Attachment 3: Best Available Science

Salting the Earth: The Environmental Impact of Oil and Gas Wastewater Spills
Lindsey Konkel, Environ Health Perspect. 2016 Dec; 124(12): A230–A235.
Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5132645/

Discusses the cumulative Impacts of wastewater spills on human health. In the Draft Assessment, the GMUG states that the Mancos Shale can be explored and developed with advanced technologies and methods. This means more hydraulic fracturing, and more produced water. The increased prevalence of briny and chemical-laden wastewater warrants higher scrutiny.

Potential Economic, Health and Environmental Impacts of Shale Gas Development
NEW BRUNSWICK COMMISSION ON HYDRAULIC FRACTURING – VOLUME II
FEBRUARY 2016
Available at: http://www2.gnb.ca/content/dam/gnb/Departments/en/pdf/Publications/NBCHF-Vol2-Eng-Feb2016.pdf?random=1511308800069

Discusses, among other things, the need for baseline water quality assessments in areas where oil and gas development is proposed. This study takes into account the economic benefits and consequences of oil and gas development, along with the health consequences and environmental impacts.

Environmental health impacts of unconventional natural gas development: A review of the current strength of evidence
Angela K. Werner, Sue Vink, Kerrianne Watt, Paul Jagals
Available at: https://www.sciencedirect.com/science/article/pii/S0048969714015290

This paper is a review of the strength of evidence in scientific reporting of environmental hazards from Unconventional Natural Gas Development activities associated with adverse human health outcomes. The end result was inconclusive, there is not enough evidence to rule out possible health impacts.

Human health risk assessment of air emissions from development of unconventional natural gas resources
Science of The Total Environment, Volume 424, 1 May 2012, Pages 79-87
Lisa M.McKenzie, Roxana Z. Witter, Lee S. Newman, John L. Adgate
Available at: http://www.sciencedirect.com/science/article/pii/S0048969712001933

Study analyzes the health impacts of unconventional natural gas development, and found that people living near wells during completion were at increased risk of developing cancer and other adverse health impacts. Used a project in Garfield County, CO.

Rapid expansion of natural gas development poses a threat to surface waters
Sally Entrekin, Michelle Evans-White, Brent Johnson, Elisabeth Hagenbuch
Available at: http://onlinelibrary.wiley.com/doi/10.1890/110053/full

The risk unconventional natural gas development poses to aquatic biota needs to be further studied. Further study is particularly needed on the impacts to surface waters. This is highly relevant to the GMUG revision as Forest Service lands are often the source for much of the surface water in the west.

Evidence from two shale regions that a riparian songbird accumulates metals associated with hydraulic fracturing
Steven C. Latta, Leesia C. Marshall, Mack W. Frantz, Judith D. Toms
Available at: http://onlinelibrary.wiley.com/doi/10.1890/ES14-00406.1/full

Study found that in watersheds where hydraulic fracturing occurs, a specific riparian song bird species accumulated heavy metals associated with the hydraulic fracturing process in their feathers. The accumulation was much greater in sites with fracking than without.

Impact of Shale Gas Development on Regional Water Quality
R. D. Vidic, S. L. Brantley, J. M. Vandenbossche, D. Yoxtheimer, J. D. Abad
Science 17 May 2013: Vol. 340, Issue 6134
Available at: http://science.sciencemag.org/content/340/6134/1235009

Gas migration, contaminant transport through induced and natural fractures, wastewater discharge, and accidental spills are all serious risks to surface water posed by hydraulic fracking.

Discriminating between natural versus induced seismicity from long-term deformation history of intraplate faults
Maria Beatrice Magnani, Michael L. Blanpied, Heather R. DeShon, and Matthew J. Hornbach
Science Advances 24 Nov 2017: Vol. 3, no. 11
Available at: http://advances.sciencemag.org/content/3/11/e1701593

Study attempts to distinguish between human-caused and natural earthquakes in Texas. Study's results support the assertion that recent FWB earthquakes are of induced origin; this conclusion is entirely independent of analyses correlating seismicity and wastewater injection practices. This is the first study to discriminate natural and induced seismicity using classical structural geology analysis techniques.

Seasonal Resource Selection and Distributional Response by Elk to Development of a Natural Gas Field
Clay B. Buchanan, Jeffrey L. Beck, Thomas E. Bills, and Scott N. Miller
Source: Rangeland Ecology & Management, 67(4):369-379. 2014.
Published By: Society for Range Management
Available at: http://www.bioone.org/doi/full/10.2111/REM-D-13-00136.1

Study evaluated elk (*Cervus elaphus*) response to disturbance associated with natural gas development in summer and winter, including shifts in resource selection and concomitant distribution. Comparison of elk resource selection prior to and during natural gas development demonstrated behavioral and distributional shifts whereby during development, elk demonstrated a higher propensity to use distance and escape cover to minimize exposure to roads. Elk distributional changes resulting from avoidance behavior led to a loss of high-use areas by 43.1% and 50.2% in summer and winter, respectively. Authors suggest reducing traffic, protecting woody escape cover, and maintaining refugia within the energy development footprint to promote persistence of elk within energy fields.

Mule deer and energy development—Long-term trends of habituation and abundance
Hall Sawyer, Nicole M. Korfanta, Ryan M. Nielson, Kevin L. Monteith, Dale Strickland
Source: Glob Change Biol. 2017; 00:1–9.
Available at: https://doi.org/10.1111/gcb.13711

Short-term studies of 2–3 years have shown that mule deer and other ungulates avoid energy infrastructure; however, there remains a common perception that ungulates habituate to energy development, and thus, the potential for a demographic effect is low. This study used telemetry data from 187 individual deer across a 17-year period, including 2 years predevelopment and 15 years during development, to determine whether mule deer habituated to natural gas development and if their response to disturbance varied with winter severity. Concurrently, the study measured abundance of mule deer to indirectly link behavior with demography. Mule deer consistently avoided energy infrastructure through the 15-year period of development and used habitats that were an average of 913 m further from well pads compared with predevelopment patterns of habitat use. Even during the last 3 years of study, when most wells were in production and reclamation efforts underway, mule deer remained >1 km away from well pads. The magnitude of avoidance behavior, however, was mediated by winter severity, where aversion to well pads decreased as winter severity increased. Mule deer abundance declined by 36% during the development period, despite aggressive onsite mitigation efforts (e.g. directional drilling and liquid gathering systems) and a 45% reduction in deer harvest. Results indicate behavioral effects of energy development on mule deer are long term and may affect population abundance by displacing animals and thereby functionally reducing the amount of available habitat.

Gunnison Sage-grouse Rangewide Steering Committee. 2005. Gunnison sage-grouse rangewide conservation plan.
Colorado Division of Wildlife, Denver, Colorado,
Available at: http://cpw.state.co.us/learn/Pages/GunnisonSagegrouseConservationPlan.aspx

Toward an Understanding of the Environmental and Public Health Impacts of Unconventional Natural Gas Development: A Categorical Assessment of the Peer-Reviewed Scientific Literature
Hays, Juke and Seth B. C. Shonkoff. 2016., 2009-2015. PLOS ONE.
Available at: https://doi.org/10.1371/journal.pone.0154164

Colorado Gunnison's and white-tailed prairie dog conservation strategy.
Seglund, A.E. and P.M Schnurr. 2010. Colorado Division of Wildlife, Denver, Colorado,
Available at: https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd563437.pdf

COMPENDIUM OF SCIENTIFIC, MEDICAL, AND MEDIA FINDINGS DEMONSTRATING RISKS AND HARMS OF FRACKING (UNCONVENTIONAL GAS AND OIL EXTRACTION) *Fourth Edition*
November 17, 2016
Available at: http://concernedhealthny.org/wp-content/uploads/2016/12/COMPENDIUM-4.0_FINAL_11_16_16Corrected.pdf

The Compendium of Scientific, Medical, and Media Findings Demonstrating Risks and Harms of Fracking (the Compendium) is a fully referenced compilation of the evidence outlining the risks and harms of fracking. Bringing together findings from the scientific and medical literature, government and industry reports, and journalistic investigation, it is a public, open-access document that is housed on the websites of Concerned Health Professionals of New York (www.concernedhealthny.org) and Physicians for Social Responsibility (www.psr.org).

John L. Adgate et al., ***Potential Public Health Hazards, Exposures and Health Effects from Unconventional Natural Gas Development,*** 48 Envtl. Sci. & Tech. 8307 (2014), http://pubs.acs.org/doi/10.1021/es404621d

David O. Carpenter, ***Hydraulic Fracturing for Natural Gas: Impact on Health and Environment,*** 31 Rev. Env. Health 47 (2016), https://www.degruyter.com/view/j/reveh.2016.31.issue-1/reveh-2015-0055/reveh-2015-0055.xml

Amber Childress et al., ***Colorado Climate Change Vulnerability Study: A Report by the University of Colorado Boulder and Colorado State University to the Colorado Energy Office*** (2015), http://wwa.colorado.edu/publications/reports/co_vulnerability_report_2015_final.pdf

Theo Colborn et al., ***Natural Gas Operations from a Public Health Perspective***, 17 Human & Ecol. Risk Assess. 1039 (2011), https://www.biologicaldiversity.org/campaigns/fracking/pdfs/Colborn_2011_Natural_Gas_from_a_public_health_perspective.pdf

Madelon L. Finkel & Adam Law, ***The Rush to Drill for Natural Gas: A Public Health Cautionary Tale,*** 101(5) Am. J. Pub. Health 784 (2011), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3076392/pdf/784.pdf

Monika Freyman, ***Hydraulic Fracturing and Water Stress: Water Demand by the Numbers*** (Feb. 2014), https://www.colorado.edu/geography/class_homepages/geog_4501_s14/ceres_frackwaterbynumbers_021014.pdf

Robert Howarth et al., ***Methane and the Greenhouse-Gas Footprint of Natural Gas from Shale Formations,*** 106(4) Climactic Change 679 (2011), https://link.springer.com/content/pdf/10.1007%2Fs10584-011-0061-5.pdf

Christopher D. Kassotis et al., ***Estrogen and Androgen Receptor Activities of Hydraulic Fracturing Chemicals and Surface and Ground Water in a Drilling-Dense Region***, 155 Endocrinology 897 (2014), https://watermark.silverchair.com/endo0897.pdf?token=AQECAHi208BE49Ooan9kkhW_Ercy7Dm3ZL_9Cf3qfKAc485ysgAAAakwggGlBgkqhkiG9w0BBwagggGWMIIBkgIBADCCAYsGCSqGSIb3DQEHATAeBglghkgBZQMEAS4wEQQMUPSr9pnOPNi4dzJ_AgEQgIIBXPAkmaxTNxBS5GHj3GbhKbKd53DA9FWwEyz-NgWKgXr5jYfqEr9Wx3XDNLYzyLdBPeIEp4aBn1KOm427r89SfUt5Z2khY5FXnz0p

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Lisa M. McKenzie et al., ***Human Health Risk Assessment of Air Emissions from Development of Unconventional Natural Gas Resources*****,** 424 Sci. Total Env't 79 (2012), https://fromthestyx.files.wordpress.com/2012/09/health-risk-assessment-of-air-emissions-from-unconventional-natural-gas-hmckenzie2012-1.pdf

Gabrielle Pétron et al., ***Hydrocarbon Emissions Characterization in the Colorado Front Range: A Pilot Study*****,** 117, J. Geophysical Research 1 (2012), http://onlinelibrary.wiley.com/doi/10.1029/2011JD016360/epdf

A.J. Prenni et al., ***Oil and gas impacts on air quality in federal lands in the Bakken region: an overview of the Bakken Air Quality Study and first results*****,** 16 Atmos. Chem. Phys. 1401 (2016), https://www.atmos-chem-phys.net/16/1401/2016/acp-16-1401-2016.pdf

Tanja Srebotnjak & Miriam Rotkin-Ellman, Natural Resources Defense Council, ***Fracking Fumes: Air Pollution from Hydraulic Fracturing Threatens Public Health and Communities*** (2014), https://www.nrdc.org/sites/default/files/fracking-air-pollution-IB.pdf

Chelsea R. Thompson et al., ***Influence of Oil and Gas Emissions on Ambient Atmospheric Non-Methane Hydrocarbons in Residential Areas of Northeastern Colorado*****,** 2 Elem. Sci. Anthropocene 1 (2014), https://www.elementascience.org/articles/10.12952/journal.elementa.000035/

Ellen Webb et al., ***Developmental and Reproductive Effects of Chemicals Associated with Unconventional Oil and Natural Gas Operations*****,** 29(4) Rev. Env. Health 307 (2014), https://www.degruyter.com/downloadpdf/j/reveh.2014.29.issue-4/reveh-2014-0057/reveh-2014-0057.pdf

Bob Weinhold, ***The Future of Fracking: New Rules Target Air Emissions for Cleaner Natural Gas Production*****,** 120 Envt'l Health Perspectives A272 (2012), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3404676/pdf/ehp.120-a272.pdf