect the quality of...ecological...values" and "provide...habitat for wildlife,"[173] a no-leasing-no-fracking alternative minimizing industrial development and its harmful effects on wildlife must be considered.

1. **Habitat Loss**

Oil and gas development creates a network of well pads, roads, pipelines, and other infrastructure that lead to direct habitat loss and fragmentation, as well as displacement of wildlife from these areas due to increased human disturbance. Habitat loss can occur as a result of a reduction in the total area of the habitat, the decrease of the interior-to-edge ratio, isolation of one habitat fragment from another, breaking up of one habitat into several smaller patches of habitat, and decreasing the average size of a habitat patch. New research has revealed the extent of this habitat loss. For example, in the western United States, the amount of high-quality habitat for the pronghorn has shrunk drastically due to oil and gas development.[174]

The indirect effects from unconventional oil and gas development can often be far greater than the direct disturbances to habitat. The impacts from the well site—including noise, light, and pollution-- extend beyond the borders of the operation site and will consequently render even greater areas uninhabitable for some wildlife. Species dependent on having an "interior" habitat will lose their habitat as operation sites or other infrastructure fragment previously buffered and secluded areas. These and other indirect effects can be far greater than the direct disturbances to land. In the Marcellus shale of Pennsylvania, for instance, research shows that 8.8 acres of forest on average are cleared for each drilling pad along with associated infrastructure, but after accounting for ecological edge effects, each drilling station actually affected 30 acres of forest.[175]

While individual well sites may cause some disturbance and destruction, the cumulative impacts of oil and gas production using unconventional methods must receive attention as well. While the actual well pads may only occupy a small proportion of a particular habitat, their impact can be much greater when their aggregate impact is considered. As discussed above, interior habitats will be destroyed by removing the buffer between the interior habitat and the operation site.

2. **Water Depletion**

Water depletion can also affect species whose habitats are far removed from the actual well site. Because of the high volume of water required for even a single well that uses unconventional extraction methods, the cumulative water depletion could have a significant impact on species that rely on water sources that serve to supply oil and gas operations. In addition, water depletion can adversely impact water temperature and chemistry, as well as

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[172] *See* Appendix A: Center for Biological Diversity, Review of Impacts of Oil and Gas Exploration and Development on Wildlife (June 20, 2015). This review presents the findings of numerous studies and reports on the impacts of hydraulic fracturing on wildlife.
[173] 43 U.S. Code § 1701(a)(8).
[174] Beckmann, J.P. et al. Human-mediated shifts in animal habitat use: Sequential changes in pronghorn use of a natural gas field in Greater Yellowstone, 147 Biological Conservation 1:222 (2012).
[175] Johnson, N., Pennsylvania energy impacts assessment: Report 1: Marcellus shale natural gas and wind, Nature Conservancy – Pennsylvania Chapter (2010) at 10.

amplify the effects of harmful pollutants on wildlife that would otherwise be diluted without the depletion.

3. Contamination from Wastewater Causing Harm and Mortality

Accidental spills or intentional dumping of wastewater can contaminate surface water and cause large-scale harm to wildlife. Numerous incidents of wastewater contamination from pipelines, equipment blowouts, and trucks accidents have been reported, and have resulted in kills of fish, aquatic invertebrates, and trees and shrubs, as well as negative health effects for wildlife and domestic animals. Contamination incidents have occurred that demonstrate that wildlife harm from contamination is a real, not just theoretical, impact that must be considered. In 2013, a company admitted to dumping wastewater from fracking operations into the Acorn Fork Creek in Kentucky, causing a massive fish kill.[176] Among the species harmed was the blackside dace, a threatened minnow species.[177] An analysis of water quality of Acorn Creek and fish tissues taken shortly after the incident was exposed showed the fish displayed general signs of stress and had a higher rate of gill lesions, than fish in areas not affected by the dumping.[178] The discharge of fracking wastewater into the Susquehanna River in Pennsylvania is suspected to be the cause of fish abnormalities, including high rates of spots, lesions, and intersex.[179] In West Virginia, the permitted application of hydrofracturing fluid to an area of mixed hardwood forest caused extensive tree mortality and a 50-fold increase in surface soil concentrations of sodium and chloride.[180]

In addition, open air pits that store waste fluid pose risks for wildlife that may come into contact with the chemicals stored in the pits. Already, there have been several documented cases of animal mortality resulting from contact with pits. A field inspection of open pits in Wyoming found 269 bird carcasses, the likely cause of death being exposure to toxic chemicals stored in the open pits.[181] Open pits can also serve as breeding grounds for mosquitoes, which serve as a vector for West Nile virus, a threat to humans and animals alike. In Wyoming, an increase of ponds led to an increase of West Nile virus among greater sage-grouse populations.[182] Recently, new information has come to light that operators in California have been dumping wastewater into hundreds of unpermitted open pits.[183] The EIS must take into account the impact of both unpermitted, illegal waste pits as well as those that are regulated.

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[176] Vaidyanathan, Gayathri, *Fracking Spills Cause Massive Ky. Fish Kill*, E&E News, Aug. 29. 2013, http://www.eenews.net/greenwire/2013/08/29/stories/1059986559 (accessed July 30, 2015).
[177] *Id.*
[178] Papoulias, D.M. and A.L. Velasco. Histopathological analysis of fish from Acorn Fork Creek, Kentucky, exposed to hydraulic fracturing fluid releases, 12 Southwestern Naturalist (Special Issue 4):92 (2013).
[179] Piette, Betsy, BP Oil Spill, Fracking Cause Wildlife Abnormalities, Workers World (April 27, 2012) *available at* http://www.workers.org/2012/us/bp_oil_spill_fracking_0503/; Pennsylvania Fish & Boat Commission, Ongoing Problems with the Susquehanna River smallmouth bass, a Case for Impairment (May 23, 2012), www.fish.state.pa.us/newsreleases/2012press/senate_susq/SMB_ConservationIssuesForum_Lycoming.pdf
[180] Adams, Mary Beth, Land Application of Hydrofracturing Fluids Damages a Deciduous Forest Stand in West Virginia, 40 Journal of Environmental Quality 1340 (2011).
[181] *See, e.g.*, Ramirez, P. Jr., Bird Mortality in Oil Field Wastewater Disposal Facilities, 46 Environ Mgmt 5: 820 (2010).
[182] Zou, Li et al., Mosquito Larval Habitat Mapping Using Remote Sensing and GIS: Implications of Coalbed Methane Development and West Nile Virus, 43 J. Med. Entomol. 5:1034 (2006).
[183] Cart, Julie. *Hundreds of Illicit Oil Wastewater Pits Found in Kern County*, (Feb. 26, 2015), *available at* http://www.latimes.com/local/lanow/la-me-ln-pits-oil-wastewater-20150226-story.html.

4. Invasive Species

Invasive species may be introduced through a variety of pathways that would be increasingly common if oil and gas activity is allowed to expand. Machinery, equipment, and trucks moved from site to site can carry invasive plant species to new areas. In addition, materials such as crushed stone or gravel transported to the site from other locations may serve as a conduit for invasive species to migrate to the well site or other areas en route.

Aquatic invasive species may also spread more easily given the large amounts of freshwater that must be transported to accommodate new drilling and extraction techniques. These species may be inadvertently introduced to new habitats when water is discharged at the surface. Alternatively, hoses, trucks, tanks, and other water use equipment may function as conduits for aquatic invasive species to access new habitats.

5. Climate Change

Anthropogenic climate change poses a significant threat to biodiversity.[184] Climate disruption is already causing changes in distribution, phenology, physiology, genetics, species interactions, ecosystem services, demographic rates, and population viability: many animals and plants are moving poleward and upward in elevation, shifting their timing of breeding and migration, and experiencing population declines and extinctions.[185] Because climate change is occurring at an unprecedented pace with multiple synergistic impacts, climate change is predicted to significantly increase extinction risk for many species. The IPCC concludes that it is extremely likely that climate change at or above 4°C will result in substantial special extinction.[186] Other studies have predicted similarly severe losses: 15-37 percent of the world's plants and animals committed to extinction by 2050 under a mid-level emissions scenario[187]; the extinction of 10 to 14 percent of species by 2100 if climate change continues unabated.[188] Another recent study predicts the loss of more than half of the present climatic range for 58 percent of plants and 35 percent of animals by the 2080s under the current emissions pathway, in a sample of 48,786 species.[189] Because expansion of oil and gas production in Colorado will substantially increase the emissions of greenhouse gases, this activity will further contribute to the harms from climate change to wildlife and ecosystems.

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[184] Warren, R. et al.,Quantifying the benefit of early climate change mitigation in avoiding biodiversity loss, 3 Nature Climate Change 678 (2013) ("Warren 2013").

[185] Cahill, A.E. et al., How Does Climate Change Cause Extinction? Proceedings of the Royal Society B, doi.10.1098/rspb.2012.1890 (2012); Chen, I. et al., Rapid range shifts of species associated with high levels of climate warming, 333 Science 1024 (2011); Maclean, I.M.D., and R.J. Wilson, Recent ecological responses to climate change support predictions of high extinction risk, 108 Proc. Natl. Acad. Sci. Early Edition 12337 (2011) ("Maclean and Wilson 2011"); Parmesan, C., Ecological and Evolutionary Responses to Recent Climate Change, 37 Annual Review of Ecology Evolution & Systematics 637 (2006); Parmesan, C., and G. Yohe, A globally coherent fingerprint of climate change impacts across natural systems, 421 Nature 37 (2003); Root, T.L. et al., Fingerprints of Global Warming on Wild Animals and Plants, 421 Nature 57 (2003); Warren, Rachel et al., Increasing Impacts of Climate Change Upon Ecosystems with Increasing Global Mean Temperature Rise, 106 Climatic Change 141 (2011). ("Warren 2011").

[186] Intergovernmental Panel on Climate Change, *Climate Change 2014: Synthesis Report, Summary for Policy Makers IPCC Fifth Assessment Synthesis Report*, 18 (2014).

[187] Thomas, C.D. et al., Extinction Risk from Climate Change, 427 Nature 8:145 (2004).

[188] Maclean and Wilson 2011.

[189] Warren 2013.

6. Population-level Impacts

Oil and gas development has been linked to population-level impacts on wildlife, including lower reproductive success of sage grouse and declines in the abundance of songbirds and aquatic species. For example, young greater-sage grouse avoided mating near infrastructure of natural-gas fields, and those that were reared near infrastructure had lower annual survival rates and were less successful at establishing breeding territories compared to those reared away from infrastructure.[190] In Wyoming, an increasing density of wells was associated with decreased numbers of Brewer's sparrows, sage sparrows, and vesper sparrows.[191] In the Fayetteville Shale of central Arkansas, the proportional abundance of sensitive aquatic taxa, including darters, was negatively correlated with gas well density.[192] The EIS must consider the population-level impacts that oil and gas development may have on wildlife in Colorado.

7. Endangered, Threatened, and Sensitive Species

The AMS identifies 19 federally protected, threatened, endangered, or proposed species that are known or suspected to occur in the planning area, as well as 34 BLM sensitive species (including both plants and animals).[193] Many of these species will be adversely affected by an increase in oil and gas activity. The species include those highly vulnerable to oil and gas development, including the lesser prairie chicken, ferruginous hawk, mountain plover, and long-billed curlew.[194] Other species are vulnerable to water depletions and stream flow changes, including the Western prairie fringed orchid, pallid sturgeon, interior least tern, Preble's meadow jumping mouse, whooping crane, yellow-billed cuckoo, and southwestern willow flycatcher.[195]

The AMS notes that populations of most special status species within the planning area "are believed to remain biologically insecure, regardless of habitat improvement efforts."[196] Certainly, allowing new oil and gas leasing and fracking conflicts with reversing such trends, while halting these activities would at least avoid further population declines. In any case, BLM should not permit any new oil and gas leasing or any oil and gas development until biological inventories of special-status species and their habitats are complete. The AMS notes there is "a deficit of baseline population data for most of the special status species listed for this planning area," and "little inventory data on the quality, quantity, location, and suitability of habitats for special status species."[197] "Focused inventories" are needed to fill these data gaps.[198] Until inventories are completed, BLM cannot have any handle on the impact of increased oil and gas development on special-status species within the planning area, and cannot make long-term planning decisions with respect to oil and gas development and species conservation. *See* 43 U.S.C. § 1711(a) ("The Secretary shall prepare and maintain on a continuing basis an inventory

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[190] Holloran, M.J. et al., Yearling Greater Sage-Grouse Response to Energy Development in Wyoming, 74 Journal of Wildlife Management 1:65 (2010).
[191] Gilbert, Michelle M. & Anna D. Chalfoun, Energy Development Affects Populations of Sagebrush Songbirds in Wyoming, 75 The Journal of Wildlife Management 4:816 (2011).
[192] Green, Jessie J. et al., Abstract: Examining Community Level Variables of Fishes in Relation to Natural Gas Development, Southeastern Fishes Council, Annual Meeting Program, November 8 - 9, 2012, New Orleans, Louisiana (2012).
[193] AMS at 98, 108.
[194] *Id.* at 98-121.
[195] *Id.*
[196] *Id.* at 121.
[197] *Id.* at 120, 121.
[198] *Id.* at 122.

of all public lands and their resource and other values...."); 43 U.S.C. § 1701(a)(2) (FLPMA declaring policy that "public lands and their resources are periodically and systematically inventoried and their present and future use is projected through a land use planning process"). It is critical that the EIS provide complete inventories.

8. **Metrics**

BLM should conduct a full assessment of the direct and indirect impacts of unconventional oil and gas development activities on wildlife and ecosystems through a suite of comprehensive studies on all species and ecosystems that could be affected. The studies should be particularly detailed for federally and state listed species, federal and state candidates for listing, and state species of special concern. The studies should address the following impacts: (1) habitat loss, degradation, and fragmentation, including edge effects; (2) water depletion; (3) air and water contamination; (4) introduction of invasive species; (5) climate change impacts; (6) health and behavioral effects such as increased stress and changes in life history behaviors; (7) changes in demographic rates such as reproductive success and survival; and (8) potential for population-level impacts such as declines and extirpations. These studies should consider these harms individually and cumulatively.

I. Fossil Fuel Development Will Impact Land Use

Increased oil and gas extraction and production have the potential to dramatically and permanently change the landscape of Colorado. Countless acres of land may have to be leveled to allow for the construction and operation of well pads and related facilities such as wastewater pits. Roads may have to be constructed or expanded to accommodate trucks transporting chemicals and the large quantities of water needed for some recovery methods. Transmission lines and other utilities may also be required. The need for new distribution, refining, or waste treatment facilities will expand industrial land use. With new roads and other industrial infrastructure, certain areas could open up to new industrial or extractive activities, permanently changing the character and use of the land.

The conversion of substantial acreages from rural or natural landscapes to industrial sites will also mar scenic views throughout the planning area. Given BLM's failure to ensure full reclamation of idle wells and the difficulty of restoring sites to their original condition, scenic resources may be permanently impaired.

J. BLM Has the Authority to Ban Unconventional Well Stimulation Methods

BLM can end the dangerous practice of hydraulic fracturing within the planning area not only through an end to new leasing, but also through a ban of this practice on existing leases. A lessee's right to extract leased minerals is subject to BLM's duty and authority to protect environmental resources and any regulation that BLM deems necessary and proper.

The Mineral Leasing Act charges the Secretary of the Interior with the protection of environmental values in its oversight of federal mineral extraction. It directs the Secretary of the Interior to "regulate all surface-disturbing activities conducted pursuant to any lease issued under this chapter," and to "determine reclamation and other actions as required in the interest of conservation of surface resources."[199] The MLA further dictates that, "[n]o permit to drill on an

[199] 30 U.S.C. § 226(g).

oil and gas lease...may be granted without the analysis and approval" by the Secretary of Interior "of a plan of operations covering proposed surface-disturbing activities within the lease area."[200]

BLM has broad discretion in how it carries out these duties. The MLA authorizes the Secretary "to prescribe necessary and proper rules and regulations and to do any and all things necessary to carry out and accomplish the purposes of this chapter ..."[201] Similarly, under FLPMA, BLM has discretion to "manage the public lands under principles of multiple use and sustained yield[,]"[202] and "by regulation or otherwise, take any action necessary to prevent unnecessary or undue degradation of the lands."[203]

Accordingly, BLM has issued regulations to protect the environment from mineral extraction. Key among them are BLM's regulations providing that leasehold rights are subject to "such reasonable measures as may be required by the authorized officer to minimize adverse impacts to other resource values,"[204] and that operators "shall conduct operations in a manner which protects the mineral resources, other natural resources, and environmental quality."[205] Thus, new operations on existing leases may be subject to reasonable measures to protect the environment post-lease.

Here, BLM has ample evidence of numerous environmental and public health harms of hydraulic fracturing and other unconventional well stimulation methods. In other respects, the safety of these practices is completely unknown. BLM should use its power to "do any and all things necessary" to protect local communities and the environment by banning new fracking and other unconventional well stimulation methods within the planning area. Such a ban may apply to all existing leases, and not just new leases that post-date a revised RMP. BLM regulations provide that all site-specific actions (presumably including drilling permit issuance) shall conform to the governing Resource Management Plan.[206] Similar requirements exist for National Forest System lands.[207] Since land use planning and plan consistency is specific and mandatory under FLPMA, BLM can require operators with existing leases to comply with the proposed fracking ban once it is adopted under a revised RMP.

III. Coal Extraction Poses Significant Risks to Public Health and the Environment

In addition to the many similar air quality, water quality, storm runoff, wildlife, and land use impacts already discussed above, the extraction of coal poses unique concerns. Coal mining is extremely destructive, and depending on the type of mining involved impacts can vary.

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[200] 30 U.S.C. § 226(g).
[201] 30 U.S.C. § 189.
[202] 43 U.S.C. § 1732(a).
[203] *Id.* at (b) (emphasis added).
[204] 43 C.F.R. § 3101.1-2
[205] *Id.* at § 3162.5-1.
[206] 43 C.F.R. § 1610.5-3(a) ("All future resource management authorizations and actions, as well as budget or other action proposals to higher levels in the Bureau of Land Management and Department, and subsequent more detailed or specific planning shall conform to the approved plan.").
[207] *See* 16 U.S.C. § 1604(i) ("Resource plans and permits, contracts, and other instruments for the use and occupancy of National Forest System lands shall be consistent with the land management plans. Those resource plans and permits, contracts, and other such instruments currently in existence shall be revised as soon as practicable to be made consistent with such plans. When land management plans are revised, resource plans and permits, contracts, and other instruments, when necessary, shall be revised as soon as practicable.")

Strip mining "involves scraping away earth and rocks to get to coal buried near the surface. In many cases, mountains are literally blasted apart to reach thin coal seams within, leaving permanent scars on the landscape as a result."[208] Strip mining causes the following:

- Strip mining destroys landscapes, forests and wildlife habitats at the site of the mine when trees, plants, and topsoil are cleared from the mining area. This in turn leads to soil erosion and destruction of agricultural land.
- When rain washes the loosened top soil into streams, sediments pollute waterways. This can hurt fish and smother plant life downstream, and cause disfiguration of river channels and streams, which leads to flooding.
- There is an increased risk of chemical contamination of ground water when minerals in upturned earth seep into the water table, and watersheds are destroyed when disfigured land loses the water it once held.
- Strip mining causes dust and noise pollution when top soil is disrupted with heavy machinery and coal dust is created in mines.[209]

Further, the destruction of forests and removal of vegetation can result in enormous releases of greenhouse gas emissions.

Underground mining causes the following harms:

- Underground mining causes huge amounts of waste earth and rock to be brought to the surface – waste that often becomes toxic when it comes into contact with air and water.
- It causes subsidence as mines collapse and the land above it starts to sink. This causes serious damage to buildings.
- It lowers the water table, changing the flow of groundwater and streams. [210]

In addition to these direct impacts of disfiguring landscapes and contaminating air, land, and water land, coal extraction results in serious indirect impacts:

- Coal processing produces a liquid waste known as slurry, which must be disposed underground or in impoundments. This sludge is liable to leak or spill and contaminate aquifers or streams.
- Coal transport via trucks or rail results in coal dust escaping train cars and being distributed over wide areas, including in streams. Coal transport also results in the combustion of diesel fuel (with attendant air pollution) to move the coal.
- The combustion of coal not only results in greenhouse gas emissions, but other harmful air pollution including sulfur dioxide, nitrogen oxides, particulate matter, and heavy metals. These emissions lead to smog, acid rain, and numerous respiratory,

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[208] Greenpeace, Mining impacts, available at http://www.greenpeace.org/international/en/campaigns/climate-change/coal/Mining-impacts/.
[209] *Id.*
[210] *Id.*

cardiovascular, and cerebrovascular effects. In addition, coal combustion can lead to mercury emissions that can harm fish and other aquatic species.

- Coal combustion also leads to enormous amounts of coal ash waste, which is disposed in landfills or surface impoundments. Precipitation filtering through these waste pits can cause toxic substances to leach out into the environment. These impoundments can also fail, causing many tons of hazardous wastes to release and contaminate nearby communities.

The entire lifecycle impacts of coal extraction, transport, combustion, and disposal should be considered in the EIS.

***

Unconventional oil and gas development and coal extraction not only fuel the climate crisis but entail significant public health risks and harms to the environment. Accordingly, the EIS should thoroughly analyze the alternative of no new fossil fuel leasing and no fracking or other unconventional well stimulation methods within the Eastern Colorado planning area.

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Appendix A: Center for Biological Diversity, Review of Impacts of Oil and Gas Exploration and Development on Wildlife (June 20, 2015)

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Quantifying spatial habitat loss from hydrocarbon development through assessing habitat selection patterns of mule deer

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Abstract

Extraction of oil and natural gas (hydrocarbons) from shale is increasing rapidly in North America, with documented impacts to native species and ecosystems. With shale oil and gas resources on nearly every continent, this development is set to become a major driver of global land-use change. It is increasingly critical to quantify spatial habitat loss driven by this development to implement effective mitigation strategies and develop habitat offsets. Habitat selection is a fundamental ecological process, influencing both individual fitness and population-level distribution on the landscape. Examinations of habitat selection provide a natural means for understanding spatial impacts. We examined the impact of natural gas development on habitat selection patterns of mule deer on their winter range in Colorado. We fit resource selection functions in a Bayesian hierarchical framework, with habitat availability defined using a movement-based modeling approach. Energy development drove considerable alterations to deer habitat selection patterns, with the most substantial impacts manifested as avoidance of well pads with active drilling to a distance of at least 800 m. Deer displayed more nuanced responses to other infrastructure, avoiding pads with active production and roads to a greater degree during the day than night. In aggregate, these responses equate to alteration of behavior by human development in over 50% of the critical winter range in our study area during the day and over 25% at night. Compared to other regions, the topographic and vegetative diversity in the study area appear to provide refugia that allow deer to behaviorally mediate some of the impacts of development. This study, and the methods we employed, provides a template for quantifying spatial take by industrial activities in natural areas and the results offer guidance for policy makers, mangers, and industry when attempting to mitigate habitat loss due to energy development.

Keywords: animal movement, Bayesian hierarchical model, energy development, habitat selection, movement ecology, mule deer, natural gas, resource selection function

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Introduction

Since the early 2000s, the exploration and production (hereafter development) of hydrocarbons has increased rapidly in North America (United States Energy Information Administration [USEIA] 2012). The landscape-level disturbance resulting from this development has had a number of negative impacts on wildlife, including driving population declines and causing large-scale spatial displacement (Northrup & Wittemyer, 2013). This recent energy boom has been driven primarily by the development of shale resources (USEIA, 2012). Shale resources are proven to exist on every continent save Antarctica and their development is projected to continue to increase (USEIA, 2013). Thus, this sector is poised to become a major driver of global land-use change and impacts to biodiversity.

Given its projected global footprint, there is a pressing need for robust quantification of habitat loss driven by hydrocarbon development. Such information can be used to aid in development planning, assess cumulative impacts, develop mitigation measures, and quantify the size of habitat offsets. However, understanding the impact of hydrocarbon development and subsequent mitigation measures is complex as the associated disturbances are spatially variable and temporally dynamic and their cumulative effects not well understood, which can obfuscate animal responses. In light of this complexity, there is a need for more complete information on the ways in which animals respond to development. Detailed understanding of the distance at which different types of development elicit responses from different species will be particularly important for

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quantifying habitat impacts and identifying effective mitigation strategies as this industry becomes a major driver of global land-use change.

Examinations of the habitat selection patterns of wildlife provide a natural means for understanding the spatial impacts of development. Habitat selection is a fundamental ecological process by which animals distribute themselves across landscapes by selecting habitats that maximize their fitness (Fretwell & Lucas, 1969). Examinations of habitat selection provide insight into individual-based ecological processes (e.g., drivers of site fidelity: Creel *et al.*, 2005; and tradeoffs between foraging and predation risk: Switzer, 1997), but also to larger scale factors that influence population distribution and abundance (e.g., population dynamics: Pulliam & Danielson, 1991; speciation: Rice, 1987; and dispersal: Shafer *et al.*, 2012).

Human disturbance can alter habitat selection patterns of animals (e.g., Sawyer *et al.*, 2006), but the nature of this response and the subsequent ramifications for different species are complex. Humans directly convert habitat, but their activities also lead to functional habitat loss disproportionately greater than the area that is directly disturbed (e.g., Sawyer *et al.*, 2006). Responses also can be more nuanced, with humans being perceived as akin to predators, driving behavioral shifts reflecting tradeoffs between security and other demands such as foraging or reproduction (Frid & Dill, 2002; Hebblewhite & Merrill, 2008). Alternatively, animals can be attracted to human developments due to associated resources, or as protection against predation (Berger, 2007). This attraction can positively impact animals, but can also lead to greater potential for negative encounters with humans (Johnson *et al.*, 2004) and the formation of ecological traps (e.g., Northrup *et al.*, 2012b). In light of the array of complex responses of animals to human disturbance, research on the mechanisms driving changes in wildlife behavior are critical for developing appropriate mitigation measures.

In many areas of the western United States hydrocarbon development has taken place on mule deer (*Odocoileus hemionus* Rafinesque) winter range, where the species faces acute welfare issues related to decreased access to high quality forage (Parker *et al.*, 1984). Mule deer have experienced major population declines across their range (Unsworth *et al.*, 1999) and recent studies have shown deer to experience alterations of habitat selection patterns and large scale displacement in response to hydrocarbon development (Sawyer *et al.*, 2006, 2009). Obtaining information on the impact of development on deer habitat selection patterns is thus a major management priority, as extraction is projected to continue to increase over the next several decades (USEIA, 2014).

We fit resource selection functions (RSFs) in a hierarchical Bayesian framework to understand responses of a mule deer population to hydrocarbon development on winter range. Resource selection functions are the most commonly used approach to examine the habitat selection process, but a major methodological and conceptual hurdle to their application is the sensitivity of results to definitions of habitat availability (Johnson, 1980; Hooten *et al.*, 2013; Lele *et al.*, 2013; Northrup *et al.*, 2013). With technological advances in global positioning system (GPS) radio collars, animal location data are being collected at increasingly fine scales revealing complex temporal autocorrelation structures (Wittemyer *et al.*, 2008; Boyce *et al.*, 2010) that can compound methodological issues related to defining availability in RSF analyses. Although methods exist for potentially managing this autocorrelation (see Fieberg *et al.*, 2010 for a review), approaches for addressing autocorrelation at the scale of the availability sample are limited. Using methods developed in the animal movement literature, Hooten *et al.* (2013) propose a dynamic movement-based method for determining availability on an individual animal and location-specific basis. We apply a similar methodology to address three questions: (1) how does hydrocarbon development (roads and well pads) influence deer habitat selection?; (2) do deer respond to energy development differently at night than during the day?; and (3) at what spatial scale do mule deer most strongly respond to different development features? Our results provide insights into the spatial and temporal factors influencing mule deer habitat selection and the influence of energy development on this behavior, while offering a template for assessing spatial habitat loss and guidance for the mitigation of development impacts on wildlife.

Materials and methods

Study area

We examined mule deer habitat selection on winter range in the Piceance Basin in Northwestern Colorado, USA, (39.954°N, 108.356°W; Fig. 1), during a time of ongoing development of natural gas. Deer in this area migrate from high elevations during the summer to low elevations during the winter, with winter range occupancy generally occurring between October and May (Lendrum *et al.*, 2013; Northrup *et al.*, 2014b). The area is topographically diverse and dominated by sagebrush (*Artemisia tridentata* Nutt.) and a pinyon pine (*Pinus edulis* Engelm.) and Utah juniper (*Juniperus osteosperma* Torr.) shrubland complex. The vegetation of the area is described in detail by Bartmann & Steinert (1981) and Bartmann *et al.* (1992). The dominant human activity in the area is

Fig. 1 Study area location in the United States, closet human settlement (Meeker, CO), and outline of winter range study area used by adult female mule deer in the Piceance Basin of Northwest Colorado.

natural gas development, with winter cattle grazing occurring primarily in the valley bottoms. Density of natural gas well pads across the study area were approximately 0.18 well pads km^{-2} in 2008, 0.20 well pads km^{-2} in 2009 and 20 well pads km^{-2} in 2010, although local densities ranged from 0–6 pads km^{-2}. The area is popular for hunting during the fall, and experiences warm, dry summers with monsoonal precipitation and cold winters, with the majority of moisture resulting from snow melt in the spring.

Mule deer data

We monitored adult (>1 year old) female mule deer on their winter range between January 2008 and December 2010. Adult females were studied as they are the age and sex class known to be the dominant driver of population dynamics. Deer were captured using helicopter net gunning during December and March of each year and were fit with store-on-board global positioning system (GPS) radio collars (G2110D, Advance Telemetry Systems, Isanti, MN, USA and model 4400, Lotek Wireless, Newmarket, ON, Canada) programmed to attempt a relocation once every 5 hours. All procedures were approved by the Colorado State University (protocol ID: 10-2350A) and Colorado Parks and Wildlife (protocol ID: 15-2008) Animal Care and Use Committees. Collars were equipped with timed release mechanisms set to release after 16 months. At this time collars were recovered, and data were downloaded. Due to the potential behavioral impacts of capture on mule deer (Northrup *et al.*, 2014a), we censored all data for one week following capture. Deer in this area are migratory, so we only included data occurring between the termination of fall migration and the initiation of spring migration. Migration termination and initiation were estimated visually in ArcMap 10 (Environmental Systems Research Institute, Redlands, CA, USA). We removed all locations for which the positional dilution of precision (PDOP) was >10 (<1% of locations: D'eon & Delparte, 2005; Lewis *et al.*, 2007). We calculated the percent of successful GPS fixes for each individual by dividing the number of total locations by the number of attempted fixes. Overall fix success rate was 93%, which exceeds the threshold commonly used to indicate the need for habitat-bias corrections in habitat modeling (Frair *et al.*, 2004; Hebblewhite *et al.*, 2007). Lastly, we divided locations into night and day, with night classified as the time between sunset and sunrise (http://aa.usno.navy.mil/data/docs/RS_One Year.php).

Predictor variables

We chose an approach for RSF modeling that maximized our understanding of the impacts of development. We first chose a set of environmental covariates for RSF modeling that we hypothesized to be important predictors of deer resource selection based on previous studies (Pierce *et al.*, 2004; Sawyer *et al.*, 2006, 2009; Stewart *et al.*, 2010). These covariates represented our best understanding of how mule deer selected habitat. We then added to these covariates different representations of natural gas development to understand deer

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response to development while also accounting for environmental characteristics that they are known to respond to. The environmental covariates included the terrain variables slope (*slope*), and elevation (*elev*), calculated from a digital elevation model. In addition, we obtained land cover data from the Colorado Vegetation Classification Project (http://ndis.nrel.colostate.edu/coveg/). This land cover database has 69 classes, however our study area is dominated by two classes (44% sagebrush and 39% pinyon-juniper). While numerous land cover classes existed in our study area, all classes other than pinyon-juniper and sagebrush were relatively rare, and not all deer interacted with all of the other categories. Thus, we combined all categories into two classes that all deer interacted with. These classes consisted of treed or open (*tree*). Lastly we calculated the distance to treed edges (*d_edge*). We also digitized all roads in the study area from aerial imagery from the National Agricultural Imagery Program (NAIP) and calculated the distance to the nearest road from each location (*d_rds*), and also included a quadratic term for the distance to roads.

To obtain information on development, we downloaded the location of all oil and natural gas wells in the study area from the Colorado Oil and Gas Conservation Commission website (cogcc.state.co.us), which maintains a daily updated database of the locations, drilling onset date and drilling completion date of oil and natural gas wells throughout the state. We classified each well in our study area into one of three classes: (1) wells actively being drilled (wells in this stage generally see continuous 24/7 human activity); (2) wells that were actively producing natural gas with no drilling activity; and (3) wells that were abandoned (see Appendix S1 for further details). We created a series of time-specific spatial layers representing the status of each well accurate to the day. These layers were generated for the entire time period during which collared deer were active on winter range in the study area (Oct–May of each year). We grouped individual wells by pad visually using a layer for well pads digitized from the NAIP imagery. We then classified each pad as a drilling, producing, or abandoned pad for every day of the study period. If a pad had any wells that were being actively drilled, the entire pad was classified as drilling. Likewise, if the pad had both abandoned and producing wells, it was classified as producing. Our ultimate unit of replication was the well pad, as pads can contain multiple wells that can be in different stages.

Using the resulting data, we created different covariates to represent active natural gas development. Our approach consisted of fitting a single model structure with nested concentric buffers around well pads. Including concentric buffers in the models allows us to identify the distance at which deer ceased to respond to well pads. We created eight covariates for this model: the number of well pads within 400 m (measured to the edge of the well pad; *drill_400* and *prod_400*), the number of pads between 400–600 m (*drill_600* and *prod_600*), the number of pads between 600–800 m (*drill_800* and *prod_800*) and the number of pads between 800–1000 m (*drill_1000* and *prod_1000*). The smallest buffer distance assessed (i.e., 400 m) corresponded to the approximate mean distance moved between successful deer relocations spaced 5 h apart. We initially attempted to assess responses to the number of pads within 200 m but convergence failed for both night and day models that included these covariates after more than 2 million iterations (traceplots showed poor mixing). On closer examination, this appeared to result from few deer locations within 200 m of well pads classified as being drilled [23 locations during the night (0.17% of night time locations) and 17 locations during the day (0.11% of daytime locations)]. We excluded abandoned pads from analysis as there was no extraction activity associated with these features.

Model formulation

We estimated RSFs separately for night and day locations using hierarchical conditional logistic regression (*sensu* Duchesne *et al.*, 2010), in a Bayesian framework where all coefficients varied by individual. In this framework, each used location is paired with a set of random locations drawn from an area deemed to be immediately available to the animal at that time (Boyce, 2006). Following Revelt & Train (1998), and Duchesne *et al.* (2010), the probability that an animal (n) chooses a resource unit (y) represented by a suite of habitat covariates (x_y) from a set of available alternative resource units (J), represented by suite of habitat covariates (x_j) at time t can be written as follows:

$$(y_{tn}|\beta_n) = \frac{\exp(x'_{y_{tn}}\beta_n)}{\sum_{j=1}^{J}\exp(x'_{j_{tn}}\beta_n)}$$

Using this probability mass function, we can estimate coefficients for each individual and the population as a whole by placing the model in a Bayesian hierarchical framework as follows:

$$\beta_n \sim \text{normal}\ (\mu_\beta, \sigma_\beta^2 I)$$

$$\mu_\beta \sim \text{normal}\ (0, 1000000I)$$

$$\log(\sigma_\beta^2) \sim \text{normal}\ (0, 1000000)$$

Characterizing availability

In a RSF model using conditional logistic regression, each used location is paired with random locations sampled within a distance of the used location presumed to be immediately available to the animal (Boyce, 2006). There is no standard approach for determining this distance for drawing availability, although methods in the literature include using the average distance moved between successive GPS locations (Boyce *et al.*, 2003), or drawing from empirical step length and turn angle distributions (Fortin *et al.*, 2005). Although such methods clearly have biological underpinnings, few definitions of availability have accounted for the dynamic movement behavior of animals.

With the proliferation of studies using GPS radio collar data, there currently exists an array of methods, developed in the animal movement literature, that model the dynamic movement behavior of animals (e.g., Hooten *et al.*, 2013). We

used the continuous-time correlated random walk (CTCRW) model described by Johnson *et al.* (2008) to categorize availability (*sensu* Hooten *et al.*, 2013). The CTCRW model describes movement as an Ornstein-Uhlenbeck process, where the velocity of an animal at the current time step is dependent on its previous velocity, an autocorrelation parameter, and an error term scaled by the time between known locations (Johnson *et al.*, 2008). Hooten *et al.* (2013) use the results of the CTCRW model to characterize resource availability as the predictor distribution for the location and velocity of an animal at any time, which is a description of the uncertainty in the location at the current time given all preceding data. The location of this predictor distribution varies with the location and speed of the animal and thus its position relative to the used location is dynamic and dependent on the current behavior of the animal.

We fit the a CTCRW model for each individual animal using the 'crawl' package (Johnson *et al.*, 2008) in the R statistical software (R Core Team, 2013). The coordinates of a set of random locations were drawn from the predictor distribution specific to each used location. To ensure a sufficiently large availability sample (Northrup *et al.*, 2013), we explored the stability of coefficient estimates from models fit to varying availability sample sizes (5, 25, 50, 100, 250, 500 and 1000 random locations per used location). Drawing from a set of 10 000 random locations per observed location, we ran 25 models at each availability sample size to examine variation in coefficient estimates as a function of the availability sample. Once the sample size that provided stable covariate estimates had been determined, we drew that number of random locations for each used location for each individual for the hierarchical model described above.

Model fitting

Using the model formulation and data described above, we fit models to deer locations across all years. We first standardized all continuous predictor covariates $(x - \bar{x})/\sigma$. We tested for correlations among covariates that appeared in the same model (Appendix S2) to ensure that no covariates were highly correlated ($|r| > 0.7$). Using the Bayesian hierarchical framework described above, we fit RSFs using a Markov-Chain Monte Carlo (MCMC) procedure written in the R programming language. We ran two parallel chains for each model for 1 000 000 iterations, discarding the first 100 000 as burn-in. We selected starting values for each parameter chain that were expected to be overdispersed relative to the posterior distributions and monitored convergence to the posterior distribution by examining traceplots of MCMC samples against iterations to determine if there was proper mixing, and by calculating the Gelman-Rubin diagnostic (mean values <1.1 indicate convergence; Gelman & Rubin, 1992). In addition to fitting the single model structure discussed above, we also fit a set of models each with a single covariate representing the number of well pads within overlapping buffer distances (see Appendix S2 for more details). This approach was taken to aid our inference in relation to the concentric buffers analysis discussed above. One of the most basic assumptions of model fitting is that the model is a faithful representation of the data generating process. To test this assumption we performed posterior predictive checks (Appendix S2; see examples in Gelman & Hill, 2007).

Results

Model specifications

We monitored 53 adult female mule deer across 3 years (18 per year, with one individual collared for consecutive years), for a total of 29 083 winter range (Oct–May) locations ($\bar{x}$ = 548.7 locations per deer). Both 250 and 500 available locations per used location provided sufficiently accurate estimation of coefficients. Upon initiation of model fitting, 500 locations proved to be computationally infeasible on a high-performance supercomputer. Thus we included 300 available locations per used location. All parameters converged to their posterior distribution (i.e., all mean Gelman-Rubin values were <1.1). There were strong similarities to the models fit with concentric buffers and additional models fit with single covariates representing the number of pads within overlapping buffers (Appendix S2), thus we only present results of the concentric buffers analysis.

Ecological and anthropogenic drivers of selection

Deer selected open areas over treed areas and areas further from edges during the night, while during the day, deer selected treed areas over open areas and areas closer to edges (Fig. 2). In addition, deer selected areas closer to roads during the night than during the day (Fig. 3). Throughout the day and night, deer selected areas with steeper slopes and at higher elevations, although the strength of this selection was greater during the night (Table 1, Fig. 2). Deer responses to drilling and producing well pads varied by buffer distance (Fig. 4). During both night and day deer avoided drilling well pads at the 0–400 m buffer and the 400–600 m buffer. During the night this avoidance persisted to the 600–800 m and 800–1000 m buffers, but was relatively weak at the furthest buffer distance. Contrarily, deer showed no avoidance of the areas 600–800 m and 800–1000 m from drilling well pads during the day (Fig. 4). During the day, deer also avoided well pads actively producing natural gas at the 0–400 m buffer and 400–600 m buffer, while showing no avoidance of the areas between 600–1000 m from these pads (Fig. 4). During the night deer displayed weaker avoidance of producing well pads within the smallest buffer (0–400 m) than during the day, while displaying selection for areas at all other buffer distances (Fig. 4).

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Table 1 Covariate names, median posterior coefficient (coeff.) values, and proportion (prop.) of posteriors above and below 0 for resource selection function models fit to GPS data from adult female mule deer in the Piceance Basin, Colorado, USA during the night and day separately.

Covariate	Night coeff.	Night prop. < 0	Night prop. > 0	Day coeff.	Day prop. < 0	Day prop. > 0
d_edge	0.11	0.00	1.00	−0.17	1.00	0.00
slope	0.17	0.00	1.00	0.05	0.01	0.99
elev	0.91	0.00	1.00	0.69	0.00	1.00
d_rds	−0.35	1.00	0.00	0.17	0.00	1.00
d_rds^2	−0.43	1.00	0.00	−0.30	1.00	0.00
tree	−0.27	1.00	0.00	0.08	0.01	0.99
prod_400	−0.06	0.71	0.29	−0.41	1.00	0.00
drill_400	−0.73	0.99	0.01	−0.82	1.00	0.00
prod_600	0.08	0.19	0.81	−0.14	0.98	0.02
drill_600	−0.40	0.96	0.04	−0.28	0.99	0.01
prod_800	0.12	0.03	0.97	−0.04	0.77	0.23
drill_800	−0.27	0.95	0.05	0.00	0.49	0.51
prod_1000	0.07	0.05	0.95	0.02	0.29	0.71
drill_1000	−0.09	0.78	0.22	0.04	0.29	0.71

Fig. 2 Posterior distributions of population-level coefficients for RSF models during the (a) day and (b) night for 53 adult female mule deer in the Piceance Basin, Northwest Colorado. Dashed line indicates 0 selection or avoidance of the habitat features. Displayed coefficients are for non-well pad covariates only, but are taken from models including well pad covariates. 'Edge' refers to the distance to treed edges in meters, 'Slope' was measured in degrees, 'Elev' refers to elevation in meters, 'Roads' refers to the distance to roads in meters, and 'Tree' refers to treed land cover.

Discussion

Hydrocarbon development is projected to continue to increase in the United States and elsewhere (USEIA, 2013, 2014) and thus is set to become a major driver of global land-use change. As such, there is a pressing need for assessments of the nature of impacts to wildlife and the spatial extent to which these impacts extend. The habitat selection patterns of deer in our system were strongly influenced by hydrocarbon development, with deer displaying both spatial displacement and alterations in temporal behavioral patterns relative to these features. The nature of these responses differed depending on disturbance type, time of day, and the distance from development. Our methodology, which accounted for the dynamic nature of deer behavior by allowing for the resource availability sample to change relative to current speed of the deer, and ensured the sample was conditioned by time and location, allowed us to identify the dynamic nature of the responses to

Fig. 3 Posterior distribution of predicted selection as a function of distance to roads from resource selection function models fit to data during the (a) day and (b) night for 53 female mule deer in the Piceance Basin, Northwest Colorado.

Fig. 4 Posterior distributions of population-level coefficients related to natural gas development for RSF models during the (a) day and (b) night for 53 female mule deer in the Piceance Basin, Northwest Colorado. Dashed line indicates 0 selection or avoidance of the habitat features. 'Drill' and 'Prod' refer to well pads where there was active drilling or not, respectively. The numbers following 'Drill' or 'Prod' represent the concentric buffer over which the number of well pads was calculated (e.g., 'Drill 600' is the number of well pads with active drilling between 400–600 m from the deer location).

development. Our results advance understanding of how animals perceive and adjust their behavior to minimize exposure to human disturbances, offering important insight for measures to mitigate the impacts of human land-use change associated with development. The approach we took can serve as a template for future work quantifying habitat take by land-use conversion.

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The drilling stage of natural gas development elicited the strongest response by deer in our system. Deer strongly avoided areas within 600 m of well pads with active drilling at all times, and this avoidance persisted out to 1000 m at night (with the strongest responses within 800 m). During both day and night, the strength of avoidance of drilling well pads increased as distance decreased, with essentially no locations falling within 200 m of these pads. Sawyer *et al.* (2009) also documented a greater avoidance of active drilling than other energy development activities by mule deer, indicating that this activity is the predominate stressor during hydrocarbon development. Thus, measures aimed at mitigating impacts from drilling, such as seasonal drilling restrictions, sound and light barriers, and reductions in vehicle traffic, are likely to have the greatest benefit to deer.

The other development infrastructure (i.e., roads and producing pads) altered deer behavior, but to a lesser extent. Deer avoided the areas closest to both of these development types to some degree, but the strength and scale of the responses varied between night and day, with stronger avoidance during the day when deer also selected areas with greater vegetative cover. It appears deer temporally modulate their behaviors so as to avoid these features during the most disturbing times of day (e.g., in relation to circadian traffic pulses). Dzialak *et al.* (2011) documented a similar pattern for elk in a natural gas field, with animals subject to disturbance selecting 'security cover' more strongly during the day. This behavior might be a common response by mobile wildlife to disturbance that has any type of temporal signature (e.g., roads; Northrup *et al.*, 2012a).

Understanding the spatial scale at which wildlife behavior is impacted by human disturbance is critical for developing effective mitigation strategies and quantifying the full footprint of development. As hydrocarbon development expands globally, developing frameworks for consistently assessing the spatial habitat take from this land-use change is a critical need. Our analysis design, examining selection or avoidance of concentric buffers around development, allowed us to identify the threshold distance where avoidance ceased and can serve as a template for future assessments. Deer displayed complete avoidance of areas within 200 m of well pad edges (approximately 2% of the critical winter range used by deer in our study). This distance should be considered the minimum at which indirect habitat loss occurs. However, avoidance was demonstrated to a distance of at least 800 m around drilling pads at night, and 600 m around producing pads during the day. These distances equate to greater than 20% of the critical winter range being impacted by producing pads (area within 600 m) and 2% by drilling pads (area within 600 m; the density of drilling pads is much lower in the study area), during the day, with 6% impacted by producing pads (area within 200 m) and 6% by drilling pads (area within 800 m) during the night. In addition, 28% of the critical winter range fell within 100 m of roads (the distance at which the relative probability of selection fell to half of the peak value during the day) and 15% fell within 50 m of roads (the distance at which the relative probability of selection fell to half of the peak value during the night). Although these values do not equate to complete habitat loss, they do indicate that more than half of the critical winter range was impacted by development during the day, and more than one quarter of the range was impacted during the night. The costs of this reduction (avoidance by deer) likely include the time lost during travel or from foraging in suboptimal areas during times of high human activity (Lima & Dill, 1990; Creel & Christianson, 2008), both of which can have impacts on nutritional condition and ultimately reproductive success (Houston *et al.*, 2012). It is important to recognize that fitness costs of range avoidance likely are compounded during the winter when deer face a negative energy balance. We note that to date the deer population in this study area has been increasing (Anderson Jr., 2014), so this avoidance at the observed development intensity has not resulted in a population decline, although it is impossible to tell if the population would be increasing at a greater rate in the absence of development. The spatial scales of reduced use relative to specific types of infrastructure as defined in this study should be considered by managers when attempting to develop mitigation strategies.

In a recent published assessment of mule deer response to natural gas development, Sawyer *et al.* (2006) found larger-scale displacement of deer from the area around development than those reported here. Although our results show similar general behavioral responses (i.e., alteration of habitat selection patterns), the scale of displacement was less. This likely relates to differences in the landscapes between the study areas, where the Piceance system has substantially greater topographic and vegetative diversity than the open, flat areas in the Pinedale area of Wyoming where Sawyer *et al.* (2006) conducted their work. We hypothesize that the structural diversity of the habitat and topography provide refuge areas for deer in our system at relatively close proximity to infrastructure that allows them to behaviorally mediate impacts. Such complexity in habitat structure can provide refuge for wildlife and should be considered and maintained by managers and developers when planning projects, through spacing of roads and pads to ensure sufficient areas outside the 800 m

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buffers around drilling pads and 50–100 m buffers around roads.

Oil and gas development is projected to continue to increase in the United States (USEIA, 2014), with major shale development likely to occur globally within the next decade. Quantifying the spatial extent of development related impacts to wildlife is critical for appropriately gauging the repercussions of this activity and identifying potential mitigation measures, which are critical for sustainable development practices (Northrup & Wittemyer, 2013). Importantly, drilling is temporary, as human activity declines once drilling is complete and wells begin producing (Sawyer *et al.*, 2009). The temporary nature of this activity provides an opportunity to either avoid drilling during the winter months, or structure development in a manner that allows refuge habitat during the most acute periods of stress. Many drilling pads in an area, as might occur with rapid development, leads to large functional losses in habitat, apparently driving abandonment of areas by deer (e.g., Sawyer *et al.*, 2006). Where development is conducted at lower densities, or in a manner that ensures that sufficient area is left undeveloped (i.e., refuge habitat is maintained), impacts are likely to be reduced. Even where drilling occurs in a manner that provides refuge, consideration of the spatial structure of the final footprint of roads, producing wells and facilities is critical to ensure adequate space for deer to structure their behaviors in a manner that mitigates negative impacts during the late stage production phase. Coupling spatial patterning of the permanent development footprint with approaches that reduce human activity at these areas, such as remote liquid gathering systems, will reduce the amount of disturbance (e.g., Sawyer *et al.*, 2009) and subsequently any negative impacts. Contrasting results from the Piceance Basin and Pinedale provides insight to features that may allow deer to behaviorally mediate disturbance (although this should not be construed as eliminating all negative impacts; Lima & Dill, 1990), although the exact nature of these components in different systems requires more rigorous examination. Therefore, it is critical for future studies to identify thresholds to gain better understanding of the disturbance-habitat relationship and ensure sustainable development practices in areas with sensitive wildlife.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1. Detailed description of well classifications.
Appendix S2. Overlapping buffers analysis, model structures, results of all fitted models and posterior predictive checks.