5-1-2023

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Journal of Maps

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tjom20

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To cite this article: W. Jay Christian, Beverly May & Jeffrey E. Levy (2023) Flood fatalities in eastern Kentucky and the public health legacy of mountaintop removal coal mining, Journal of Maps, 19:1, 2214159, DOI: 10.1080/17445647.2023.2214159

To link to this article: https://doi.org/10.1080/17445647.2023.2214159

JOURNAL OF MAPS
2023, VOL. 19, NO. 1, 2214159
https://doi.org/10.1080/17445647.2023.2214159

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Science

Flood fatalities in eastern Kentucky and the public health legacy of mountaintop removal coal mining

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ABSTRACT

Heavy rains at night caused severe flooding in eastern Kentucky on 28 July 2022, resulting in 39 deaths. Using publicly available information, we assembled a database of these fatalities, including demographic characteristics and location of death. We perturbed fatality locations and plotted them on a topographical map highlighting mountaintop removal mining with valley fill sites, where mountaintops were excavated to mine thin seams of coal. This map reveals many flood fatalities occurred along rivers or streams near such sites. Previous research suggests that surface mining has contributed to the majority of land cover change in this region, and this has increased storm water runoff. The legacy of coal mining in Central Appalachia could thus present immediate challenges to public health and safety beyond more frequently studied health outcomes associated with occupational and environmental exposures. A review of prior surface mining legislation to assess its effectiveness is warranted.

ARTICLE HISTORY
Received 1 December 2022
Revised 31 March 2023
Accepted 1 May 2023

KEYWORDS
Flood; Kentucky; Appalachia; coal; mining; health

1. Background

1.1. The flood of 28 July 2022

Heavy rains caused severe flooding in eastern Kentucky on 28 July 2022, which ultimately resulted in the deaths of at least 39 people, including four children (Spears, 2022). This tragedy was covered nationally and internationally by multiple media outlets, such as CNN and BBC, where it was noted as one of the most significant flooding events in the mountains of eastern Kentucky for several decades (BBC, 2022; CNN, 2022). Shortly after the flood event, the Federal Emergency Management Agency (FEMA) designated 13 counties for individual assistance (IA) and another seven for public assistance (PA) (FEMA, 2022).

1.2. The central appalachian sub-region

Eastern Kentucky is part of the Central Appalachian sub-region of the greater Appalachian region of the United States, which stretches from New York state to Mississippi, as defined by the Appalachian Regional Commission, an economic development organization formed as a partnership among federal and state governments (ARC, 2022). The Central Appalachian sub-region includes parts of eastern Kentucky, eastern Tennessee, southwestern Virginia, and all of West Virginia. The economy of this area has relied on coal mining since the early 20th century, but in recent decades the industry has declined rapidly. Production in the Eastern Kentucky Coal Field peaked in 1990 at just under 131 million short tons, when the industry employed almost 25,000 people. By 2022, however, coal production in this region had fallen to about 12 million short tons annually, and employment had dropped to just 3178 jobs (KEEC, 2022).

When coal was first mined in the Central Appalachian region, underground mining was the chief method of extraction. Later, after mining depleted larger seams of coal underground, mining engineers developed surface mining techniques to reach coal closer to the surface. Mountaintop removal with valley fill (MTRVF) mining, where mountaintops are excavated to expose thin seams of coal, became common in Central Appalachia in the 1990s. This technique requires the removal of vegetation, soil, and rock from the tops or sides of mountains to access coal just beneath the surface. The huge volume of this non-coal 'overburden' material is then deposited into nearby valleys. One research study estimated that MTRVF and related reclamation efforts were responsible for 65% of land use and land cover (LULC) change over a ten-year period (2001-2011) in the North Fork of the Kentucky River watershed, where the flood of 28 July 2022

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Supplemental map for this article can be accessed at https://doi.org/10.1080/17445647.2023.2214159.

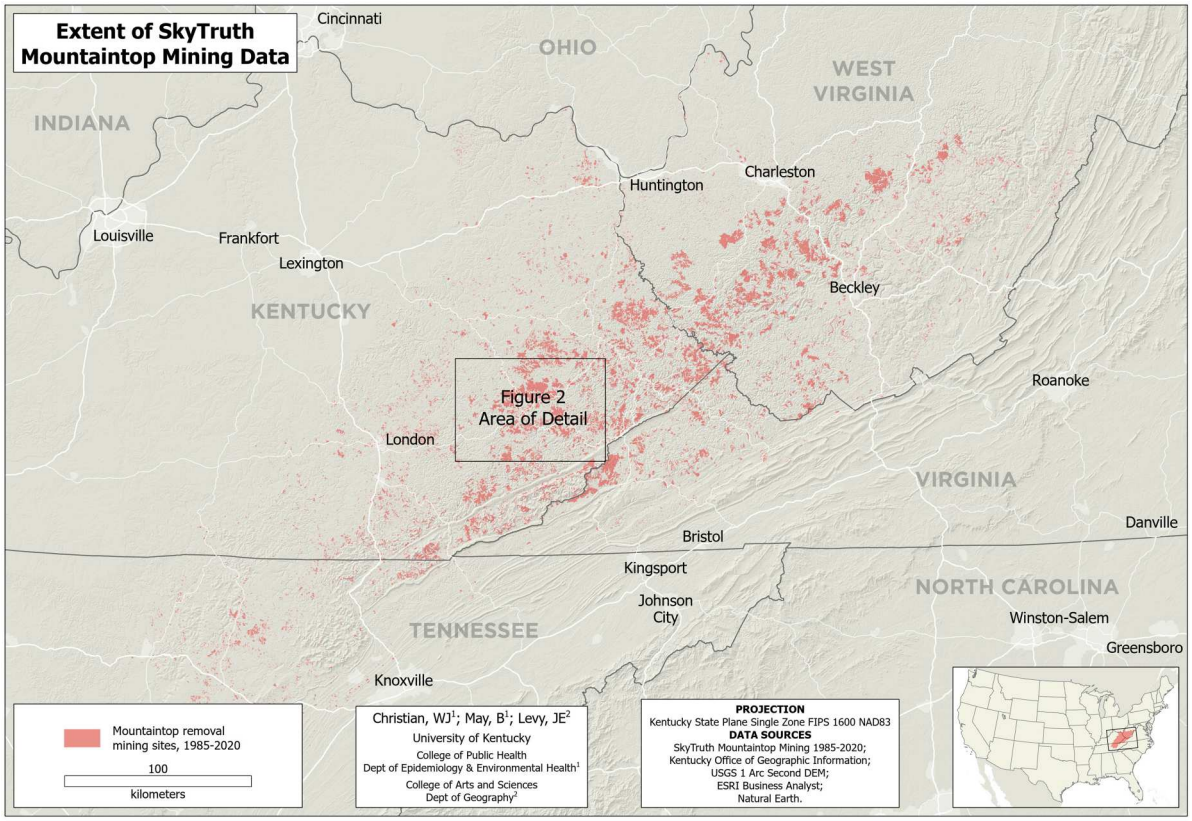

Figure 1. Cumulative extent of MTRVF in Central Appalachia, 1985-2020.

occurred (Gurung et al., 2018). Current and previous MTRVF sites are scattered across 4 states in the Central Appalachian region (Figure 1), and are plainly visible in satellite imagery, such as that displayed by Google Maps and similar online applications. And although coal mining production and employment in Central Appalachia have both declined rapidly, the impact of MTRVF mining might persist for several decades more.

1.3. Previous research on surface mining & MTRVF

Several published research papers have described hydrological changes or environmental degradation that results from surface mining practices or reclamation of mining sites. Forests, which provide a range of ecosystem services, can be difficult to re-establish on reclaimed surface mine land and is rarely successful (Thomas et al., 2022). Gyawali et al. (2022) used a Soil and Watershed Assessment Tool (SWAT) model to assess the effects of LULC on hydrology in another heavily forested and rural watershed dominated by surface coal mining in southeastern Kentucky. Their model suggested that both discharge and sediment yield increased significantly between 1992 and 2019. These findings are consistent with other studies in the Appalachian region suggesting that MTRVF – an extreme type of surface mining – and related reclamation efforts can increase stormwater runoff (Bonta et al., 1997; Negley & Eshleman, 2006; Phillips, 2004).

Additional work has indicated that runoff from MTRVF sites can contain potentially harmful trace elements and other substances. Lindberg et al. (2011) noted higher concentrations of selenium, sulfate, magnesium, and other inorganic solutes; these concentrations were closely associated with the extent of mining upstream from sampling sites. Furthermore, samples taken downstream from some mining sites reclaimed decades previously still showed higher concentrations of some pollutants. These results are again consistent with other research in the region, such as Brooks et al. (2019), who found nitrate concentrations substantially higher in watersheds with surface mining compared to forested watersheds. Yet more research documents the negative effects of such pollution on local aquatic life (Evans et al., 2021; Voss & Bernhardt, 2017).

Many studies have suggested that MTRVF has negative effects on the health of local human populations. Much of this research relates to occupational exposure among coal miners, who can develop respiratory diseases like coal miner's pneumoconiosis ('black lung') after years of exposure to mineral dust, even in surface mining operations (Halldin et al., 2015). There is also a body of research investigating health risks to the general population. A variety of research studies have documented higher risk of cancers (Ahern & Hendryx, 2012 Christian et al.,

2011; Jenkins et al., 2013), birth defects (Ahern et al., 2011; Cooper et al., 2022), mental illness (Cordial et al., 2012), and other health problems among those living near MTRVF mining sites. To be clear, however, there is strong potential for bias in many of these studies, and a systematic review published just a few years ago remained cautious in its conclusions; the authors ultimately suggested more research is needed to firmly establish links between MTRVF and human health (Boyles et al., 2017).

1.4. Objectives

A recent analysis examined high-resolution flood risk data and FEMA undercounts of properties exposed to the 100-year floodplain (Waweru, 2022). The findings showed that the Central Appalachian region was one of four U.S. regions with both high flood risk and high undercounts of flood-prone properties. But despite the still-growing body of literature on population health risks associated with active or reclaimed MTRVF sites, and some notable work examining the effects on hydrology and forest ecology, we are unaware of epidemiologic studies examining the influence of local MTRVF sites on the risk of flood-related morbidity or mortality in the Central Appalachian region. Through visualization of the fatalities associated with the flood of late July 2022 relative to these local environmental hazards, and some examination of local context and history, we hope to generate hypotheses for subsequent research, consider data sets that might help to address them, and encourage broader study of MTRVF and flood-related health outcomes.

2. Methods

The University of Kentucky Medical Institutional Review Board reviewed this research and ruled that it did not meet the definition of human subjects research, as all individuals were deceased.

2.1. Data sources

We assembled a database of confirmed fatalities directly due to the 28 July 2022 flood using reports from the *Louisville Courier-Journal* and the *Lexington Herald-Leader* – the two newspapers with the largest circulation in Kentucky – and an online news source, *The Deseret News*. Additionally, we included a victim who was still missing as of this writing. We recorded name, age, and the stream in which the victim drowned or was last seen, from these sources. We supplemented this information with details from funeral home obituaries and personal communications with local people knowledgeable of the deaths. We used Google Maps to identify approximate latitude and longitude coordinates for all residences or other locations of death. In instances where we could not discern the location of death, we recorded coordinates for the neighborhood of residence.

Researchers have previously estimated the full geographic extent of MTRVF in Central Appalachia using satellite imagery and federal mining data (Pericak et al., 2018). We used their updated cumulative data layer, which contained polygons delineating all areas mined in this manner from 1985 to 2020, for our map of flood fatalities. These data are available online from SkyTruth.org, a non-profit organization that monitors resource extraction sites using satellite imagery and other data (SkyTruth, 2021). We have used previous iterations these data to examine risk of birth defects and lung cancer among those who lived near MTRVF sites (Christian et al., 2020; Cooper et al., 2022).

We obtained additional base data layers for other features in the map of fatalities from the Kentucky Office of Geographic Information's KyGeoPortal (KOGI, 2022). These layers included municipal, county and state boundaries, water features from the National Hydrography Dataset (USGS, 2022a), and aerial imagery from the National Agriculture Imagery Program (USGS, 2022b).

We symbolized the map such that age is discernible to the viewer, since many of the fatalities were senior citizens or children. We included an inset map showing the location of the fatalities relative the thirteen counties whose residents are eligible for IA from FEMA for Disaster 4663, the official designation for this flood event (FEMA, 2022).

3. Results

Figure 2 displays the map of flood fatalities. This map demonstrates that many deaths occurred along rivers or streams adjacent to MTRVF sites, or downstream from such sites. Troublesome Creek runs from Hindman to the North Fork of the Kentucky River near some of the largest MTRVF sites. Distance analysis showed 14 of the 36 fatalities (38.9%) occurred within about 300 ft (100 m) of the usual course of Troublesome Creek, as defined by the NHD Area features data set, and 15 (41.7%) were within ½ mile (0.8 km) of Troublesome Creek. Overall, 17 of 36 (47.2%) fatalities occurred within about 300 ft (100 m) of any stream or river in NHD Area features, and 25 (69.4%) occurred within ½ mi (0.8 km). Symbology for fatalities demonstrates that most deaths (n = 19, or 52.7%) occurred among those age 65+, and four (10.3%) of the fatalities were under 18 years of age.

4. Discussion

The map in Figure 2 cannot prove that MTRVF mining is responsible for the deaths resulting from

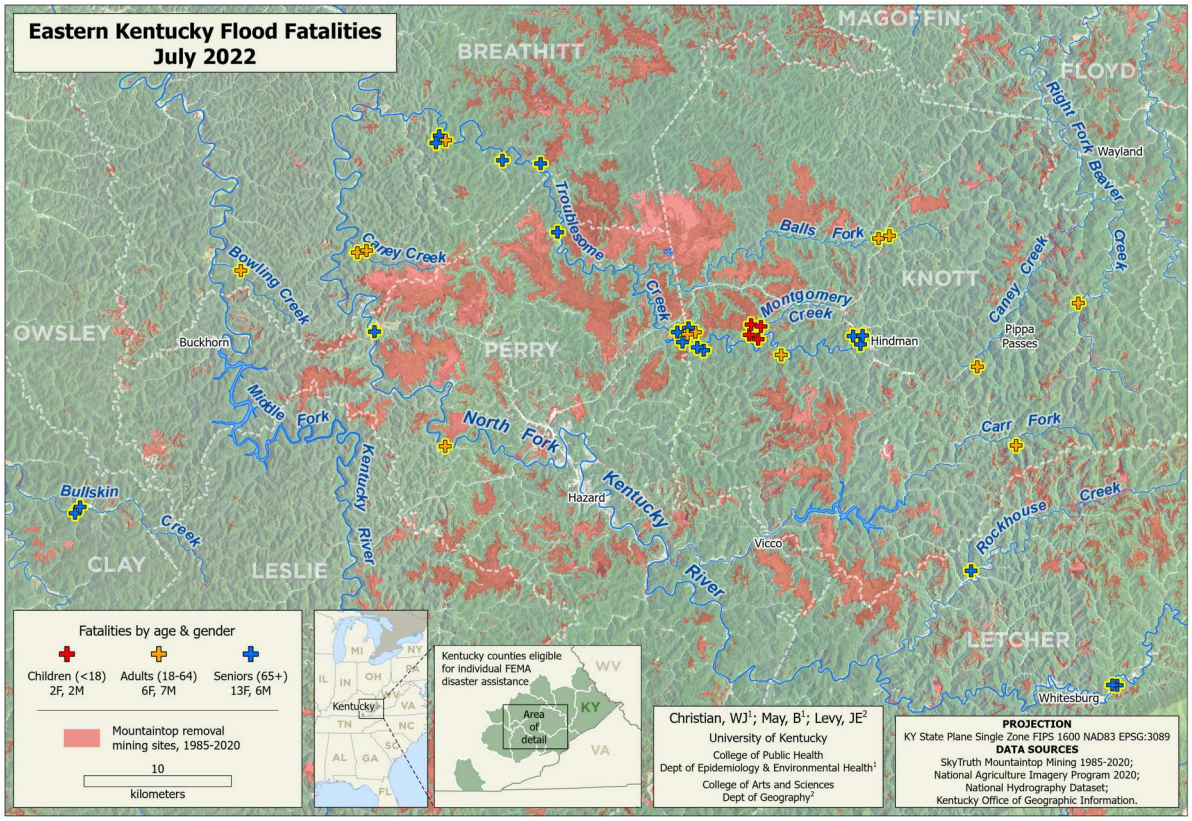

Figure 2. Flood fatalities in eastern Kentucky, July 2022.

the floods of 28 July 2022. During these floods, the North Fork of the Kentucky River rose to 22 feet in nearby Whitesburg in Letcher County (see Figure 2), where the previous record was less than 15 feet. These measurements demonstrate the magnitude of this event, which the Kentucky Geological Survey estimated to be a 600-year flood (Haneberg, 2022). In other words, a flood of this magnitude should only be expected approximately every 600 years on the North Fork of the Kentucky River. Still, the map is compelling because it shows many fatalities occurred along rivers or streams in areas adjacent to, or downstream from, MTRVF mining sites. Like most interesting maps, this one is a 'conjunction of analytic presentation and experimental argumentation in a visual exposition' (Koch, 2011, p. 13). As such, it is best applied to the process of hypothesis generation for future population-level studies.

Certainly, the map in Figure 2 suggests that residence near MTRVF sites could increase risk of flood-related injury or death. There are several data sources and analytic options for future research focused on this question. For example, data from FEMA declarations and the National Oceanic and Atmospheric Administration's (NOAA) Storm Events Database (NOAA, 2022) could be used to examine flood frequency and severity over time in the Central Appalachian region. An indication of increasing frequency or severity alone could arguably indicate higher risk of flood-related injury or death to local residents. Additionally, analysis of hospital discharge data could identify trends in rates of hospitalization due to injuries associated with flooding over the past few decades in Central Appalachian counties. There is a specific International Classification of Diseases (10th edition) code for external causes of injury – X38 Flood – that specifically includes floods resulting from storms (CDC, 2022). Such codes are routinely attached to inpatient hospital visit records, along with additional patient information. Similarly, researchers might examine other health effects known to be associated with residential flooding. Beyond injury or drowning, it is known that risk of respiratory illness can increase in the aftermath of flooding, as mold and humidity can trigger asthma- or allergy-related episodes (Azuma et al., 2014 Oluyomi et al., 2021; Paterson et al., 2018; Peirce et al., 2022). Flooding can also increase risk for gastrointestinal illness and communicable diseases in their wake (Paterson et al., 2018; Wade et al., 2014). These health outcomes might similarly produce hospitalizations or emergency department visits that yield information for analysis relative to the spatial and temporal distribution of flood events during the MTRVF era in Central Appalachia.

Additional research might focus on the influence of policy and legislation on flood-related morbidity and mortality in the region, because this was not the first lethal flood event that has prompted inquiry into the impact of coal mining on the safety of the Central

Appalachian population. Severe flooding of the nearby Tug Fork River in 1977, affecting West Virginia and Kentucky, killed dozens of people (including ten in Kentucky) and left thousands more homeless. As Charles C. Geisler describes in the introduction to *Who Owns Appalachia: Landownership and Its Impact*, 'Regional land abuses which intensified the flooding, such as forced inhabitation of flood plains and the inability of government to find alternative homesites for the victims, were manifestly traceable to the monopoly of local land by coal companies' (ALOT 1983). As a response to the disaster, citizens initiated a study of landownership patterns in dozens of Appalachian counties across multiple states. Eastern Kentucky was found to have over a million surface acres held by absentee landowners, largely corporations, amounting to 40% of the total acreage in the counties surveyed (ALOT 1983). The Surface Mining Control and Reclamation Act (SMCRA) of 1977, passed shortly after the flooding, was drafted with human safety as a foremost concern. The House Committee on Internal and Insular Affairs which drafted SMCRA was 'keenly aware of public hazards' (FitzGerald, 1984) and in its report cited another flood in West Virginia – at Buffalo Creek – in which 125 people were killed by the failure of a coal waste impoundment during heavy rainfall in 1972 (USDOL, 2022). At a minimum, the map in Figure 2, combined with other available research, suggests that time has come for serious examination of legislative and regulatory efforts to meet Congresses' stated objective of protecting human life from surface mining. If not, Congressional reevaluation of SMCRA seems warranted, if perhaps unlikely, given the declining state of the coal mining industry in recent years.

5. Final thought

A recently published article described huge investments in infrastructure that might someday be required for Central Appalachia to provide a 'safe and livable environment' for 'American climate refugees' fleeing worsening conditions in the southern and western U.S. (Hirschman, 2022). The author noted, for example, that installation of flow-through dams could help to control flooding without some of the negative aspects of conventional reservoir dams. Presumably, the current residents of Central Appalachia could attest to the need for a safe and livable environment without the arrival of climate refugees.

Software

We produced the maps for this article using Esri's ArcGIS Pro software version 3.0.2.

Acknowledgments

The authors would like to thank the editors of the *Journal of Maps* Special Issue: Mapping Health, as well as those who reviewed this manuscript prior to publication.

Data availability statement

Due to ethical concerns about the release of personal information regarding multiple decedents in a small community, we chose not to share the flood fatality locations, or their personal characteristics, which comprised our primary data set.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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